The Understand Energy Learning Hub is a cross-campus effort of the Precourt Institute for Energy.

Introduction to Renewable Energy

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Fast Facts
View our summary of key facts and information.
(Printable PDF, 270 KB)

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Maximize your learning experience by reviewing these carefully curated readings we assign to our students.

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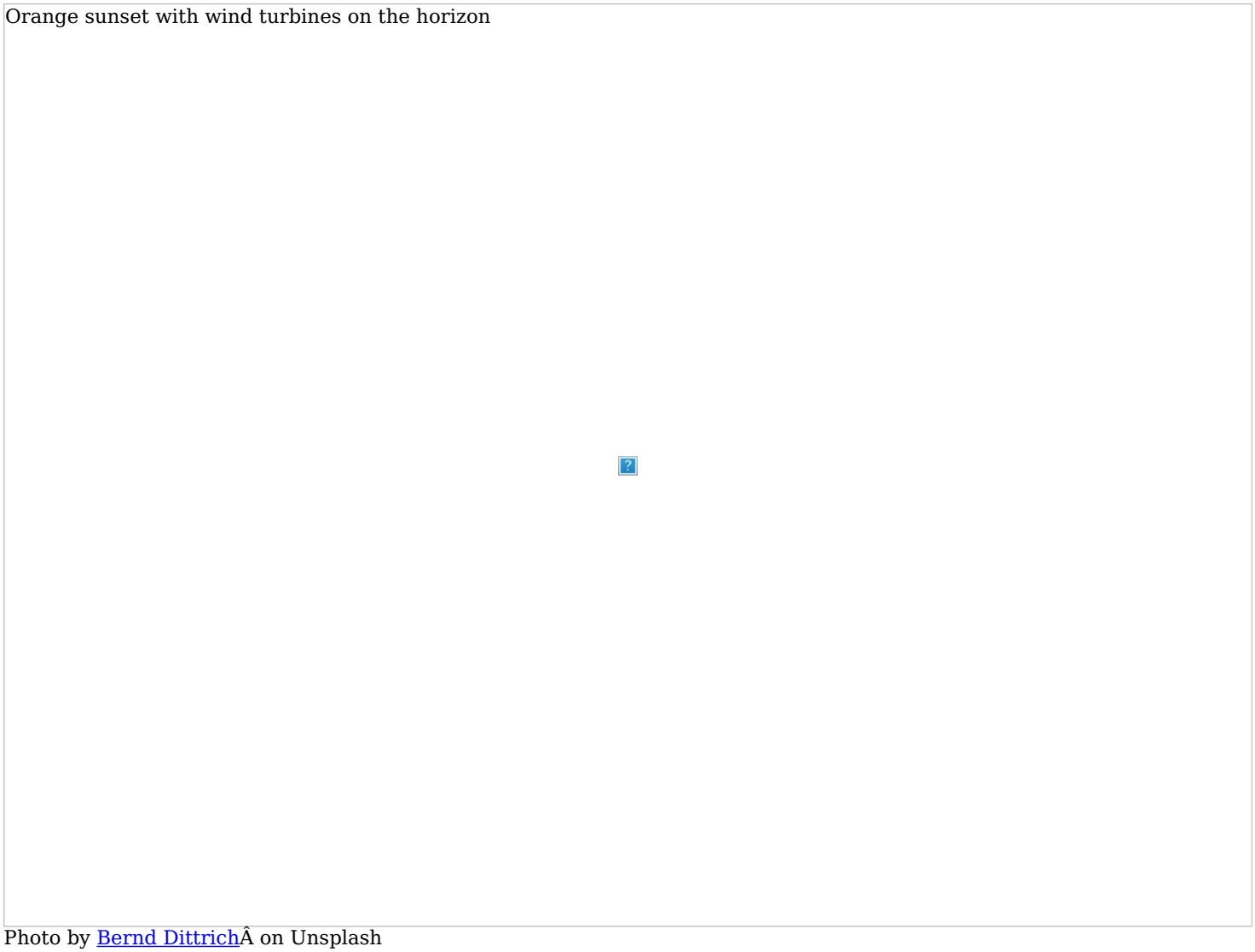

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Fast Facts About Renewable Energy

Principle Energy Uses: Electricity, Heat
Forms of Energy: Kinetic, Thermal, Radiant, Chemical

The term â€œrenewableâ€ encompasses a wide diversity of energy resources with varying economics, technologies, end uses, scales, environmental impacts, availability, and depletability. For example, fully â€œrenewableâ€ resources are not depleted by human use, whereas â€œsemi-renewableâ€ resources must be properly managed to ensure long-term availability. The most renewable type of energy is energy efficiency, which reduces overall consumption while providing the same energy service. Most renewable energy resources have significantly lower environmental and climate impacts than their fossil fuel counterparts.

The data in these Fast Facts do not reflect two important renewable energy resources: traditional biomass, which is widespread but difficult to measure; and energy efficiency, a critical strategy for reducing energy consumption while maintaining the same energy services and quality of life. See the Biomass and Energy Efficiency pages to learn more.

Significance

Energy Mix

14% of world ðŸŒŽ
9% of US ðŸ‡ºðŸ‡¸

Electricity Generation

30% of world ðŸŒŽ
21% of US ðŸ‡ºðŸ‡¸

Global Renewable Energy Uses

Electricity 65%
Heat 26%
Transportation 9%

Global Consumption of Renewable Electricity Change

Increase:
â¬† 33%
(2017 to 2022)

Energy Efficiency

Energy efficiency measures such as LED light bulbs reduce the need for energy in the first place

Renewable Resources

Wind
Solar
Ocean

Semi-Renewable Resources

Hydro
Geothermal
Biomass

Renewable Energy Has Vast Potential to Meet Global Energy Demand

Solar >1,000x global demand
Wind ~3x global demand

World

Share of Global Energy Demand Met by Renewable Resources

Hydropower 7%
Wind 3%
Solar 2%
Biomass <2%
Â

Share of Global Electricity Generation Met by Renewable Resources

Hydropower 15%
Wind 7%
Solar 5%
Biomass & Geothermal <3%

Global Growth

Hydropower generation increase â¬†6%
Wind generation increase â¬†84%
Solar generation increase â¬†197%
Biofuels consumption increase â¬†23%
(2017-2022)

Largest Renewable Energy Producers

China 34% ðŸ‡¨ðŸ‡³
US 10% ðŸ‡ºðŸ‡¸
of global renewable energy

Highest Penetration of Renewable Energy

Norway 72% ðŸ‡³ðŸ‡´
of the countryâ€™s primary energy is renewable

(China is at 16%,
the US is at 11%)

Largest Renewable Electricity Producers

China 31% ðŸ‡¨ðŸ‡³

US 11% ðŸ‡ºðŸ‡¸
of global renewable electricity

Highest Penetration of Renewable Electricity

Albania, Bhutan, CAR, Lesotho, Nepal, & Iceland 100%

Iceland, Ethiopia, Paraguay, DRC, Norway, Costa Rica, Uganda, Namibia, Eswatini, Zambia, Tajikistan, & Sierra Leone > 90%
of the countryâ€™s primary electricity is renewable

(China is at 31%,
the US is at 22%)

US

Share of US Energy Demand Met by Renewable Resources

Biomass 5%
Wind 2%
Hydro 1%
Solar 1%

Share of US Electricity Generation Met by Renewable Resources

Wind 10%
Hydropower 6%
Solar 3%
Biomass 1%

US States That Produce the Most Renewable Electricity

Texas 21%
California 11%
of US renewable energy production

US States With Highest Penetration of Renewable Electricity

Vermont >99%
South Dakota 84%
Washington 76%
Idaho 75%
of stateâ€™s total generation comes from renewable fuels

Renewable Energy Expansion Policies

The Inflation Reduction Act continued tax credits for new renewable energy projects in the US.

Production Tax Credit (PTC)

Tax credit of $0.0275/kWh of electricity produced at qualifying renewable power generation sites

Investment Tax Credit (ITC)

Tax credit of 30% of the cost of a new qualifying renewable power generation site

To read more about the credit qualifications, visit this EPA site.

LCOE of US Resources, 2023: Renewable Resources

Resource (Renewables)	Unsubsidized LCOE*	LCOE with ITC/PTC Tax Subsidy
Wind (Onshore)	$24 - $75	$0 - $66 (PTC)
Solar PV (Utility Scale)	$24 - $96	$16 - $80 (ITC) $0 - $77 (PTC)
Solar + Storage (Utility Scale)	$46 - $102	$31 - $88 (ITC)
Geothermal	$61 - $102	$37 - $87
Wind (Offshore)	$72 - $140	$56 - $114 (PTC)
Solar PV (Rooftop Residential)	$177 - $282	$74 - $229 (ITC)
Wind + Storage (Onshore)	$24 - $75	$0 - $66 (PTC)

LCOE of US Resources, 2023: Non-Renewable Resources.
(The ITC/PTC program does not provide subsidies for non-renewable resources. Fossil fuel and nuclear resources have significant subsidies from other policies.)

Resource (Non-Renewables)	Unsubsidized LCOE*

Natural Gas (combined cycle)	$39 - $101
Natural Gas Peaker Plants	$115 - $221
Coal	$68 - $166
Nuclear	$141 - $221

**LCOE (levelized cost of electricity) - price for which a unit of electricity must be sold for system to break even*

Important Factors for Renewable Site Selection

- Resource availability
- Environmental constraints and sensitivities, including cultural and archeological sites
- Transmission infrastructure
- Power plant retirements
- Transmission congestion and prices
- Electricity markets
- Load growth driven by population and industry
- Policy support
- Land rights and permitting

Drivers

- Competitive and declining costs of wind, solar, and energy storage
- Lower environmental and climate impacts (social costs) than fossil fuels
- Expansion of competitive wholesale electricity markets
- Governmental clean energy and climate targets and policies
- Corporate clean energy targets and procurement of renewable energy
- No fuel cost or fuel price volatility
- Retirements of old and/or expensive coal and nuclear power plants
- Most renewable resources are abundant, undepletable

Barriers

- Permitting hurdles and NIMBY/BANANA* concerns
- Competition from subsidized fossil fuels and a lack of price for their social cost (e.g., price on carbon)
- Site-specific resources means greater need to transport energy/electricity to demand
- High initial capital expenditure requirements required to access fuel cost/operating savings
- Intermittent resources
- Inconsistent governmental incentives and subsidies
- Managing environmental impacts to the extent that they exist

**NIMBY - not in my backyard; BANANA - build absolutely nothing anywhere near anything*

Climate Impact: Low to High

- Solar, wind, geothermal, and ocean have low climate impacts with near-zero emissions; hydro and biomass can have medium to high climate impact
- Hydro: Some locations have greenhouse gas emissions due to decomposing flooded vegetation
- Biomass: Some crops require significant energy inputs, land use change can release carbon dioxide and methane

Environmental Impact: Low to High

- Most renewable energy resources have low environmental impacts, particularly relative to fossil fuels; some, like biomass, can have more significant impacts
- No air pollution with the exception of biomass from certain feedstocks
- Can have land and habitat disruption for biomass production, solar, and hydro
- Potential wildlife impacts from wind turbines (birds and bats)
- Modest environmental impacts during manufacturing, transportation, and end of life

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Sources
Printable PDF, 270 KB

Updated January 2024

Before You Watch Our Lecture on Introduction to Renewable Energy

We assign videos and readings to our Stanford students as pre-work for each lecture to help contextualize the lecture content.

We strongly encourage you to review the **Essential** reading below before watching our lecture onÂ IntroductionÂ toÂ RenewableÂ Energy . Include the **Optional and Useful** readings based on your interests and available time.

Essential

- The Sustainable Energy in America 2024 Factbook (Executive Summary pp. 5-10). Bloomberg New Energy Finance. 2024. (6 pages)
  Provides valuable year-over-year data and insights on the American energy transformation.

Optional and Useful

- Renewables 2024 Global Status Report (Global Overview pp. 10-39). REN21. 2024. (30 pages)Â
  Documents the progress made in the renewable energy sector and highlights the opportunities afforded by a renewable-based economy and society.

Our Lecture on Introduction to Renewable Energy

This is our Stanford University Understand Energy course lecture that introduces renewable energy. We strongly encourage you to watch the full lecture to gain foundational knowledge about renewable energy and important context for learning more about specific renewable energy resources. For a complete learning experience, we also encourage you to review the Essential reading we assign to our students before watching the lecture.

Kirsten Stasio

Presented by: Kirsten Stasio, Adjunct Lecturer, Civil and Environmental Engineering, Stanford University; CEO, Nevada Clean Energy Fund (NCEF)
Recorded on:Â May 15, 2024Â **Duration:** 68 minutes

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(Clicking on a timestamp will take you to YouTube.)

Lecture slides available upon request.

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Additional Resources About Renewable Energy

Stanford University

- Precourt Institute for Energy Renewable Energy, Energy Efficiency
- Stanford Energy Club
- Energy Modeling Forum
- Sustainable Stanford

- Sustainable Finance Initiative
- Civil and Environmental Engineering
  - Mark Jacobson - Renewable energy
  - Michael Lepech - Life-cycle analysis
  - Leonard Ortolano - Environmental and water resource planning
- Earth System Science Department
  - Chris Field - Climate change, land use, bioenergy, solar energy
  - David Lobell - Climate change, agriculture, biofuels, land use
- Energy Science and Engineering Department
  - Sally Benson - Climate change, energy, carbon capture and storage

Government and International Organizations

- International Energy Agency (IEA) Renewables Renewables 2022 Report.
- National Renewable Energy Laboratory (NREL)
- US Department of Energy (DOE) Office of Energy Efficiency & Renewable Energy (EERE)
- US Energy Information Administration (EIA) Renewable Energy Explained
- US Energy Information Administration (EIA) Energy Kids Renewable Energy
- US Energy Information Administration (EIA) Today in Energy Renewables

Other Organizations and Resources

- REN21: Renewable Energy Policy Network for the 21st Century
- REN21 Renewables 2023 Global Status Report Renewables in Energy Supply
- BloombergNEF (BNEF)
- Carnegie Institution for ScienceÂ Biosphere Sciences and Engineering
- The Solutions Project
- Renewable Energy World
- World of Renewables
- Energy Upgrade California

Next Topic: Energy Efficiency Other Energy Topics to Explore

Fast Facts Sources

- **Energy Mix (World 2022):** Energy Institute. Statistical Review of World Energy. 2023.
- **Energy Mix (US 2022):** US Energy Information Agency (EIA). Total Energy: Energy Overview, Table 1.3.Â
- **Electricity Mix (World 2022):** Energy Institute. Statistical Review of World Energy. 2023.
- **Electricity Mix (US 2022):** US Energy Information Agency (EIA). Total Energy: Electricity, Table 7.2a.Â
- **Global Solar Use (2022):** REN21. Renewables 2023 Global Status Report: Renewables in Energy Supply, page 42. 2023
- **Global Consumption of Renewable Electricity Change (2017-2022):** Energy Institute. Statistical Review of World Energy. 2023.
- **Renewable Energy Potential:** Perez & Perez. A Fundamental Look at Energy Reserves for the Planet. 2009
- **Share of Global Energy Demand (2022):** Energy Institute. Statistical Review of World Energy. 2023.
- **Share of Global Electricity Demand (2022):** Energy Institute. Statistical Review of World Energy. 2023.
- **Global Growth (2017-2022):** Energy Institute. Statistical Review of World Energy. 2023.
- **Largest Renewable Energy Producers (World 2022):** International Renewable Energy Agency (IRENA). Renewable Capacity Statistics 2023. 2023.
- **Highest Penetration Renewable Energy (World 2022):** Our World in Data. Renewable Energy. 2023.
- **Largest Renewable Electricity Producers (World 2022):**Â Energy Institute. Statistical Review of World Energy. 2023.
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- **Share of US Energy Demand (2022):** Energy Information Administration (EIA). Electric Power Monthly. 2023.
- **Share of Electricity Generation (2022):** Energy Information Administration (EIA). Electric Power Monthly. 2023.
- **States with Highest Generation (2022):** Energy Information Administration (EIA). Electric Power Monthly. 2023.
- **States with Highest Penetration (2021):** Energy Information Administration (EIA). State Profile and Energy Estimates. 2023.
- **LCOE of US Renewable Resources:** Lazard. LCOE. April 2023.
- **LCOE of US Non Renewable Resources:** Lazard. LCOE. April 2023.

More details available on request.
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