

RENEWABLE AND GEOTHERMAL ENERGY POTENTIAL IN SYRIA TOWARD 2035

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Abstract: Syria's energy sector faces rising demand, depleted resources, and infrastructure damage. This paper evaluates the country's renewable and geothermal potential within Energy Vision 2035 using national energy data and geothermal field tests. Findings indicate strong solar irradiation (>6.5 kWh/m²/day), significant wind potential (~490 TWh/year), and favorable geothermal conditions in Hama (thermal conductivity 2.011 W/mK), supporting ground-source heat pump use. Expanding solar, wind, and geothermal systems would enhance energy security, reduce emissions, and support post-conflict recovery through a diversified renewable strategy.

Keywords: *renewable energy, geothermal energy, Syria energy transition, ground-source heat pump, thermal response test*

1. INTRODUCTION

A small but growing body of literature has examined whether renewable and geothermal energy systems can be integrated in Syria. Initial energy reviews in the country focused on the reliance of the Syrian population on fossil fuels and the susceptibility of the energy infrastructure. However, in the study by Al Jamil and Sidorenko (2020), the long-term energy demand and generation trends showed that primary energy supply declined sharply from 23 Mtoe in 2008 to 8.9 Mtoe in 2017 due to the impacts of the conflict. They estimated that the electricity demand may increase 3 times in the year 2035 as compared to the one experienced in 2017 in the event of the reconstruction and industrial recovery. Their scenario analysis indicated that renewable energy resources particularly solar energy and wind energy could comfortably meet this forecasted demand, if investment and institutional capacity are enhanced.

The regional studies of the Middle East and North Africa (MENA) that support the geographic and climatic advantages also support the literature on the renewable potential of Syria. The International Renewable Energy Agency (IRENA, 2023) reports solar irradiation levels of 5–7 kWh/m²/day across the region, which also indicates that the MENA region is one of the regions that receives the highest levels of solar irradiation in the world. The latitude (32°–37° N) of Syria was found by

several authors such as Hepbasli (2008) and Omer (2008), to be conducive to photovoltaic and concentrated solar power (CSP). The technical solar potential estimated by Al Jamil and Sidorenko (2020) through empirical measurements was more than 2,400 TWh per year, which is much higher than the national electricity demand.

Evaluation of wind energy is relatively new yet equally promising. (Al Jamil and Sidorenko, 2020) estimated the gross and technical wind potentials with the help of 24 meteorological zones and assumed that the hub heights are 80 m, and the mean wind speed in at least 15 out of them is above 6 m/s, corresponding to approximately 490 TWh/year. Palmyra, Barshin, and Sendiania were the most suitable sites. Similar results by (Said et al., 2022) also indicate that rural component-based solutions hybrid solar wind microgrids could be used as off-grid systems in rural Syria.

In addition to wind and solar, the geothermal potential of Syria has been checked by direct field analysis (Kharseh and Nordell, 2008), which examined the possibility of a Ground Source Heat Pump (GSHP) system to be used in the agriculture sector, specifically in the rearing of poultry and livestock. They proved that GSHPs would save up to 70 percent of heating energy when used in place of a traditional coal furnace and would offer free cooling throughout hot seasons. They estimated that if the GSHP system used in the Hama poultry-farm model were replicated nationwide across all similar agricultural facilities, it could theoretically reduce national coal consumption by up to 168,000 tons per year.

Kharseh and Nordell (2009) used the first Thermal Response Test (TRT) in Syria to test their theoretical models. Their findings provided a successful base thermal conductivity of 2.011 W/mK and borehole thermal resistance of 0.111 K/Wm. This test showed that Syria's underground is capable of being home to efficient heat transfer systems and holds great potential for an alternate to intermittent renewable energy sources such as solar power and wind energy. This result was further replicated by several studies conducted for the region (Abu-Rumman et al., 2021; Shami and Hassan, 2023), which have shown great scalability for GSHP technology use in both urban and rural areas.

Policy and planning-wise, the energy trend of renewable energy is in line with international sustainability constructs in Syria. According to the UNDP (2023), renewable energy is one of the most important facilitators of the reconstruction process and estimates that decentralized renewables would meet 35 percent of post-war electricity needs by 2035. The World Bank and IEA (2024) also note that integration of renewables in weaker states fosters resilience because of decentralization of power generation and reliance on imported fuels. Taken together, these studies come out to the conclusion that Syria has both the resource endowment and technological capability to shift to a low-carbon energy secure future.

2. MATERIALS AND METHODS

This study adopts a synthesized analytical approach that combines secondary data analysis, field-based evidence, and comparative modeling. The methodology is

structured around three pillars: data sources and scope, the analytical framework, and comparative scenario evaluation.

The first pillar, data sources and scope, draws on a combination of established studies and recent datasets. Key references include Energy Visions 2035 for Syria (Al Jamil and Sidorenko, 2020), The Potential of Ground Source Heat Pump Systems for Heating/Cooling in Syria (Kharseh and Nordell, 2008), and First Thermal Response Test in Syria (Kharseh and Nordell, 2009). These are complemented by data from the International Energy Agency (IEA), UNDP, and IRENA for the period 2023–2025. Overall, the analysis covers the period from 1991 to 2035, in line with Syria's long-term energy planning horizon.

The second pillar is the analytical framework, which follows a resource–technology–policy model. This framework links three dimensions. Resource assessment evaluates the availability of renewable energy sources, including solar irradiation, wind potential, and geothermal conductivity. Technological analysis examines system performance through indicators such as conversion efficiency, capacity factors, and grid integration. Policy linkage then connects these technical findings to national energy strategies and broader sustainable development objectives.

The third pillar involves comparative scenario evaluation. Two scenarios from Al Jamil and Sidorenko (2020) are revisited. The Business-as-Usual (BAU) scenario assumes continued reliance on fossil fuels, with renewables contributing no more than 10% of total energy supply. In contrast, the Sustainable Transition (ST) scenario models a rapid expansion of solar, wind, and geothermal energy, targeting at least 60% renewable electricity generation by 2035. Energy outputs and emissions reductions under both scenarios are estimated using parameters from the cited studies, alongside IEA (2024) emission factors (0.43 kg CO₂/kWh for natural gas and 0.88 kg CO₂/kWh for fuel oil).

3. RESULTS OF THE ANALYSIS

3.1. Solar and wind potential

The geographical distribution of renewable energy resources is closely related to the climatic differences of Syria. It is apparent from Figure 1 that hot desert and cold desert/semi-arid regions (BWh, BWk and BSh, BSk) cover major areas of Syria and have high solar radiation intensity. This climatic advantage is also apparent in the assessment of renewable energy resources of Syria because solar energy is recognized as the most plentiful energy source among all renewable energy sources assessed for this country. According to Al Jamil and Sidorenko (2020), Syria's technical solar potential is approximately 2,410 TWh/year, calculated using an average solar irradiation of 6.5 kWh/m²/day applied to 18,543 km² of land considered suitable for solar development. Particularly, the central and eastern governorates—corresponding to the warm desert and steppe climate belts show the highest productivity, with estimated potentials of 473 TWh/year and 441 TWh/year, respectively. Wind energy potential is also significant: among 24 meteorological

zones, 15 exhibits mean wind speeds exceeding 5 m/s, yielding a combined technical potential of roughly 490 TWh/year. The Palmyra region has the potential of producing up to 157 TWh/year because topographical climatic interactions were favorable.

Together, the solar and wind resources—far surpassing the current national electricity demand of approximately 40 TWh/year—demonstrate that Syria possesses more than sufficient renewable capacity to support future energy needs even under high-growth scenarios.

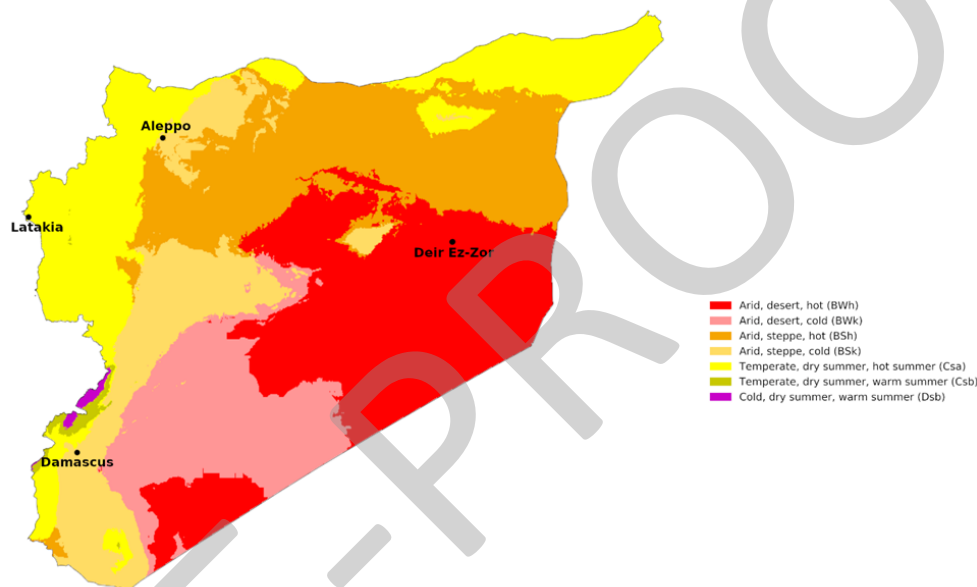


Figure 1

Present Köppen–Geiger Climate Classification Map of Syria (Beck et al., 2018)

3.2. Geothermal Resource Characteristics

The empirical investigation of the viability of geothermal conditions was first confirmed in the First Thermal Response Test in Syria (Kharseh & Nordell, 2009). Hama measurements provided an undisturbed ground temperature of 21.2°C, thermal conductivity (2.011 w/mK) of the ground measured using a borehole of 2.011 W/mK with a borehole thermal resistance of 0.111 K/W/m. These values endorse the implementation of GSHP systems with the ability to sustain high coefficients of performance (COP \approx 4.5–5.0).

A hybrid system that was designed to operate in case of the Kharseh Chicken Farm (Kharseh and Nordell, 2008) showed an annual heating and cooling of 223 MWh and 33 MWh, respectively, and met this with ten boreholes of 120 m length and 85 m² of solar collector areas. This design saved energy by 70 percent from coal-based heating and eliminated 168,000 tons of CO₂ every year should this de-

sign be replicated across the sector. A comparative overview of the technical potentials of solar, wind, and geothermal resources is shown in Figure 2, illustrating the dominance of solar irradiation but also confirming the complementary potential of wind and ground-source geothermal systems.

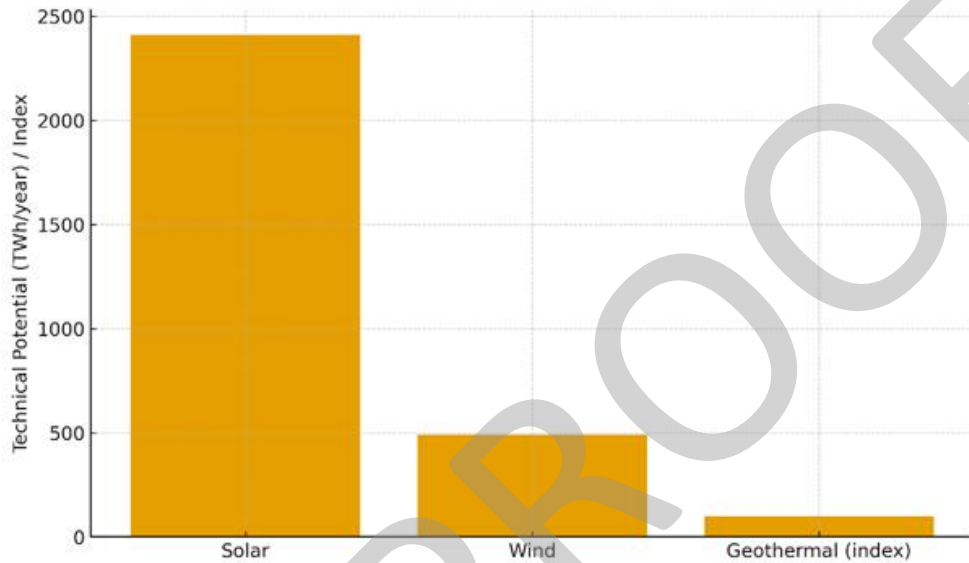


Figure 2

Combined renewable energy potential in Syria. Solar and wind potential represent the estimated technical potential in TWh/year

3.3. Scenario Comparison

More than 85 percent of Syria's electricity generation depends on fossil fuels, resulting in the carbon emission of +30 Mt CO₂/year in 2035 (Al Jamil and Sidorenko 2020). Sustainable Transition scenario, which involves 40 percent solar, 20 percent wind and 5 percent geothermal capacity would provide 65 percent of the total generation which would be renewed. This would cut down CO₂ emissions (19 Mt CO₂/yr) and reduce generation costs through localized production. Figure 3 presents the projected CO₂ emissions under the two modeled scenarios, illustrating the substantial reduction achieved through the Sustainable Transition pathway.

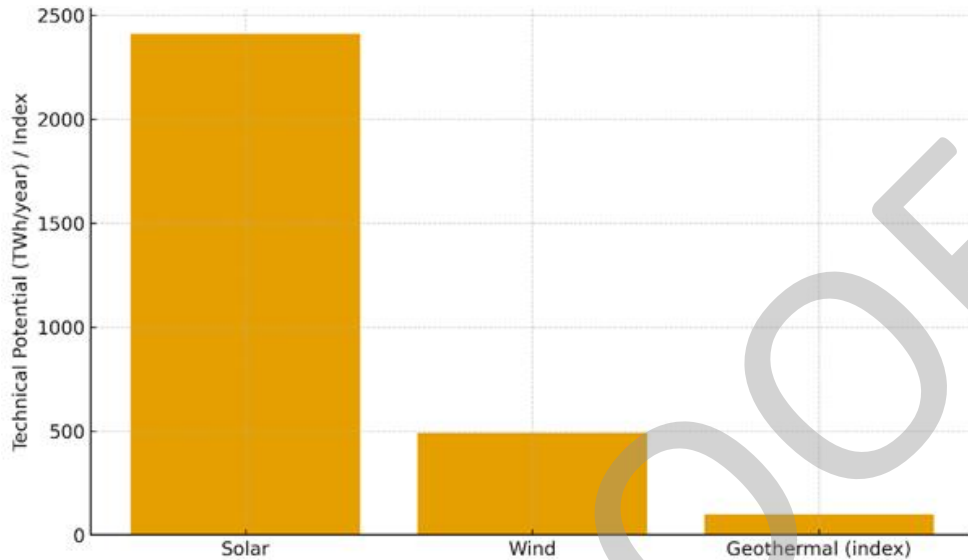


Figure 3

Projected CO₂ emissions in 2035 under the Business-as-Usual (BAU) and Sustainable Transition (ST) scenarios

4. DISCUSSION

The analysis of the available data synthesis demonstrates that the renewable energy sources and geothermal sources in Syria are not only technically, but also strategically, necessary. Solar energy is a low-cost and high-availability alternative that can be used in centralized and distributed generation. In the high-wind areas, wind resources are geographically fluctuating, but they can be used to complement solar production and support the baseload. Geothermal systems, though more expensive to capitalize on, provide year-round energy supply and heating/cooling to the residential, agricultural and industrial sectors.

The results substantiate the claim made by Kharseh and Nordell (2008, 2009) that geothermal integration allows for improving the reliability of the system by balancing the intermittency of solar and wind. Practically, hybrid configurations, like solar-assisted GSHPs, can sustain constant energy production and minimize storage needs. Low-enthalpy geothermal systems also have strong international precedent—particularly in Turkey and Iceland—where they play a significant role in urban heating and agricultural productivity (Balaban and Özdemir, 2011; Lund et al., 2020). In Syria, similar models would have the potential to decentralize power generation, free up grid capacity, and provide local jobs in the drilling, installation and maintenance departments.

Economically, the transition is not only costly in the initial stages but also has good returns in the long term. (IRENA, 2023) reports that the average solar PV installation costs in the MENA region have dropped more than 80 percent since 2010, and payback periods of GSHP systems vary between 4 and 7 years under

stable energy tariffs. International climate finance techniques, including the Green Climate Fund (GCF) and the Climate Promise of the UN Development Program (UNDP), can narrow initial investment gaps in the post-conflict situation in Syria.

On the institutional level, Energy Vision 2035 needs regulatory changes: the introduction of feed-in tariffs, opening the door to the participation of the private sector, and a new grid that supports distributed generation. Strengthening research capacity, especially through institutions such as the National Energy Research Center, is very necessary for supporting long-term advancements in renewable and geothermal technologies.

5. CONCLUSIONS

This study concludes that Syria has exceptional renewable and geothermal energy potential that can meet and exceed projected national demand in 2035. Solar resources are ample across the country, regionally significant wind energy potential exists, and empirical geothermal data confirm favorable subsurface properties. Hybrid integration of these resources offers a technically viable and economically sustainable pathway to national energy independence.

Accomplishing this would, among other things, involve taking the following measures:

- **Strategic planning:** A National Renewable Energy Roadmap in line with Energy Vision 2035, with hybrid solar-wind-geothermal development.
- **Policy Reform:** Introduce clear investment incentives such as tax relief, feed-in tariffs, and net-metering policies to encourage private sector participation and accelerate renewable energy expansion.
- **Capacity Building:** Through collaborations with academic institutions and foreign organizations, increase national research on geothermal and renewable technologies.
- **Pilot Projects:** Scale up the success stories, e.g., the Hama TRT and the poultry-farm GSHP systems, into demonstration programs carried out at a governorate level to facilitate the adoption of the programs throughout the region.
- **Financing Mechanisms:** This would entail the mobilization of investment in the rehabilitation of infrastructure and the implementation of renewable use of global climate funds and development partnerships.

A balanced mix of renewable and geothermal energy within modernized policy frameworks will effectively help reduce carbon emissions and accelerate socio-economic recovery in Syria. Thus, attaining the goals under Energy Vision 2035 is not only an environmental imperative but also one for sustainable national reconstruction.

The development of islanded (off-grid) renewable systems in remote rural areas of Syria is indeed a technically viable and strategically important solution, especially given the country's high solar and wind potential and the need for decentralized power in post-conflict reconstruction. However, the successful implementation

of such systems depends not only on the availability of renewable resources but also on the adequacy of local infrastructure.

Currently, many rural areas in Syria face challenges, including:

- Limited electrical distribution networks: Many settlements may not have robust grid connections, which reinforces the value of islanded systems but also means that integration with existing infrastructure could be minimal initially.
- Insufficient local technical capacity: Installation, operation, and maintenance of hybrid solar–wind–geothermal systems require trained personnel. Local technicians may need capacity-building programs to ensure long-term sustainability.
- Ancillary infrastructure needs: Supporting facilities, such as energy storage systems, small substations, and communication links for system monitoring, may need to be developed alongside the energy system.
- Water and land access: Some renewable and geothermal installations, especially ground-source heat pumps, require adequate land and sometimes water resources for operation, which must be assessed at a municipal level.

In conclusion, although the high renewable energy potential makes islanded systems an attractive solution, these systems cannot be deployed in isolation. Parallel development of supporting infrastructure—including training programs, basic grid or microgrid facilities, storage systems, and local maintenance capabilities—will be necessary to ensure reliable, resilient, and scalable off-grid energy supply in rural Syria.

ACKNOWLEDGMENTS

The authors thank the University of Miskolc (Institute of Mining and Energy) for academic support and appreciate the constructive feedback from the managing editor and reviewers. No specific external funding was received for this study.

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