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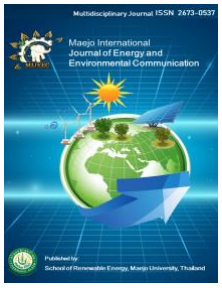

ARTICLE

Energy commerce and business economics: A review of trends, challenges, and opportunities

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ABSTRACT

The energy industry globally is being reshaped by the influences of going green, reducing reliance on large utilities, and increased technology. These shifts prove that energy commerce and business economics greatly affect the changes in how, where, and what energy is used. Now that energy transactions are digital, they run smoothly, and the fairness of competition is boosted. Digitalization also helps businesses improve and achieve growth. The growth of this sector has come from steps like creating the market, dealing with issues in the market, supporting creative business ideas, fueling digital change, lessening regulations, and supporting consumer interests. Whenever the government is involved in projects, the team should pay special attention to the financial aspect, regulations, and sustainability during planning and implementation. Changes in energy markets are determined by rules set by regulators and the way they handle carbon trading. Thanks to AI, blockchains, and FinTech, there are now more opportunities for providing and trading energy. Still, the industry must deal with issues brought on by changes in regulations, swings in the market, and cybersecurity dangers. Soon, using Energy-as-a-Service, environmental, social, and corporate governance (ESG) finance, and merging AI, big data, and circular economy principles will make a big impact on sustainable development. Consequently, this research review demonstrates the value of combining technology, reorganizing systems, and developing economic approaches to drive the changes in energy commerce.

1. Introduction

The energy industry worldwide is being transformed by the main factors of decarbonization, decentralization, and digitalization (Huang & Lin, 2023; Monaco et al., 2024). Commercial energy transactions are involved in the modern energy sector and include its activities in production and trading as well as the digital business arrangements for using energy (Wang et al., 2023). Using economic methods and models, below helps those in business and government form strategies and decide on energy-related investments. Through this union, possible to explain why energy business transactions have changed because of new

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technologies and changes in the marketplace. This location is highly significant as the energy industry accounts for a trillion dollars and supports the whole world's economy, but switching to sustainable systems is necessary immediately for environmental reasons (Sułek & Borowski, 2024).

In the past several decades, a lot of nations changed their system of state-run utilities that combined different services to ones with competitive energy markets. To open the energy sector to more competition, many places in the early 1990s split tasks so that networks were independently managed from those used for producing and selling energy (Verdejo-Fredes et al., 2022). Due to digitalization and quick advancements in information technology, energy companies now use smart grids and smart meters that provide advanced analytics to help boost operations as well as reliability in distribution and easier customer communication (Nazari & Musilek, 2023). The sector has experienced two changes, one being the replacement of large centralized power plants with small DERs, and the other being the distribution of energy through decentralized units such as solar panels on roofs, wind turbines, and battery energy storage systems. Due to decentralization, customers can produce their own energy and take part in trading energy locally, as well as join energy models centered around peers and community groups. According to experts, the energy transition mainly focuses on three trends, which they label the 3Ds (decarbonization, decentralization, and digitalization). All these trends change and shape the way the energy business works at present (Zhang & Dilanchiev, 2022).

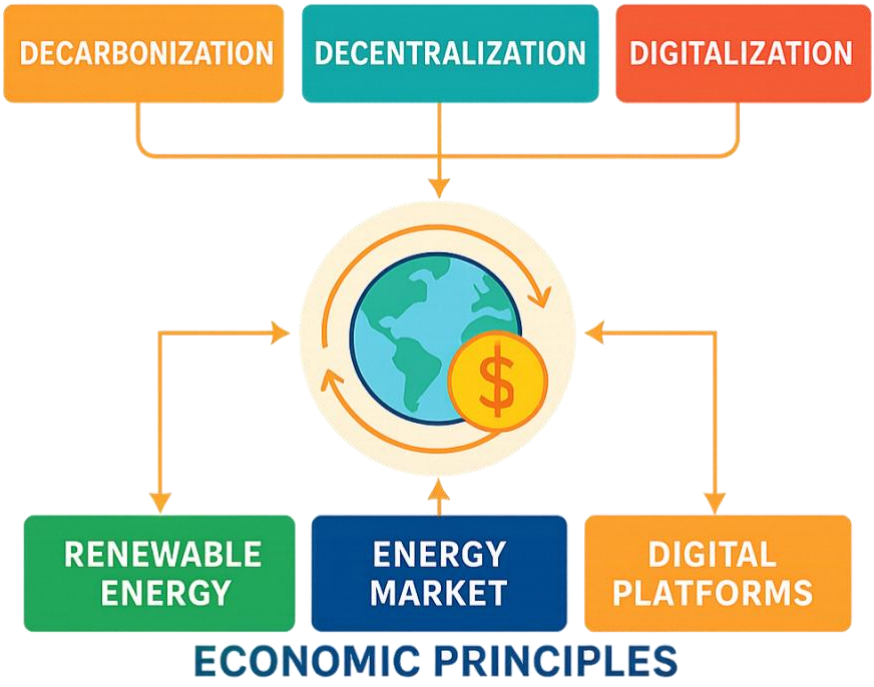

Figure 1. The main parts of energy transformation focus on bringing together decarbonization, digitalization, decentralization, and economics.

Each important factor for energy transition is displayed in Figure 1 with images and questions that relate to sustainable development and proper strategies. Energy commerce and business economics studies are especially important as they expose the latest ways energy is generated and captured in the modern world, as people respond to both challenges and new solutions in the field. To cope with climate change and move toward a zero-carbon economy, businesses should invest in new systems for using renewable energy and becoming more energy efficient. Customers and prosumers are now looking for more energy options and excellent services, and they also want to use their surplus solar power by selling it. Governments set guidelines for the industry by creating laws and using positive and negative aspects of economic pressures to help environmental development. Modern developments in the energy sector occur because of the close connection between technological progress, the organization of the market, and new economic approaches, so it is important to carefully watch these new changes.

The paper examines the progress happening in the global energy sector, along with the concepts behind it, and what business opportunities are expected in the energy and economic industries. The report looks into modern peer-reviewed studies, practical case studies from recent times, and the following aspects: (1) basic energy economics and innovations in business structure behind today's market forms; (2) the way energy commerce is developing, focusing on key digital, liberal, and decentral changes; (3) economic trends and standards guiding decisions for investing in energy enterprises; (4) regulatory systems, carbon pricing, and related policies shaping energy markets; (5) innovative technology and business innovations making their way into energy business; (6) the continued challenges, risks, and instability in energy The review merges several aspects to show educational material and modern knowledge concerning the behaviour of the current energy market and its business economics for future reference. It first describes the theory behind the paper, then goes into detail about the various themes, and finishes by pointing out the main findings and making suggested recommendations.

2. Theoretical foundations and frameworks

Energy Economics, business model innovation, and sustainable business models display the main themes that control and shape the energy sector, as shown in Figure 2. Strategic planning and developing today's energy systems have benefited from different theoretical models that are woven together.

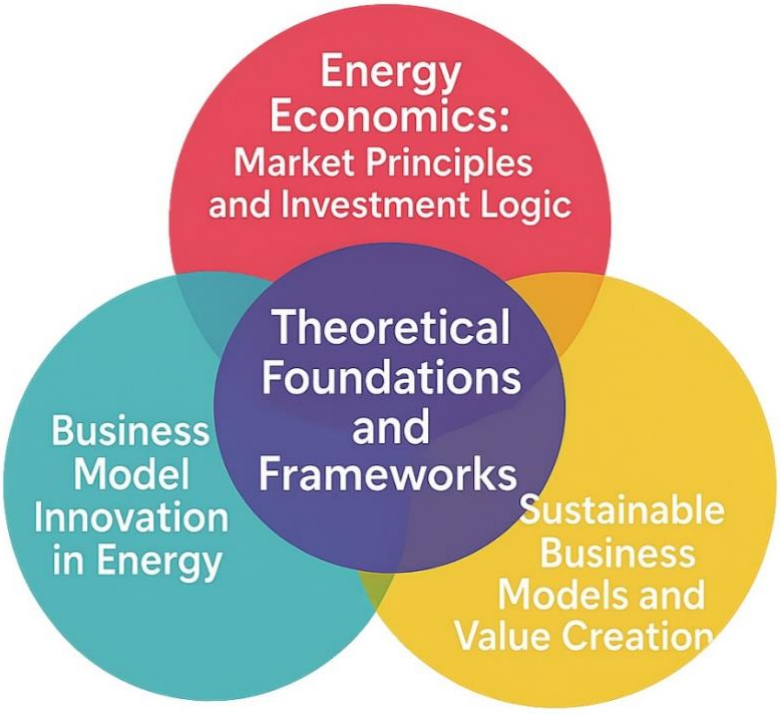

Figure 2. The energy sector operates through interconnected fundamental elements

2.1 Energy economics: Market principles and investment logic

Figure 3 lays out the main aspects that make up energy economics. They change and improve based on their sources of supply and demand, the way prices happen, and the types of markets, as well as how competitive they are. When looking at energy projects, Investment Economics looks at NPV, IRR, real options, and LCOE as major evaluation tools. Relying on economic mechanisms for carbon emissions and ensuring the Energy Trilemma helps maintain safety, manage costs, and preserve the environment. Such theories of energy economics describe how the energy markets run and how they provide economic benefits due to the use of resources. There are five main components: energy commodity supply and demand, as well as optimization of the market framework, together with energy pricing and considering the effect on the environment (Zadeh & Romagnoli, 2024).

Since it was hard to set up and maintain extensive energy networks, like electricity, such systems were initially labeled natural monopolies, and so laws about regulating them were designed. Expert thinking on competition in markets, as well as market efficiency problems, caused these markets to be changed. According to market design theory, electricity supply should be managed through fair wholesale markets that carry out marginal cost operations and competitive bids based on demand to cut costs and improve performance. People supported the splitting of utility services into generation, transmission, and distribution, as well as retail branches, since it allowed monopoly areas to be distinct from competitive areas. In the 1990s, the theory helped guide the reforms made in European and American parts and regions across Asia (Stern & Holder, 1999).

The assessment of energy infrastructure investment is based on important economic approaches to investment. Because of the big early costs, the long life of assets, and a lot of rules, projects in the energy sector have to use different versions of net present value and internal rate of return. In energy markets, firms use real options theory to examine uncertainties by investing in power plants they can decide may not deliver solid profits when it is not economically favorable, States and Markets. When carbon pricing is unclear, risk-averse firms change their investment decisions in differing ways from risk-neutral firms since uncertainty regarding this policy influences installations (Bruno et al., 2016). It works as a useful benchmark to measure the lifetime energy costs of different generation technologies, so it is used to plan new policies and investments.

In energy economics, public goods and externalities are taken into account when the topic is studied. Since there are negative consequences from greenhouse gas emissions, governments decided to use taxes and cap-and-trade systems in their carbon pricing program (Green, 2021). This principle in economics says that taxing carbon in markets causes resources to be distributed better towards technologies that use less carbon, which will be explained in different sections later. Making assessments when

developing energy strategies, authorities consider the trilemma between providing safe and cheap energy and also protecting the environment (Zadeh & Romagnoli, 2024). Today's developments in energy commerce use knowledge from several fields, for example microeconomic market theory, laws regarding monopolies, financial models for investment in uncertain conditions, and economic methods of pricing effects on the environment.

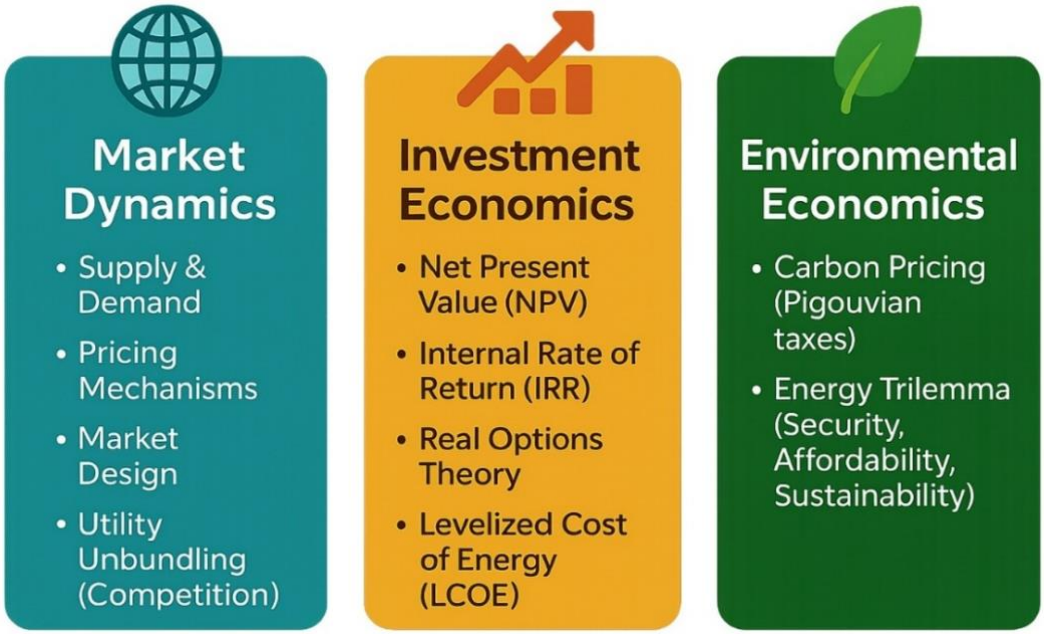

Figure 3. Pillars of the energy market and investment economics

2.2 Business model innovation in energy

The study of changes in energy commerce relies on both the business model framework and economic analysis. Business Model Canvas (BMC) can be used by energy companies to look at traditional and innovative ways to run an energy enterprise. In the traditional energy business, things are managed by the central utility, but new businesses choose to decentralize and aim to provide services directly to customers to earn their income. A business model shows the steps taken by a company to add value and get paid for offering services. Customers in the energy industry used to pay based on how the grid delivered the following services: the purchase of electricity and the supply of energy. According to Sułek & Borowski (2024), new business models that come from technology and rule changes should be studied by using conceptual and analytical frameworks.

The Business Model Canvas (BMC) includes information on the strategies adopted in energy entities for easy analysis, listed in Table 1. Energy systems past and present were usually central but new ones are designed in a decentralized way where customers decide what they want, and the power firms earn income by offering many forms of value. To use the BMC, a business model is divided into nine parts, including the value proposition, the customer segments, the channels, how customers are handled, the main activities involved, important resources, partner firms, the cost setup and the revenue streams. With the use of systematic processing, the BMC enables researchers and practitioners to investigate and design the best energy business models. The canvas is used by researchers to group and examine new business models from local participants like prosumers and aggregators by comparing them with the typical utility model (Schwidtal et al., 2023). With its help, the framework brings to light that customers are turning into energy partners and making way for income from services instead of commodities.

2.3 Sustainable business models and value creation

Innovation in energy business models is connected to sustainability, which results in sustainable ways of operating businesses. In sustainable business, the company works towards both economic and social goals as well as protecting the environment. ESCOs assist clients in getting funding and performing energy conservation work so that the clients benefit from the lower prices. The model stresses the possible compatibility of making profits and using less energy, while providing sustainability, an advantage that helps in public institutions as well as in private businesses. ESCOs focus on performance contracting since these companies ensure energy savings for their clients and bill their customers only for the actual results. Because of this model, ESCOs are encouraged to find the best methods to boost how efficiently the client operates. With these two upgrades, ESCOs can recover their initial expenses by dividing the saved energy between the facility and the energy company (Richter, 2013). When ESCOs invest their money upfront, the financial hurdles are removed, and this allows businesses to focus on environmental benefits.

Because of the "X-as-a-Service" model, businesses in different areas are now managing energy more effectively. Seeing how other sectors use SaaS, energy businesses are motivating themselves to begin selling services instead of just energy monitors. Theoretically, this approach means Energy-as-a-Service (EaaS) is likely to develop. The business provides customers with comfort,

assures that services work round-the-clock, and manages to reduce their bills for fuel as a service package. When merging digital sensors, IoT, and remote management with energy services, constant management is possible for the clients. The literature on servitization forms the basis for the concept as producers increase their services by using new methods (Feng et al., 2021).

Table 1. Comparison of traditional and emerging business models in energy commerce, adapted from the business model canvas (BMC) framework

Characteristics	Traditional utility model	Emerging business models
Value Proposition	Energy generation and reliable delivery	Integrated services, renewable energy solutions, community empowerment
Customer Segments	Passive energy consumers	Active participants, prosumers, communities
Channels	Centralized grid networks	Decentralized grids, digital platforms
Customer Relationships	Transactional, regulated, passive	Collaborative, participatory, co-creative
Key Activities	Generation, procurement, delivery of energy	Energy management, aggregation, demand response, service provisioning
Key Resources	Large-scale generation assets, transmission networks	Renewable energy technologies, storage systems, digital platforms
Key Partners	Fuel suppliers, regulators	Customers as co-producers, technology providers, local communities
Cost Structure	Asset-intensive, regulated cost-plus basis	Flexible, innovation-driven, optimized through decentralization
Revenue Streams	Commodity-based, regulated tariffs	Service-based (energy management, demand response), diverse revenue streams

The energy sector is shaped differently due to digital platforms, so the multi-sided market framework is very useful. Such energy platforms need to attract and keep both prosumers and consumers as users because it benefits both the platform and its customers as more people join. Concepts from market design and transaction cost economics are used in real-time energy and flexibility trading so that devices and agents are properly managed (Kumar et al., 2022). The known theories and business model innovations of energy economics help to study the recent developments in the market. The organization of markets and strategic corporate investments are linked to energy economics, while successful business models offer knowledge about the way businesses deliver value in established markets. We proceed to examine what is happening in the energy sector today by paying attention to digitalization, liberalization, and decentralization in practice.

3. Evolution and current status of energy commerce

Figure 4 is an illustration of how renewable energy can be moved into regular electricity networks for many homes. With smart meters, sensors, and analytics, energy systems become more efficient and allow people to enjoy greater control of their energy usage.

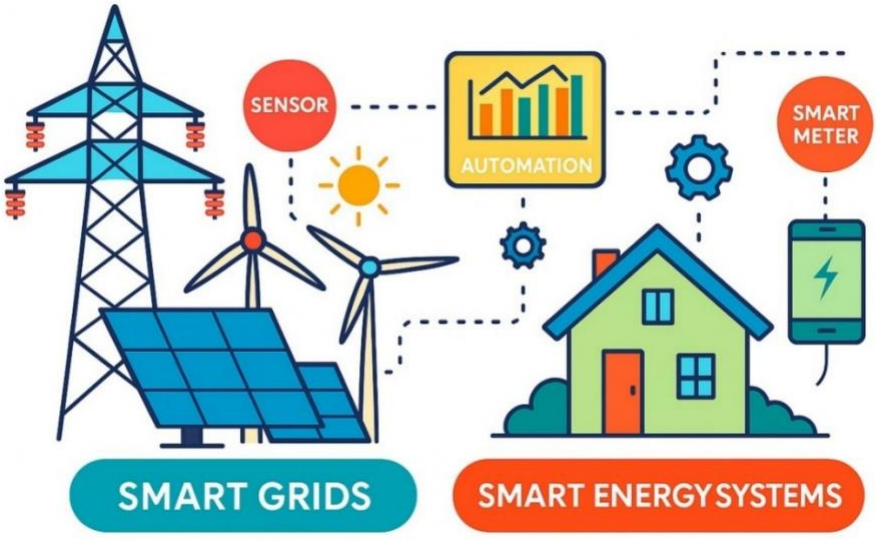

Figure 4. Digitalization of energy systems: Smart grids and smart energy applications

3.1 Digitalization of energy systems

The introduction of digitalization brought in new technology for collecting and transmitting information, giving electricity systems powerful analytics tools. Different digital technologies, for example, sensors, meters, automation systems, and software, join together to monitor both the making and use of energy (Figure 5). For the past several years, the energy business has started using smart technology to develop both new grids and energy systems. As a result of digital transformation, a business becomes more efficient, lowers its costs, and offers remarkable support to customers (Nazari & Musilek, 2023). Being able to monitor sensors and IoT gadgets gives operators the means to assess the grid, handle power consumption, and respond to many outages speedily. By processing data daily and combining it with machine learning methods, control of machines and forecasts for their operation becomes better. Sales dynamics have changed because customers can easily find out about the products they want on the internet. With access to smart meters and home energy management systems, people can watch their energy use and decide whether to take part in demand response activities (Liu & Lu, 2021). People become active users instead of just consumers thanks to the new opportunities to use information and control settings. By using digital tools, prosumers get to take part in market transactions with others and decrease demand. Being equipped with digital tools, customers are able to share their flexibility and generate power, fully fulfilling what the experts suggest. Custom energy services are delivered in a way that makes customers happy and offers many benefits. You can see in Figure 1 the essential elements and history of energy market liberalization, along with its leading drivers and main outcomes, and main problems caused by dominance and a concentrated market, which are exposed to shocks. The framework pays attention to important regulations and outlines the requirements of the market now and in the future for a properly functioning market system.

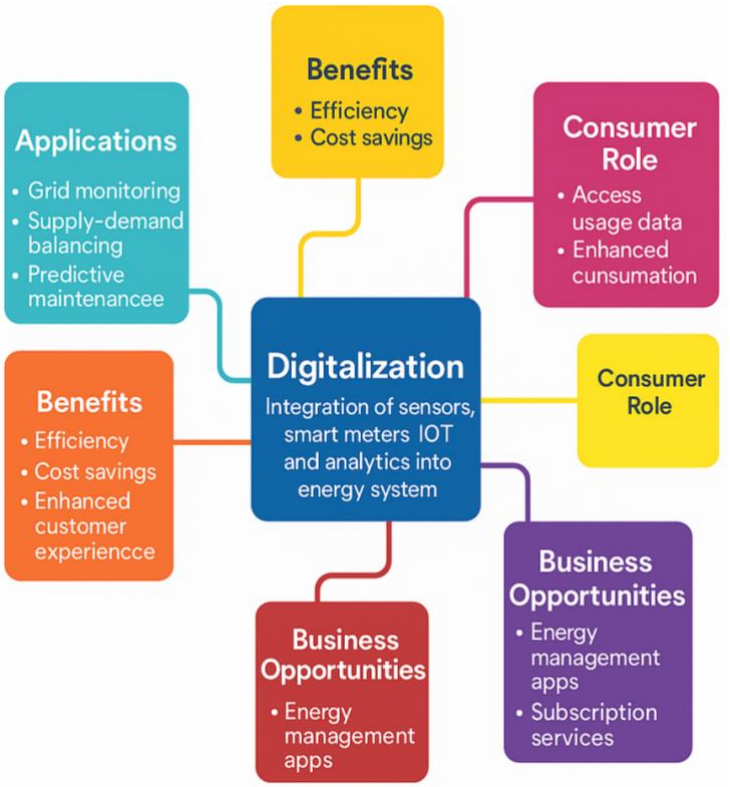

Figure 5. Illustrates the main components related to energy market liberalization, together with its effects

Digital trends keep forming fresh energy business models that can still create value for different branches of the industry. Using digital tech, these businesses set up services to check a user's energy consumption and to manage smart devices with an app that comes as part of the package. Experts Weigel and Fischedick mention that energy management technology helps in customer service as well as system reliability and the daily running of the organization (2019). Power grid operators got access to cutting-edge business services and inexpensive resources as a result of digitalization. Digital projects tend to be successful mainly because they cut down the daily operating costs. Reliable maintenance relies on using big data analysis, which means there are fewer breakdowns and a drop in the costs of running operations. With the rise of digital trends, organizations face new challenges that they have to deal with. The more that energy issues are linked and require data, the more likely problems related to security and privacy will arise. Because of digital technology, methods of accelerating operations lead to problems related to defending company systems and storing customer information safely. The number of workers needs to change with automation, but businesses are required to hire data science experts and help employees get ready for new roles. The implementation of digitalization in the energy sector keeps advancing through these difficulties. Markets that incorporate artificial intelligence (AI), blockchain, and cloud computing now allow energy trading to be

done automatically. Thanks to digitalization, an intelligent and connected energy system is created, which supports current business approaches among those working in the industry.

3.2 Market liberalization and competitive structures

In the final decades of the 20th century, regulators worldwide embraced the idea of deregulating energy markets involving electricity and natural gas. Market liberalization means that utilities should have separate units so that producers and retailers can take part in market deals. As a result of liberalization, customers get access to services or goods that cost less and provide better solutions since several firms compete (Table 2). Because of various levels of market openness in European and American countries over Asian-Pacific countries, knowledge was exchanged during the liberalization process (Grandclément & Nadaï, 2018). The history of business is shown in its various milestones. In 1989, the British government released a deregulation of electricity markets as outlined by the Electricity Act. In the late 1990s, citizens of Britain were able to buy energy from electricity suppliers in the commercial market. In 1992, powerful federal regulations and FERC Orders 888/889 appeared, which created wholesale electricity markets everywhere in the United States, and states followed a few years later with retail competition overseen by the government (Littlechild, 2021). Between 1997 and 2012, European member states carried out EU directives to deregulate the electricity business through fair treatment of the power grid. In the 1980s, Chile was the first country in Latin America to separate the tasks of generating electricity from managing its transmission (Serra, 2022).

Table 2. Overview of energy market liberalization – Trends, outcomes, and challenges

Characteristics	Description
Definition	Introducing competition into previously monopolistic energy markets via utility unbundling.
Rationale	Increased efficiency, innovation, and potentially lower consumer prices through competition.
Historical milestones	- UK (1989 Electricity Act) - US (1992 Energy Policy Act, 1996 FERC Orders 888/889) - EU directives (late 1990s-2000s) - Chile (1980s pioneering electricity market liberalization)
Positive outcomes	- Increased innovation and new entrants (IPPs, energy traders) - Consumer choice (renewable energy, time-of-use tariffs) - Improved cross-border electricity trade (EU)
Challenges & limitations	- High market concentration and oligopolies persist - Incumbents maintain dominance through mergers - Limited retail price reduction and competition - Vulnerability to external shocks (e.g., 2021-2022 energy crisis)
Regulatory issues	- Need for careful oversight to avoid oligopolistic outcomes - Balancing market forces and social objectives (energy access, reliability) - Government interventions (subsidies, price caps, emergency measures during crises)
Current market Characteristics	- Competitive wholesale markets, diverse retail options - Ongoing debates about market power, reliability (capacity mechanisms), and consumer protection
Future considerations	- Finding the right balance between competition and regulation - Ensuring market stability, innovation, and consumer protection

There are obstacles in a deregulated market, but it can also lead to good results in its performance. Fresh products for sale appeared because of marketing institutions. Thanks to IPPs and energy traders with retail services, the market got access to green energy solutions and unique rates for retail customers. Liberalization in electricity markets allows people to access renewable and time-based service, as it was not provided by the previous monopoly suppliers. Because of today's price structures, people can make the most of them as markets become more competitive. With these new networks, European countries have been able to increase energy trade because of better alignment of their supply and demand. The new liberalization policies did not lead to a market where both prices and competition in retail were fair. Top companies have still controlled the market after markets were liberalized following privatization. Electricity companies kept leading the market thanks to agreements between the companies and the benefits they already had. Green (2021) states that liberalization granted firms the permission to combine their operations, but the merger did not increase the market competition. If there is bad regulation, many companies are likely to dominate, causing studies to show that India and Israel have higher prices and a lower number of choices for customers (Eitan, 2023). The EC noticed that falling wholesale prices owing to company mergers in the various EU territories had no impact on consumer prices.

Innovation allowed the UK's energy market to improve its conditions, but suppliers were interrupted, and prices were controlled by outside factors and changed policies during the early 2000s. Overseeing the energy marketplace by following

procedures is required since it depends on keeping power levels steady while providing access to all. Gas price rises by Russia in Ukraine caused many countries to start exploring the best ways to plan their power systems. As a result of the energy crisis, the government helped electricity companies and also gave special help in the form of lowered prices and tax relief to users of electricity (Pabst, 2021). The state provides protection to public order as well as public needs, while letting the market work efficiently through its operations. Since energy is so important, governments changed their strategy for granting access to emergency resources. They organize whichever companies into different sectors to take charge of wholesale trading and selecting retail customers. Because stakeholders focus on market dominance, they may not be able to reach better market performance soon due to spending time on creating rules and ensuring the safety of vulnerable consumers. A solid foundation for energy commerce comes from good relations between competitive markets and the officials in charge of regulations.

3.3 Decentralization and the rise of prosumers

The way energy commerce works changes because of the rise of decentralized energy supplies and the use of digital and liberal methods (Table 3). It involves installing solar PV panels on roofs, placing wind turbines, and including both batteries and CHP units together with micro-generation devices. It was the mix of small and affordable renewables, helpful policies, and worries over pollution that launched this move towards clean energy. Thanks to site-based power solutions, prosumers exist as they simultaneously create and use energy that goes against old utility approaches of either producing or buying energy from a network. Because of these energy communities, residential and commercial buildings can now exchange electricity directly using platforms and organizations based locally. You can sell solar power by sending it to your neighbor's home or by offering it to your local community using solar gardens and microgrids. Because peer-to-peer and community self-consumption follow different business forms, they offer different types of services, from simple product exchange to working with companies for organized transactions. Such divided frameworks will make it possible for energy trading to be handled locally and directly by communities.

Blockchain combined with smart contracts enables people to participate in unscheduled energy transactions. This technology makes it easy for small energy companies to trade and manage transactions without depending on main intermediaries. Tests done at the Brooklyn Microgrid and Power Ledger have led to blockchain-based P2P energy trade system automation. Blockchain technology makes it possible for people to do decentralized trading with peers if their main concerns and challenges are solved (mdpi.com). Using the solution, one can confirm transactions, store smart contracts, and benefit from new trading opportunities. It's sensible to use decentralization in setting up microgrids that work as independent power systems with DERs separated from the main power system. Microgrids operators help manage systems that hold DERs accountable for community-based electricity production as well as routine grid operation. Members of some industry sectors are permitted to work with virtual power plants by having legal definitions that give the role of a community energy supplier and enable such plants to join wholesale markets. Prosumerism is being shaped by the directives set by the EU, while Germany leads in simple solar energy production projects. A large number of solar installations can be seen in northern and western California as well as the northeastern areas of New York. Since it's affordable, decentralization in developing areas now counts on solar panels and batteries to fill the electricity needs in lesser-connected places.

Table 3. Overview of Energy Decentralization—Key Trends, Opportunities, and Challenges

Characteristics	Description
Definition	Shift from centralized large-scale power plants to distributed generation near consumption points.
Driving Factors	Cost reduction in renewables, supportive policies, climate concerns.
Technologies & Resources	Rooftop solar PV, small wind turbines, battery storage, CHP, micro-generation.
Emerging Actors	Prosumers (produce & consume energy), local energy communities, aggregators.
Market Structures	Local trading (P2P), community schemes, microgrids, blockchain-based platforms, smart contracts.
Current Status	Growing globally; extensive adoption in EU, US states (California, NY, Hawaii), and off-grid regions in developing countries.
Opportunities	Consumer empowerment, improved energy security, renewable adoption, new business models (DER management, aggregation).
Challenges	Grid stability, fair tariff structures, equity (avoiding consumer-prosumer disparity), regulatory adaptation.
Regulatory Responses & Trends	Flexibility markets, virtual power plants, aggregators in wholesale markets, evolving frameworks recognizing community energy companies.

The sector experiences benefits as well as obstacles because of this decentralization pattern. With this model, consumers take charge, and the overall security of power supply is boosted because fewer resources are drawn from distant plants, and the use of renewables is encouraged. In the market, there are opportunities for new DER management, funding of installations, and financing various projects (Meng et al., 2024). When several energy sources are injected into the grid, it becomes difficult to maintain its stability, and also needs new rules for fair electricity generation among all participants. Flexibility markets introduced by sanctioning bodies intend to make use of many small resources by directing them to charge or discharge power as needed (Aydın & Yardımcı, 2024). Combining resources on their own, aggregators have become a common group on wholesale markets because this makes their demand bids more competitive. Some parts of the world are seeing increases in the chance for decentralized energy transactions to take off. When decentralized energy becomes less centralized, there is an increase in the surrounding community's

use of renewable energy with digital and regulatory help. Because of technology, new types of community and individual energy dealings are made possible. A number of energy firms are now working together with end-users and platform-based service providers in such a difficult market. Well-functioning distributed power systems are achieved through market processes that unite many assets and still maintain grid balance and reliability.

4. Investment models and economic decision-making

Making investment decisions in the energy sector depends on five main factors, as seen in Figure 6, using financial modelling, scenario analysis, real options, Levelized Cost of Energy (LCOE), and policies, in addition to portfolio strategy. Recognizing these models, energy companies can handle uncertainty and consider risks when planning for their future expansion, since these models join as if they orbit a financial growth icon in a circular arrangement. Since energy companies need huge financial investments, investment becomes essential at every stage of business activity. Economic models let companies choose where to invest in energy generation and which technology to employ. Organizations use financial models to find out the return on their investment. Energy firms use DCF analysis for evaluations by relying on IRR and NPV (Trijayanto & Hakam, 2025). A project is carried out if its NPV turns out positive, and its IRR beats the required hurdle rate. All metrics used to assess energy projects must pay close attention to timely results and factors that are hard to predict.

Various infrastructure, including power plants, go through 20 to 40 years of using established technologies before new technologies and regulations appear. Dealing with uncertainties in the investment process for some investors involves looking at different scenarios and real options (Yang et al., 2023). When using scenario analysis, one can consider several possibilities, while real options theory allows businesses to adjust their bets on certain developments or abandonments according to the outcomes needed. Evidence demonstrates that when uncertainties are very high, organizations that avoid risks will not make their final investment decisions right away. Before investing, investors are required to carry out LCOE calculations. All major construction and maintenance costs during the lifetime of a project, fuel use, and money required for financing are shown in the LCOE value. LCOE comparison makes it possible for companies to see how solar and wind technologies measure against each other. Studying renewable energy cost through the LCOE method demonstrates that prices have gone down and are now equal to those charged for fossil fuels. People use market value models with LCOE, as the moment of electricity generation is not part of LCOE analysis.

Figure 6. Investment models and economic decision-making in the energy sector

The strategies developed by government officials to handle energy and the resulting regulations play a role in investors' decisions to put their money into energy ventures (Cedeno & Wei, 2024). Due to their unviability, many energy projects count on policies like feed-in tariffs and quotas or tax credits and capacity payments to help them succeed. Renewable energy was invested in more by nations that had set-rate or auction systems for buying electricity and provided guaranteed revenue with purchase deals (Balakrishnan et al., 2023; Nasution et al., 2024; Onyemowo et al., 2024). Projects that save energy must be financed either through ESCO contracts or help from the government in terms of incentives. Companies take into account the current rewards and possible new rules before deciding where to invest. Managing risk versus return is possible by combining fossil fuel activities, renewable energies, and transmission of electricity in large energy businesses. Engaging in renewable energy activities gives

businesses a safety net from the ups and downs in fossil fuel prices and carbon rates. To take part in renewable energy, oil and gas corporations analyze risks due to the difference in cash flows from renewables and their regular oil activities. While building the storage infrastructure and the resources for customers, businesses purchase utility networks or EV charging platforms to achieve their goals related to lowering carbon emissions.

Making energy investment decisions in the sector of sustainability is currently shifting to MCDA as its better accounts for the low recognition given to carbon reduction and getting social approval by other evaluation methods (Manoj et al., 2024). MCDA combines watching results and using figures to compare investment projects by considering their returns, how much they contribute to the climate, and their performance in environmental and social areas, and where they are innovative. Extra ways of looking at investments must be used in business because they include aspects that are hard to measure and require professionals' views. All kinds of risks, including those related to changes in market prices, possible credit issues, regulations, operations, and cyberattacks, should be effectively managed in risk management. As soon as possible before construction, renewable developers sign PPAs to help secure the revenue of the energy company. Merchant power plants find it hard to gain enough returns due to the high risks caused by not signing long-term agreements (Cedeno & Wei, 2024). When specialized sector analysis is united with financial analysis, it forms economic models for the industry. Today's businesses use strategies that put together examinations of the market, predictions of policies that might impact the environment, and the use of innovative measures. Since the renewable energy sector is growing and focusing on decarbonization, companies should update their investment approach using carbon risk reviews and consider principles of environmentally friendly finance, which enables them to be flexible and attract investors who care about ESG issues.

5. Regulatory frameworks and policy impacts

Energy businesses operating now rely on the existing frameworks and policies made by the government for support. It is the job of official bodies to closely control energetic entities since the energy industry is one of the most regulated all over the globe (Ahmed et al., 2024). It is necessary to study the current laws and changes in carbon markets and energy rules to present business models and investment plans in different international markets. Based on Figure 7, public policies join forces with regulatory policies to decide how energy funds should be used. The main parts of regulation are market watch, using carbon prices, promoting renewables, and applying ESG in business operations. The collisions of these market factors influence the energy sector's business models as well as how it plans, in turn speeding up changes in the industry's costs.

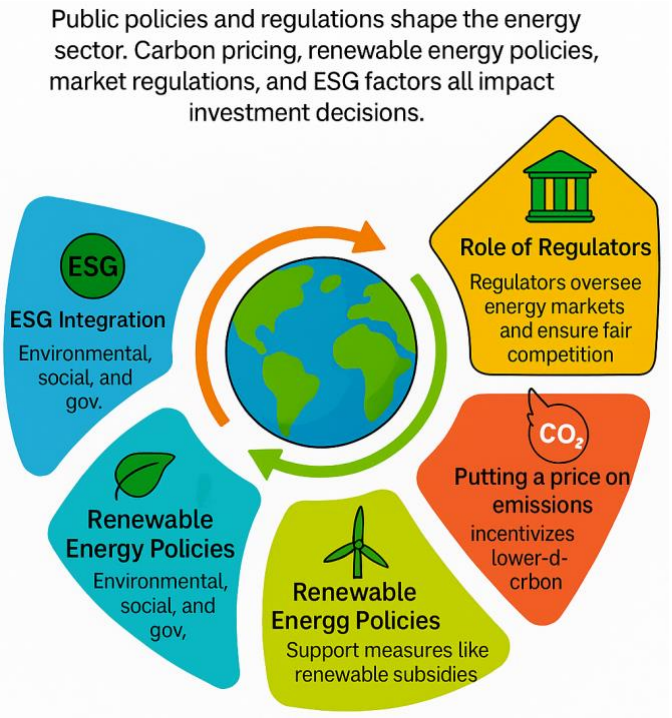

Figure 7. Regulatory frameworks and policy impacts on energy investment decisions

5.1 Role of regulators in energy market design

Market systems with liberalization have regulations focused on checking fair competition within markets and making sure consumers benefit. While doing so, regulators make it necessary for owners of the grid to grant fair access to competing electricity generators and ensure that fees are fair to block anti-competitive practice. Regulatory tariffs decide the process of covering the power grid's cost and have an impact on prosumer credits, which in turn shape several business models. Energy management solutions and demand response aggregators may develop because of time-of-use electricity tariffs and prices set by the authorities in real time. The introduction of fees for rooftop solar could make producers of energy less eager to invest since

these fees reduce the benefits they can enjoy. A lot of jurisdictions are concerned with distributed energy resources regulation since they work on developing balanced policies to add distributed energy resources to the grid.

Regulators consider the modernization of utility functions and how electricity rates are set to be the main challenge they face. Some areas consider using performance-based regulation (PBR) for utilities since it means they are rewarded for higher reliability, strong improvements, and higher use of clean energy, not just for expenditures they have made (Joskow, 2024). Utilities need their rewards in line with the energy sector's goals, so these new regulations are being implemented. Certain countries set up regulatory sandboxes to allow quick changes in some rules, so new services and technology (related to vehicle-to-grid or peer-to-peer product exchange) can be tried with real users.

5.2 Carbon pricing and emissions trading schemes

Energy businesses must face major changes due to carbon pricing policies that were recently introduced. The way this method works helps to lower emissions and encourages greater use of alternatives that give out less gas. Carbon pricing reached further into the real world in the middle of the 2020s, using both emission-trading and carbon taxes that several countries around the globe enforced. Last year, 75 carbon pricing instruments collected over 100 billion dollars. Emissions across the globe recently saw their carbon charges rise to 24%, while they stayed at just 7% a decade before (Tao et al., 2024). It is the biggest carbon market, and it manages emissions rules for the power and heavy industries in all EU member countries at once. Within the cap-and-trade system, companies have to own CO_2 emission rights that are determined by economic demand and supply. Prices of EU carbon credits will likely stay between €50–100 per ton until 2024, changing the expense of energy generation. The introduction of the EU's Carbon Border Adjustment Mechanism will change how imported products are dealt with in search of carbon neutrality.

Examples of carbon pricing are the WCI in California and Quebec, RGGI used under the U.S. power plant system, and the UK and New Zealand's national carbon pricing, plus South Korea and China's new power sector ETS. European places and Asian regions, including Singapore, enforce carbon taxes, while countries across Canada do the same (Papy et al., 2024). Despite the range of carbon pricing options at different financial levels, companies are implementing them more and more. Prices of fossil fuels go up when compared to energy from renewable sources and nuclear, which leads electricity companies to prefer cleaner ways of generating energy (Onyemowo et al., 2023). Many companies see internal carbon pricing as an essential step for planning their business. Money from carbon pricing can be spent to establish more efficient energy systems or delivered as payment to households. Though more countries are embracing carbon pricing, tariffs should be increased to match the objectives set by the Paris Agreement. The size of the markets having to pay the necessary price range ($50–100/ton) equals less than 5% of total worldwide emissions (Forsberg & Foss, 2023). Both regulations and subsidies from the government aim to get businesses to manage between these two systems.

5.3 Renewable energy and clean energy policy instruments

Figure 8 displays the policies available for promoting development in renewable and clean energy infrastructure. This figure highlights what can be done with policy instruments to guide the world's energy transition to sustainability. A globe-shaped structure shows that the building cares about renewable energy, displaying both wind and solar energy sources (Ponnambalam et al., 2023). Anyone will notice that four policy instruments are arranged around the main graphic in the figure. Feed-in Tariffs give money above the average price to companies that produce sustainable energy, promoting such investments. The utilities are forced to add more renewable electricity to their lineup thanks to Renewable Portfolio Standards, which raises the demand in the market (Denholm et al., 2021).

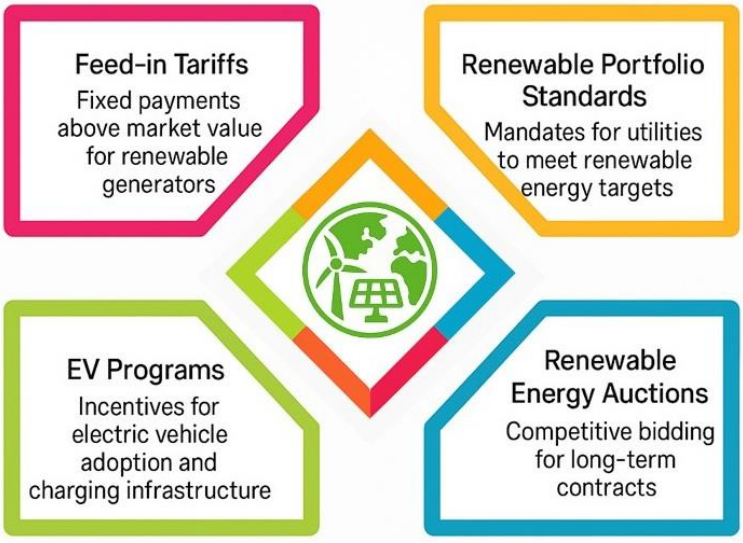

Figure 8. Renewable energy and clean energy policy instruments

They provide money for electric cars while building new charging stations to decrease emissions from driving. Bidding for renewable energy arrangements in auctions helps to reduce costs and improve how they are carried out. They build a framework for clean energy advancement and look after the environment. Besides carbon pricing, other energy-related rules affect how the market operates. Some renewable energy promotion policies from the last decades are based on feed-in tariffs (FITs), which pay above market rates to renewable generators, renewable auctions for long deals (Azhgaliyeva et al., 2024) and also require utilities to reach specific percentages of renewable energy by using renewable portfolio standards (RPS). Wind and solar energy were more widely available in Brazil, India, South Africa, and in many U.S. states thanks to these policies (Mejica et al., 2022a). Because of public policies, new firms and utility companies have the assurance of finances, helping them initiate clean energy projects. Boosting the sector with funds obtained through the Production Tax Credit and Investment Tax Credit made it possible for the United States to develop wind and solar energy further. The Inflation Reduction Act of 2022 made it possible for clean energy companies to gain support from new storage and hydrogen credits, along with the existing ones. Various nations offer finances to help reduce energy consumption and introduce EV programs so their customers are more likely to buy such cars, while encouraging companies to make chargers available.

Organizations that regulate the industry can introduce changes to the energy commercial sector. The EU and some American states are taking steps to stop using cars with internal combustion engines by 2035, so the demand for electricity for transportation will increase. Governments in Europe and Canada are urging power utilities to either switch to green energy, gas, or import it from elsewhere, which means installing new power plants instead of coal (Möring-Martínez et al, 2024). Nationally, decisions about using nuclear power vary because some countries, like Germany, shut down their reactors while others extend theirs or add new ones, which is important for market patterns in the power sector. The recent high energy prices made people rethink the design of electricity markets. Authorities in the EU are still debating ways to improve the electricity market, as letting gas take over from other sources causes electricity costs to rise due to the recent experience in 2022. Some of the possible strategies include splitting markets and including capacity payments for firm resources and possible extensions in long-term contracts (Weyman-Jones, 2023). The decision on how to carry out energy market transactions will affect whether long-term deals with another company or short-term spot buying will be chosen, and it will also set rules for managing price risks. Several places have begun capacity market or auction programs to ensure adequate generating capacity, so only availability is paid for rather than the actual amount of energy produced.

5.4 ESG Integration and policy-driven investment behaviour

Technical knowledge cannot replace having strong planning and compliance in the business world due to the challenging rules in different industries. For this reason, companies create groups that study and push for better policies, because valuable additional business and earnings result from favorable regulations, but unfavorable policies may jeopardize their main assets, such as their first-line gas pipelines. It is now popular practice for many energy firms and associations to actively push for fair rules in energy storage and demand response markets by becoming involved in regulation development (example). Because of changes in policies, Environmental Social and Governance criteria, and sustainable finance have been valued more in the financial world (Dmuchowski et al., 2023). Now, financial companies regulated by some agencies focus on understanding the risk climate change brings to their financial assets, while other authorities are planning to require companies to publicly state their climate-related risks. The degree of carbon emissions by energy companies leads to spending more on borrowings and the withdrawal of investments by interested investors. The money needed for projects that help with climate goals is currently provided by both governments and development banks. Environmental, social, and governance (ESG) investment assets now make up $30 trillion across the world, showing the rising support for ESG. Under the EU's sustainable finance plan, transitional projects for natural gas will be favoured for financing in energy projects over renewable ones.

In their economic strategies, companies join forces in carbon trading and help offset emissions through green markets. Those energy companies that achieve their emission reduction goals receive money by selling surplus permits, yet those that emit more must pay for them. Several organizations in the energy sector deal with their carbon emissions by either planting trees or capturing carbon dioxide in special projects. Oil and gas companies now acquire nature-based offset projects and carbon removal methods, which they expect to use to ensure zero emissions in future products (Christiansen et al., 2023). Every energy trade is guided by the right regulations and policies. In 2015 and afterwards, more countries have started adopting climate policies in the form of broader carbon pricing and stricter energy requirements for the market to accommodate new technology (Dmuchowski et al., 2023). Market status updates include adding carbon trading platforms, controlling transport and energy costs, enabling competition, and setting product requirements. Energy firms must remain flexible to policy changes that may require economic strategy adjustments. The connection between policies and energy businesses remains crucial for achieving energy security and sustainability.

6. Emerging innovations in energy markets

Modern technologies keep changing both energy commerce and business economics over time. Recognition of new technology and changes in business procedures are introduced for the trading infrastructure and financing the improvement of energy systems. Blockchain, transactive energy technology, energy FinTech, coupled with green sustainable solutions, are the main reasons for changes in the energy industry. Innovation based on blockchain allows three industries in the graphic to function through peer-to-peer energy, FinTech funding, and renewable energy for a greener approach.

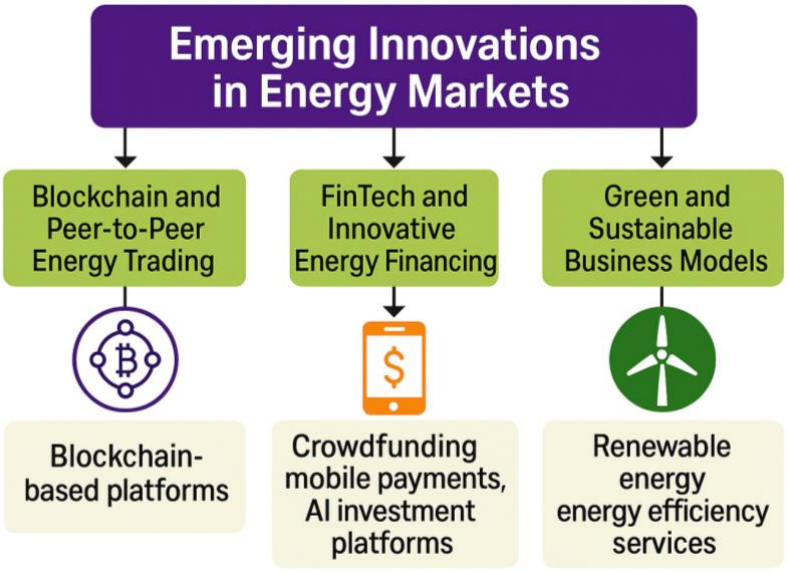

Figure 9. Emerging innovations in energy markets

6.1 Blockchain and peer-to-peer energy trading

A core part of cryptocurrency called Blockchain encourages the development of applications in energy by giving networks new ways for decentralized trading. The basic blockchain system is a decentralized ledger that provides secure and clear storage of data, not needing anyone to supervise it directly. Due to the adoption of this technology, the energy market makes it safe for prosumers to trade with each other and handle their energy and certificate deals automatically. Operations in the energy market make use of blockchain since it helps deal with numerous small transactions effectively. All deals of homeowners selling one unit of solar power to their neighbors are added to the ledger using smart contracts that convey the agreement and conduct the necessary payment automatically. The implementation of tests proves that blockchain technology bypasses middlemen and sets up direct business relationships between market players (Gitelman & Kozhevnikov, 2023).. All homes on the same community network, equipped with solar panels, could send their extra energy directly to local residences with the help of blockchain technology. Blockchain technology keeps an eye on energy trades and completes settlement duties, so there is less money spent on administration. Blockchain introduction helps form business relationships between electricity suppliers and customers, as reported by Dehshiri et al. (2024). In addition, blockchain enables all users to tell whether a trade has settled properly, thus contributing to the confidence in the market and avoiding unfair treatment.

REC trading and managing carbon credits now rely upon blockchain technology. Because Energy Web uses blockchain to keep records, they and their partners in Europe can trade certificates at any time. With a blockchain system, companies have the opportunity to follow their energy needs and meet their obligations, since the crypto-log continuously saves records of all events involving energy certificates. Blockchain's use in energy is still in the early stages since it deals with some significant challenges (Bhattacharjee et al., 2024). Bullying up blockchain at a national level encounters numerous technical difficulties, as the first platforms burned a lot of power and could not operate well. Nevertheless, new platforms solve this inefficiency today. Most energy markets are restricted by regulations, as they will not allow blockchain-based transactions for energy deals. Most energy organizations see the fluctuating features of blockchain systems as a risk for their operations. An increasing amount of money is going into the blockchain-in-energy industry as experts expect many billions of dollars to be invested in this area in the forthcoming decade. Blockchain makes it possible for upcoming market transactions in this sector not to be controlled by any single company. This technology is the infrastructure that allows independent transactions in the energy field, which is called the Internet of Energy, to take place using its technology. If there are schemes that include blockchain, cybersecurity, and fair access along with regulation, future energy markets will have decentralized distribution and remain transparent, all the while working smoothly.

6.2 FinTech and innovative energy financing

FinTech technology solutions help the energy sector by creating crowdfunding platforms for community energy projects, introducing mobile payments for new business ideas, and using AI and digital tools for collecting sustainable funds, as illustrated in Figure 9.

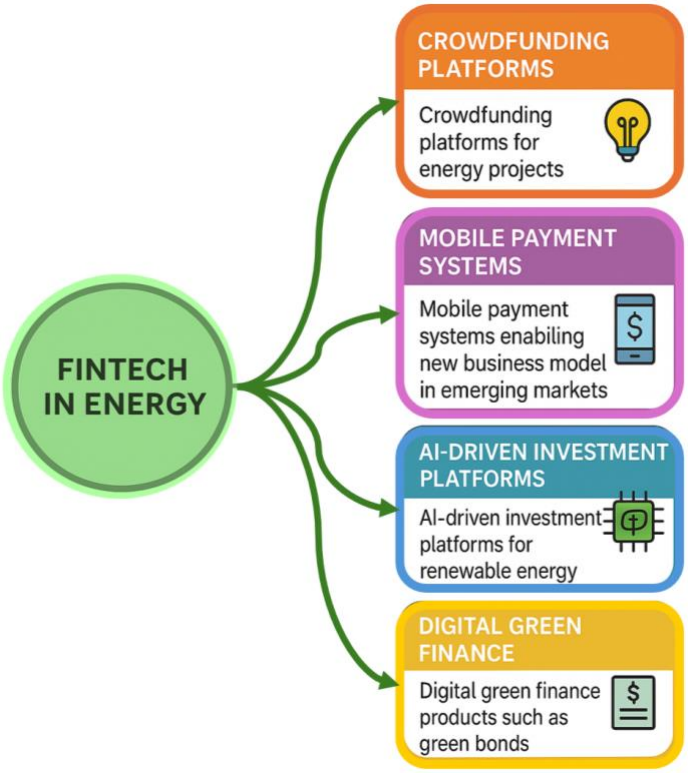

Figure 9. FinTech Applications in the Energy Sector create better access to sustainable global energy financing solutions

The use of new technologies in financial technology causes improvements in traditional services provided in finance. More and more, FinTech is shaping how energy projects are funded and payments for power are made by customers and sustainable ideas are supported. Many parts of FinTech, including support for crowdfunding energy infrastructure, offer new payment systems, as well as AI and green-bond applications, are boosting the energy industry's developments in both mature and growing markets (Omeragic et al., 2024). Funding for energy projects has become more available to people through the help of FinTech. Most traditional projects needed many complicated organizations and detailed plans to arrange their financing. Thanks to today's crowdfunding and peer-to-peer lending sites, ordinary people can take part in solar farm and wind turbine projects that also feature energy efficiency measures. The platform, Trine, together with Solarize, has allowed many people to contribute to clean energy by investing in solar panels collectively. This process makes it possible for project developers to use different sources of money and makes people in the community see more value in renewable energy.

Energy supply in developing nations has improved a lot because of FinTech changes using pay-as-you-go (PAYG) models. Businesses in South Asia and Africa add mobile payments to solar home systems so poor families are able to use electricity in their homes. People living without regular bank services can now rent solar panel and battery systems each week or day through payments processed by mobile money. Furthermore, the payment and credit review processes (using AI and mobile database details) are parts of FinTech operations. This idea came from M-KOPA and Off Grid Electric, and it has made it possible for millions of households to get electricity. Sustainable energy companies are made sustainable by financial innovation, which matches payments with people's mixed incomes. The application of FinTech allows investors to use capital better for investment in energy projects. Advanced techniques in data analysis assist investors in judging the success and risk of renewable projects with better results. Banks use FinTech systems, which gather weather pattern records, plant benchmark data, and energy statistics to support them with important loan decisions. Currently, trading of energy and carbon credits is done automatically, and artificial intelligence (AI) continuously improves the performance of investment portfolios. Acknowledgements to FinTech, the process of overseeing green bond and sustainability-linked loan funds as well as their effects has become simpler (Teng & Shen, 2023). A number of startups join the use of blockchain with solutions for green bond protection and matching partners with projects that help the environment. Now, citizens make clean energy funding possible by using platforms, organizations, and carbon markets, besides regular loan and equity funding sources.

They are now able to determine how Fintech is involved in the energy sector. An increase in using renewable energy at the city level in China was made possible by FinTech because it helped operations and gave extra financing to such projects. Through FinTec, more funds can be made available and new chances are given to green financial products with diverse solar projects in urban zones (Omeragic et al., 2024). Because of these mechanisms, more funds can be given to renewable energy projects and the required technology, which makes the process faster. Through FinTech activities, financial options become available to many, transactions run smoothly, and there is a stronger push to make

financial decisions ecologically friendly. The use of FinTech helps suppliers and recipients face fewer difficulties when working with energy funds. With over $30 trillion in invested funds, those interested in sustainability are bound to find FinTech tools for connecting capital with energy projects helpful and more relevant through crowdfunding and other solutions, as well as green cryptocurrency (Teng & Shen, 2023). FinTech companies join hands with organizations in the utility and energy sector to introduce new ideas, such as monthly installment plans for home improvement on energy bills and apps that reward people who manage electricity efficiently. They work on connecting different payment systems to support right power usage. When technology components, finance aspects, and energy systems come together, the business capital flows easily to support the required projects for sustainability in energy.

6.3 Green and sustainable business models

Energy companies are encouraged by sustainability to improve their business methods to support both the economy and the environment (Table 4). Three services involving renewable energy, efficiency, and clean energy projects are innovative models that give value to customers (Unpaprom et al., 2015; Reansuwan et al., 2024). It was clear from the review that ESCO (Energy Service Company) is paid for saving energy resources. In the present time, the main business model is Energy-as-a-Service (EaaS). Paying for energy means covering the entire package and not just buying specific energy unit types like kWh and BTUs. Paying more attention to the environment comes with using new comfort systems in commercial buildings. Before any charges to the customer begin, service providers get solar panels(Mejica et al., 2022b), smart thermostats, batteries, and LED lights (Bhat et al., 2024). Requirements to the solution, providers can keep making a profit while guaranteeing their customers' financial health leads to better system success. Servicing these clients requires more money than what the provider needs to make a profit. According to studies, EaaS firms attach efficiency in energy use to coming up with renewable technology and storage solutions for groups. This way, organizations without in-depth information about power can still access clean energy. This approach helps to make sure that energy technology is included in EaaS business models (Brown et al., 2022). Because of changes in the market, manufacturers now sell packages that include delivery instead of just selling products. The HVAC providers sell a cooling service which means they keep the chiller systems and the building owners only pay for the cooling used. They gain from this service by increasing productivity and having consistent results.

The use of a VPP aggregator is a great way for a business to be environment-friendly. A Virtual Power Plant allows managing multiple solar systems, batteries in homes, electric cars, and controllable residential devices with the help of software to run them as if they were under one roof. The operator of the VPP earns money when it handles energy from millions of devices and manages to bring down energy usage across several utility suppliers and wholesale markets. Those who use the contactless method enable the operators to look at the device during payment and help them get savings (Gitelman & Kozhevnikov, 2023). It relies on renewable energy and storage devices that are able to perform the main function ever handled by peaking stations using fossil fuels. Businesses are making their energy sustainable by regulating the changes in renewable energy along the power supply. The framework brings both controls and market methods to link AI and IoT networks, helping Germany and Australia, and the United States increase their operations. It has now become common to incorporate green retail electricity costs and energy trading platforms in business. Currently, suppliers try to sell high-level priced electricity products that use renewable energy sources or make such products available at no cost when renewable energies start matching the prices of other fuels. People who looked for independent energy providers helped power companies establish themselves by focusing on sustainable practices. Energy customers can pick from various options while businesses keep tracking their carbon emissions and integrate their systems with homes to create more value.

Table 4. Emerging green business models in sustainable energy commerce

Business Model	Description	Examples
Energy-as-a-service (EaaS)	Fixed-fee integrated energy services	Commercial buildings, campuses
Equipment-as-a-service	Pay-per-output equipment use	Cooling, heating, and solar services
Virtual power plants (VPP)	Aggregated, software-controlled distributed resources	Battery networks, flexible EV charging
Green retail tariffs	Renewable energy supply products	Renewable tariffs, green marketplaces
EV charging infrastructure	Innovative EV charging business models	Subscription-based, solar bundling
Circular economy (Batteries)	Leasing, reuse, and recycling of batteries	EV battery second-life storage

Sustainable EV transportation systems are built by using effective business models in EV charging systems (Yong et al., 2023). Network management fees have special pricing by inviting members to pay and ads to be shown, so members can use the services without cost. Because these companies have solar systems, batteries for homes and EVs, they can supply their customers with complete renewable energy solutions. Systems in this sector make new energy buying and selling processes without affecting traditional utility methods. Battery leasing is one of the innovative concepts that come out of circular economies and their recycling activities. The capacity left after using EV batteries allows them to be used for storage before they are recycled. Using the system,

businesses gain income from their assets, customers do not pay more than the regular fee, and the system wastes the least amount of batteries. Since the number of used batteries keeps increasing, we will begin to rely on more sustainable models. Businesses tend to use sustainable strategies because of ESG finance and changing consumer demand. Taking a clear green approach, organizations can obtain climate solutions as well as clean technology investments. Investors who put money into green bonds are assured of financial benefits and enjoy the advantages that come with the use of solar energy and energy conservation. Energy solutions that come from sustainable sources are valuable for businesses because more consumers care about environmental concerns. Due to new approaches such as EaaS and ESCOs, and VPPs, markets are no longer only interested in commodities but in offering solutions. Technology, finance tools, and the ability to build good customer relationships are the basic parts needed for these models. They confirm that these operations are sustainable since model validation is necessary for them, despite being known solutions for sustainable development. Such business models will play a greater part in the industry since they connect operating a company successfully with using zero-carbon resources.

7. Current barriers, risks, and market volatility

Regardless of the positive developments, the sector faces many obstacles and threats that could slow down its progress or become a problem for businesses (Table 5). Also, the energy markets experience a lot of changes that can cause uncertainty and offer new opportunities at the same time. In this part, we will list some of the biggest difficulties, dangers, and trends that lead to high volatility in today's energy business.

7.1 Regulatory barriers and legal challenges

Making progress can be difficult if the regulations in place are too old or too tough. There are many regulations meant for big utilities that can stand in the way of new energy models. Certain places have rules preventing people from selling energy from one person to another. Smaller companies may have to pay more for licenses than the already established ones. Rules on what retailers can charge can negatively impact suppliers' profits or discourage launching extra services. Because the rules for energy storage and aggregators are not clear, it takes longer for them to be active in the market. Since laws tend to lag technological advancements, sometimes new inventions are unable to grow promptly. When standards for rooftop PV and batteries change, that means years of solar adoption may be missed. Rate-basing restrictions on digital infrastructure or EV chargers could keep electric utilities from making important investments. Having no clear direction on policy makes things risky. Former support from governments has created sudden upswings and downfalls in the renewable sector. It is difficult to make sustainable investments because the rules for carbon emissions are not clear for the long term. The cause of regulatory barriers is either very tight or unreliable regulations. According to the survey, problems such as weak laws, no set rules, and missing policies prevent the introduction of new technologies.

Table 5. Key Barriers, Risks, and Volatility in Energy Commerce

Category	Key Challenges
Regulatory barriers	- Outdated or restrictive rules (e.g., limits on peer-to-peer trading) - High licensing and compliance costs - Slow regulatory updates vs. fast tech evolution - Unclear legal status of storage and aggregators - Policy uncertainty hindering long-term investment
Financial and market risks	- High capital needs and financing difficulties - Fuel and electricity price volatility; geopolitical market shocks - Risk of tech obsolescence and underperformance - Cybersecurity threats to digital infrastructure - Labor shortages and supply chain bottlenecks
Geopolitical, climate, and tech risks	- Energy disruptions from geopolitical conflicts - Climate-related events (e.g., wildfires, storms) impacting supply/demand - Stranded asset risk due to climate transition policies - ESG-related reputational risks affecting investments
Consumer behavior and adoption barriers	- Consumer inertia and low awareness - Trust and convenience concerns for adopting new solutions - Volatility leading to risk-averse attitudes - Difficulty in scaling consumer participation in innovative models (e.g., P2P trading)

7.2 Financial and Market Risks

Many energy projects are affected by usual business threats as well as certain specific risks in their industry. It takes a lot of capital to start most clean energy projects, since their benefits come over time. It may not be hard to start a business that makes money, but assembling the capital at first is not always simple in developing

countries. Projects may be stopped if the risk involved in them is seen as too high. Prices in the energy markets are still changing and could harm the economy. As recently seen in 2021-2022, ultra-high energy prices all over the globe led to major problems, including selling out UK energy suppliers and leaving utilities globally in financial trouble. They prove that unexpected events in the world can still lead to risks for the market, regardless of its condition. Even though businesses use hedging, it does have its own limitations. More challenges are caused by technological changes and possible issues with performance (Yong et al., 2023). When businesses focus on certain technologies, they could end up behind others in the market. Smart meters could eventually be outdated by even better technologies, and so could batteries, as new inventions come along. The use of new technologies in the grid increases the risk of cyber-physical issues, since such systems can be hacked or their software may fail. The more items that link up to the infrastructure, the higher the risk of cybersecurity threats. Gaps in the workforce and supply are creating more problems. A lot of workers with new skills are required due to the energy transition. Shortages in skills among employees can delay ongoing work, which also creates different economic issues. Difficulties brought by supply chain issues can prevent the use of solar panels, battery materials, and grid transformers and add to their cost. Any critical mineral windfall for batteries could impact the growth of EV and storage markets and place those companies in danger.

7.3 Geopolitical, climate, and technological risks

Energy and politics have always been related. Markets and the supply of goods can be disrupted for companies and countries by geopolitical happenings (Wang et al., 2024). Because of the Ukraine war, energy prices rose in Europe, and the region switched its supply of gas, worked on its energy safety, and hastened renewables. Rising geopolitical tensions may lead to the imposition of sanctions that affect buying and selling energy (Shu et al., 2024). Prices are influenced by OPEC's decision to change the output of oil, having an effect on oil companies, utilities, and renewables through the market. Climate change poses both physical and transition risks. Severe weather incidents threaten infrastructure, causing supply fluctuations. The Texas freeze of 2021 showed weather changes can disrupt market stability, as power outages led to higher prices and financial problems.As governments move toward climate goals, the coal industry has to shut down early, and natural gas facilities are at a serious long-term risk (Yong et al., 2023). Companies should watch for asset write-downs and invest in lasting assets. Negative investor views on sustainability can lead to exclusion and reduced funding ability. Strong ESG performance may increase inclusion in sustainable funds.

7.4 Consumer behavior and adoption barriers

Marketwise, consumers keep happening across many hindrances. Even during prosperous economic times, some of us may not easily switch to new energy products because we are unaware, do not trust them, or find them inconvenient. Residential customers may not alter their habits or go with another energy supplier because of how complex switching can be. Setting up peer-to-peer trading or demand response is not easy unless the process is understood by many consumers. It is challenging to build customer trust in new technologies from both a social and technical angle. When investors or policymakers become too cautious due to systemic risk and volatility, it may cause extra problems. As a result of the 2022 European energy crisis, a few people began to discuss if authorities should take over price control or swap short-term deals for long-term contracts to ensure consumers do not face risks as much (Shu et al., 2024). Because of such changes, new business opportunities may appear. Adaptation to changes in policies becomes vital when registering big fluctuations in the markets. As energy trade turns toward new and greener ways, problems from uncertain rules, possible losses, and shifting markets arise. For a company to succeed, it must manage risks through holding diverse assets, hedging, building good stakeholder ties, and enduring through challenges in the markets. The structure of policies should give clarity about carbon, regulate new technologies as needed, and support the grids. This transformation in the energy sector can be achieved if everybody works together, such as industry, regulators, and policymakers.

8. Future directions and strategic opportunities

In the future, the changing environment in energy commerce and business economics will continue to be shaped by new trends and changes in thinking. Next, we mention a number of important future directions that are attracting recognition: Energy-as-a-Service models are being adopted, ESG finance and sustainable investing are gaining popularity, artificial intelligence and big data are being mixed into energy systems, and the circular economy is being adopted. These directions offer a chance for new changes and also new issues to overcome as the energy industry becomes greener, sturdier, and rewards its customers. The figure points out how four areas will determine the future of energy commerce: Energy-as-a-Service offers managed energy to fit customers' needs, ESG Finance directs investments into sustainable projects, AI and Big Data help operate and predict energy resources, and the Circular Economy stands for reusing and recycling resources. With these directions, energy systems will become more sustainable, intelligent, and aimed at helping users (Figure 10).

8.1 Energy-as-a-Service (EaaS) and servitization

Energy-as-a-Service is all about buying energy as a service, not by buying the actual commodity. More EaaS solutions will likely be available due to what consumers choose and the way technology evolves. What end-users care about are cheaper bills, less effect on the environment, and a strong energy supply, and not the actual amount of energy provided in kWh. They do this by joining solar, battery, efficient tools, generator, monitoring, upkeep, and enhancement services together and requiring users to pay monthly subscriptions (Wang et al., 2024). It simplifies tasks for the users.

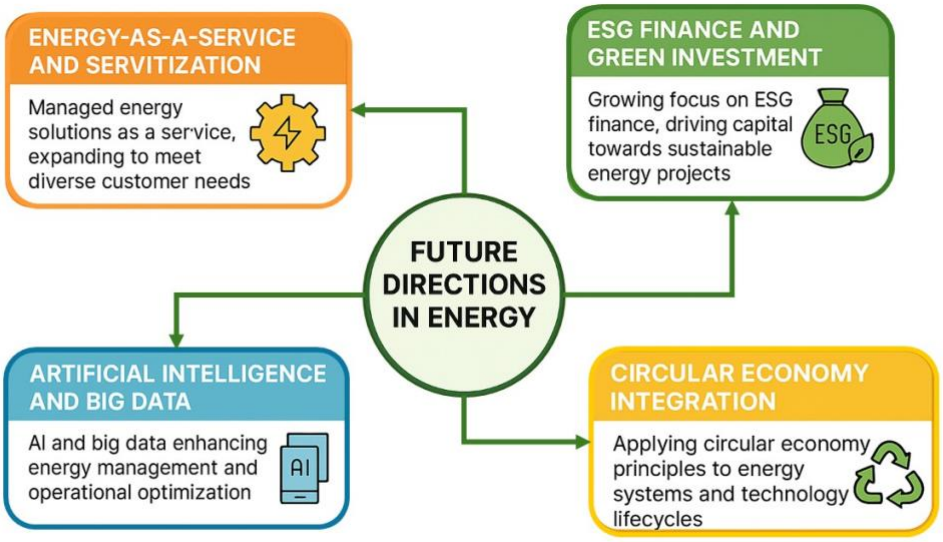

Figure 10. Future directions and strategic opportunities in energy commerce

With more distributed energy, it's hard for people to handle management the right way; EaaS providers handle this by automating, so you always get the results you expect. It is much the same as cloud computing – you pay for computer capacity you need, not for servers (Gitelman & Kozhevnikov, 2023). Microgrids may provide support to communities, companies may benefit from "solar + storage" options, and EV fleet managers can sign up for complete "mobility-as-a-service" packages, including charging stations. These companies are changing from selling electricity to providing a variety of services, as they already join forces with ESCOs and businesses that manage energy at local levels. Adopting EaaS more broadly may help control energy use more smoothly and efficiently, since this helps EaaS companies earn more. Supplying renewable energy and energy-savings become part of the agreements between businesses and their energy providers. As a result, businesses can follow climate goals more easily and may speed up the process of reducing carbon emissions, as EaaS helps save energy.

8.2 ESG finance and green investment

The influence of ESG criteria on finance is rising, which will have a major effect on energy commerce. Many investors are making decisions by looking at a company's ESG results, encouraged by the importance of transparency (Arenas et al., 2024). Those energy companies that focus on sustainability often benefit from lower costs, compared to those who work more with fossil fuels, which could mean facing high expenses or selling commitments. Resources are moving to clean energy, smartening up the power grid, and improving low-carbon technologies. Since $30 trillion is currently invested sustainably worldwide, joining that movement can have great influence on energy projects. Various new instruments, including green bonds and sustainability-linked loans, attach certain terms to sustainability – this helps companies comply with their climate targets. Institutional investors are involved in corporate governance, which includes projects such as Climate Action 100+ changing oil and gas companies' decisions. Overlooking these changes can harm a company's reputation and make investors lose their money (Malik & Kashiramka, 2024). ESG finance could direct companies away from things that hurt society and towards things that benefit society. In developing countries, governments are taking part in financing clean energy projects with help from investors. From 2023, companies will face more barrier in the market and loan conditions for poor sustainability reporting of emissions, climate risks, and circularity, mainly due to European and international regulations. Businesses that work to shift toward a clean environment will gain advantages, unlike companies that take their time.

8.3 Artificial intelligence and big data in energy

The use of artificial intelligence (AI) and big data analytics in energy commerce is likely to increase and support better operations and more services. Always, the energy industry has required a lot of data (forecasting electricity demand, weather changes, and similar), but the accessible amount of data has never been so impressive. By using machine learning, AI programs can forecast renewable energy production and energy prices with a lot more precision than older methods (Kristian et al., 2024). AI models can make their predictions more accurate by paying attention to several variables (such as weather, events, the way language has been used in history, and buzz on social media). Trusting in better forecasts, energy companies spend less on balancing their supply and demand, and make it easier to add renewables to the grid. We discussed earlier that AI and ML have been proven to raise the accuracy of predicting demand and generation. As a result, operating costs go down and fewer backup units are needed, which is good for the economy (Entezari et al., 2023). One more important field is maintaining and optimizing assets. The people who work in utilities and plants are making use of

Through AI, turbines, transformers, and pipelines data is

checked to identify potential failures earlier, allowing companies to act before something happens and shorten the time a machine is out of operation. AI ensures that power plant or wind farm operations are improved on a regular basis for the best results. AI in trading makes energy trades at speed many times faster than anyone with manual processes can. Smart energy management is made possible for consumers through AI. Smart thermostats adapt to people's preferences and the building to save energy while making the rooms comfortable. AI is used by aggregators to handle home gadgets and respond to energy demands. As systems at home get larger (PV on the roof, batteries, charging for electric vehicles, and smart appliances), AI will handle them for your benefit or for the grid's needs. AI drives automatic planning and redistribution of power on energy grids after parts of the network are not functioning. The use of AI and big data brings certain issues: the importance of good data, risks to critical infrastructure, and rules about the unclear process behind AI decisions. Even so, there is a big chance to increase efficiency. It is estimated that digital solutions could help cut utility expenses by around 20-30%mdpi.com and enable managers to handle big and complex tasks. The use of AI will improve the standing of energy businesses among rivals. Companies using data for customer insights or to make better use of their assets will perform better than others (Wang et al., 2024). Utilities are allowed to make money from anonymous data on the grid for planning new infrastructure. More cooperation is emerging between tech firms and utilities; tech companies are already leading in handling home energy and might change the way people buy power through smart home platforms.

8.4 Circular economy integration in energy systems

In the energy sector, the circular economy idea is becoming popular because it reduces waste and makes the life cycle of energy technologies more sustainable. In the past, energy discussions mainly looked at the operation stage (whether fueled or not, and the emissions produced at that time). Nowadays, what energy infrastructure systems are made from and what happens to them after their end-of-life is very important for sustainability and resources. By using circular economy methods, we should create energy products that last a long time, can be used again, and can still be recycled, instead of letting waste end up as garbage. Another factor is the number of resources that are necessary for clean energy to work. All over the world, solar PV systems are being set up more rapidly, and the panels can work for 25-30 years. It is estimated that during the 2030s and 2040s, a lot of solar panels will no longer be in use. Greenpeace says IRENA expects that the annual waste from solar panels could be 200 million tons by 2050 in a world that uses more renewables. If waste is not managed ahead of time, then it becomes a challenge to handle what is thrown away. At the same time, decommissioned panels are made up of materials such as silicon, glass, and silver. By following circular economy ideas, we can reuse these materials. IRENA predicts that in the year 2050, PV recycling could provide 17.7 million tons of materials valued at $8.8 billion, encourage new industries, and lower the need to obtain fresh raw materials (Nikolina, 2016). Batteries for electric cars and wind turbines' blades (mainly centered on fibers and resins that are usually hard to recycle) have similar recycling problems. Nowadays, businesses are exploring new ways to help electronics and wind turbines be more easily fixed and updated. As a result, this leads to new business Tokyo Car Center in recycling and using energy materials for different purposes. Utilities could work with or build subsidiaries to take care of used renewable assets and turn what is considered waste into useful resources. New markets are appearing, in which used EV batteries are saved for power-station use and then recycled to take out more value.

The thought behind a circular economy is to use waste as energy and promote links between companies (Palanisamy et al., 2022). Although using waste for energy causes some environmental concerns, better ideas are using organic waste to make biogas, heating homes with industrial waste heat, and converting CO_2 into synthetic fuels (power-to-X), recycling carbon (Tongmee et al., 2023; Yongphet et al., 2024). Because of these approaches, energy, waste, agriculture, and manufacturing are linked, making it possible to close the loops (Oteikwu et al., 2024; Pandi et al., 2024). Oil and gas enterprises are figuring out how they can use their experience managing CO_2 by making it a service, for instance, using the substance for algae to make biofuels (Behera et al., 2021; Bhuyar et al., 2022; Pathy et al., 2022). Making recycling official through policies (such as those on battery recycling in the EU, with more PV recycling being created) will help achieve this objective. Sometimes, businesses keep their panels or batteries until they need to be collected, so produce them to ensure long life and better recycling control. If we use circular economy, recycling EV motors and wind turbine magnets could help avoid running out of rare earth elements because a few nations control their mining. It is obvious to policymakers that security policy is useful, as it acts as a backup plan for economic and political safety. The future of energy business aligns with sustainable development and new technology. Our energy approach aims to be helpful, environmentally friendly, advanced, and resource-wise. Through transformation, AI adoption, ESG practices, and circular planning, companies will lead the industry forward. Enterprises with outdated models may struggle as regulations tighten. We must ensure these changes create a future where sustainable energy supports economic growth.

9. Conclusion and strategic recommendations

The article points out that energy commerce is moving from old, single-source systems powered by fossil fuels to new, multiple-source systems that are more digital and greener. Digital advancements and reforms in the market have raised the level of efficiency and helped customers but have only brought mixed success when it comes to saving money. Because of decentralization, more power is given to people and communities, which now requires different ways of managing both the market and the grid. Amongst their contributions, blockchain, FinTech, and AI make it possible to trust the industry more, have more flexible ways to borrow, and improve how things are run. Energy companies must start using flexible and green strategies; policymakers should update their policies, sustain their

frameworks, and back balanced changes; investors should handle the ups and downs, choosing in favour of sustainability; and consumers can make better choices now that they have more options and should still learn about the changes ahead. New recommendations call for the use of Energy-as-a-Service, ESG finance, AI, and circular economy ideas to lead toward a cleaner, linked, and active energy system in the future. Even so, with transportation, industry, and urban infrastructure expected to join forces, the mix might be limited by issues such as technology, geopolitical changes, and variations in the economy. It is important that the next decade works on launching pilot projects for new ideas, pumping greater money into reforming the power network, and creating markets for flexible energy. All types of policies in the economy, environment, and industry should include circular economy approaches. To allow the industry to change, it is necessary to develop the workforce and educate consumers, along with strong monitoring and flexible policy changes. To sum up, although it requires great effort, the move offers plenty of benefits. It will be very important for technologists, policymakers, economists, and entrepreneurs to team up to ensure a smart, fair, and clean energy future.

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