A Comparative Assessment of Environmental, Social, and Economic Impacts of Renewable and Non-Renewable Energy Systems

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Introduction

Global energy demand is increasing while fossil fuels still dominate the energy mix. This creates environmental, economic, and social challenges. Drain-water heat recovery systems can improve energy efficiency, but the sustainability of different energy sources used with these systems needs direct comparison.

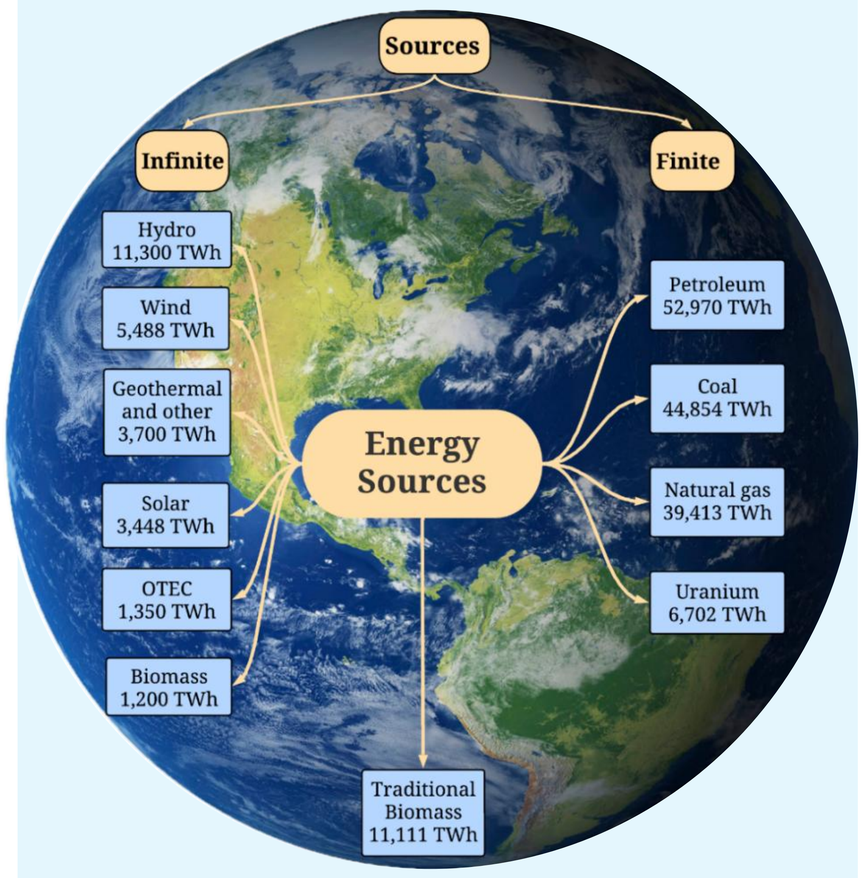

Fig. 1. Worldwide energy consumption by sources and renewable energy sources [1].

Methodology

Compare renewable and non-renewable energy sources in a multi-drain water heat recovery (DWHR) system using three criteria:

three pillars

- Economic cost → Levelised cost of energy (LCOE)
- Environmental impact → OpenLCA
- Social impact → Qualitative

The study used a DWHR system for different energy sources.

- Renewable energy
  - Hydro power
  - Solar
  - Wind
  - Biomass
  - Pumped storage
- Non-renewable energy
  - Gas
  - Diesel
  - Coal
  - Electricity
    - France
    - US

Results

Renewables performed better in the DWHR system, with lower economic costs (3.3–8.9 c€/kWh) and much lower environmental costs (0.036–1.04 c€/kWh) than non-renewables, which reached up to 25 c€/kWh economically and 23.4 c€/kWh environmentally. Wind and hydropower were the most sustainable options.

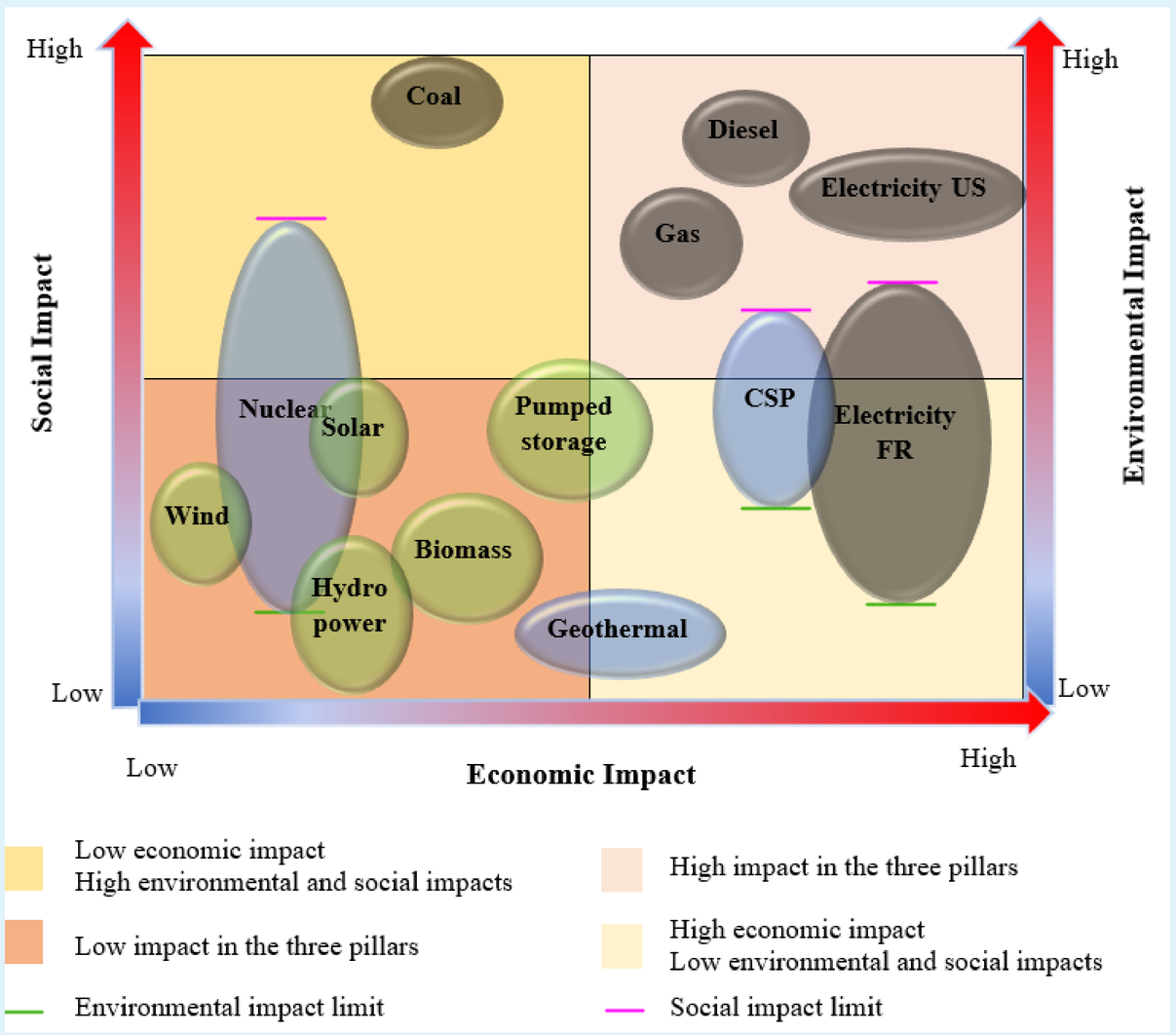

Fig. 2. Multi-dimensional sustainability assessment of energy sources based on economic, environmental, and social impacts.

Nuclear electricity produced in France, may have relatively low environmental impacts but still face higher social or economic concerns (safety perception, public acceptance, infrastructure cost, and energy system dependency).

Higher left area

Higher right area

Diesel, coal, gas, and U.S. electricity are positioned in the high-impact zones, reflecting greater environmental and social burdens mainly due to emissions, resource depletion, and health-related impacts.

Wind, hydropower, biomass, and solar show the lowest overall impacts, combining lower costs with reduced environmental and social burdens, making them the most sustainable options.

Lower left area

Lower right area

French electricity, geothermal energy, and CSP are positioned in the lower-right area, reflecting lower environmental and social burdens but higher economic costs.

Conclusion

Renewable energy sources demonstrated better overall sustainability in the DWHR system than non-renewable alternatives. Wind and hydropower appeared as the most sustainable options, while coal and U.S. grid electricity showed the highest combined impacts. Therefore, integrating renewable energy into DWHR systems offers a more sustainable solution under the same operating conditions.

[1] R. Aridi, "Advanced Heat Recovery Systems: Use of Vortex Generators and hybridization with thermoelectric generators, considering renewable energy sources and Life Cycle Assessment," 2023, doi: 10.13140/RG.2.2.12482.56008.