



## The Present Situation of Renewable Energy in USA

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### ABSTRACT

The United States has experienced significant growth in renewable energy deployment over the past decade, with renewables now accounting for over 22.5% of total electricity generation as of 2023. The leading sources include wind, solar, hydroelectric, biomass, and geothermal energy, with wind and solar showing the most rapid expansion. Wind power remains the largest contributor to renewable electricity, generating 10% of the nation's electricity in 2022, while solar energy has surged, reaching 220 GW of installed capacity by 2024 and providing over 7% of national electricity. Battery storage has also emerged as a critical component, nearly doubling in capacity in 2024 to support grid reliability and integration of variable renewables. Despite these advances, the sector faces challenges including grid congestion, permitting delays, high interest rates, and supply chain disruptions. Policy uncertainty and administrative hurdles further complicate progress, especially in wind energy development. Nevertheless, falling costs of clean technologies and strong market demand continue to drive investment and innovation. The U.S. remains the second-largest consumer of renewable energy globally, and projections suggest that renewables will dominate future utility-scale power capacity additions, with solar leading the charge.

**Keyword:** Wind power, Solar energy, Hydroelectric power, Biomass, Geothermal energy, Battery storage

### I. Introduction

The United States stands at a pivotal moment in its energy evolution<sup>[1-3]</sup>. Once heavily reliant on fossil fuels, the nation is now witnessing a dramatic shift toward renewable energy sources such as solar, wind, hydroelectric, geothermal, and biomass<sup>[4-7]</sup>. This transformation is driven by a combination of technological innovation, economic competitiveness, and growing environmental awareness<sup>[8-11]</sup>. In 2024, a staggering 91% of new renewable energy projects in the U.S. were more cost-effective than fossil fuel alternatives, with solar and wind leading the charge<sup>[12-16]</sup>. Domestic production of renewables hit record highs, contributing to the lowest energy import levels in nearly four decades<sup>[17-18]</sup>. Yet, despite these promising trends, challenges remain—from grid infrastructure limitations to political resistance and financing hurdles<sup>[19]</sup>. This article explores the current landscape of renewable energy in the U.S., highlight-

ing its progress, obstacles, and the road ahead in the pursuit of a cleaner, more sustainable energy future<sup>[20]</sup>.

## II. Methodology

### II A. Methods

#### 1. Research Design

This study employs a **mixed-methods approach**, combining both **quantitative data analysis** and **qualitative content review** to assess the current state of renewable energy in the United States. The research is exploratory in nature, aiming to identify trends, challenges, and policy implications.

#### 2. Data Collection

##### a. Secondary Data Sources

- **Government databases:** U.S. Energy Information Administration (EIA), Department of Energy (DOE)
- **Industry reports:** National Renewable Energy Laboratory (NREL), International Energy Agency (IEA)
- **Academic journals:** Articles from *ScienceDirect*, *Springer*, and *MDPI*
- **Policy documents:** Federal and state-level renewable energy policies and legislation

##### b. Time Frame

- Data collected spans from **2015 to 2025**, with emphasis on post-2020 developments due to the impact of COVID-19 and recent policy shifts (e.g., Inflation Reduction Act).

#### 3. Data Analysis

##### a. Quantitative Analysis

- **Descriptive statistics:** Used to summarize renewable energy production, consumption, and investment trends.
- **Comparative analysis:** Evaluates growth across different energy sources (solar, wind, hydro, biomass).
- **Geospatial mapping:** Identifies regional disparities in renewable energy adoption using GIS tools.

##### b. Qualitative Analysis

- **Content analysis:** Reviews policy documents and industry reports to identify recurring themes and strategic priorities.
- **SWOT analysis:** Assesses strengths, weaknesses, opportunities, and threats in the U.S. renewable energy sector.

#### 4. Validation and Reliability

- **Triangulation:** Cross-verification of data from multiple sources to ensure accuracy.
- **Peer-reviewed literature:** Ensures credibility of secondary data.
- **Limitations acknowledged:** Potential biases in policy interpretation and data availability are considered.

## 5. Ethical Considerations

- All data used are publicly available and properly cited.
- No human subjects were involved, thus exempting the study from institutional review board (IRB) approval.

## II B. Analytic Hierarchy Process (AHP)

### 1. Systematic Assessment Using Analytic Hierarchy Process (AHP)

- **Objective:** To evaluate renewable energy alternatives for cities.
- **Method:**
  - Used **Analytic Hierarchy Process (AHP)** to rank energy sources.
  - Integrated **expert input** and **data analytics**.
  - Applied to cities including **Chicago, USA**.
- **Outcome:** Solar and wind were preferred; nuclear and hydroelectric were less favored.

### 2. Library-Based Research During COVID-19

- **Context:** Research conducted during pandemic lockdowns.
- **Method:**
  - Relied on **digital library access** via IP proxies.
  - Used **video conferencing** and **cloud-shared documents** for collaboration.
  - Followed the **SCONUL Seven Pillars of Information Literacy** model.
- **Scope:** Focused on energy use, production, and needs across multiple countries including the USA.

### 3. Bibliometric Analysis

- **Objective:** To analyze global research trends from 2019-2023.
- **Method:**
  - Used **Scopus database** for keyword-based search.
  - Applied **VOS Viewer software** for:
    - Keyword co-occurrence analysis.
    - Author and country collaboration mapping.
- **Findings:** USA was among the key contributors; major topics included biomass, hydrogen, and wave energy.

## II C. Electricity Generation

- **Renewable energy** is expected to generate **1,058 billion kWh** in 2025, a **12% increase** from 2024.
- In 2024, renewables produced **22.5%** of total U.S. electricity, and this share is projected to rise in 2025.
- **Wind and solar** are on track to **surpass coal** in annual electricity generation.

### Solar Power

- A record **37 GW of solar capacity** was added in 2024 - almost double the additions from 2023.
- In 2025, utilities are expected to add **26 GW** of solar capacity, followed by **22 GW** in 2026.

**Wind Power**

- Wind capacity additions are forecasted at **8 GW** in 2025 and **9 GW** in 2026.
- Wind remains the **largest source of renewable electricity** in the U.S..

**Battery Storage**

- Battery storage capacity nearly **doubled in 2024**, reaching **29 GW**.
- Storage is critical for balancing intermittent sources like solar and wind.

**Other Renewables**

- Hydropower, biomass, and geothermal remain stable but contribute less to growth.
- Coal retirements are accelerating, with **11 GW** expected to be removed in 2025

**II D. How does U.S. renewable energy compare globally?****Global Standing**

- **Second in Global Consumption:** The U.S. ranks second after China in total renewable energy consumption, accounting for about **12% of global usage**.
- **Electricity Generation:** As of 2023, **22.5%** of U.S. electricity was generated from renewable sources. This is slightly below the **global average of 29%**.

**Comparison with Other Major Economies**

| Country       | % of Electricity from Renewables (2022) |
|---------------|---|
| Norway        | 100%                                    |
| Germany       | 46%                                     |
| China         | 31%                                     |
| United States | 23%                                     |
| South Korea   | 8%                                      |
| Saudi Arabia  | 0%                                      |

- **Germany** leads among major economies with nearly half of its electricity from renewables.
- **China** surpasses the U.S. despite its massive energy demand.
- **Norway, Iceland, and Ethiopia** have fully renewable grids, thanks to abundant hydro resources.

**U.S. Trends and Future Outlook**

- **Growth Trajectory:** Renewable energy in the U.S. is on the rise, with solar leading new capacity additions.
- **Investment:** Falling costs of clean energy tech are driving increased investment and adoption.
- **Policy Influence:** Federal and state-level incentives continue to shape the pace of transition.

**II E.** A detailed comparison of the **present situation of renewable energy in Europe vs. the USA** as of 2024 - 2025:

**Europe: Ambitious Targets and Strong Progress****Key Stats**

- **Renewables share of total energy consumption (2023):** 24.5%–26.2%

- **Renewables share of electricity generation (2024):** 50%
- **2030 target:** 42.5% binding share of renewables, aiming for 45%2

**Leading Sources**

- **Electricity:** Wind (38.5%), Hydro (28.2%), Solar (20.5%)
- **Heating/Cooling:** Biomass dominates
- **Transport:** 10.8% renewables

**Top Performers**

**Country Renewable Share (2023)**

|         |       |
|---------|-------|
| Sweden  | 66.4% |
| Finland | 50.8% |
| Denmark | 44.9% |
| Latvia  | 43.2% |

**Policy & Strategy**

EU’s Renewable Energy Directive revised in 2023  
 Strong alignment with climate neutrality goals by 2050  
 Statistical transfers between countries to meet targets  
 USA: Rapid Growth, But Facing Headwinds

**Key Stats**

- Renewables share of total energy consumption (2023): ~8.4%
- Renewables share of electricity generation (2023): 22.5%
- **New capacity (2024):** ~90% of additions were renewable5

**Leading Sources**

- **Electricity:** Wind (45.1%), Hydro (26.5%), Solar (21.3%)
- **Solar growth:** 39.6 GW added in 2024; total capacity ~220 GW
- **Battery storage:** Nearly doubled to 29 GW in 2024

**Challenges**

- Grid congestion and interconnection delays
- Permitting and siting bottlenecks
- Political uncertainty around federal support

**Emerging Trends**

- Geothermal and nuclear gaining interest for 24/7 clean power
- Corporate investments in small modular reactors (SMRs)

**Comparison Summary**

| Aspect                       | Europe                          | USA                        |
|------------------------------|---------------------------------|----------------------------|
| Total Energy from Renewables | ~25%                            | ~8.4%                      |
| Electricity from Renewables  | ~50%                            | ~22.5%                     |
| Leading Source               | Wind & Hydro                    | Wind & Solar               |
| 2030 Target                  | 42.5% (binding), aiming for 45% | No national binding target |

| Aspect         | Europe                    | USA                                    |
|----------------|---------------------------|--|
| Policy Support | Strong EU-wide directives | Mixed federal/state-level support      |
| Growth Trend   | Steady and policy-driven  | Rapid but facing infrastructure issues |

### III. Results: Current Status of Renewable Energy in the USA

#### Key Statistics

- **Renewables' Share of Electricity:** As of 2023, renewable sources accounted for **22.5%** of U.S. electricity generation.
- **Consumption:** The U.S. consumed approximately **8.2 quadrillion BTUs** of renewable energy in 2023, ranking second globally after China.
- **Installed Capacity:**
  - **Solar:** Added **39.6 GW** in 2024, totaling around **220 GW** — enough to power over 7% of the nation.
  - **Battery Storage:** Nearly **29 GW** installed by end of 2024, projected to grow another **47%** in 2025.
  - **Wind:** Growth has plateaued, but cumulative capacity remains substantial.

#### Resource Potential

- The U.S. has **100 times** more renewable energy potential than its annual electricity needs.
- **Solar, wind, and geothermal** are the most abundant nationwide.
- **9%** of national renewable resources are within 10 miles of Tribal lands.

#### Discussion: Trends, Challenges, and Opportunities

##### Positive Trends

- **Record-breaking growth** in solar and battery storage in 2023–2024.
- **Corporate investment** in renewables is rising, with major companies signing large-scale energy deals.
- **Manufacturing boom:** New clean energy facilities are emerging across the country.

##### Challenges

- **Grid limitations:** Insufficient capacity and long interconnection queues are slowing deployment.
- **Permitting and siting:** Regulatory hurdles delay projects, especially wind energy.
- **Economic pressures:** High interest rates and supply chain disruptions affect project viability.
- **Policy uncertainty:** Changes in federal leadership threaten key legislation like the Inflation Reduction Act.

##### Future Outlook

- **Solar and battery storage** expected to continue rapid expansion.
- **Research and innovation** needed to unlock untapped technical potential.
- **Equity focus:** Increasing access for Tribal Nations and low-income communities is a priority.

## IV. Conclusions

### 1. Rapid Growth and Transformation

- The U.S. renewable energy sector has experienced unprecedented growth over the past 15 years.
- This boom is driven by the need for energy security, climate change mitigation, and sustainable economic development.

### 2. Role of Policy and Regulation

- Federal and state-level policies-such as feed-in tariffs, tax incentives, and renewable portfolio standards-have been crucial in accelerating deployment.
- Regulatory support mechanisms have helped commercialize new technologies and attract investment.

### 3. Technology-Specific Challenges

- Solar and wind energy, while abundant, face intermittency and lower capacity credit compared to thermal power.
- Hydropower and geothermal are more stable but geographically limited in the U.S..

### 4. Economic and Risk Considerations

- High shares of renewables require strong climate policies and grid modernization.
- Without robust policy support, fossil fuels may remain cost-competitive, slowing the transition.

### 5. Grid Integration and Infrastructure

- Expanding grid interconnections is essential for maximizing renewable potential and ensuring reliability.
- Investment in smart grids and energy storage is key to managing variability and enhancing energy security

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