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Assessment of Biomass Resources in Iran and Worldwide: Diversity Analysis in Rural Areas with a Focus on Municipal Solid Waste and Livestock Manure

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ABSTRACT

This research provides an in-depth evaluation of biomass resources both in Iran and globally, emphasizing rural areas and the potential conversion of municipal solid waste and livestock manure into energy. It examines the current landscape of biomass energy production and its role as a sustainable alternative to fossil fuels. In Iran, considerable biomass is available through agricultural residues, animal waste, and municipal solid waste (MSW), although these resources remain largely underexploited. Conversely, evidence from South-East Asian nations (SEAN) reveals a more advanced utilization of biomass, presenting a clear opportunity for Iran to improve its approach. The study highlights that challenges related to regulation, technology, and market acceptance are key obstacles preventing the broader adoption of biomass energy in Iran. Moreover, recent progress, such as the launch of large-scale biomass facilities, indicates that a concerted shift toward renewable energy could bolster energy security, lower greenhouse gas (GHG) emissions, and drive socio-economic development. The results advocate for further research into more efficient biomass conversion technologies and the formulation of tailored, region-specific policies to unlock the full potential of biomass energy in Iran and similar regions.

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INTRODUCTION

Despite global climate commitments, the world's energy supply remains overwhelmingly dependent on fossil fuels (Welsby et al., 2021), which still account for the majority of global primary energy consumption. This entrenched reliance on finite, carbon-intensive resources has wrought profound consequences: fossil fuel combustion is the dominant source of anthropogenic greenhouse gas emissions, driving global climate change and environmental degradation (Osman et al., 2023). Equally alarming are the geopolitical ramifications of this dependence: the uneven geographic distribution of coal, oil, and gas reserves means that nearly 80% of the world's population lives in countries that import fossil fuels, leaving billions vulnerable to supply shocks and price volatility (Osman et al., 2023, Ghasemzadeh et al., 2025). The convergence of escalating climate risks and energy security challenges underscores the urgency of transitioning to renewable energy sources (Osman et al., 2023), making the accelerated adoption of renewable energy alternatives a strategic imperative. Among these alternatives,

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biomass energy is increasingly seen as a vital component of a more secure and low-carbon energy future, offering a pathway to reduce net carbon emissions and alleviate reliance on fossil fuels, thus making it a focal point of sustainable energy research.

Biomass energy, derived from organic materials (e.g., plants, agricultural residues, and waste), has emerged as a versatile renewable resource that can be harnessed for electricity, transportation fuels, and heating. Biomass feedstocks can be burned directly to generate power and provide thermal energy, or converted into biofuels (such as ethanol and biodiesel) to substitute for fossil fuels in vehicles (Moriarty & Honnery, 2012; Twidell, 2021, Pazoki et al., 2024). Unlike intermittent solar and wind sources, biomass can be stored and used on demand, enabling a reliable year-round energy supply (Twidell, 2021). This dispatchable quality gives bioenergy a strategic advantage in balancing energy systems and supplying hard-to-electrify sectors. Globally, bioenergy already contributes significantly to the energy mix – modern biomass accounts for roughly 5.5% of all renewable energy and about 6% of total primary energy supply (International Energy, 2024). As shown in Figure 1, renewable energy sources, including biomass, are projected to grow steadily by 2030, reaching approximately 5.5% of global energy consumption, highlighting biomass's significant yet still limited role compared to overall energy demand. The final energy provided by bioenergy (for heat, power, and fuels) is several-fold greater than that from wind and solar combined.

Furthermore, it illustrates that the share of biomass energy in the overall renewable mix is projected to climb steadily from 2020 to 2030, reflecting both policy shifts toward decarbonization and improvements in conversion technologies.

Schematic of waste-to-energy conversion routes for biomass, spanning first-generation pathways (biofuels from edible crops), second-generation pathways (energy from non-food biomass residues and wastes), and third-generation pathways (bioenergy from algae). Thermochemical processes (red boxes) like combustion, gasification, and pyrolysis convert biomass into heat, syngas, or bio-oil, while biochemical processes (yellow boxes) such as

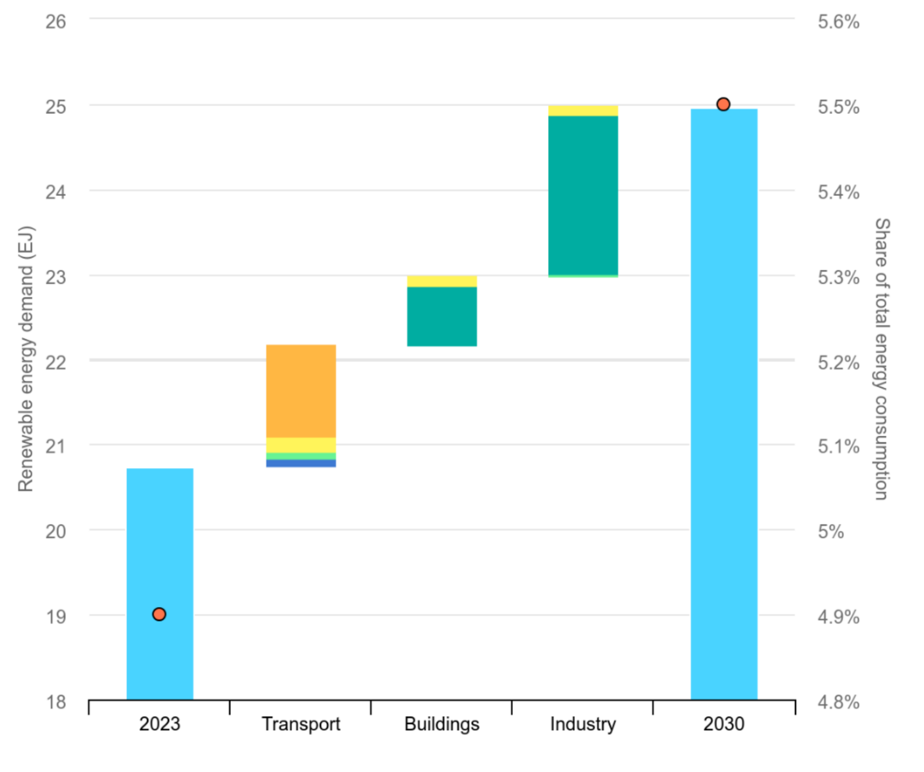

Fig. 1. Renewable fuel growth by fuel type, main case, 2023-2030 (International Energy, 2024)

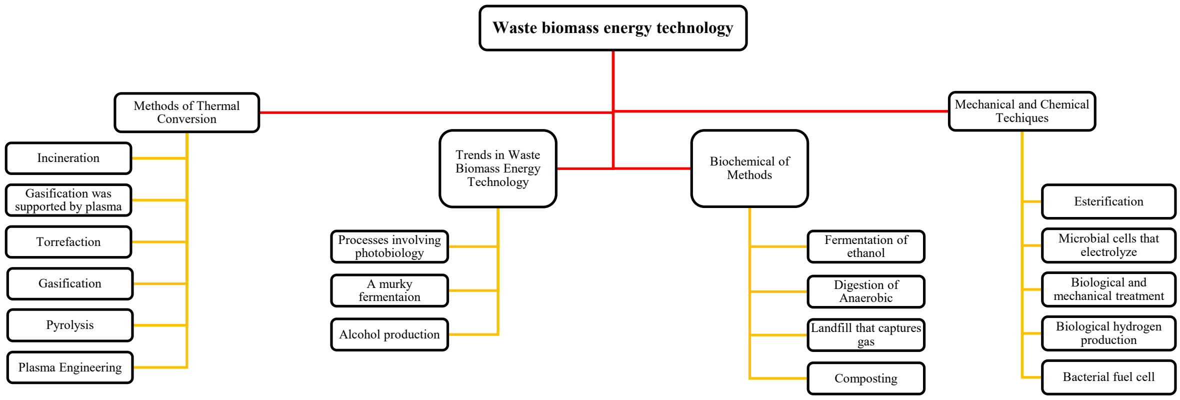

Fig. 2. Classification of waste-to-energy conversion methods (Yana et al., 2025)
Meanwhile, Figure 2 breaks down that growth by feedstock type, showing a rapid expansion in agricultural residue utilization alongside more modest gains in municipal solid waste and dedicated energy crops.

anaerobic digestion and fermentation yield biogas or bioethanol. Other methods, like chemical transesterification (green box), produce biodiesel from oils. (Lee et al., 2019). In bioenergy literature, first-generation biomass typically refers to food-based feedstocks (e.g., starch or oil crops), second-generation denotes lignocellulosic or waste biomass, and third-generation covers microalgae and other advanced sources (Mignogna et al., 2024). A wide array of conversion technologies exists to transform these feedstocks into useful energy, generally classified as thermochemical, biochemical, or chemical routes (Saravanathamizhan et al., 2023). Figure 2 illustrates how various organic wastes, agricultural residues, MSW, and manure can be routed via mechanical/chemical, thermal, or biochemical processes into electricity, heat, or biofuels instead of becoming pollutants. This spectrum of feedstocks and conversion technologies underscores biomass's emerging role in a circular economy, valorizing waste streams into valuable energy, and its critical importance for sustainability transitions away from fossil fuels (Al-Bawwat et al., 2023).

In Figure 2, the significant promise of renewable energy sources, particularly biogas derived from animal waste, is illustrated for both residential and industrial applications. The alignment of this approach with Sustainable Development Goals 7 (affordable and clean energy), 9 (industry, innovation, and infrastructure), 12 (responsible consumption and production), and 13 (climate action) has been underscored as essential for the preservation of planetary systems. Research has been directed toward refining waste-to-energy conversion pathways and enhancing process efficiencies, with multiple technological innovations having been evaluated to minimize waste streams and environmental impacts (Fernandez-Lopez et al., 2015).

Interest in biofuel production has been intensified as fossil fuel reserves have declined and the environmental consequences of their use have become more pronounced (Fernandez-Lopez et al., 2015). Current global oil consumption has been estimated at approximately 97 million bbl/d, and in Q4 2022, demand was recorded to have fallen from 110 million bbl/d to 100.8 million bbl/d (Citaristi, 2022; Worldometer, 2025). Projections for non-Developing Country liquid production were revised downward by OPEC by 0.1 mb/d for 2025, although a year-on-year increase of 1.1 mb/d was nonetheless forecast, driven by anticipated output in the United States, Brazil, Canada, and Norway; similar downward adjustments of 0.1 mb/d were applied to 2026 estimates (Forum, 2025). The EIA's projections for non-OPEC supply were subsequently adjusted upward by approximately 0.2 mb/d for 2025 and 0.3 mb/d for 2026, owing to enhanced production in the United States, Canada, Brazil, and Guyana (Forum, 2025). Concurrently, the IEA's forecasts for non-DoC and non-OPEC liquid supply growth were maintained for

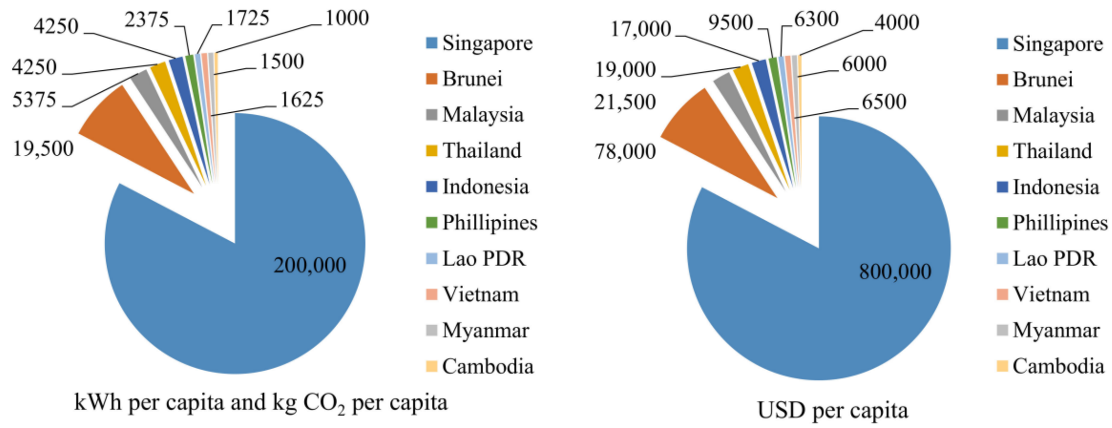

Fig. 3. Per-capita electricity use, CO_2 emissions, and PPP income across Southeast Asian nations (Makul et al., 2021)

2024, although a slight contraction of 0.1 mb/d was anticipated for 2025, reflecting production variances in North American regions (Forum, 2025).

Global natural gas demand has been projected to rise by 140 billion m³ between 2021 and 2025 (Botão et al., 2023; Ediger & Berk, 2023), against proven reserves reported at 7,299 Tcf as of 2021. Moreover, the supply disruptions and price volatility precipitated by the Russia–Ukraine conflict have been shown to exacerbate energy security concerns, thereby reinforcing the strategic appeal of biomass as a dispatchable renewable resource (De Almeida Moreira et al., 2025; Kożuch et al., 2024).

Biomass refers to renewable organic materials derived from both plant and animal sources. This resource can be utilized in two primary ways: it can be combusted directly to produce heat or transformed into liquid and gaseous fuels. Prior to the mid-1800s, biomass served as the predominant energy source in the United States. As of 2023, biomass accounted for approximately 5% of the nation's total energy consumption. This energy source is versatile, finding applications in heating systems, electricity generation, and as a fuel for transportation. Numerous developing nations, along with others globally, continue to rely significantly on biomass for cooking and heating purposes (Hosen et al., 2022; Liu et al., 2022; Wang et al., 2024).

Understanding biomass classifications is crucial for selecting appropriate conversion technologies. First-generation (1G) biomass, used primarily for heating, can be transformed into bioethanol, biochar, and biogas. Second-generation (2G) biomass, sourced from more complex feedstocks, enables the production of biodiesel, biochar, biogas, and various biochemicals. Meanwhile, third-generation (3G) biomass, such as algae, is processed into biodiesel, biogas, and bioethanol, offering promising efficiencies for renewable energy production (Osman et al., 2021).

As illustrated in Figure 2, waste biomass energy technology can be broadly categorized into mechanical and chemical techniques, methods of thermal conversion, and biochemical processes. These approaches encompass everything from basic incineration and gasification to more advanced methods such as plasma-assisted gasification, esterification, and anaerobic digestion. By highlighting the diverse pathways for converting waste biomass into useful energy, Figure 3 underscores the growing complexity and potential of this sector.

Recent investigations indicate that animal manure, a major component of organic waste, not only provides an effective substrate for renewable energy generation (El-Nahhal et al., 2020) but also holds promise for producing biofertilizers (Richards & Yabar, 2023). However, the optimization of manure for fertilizer production has not been extensively explored, presenting a notable research opportunity. Non-woody biomass, such as manure, possesses a lower lignin content compared to woody biomass and is often categorized as waste (Cao et al., 2022). In certain regions of the country, concentrated animal feeding operations (CAFOs) generate manure in quantities that exceed agricultural utilization capacities. Consequently, the accumulation of organic waste, especially from livestock, contributes significantly to land, water, and air pollution. Greenhouse gas (GHG) emissions from small farms are estimated at 45,538 g CO_2 equivalent per ton of feedstock, while larger farms (with 200 to 999 animals) produce approximately 104,856 g CO_2 equivalent per ton of manure (Aguirre-Villegas & Larson, 2017; Awasthi et al., 2019). This situation arises from a lack of comprehensive understanding regarding the management and handling of substantial manure volumes, particularly in terms of storage, processing, and land application (Awasthi et al., 2019). Manure management in the United States accounts for 47.3% of total emissions, representing nearly 10% of all anthropogenic methane emissions. Effective manure management practices are essential to maximize its utility while minimizing negative impacts on surrounding communities and the environment (Köninger et al., 2021; Niles et al., 2022). In Australia, agriculture is the predominant source of greenhouse gas emissions, contributing 14% overall, and is responsible for 56% of methane and 73% of nitrous oxide emissions (Hoyos-Seba et al., 2024).

Iran, a country rich in fossil resources in the Middle East, holds the world's second-largest natural gas reserves, accounting for 17.3% of the total, and the fourth-largest oil reserves, comprising 9.5% of global reserves (Worldometer, 2025). These vast fossil fuel resources have played a central role in shaping Iran's energy supply and economic structure (Rouhandeh et al., 2024).

Fossil fuels, specifically natural gas and oil, provide more than 98% of Iran's energy supply today. Through 2022, natural gas made up 71.8% of the total energy supply, amounting to 8,793,237 TJ, while oil stood at 26.3% equivalent to 3,214,281 TJ (Mohsen et al., 2020; Solaymani, 2021). Fossil fuel consumption has risen substantially during the last twenty years, with natural gas availability increasing by 299% from 2000 until 2022, while oil availability rose by 12% during this time period (Holechek et al., 2022; Wang & Azam, 2024). Airplanes and ships around the world stay on oil-based fuels while flying or shipping throughout the day, despite increasing worldwide decarbonization efforts. The efforts to decrease dependence on petroleum products look to succeed everywhere except aviation because electricity and other energy sources can hardly compete with petroleum fuels in terms of energy density (Sharmina et al., 2020; Urban et al., 2024). Furthermore, Iran has ample potential for the development of renewable energy despite having vast fossil fuel resources. Modern renewables made up just 0.78% of the final energy consumption in 2021. This sector has witnessed growth, and the increase between 2000 and 2021 was 117%. It is vital to separate modern renewables from traditional biomass usage. Biomass, traditional energy sources, including wood collecting, agricultural waste, and dung for boiling and heating, cause major environmental and health effects that lead to millions of deaths each year from air pollution. International development frameworks and climate policies, including the IEA's Net Zero scenario, target the phase-out of traditional biomass use in favor of cleaner energy sources (Zahedi et al., 2024).

Therefore, the primary objective of this study is to assess the current status, diversity, and potential of biomass resources in Iran with a focus on rural areas, particularly municipal solid waste and livestock manure. By comparing these findings with global biomass data, especially from Southeast Asian countries, this research aims to identify gaps, highlight opportunities, and provide insights for enhancing biomass utilization strategies in Iran.

MATERIAL AND METHODS

In this study, extensive research has been performed on the available quantity of biomass resources, types, and factors that affect their availability. Furthermore, the assessment and selection of biomass resources and the evaluation of energy recovery potential from different sources have been performed based on the experiences of both developed and developing countries, including Iran.

RESULTS AND DISCUSSIONS

A variety of organic materials, including wood, agricultural residues, municipal solid waste (MSW), landfill gas (LFG), and biofuels such as ethanol and biodiesel, are utilized to produce biomass energy, thereby reducing fossil fuel dependence and addressing environmental concerns (Ibitoye et al., 2023; Sikiru et al., 2024). Wood-based materials (e.g., logs, chips, bark, sawdust) and agricultural byproducts (e.g., fruit pits, corncobs) are frequently employed, with approximately 44% of total biomass energy contributed by wood feedstocks (Ibitoye et al., 2023; Yu et al., 2021). Electricity is often generated from wood waste in paper mills and sawmills through cogeneration processes, although additional power is usually obtained from external sources due to high energy demands (Balcioglu et al., 2023). MSW is incinerated to produce energy, with one ton of garbage providing heat energy equivalent to 500 pounds of coal. However, not all waste is classified as biomass, since plastics derived from petroleum and natural gas are typically included in municipal refuse. Waste-to-energy plants generally operate similarly to coal-fired facilities but rely on combustible garbage as the primary boiler fuel. LFG and biogas are also harnessed as biomass energy sources. Methane, which is released during the decomposition of organic waste, is captured in compliance with regulatory mandates aimed at preventing atmospheric emissions and explosion hazards. This methane is subsequently purified and employed in electricity generation, heating, and cooking. Moreover, biogas is produced through anaerobic digestion, whereby organic material ferments in airtight containers to yield a methane-rich gas. Ethanol, an alcohol-based biofuel, is manufactured by fermenting plant-derived sugars and starches, followed by distillation. Although the majority of ethanol in the United States is obtained from corn, advancements in technology have enabled its production from cellulose, trees, grasses, and crop residues. Ethanol is commonly blended with gasoline, as demonstrated by E10, E15, and E85 formulations. Biodiesel is produced from vegetable oils, animal fats, or recycled grease and is blended with petroleum diesel in varying proportions, including B2, B5, and B20. Compatibility with existing diesel engines and fueling infrastructure is facilitated by biodiesel's lower sulfur content and superior lubrication properties. A 97% reduction in sulfur levels in diesel fuel was mandated by the EPA, underscoring the advantages of biodiesel over conventional diesel. Biomass energy, therefore, offers a suite of renewable solutions that can mitigate reliance on fossil fuels. Ongoing technological progress and increasing environmental awareness are anticipated to drive further development and adoption of biomass-based energy systems (Project, 2019).

In several South-East Asian countries (SACs), rapid economic growth has driven energy consumption to rise substantially, with projections indicating that overall energy use could increase by 2.6 times between 2005 and 2030 (Bhatt & Affljulla, 2017). By 2040, energy demand may grow by around two-thirds, representing approximately 10% of the global increase in energy consumption (Fischer & Schrattenholzer, 2001; Tun et al., 2019). Greenhouse gas emissions related to energy production are also expected to escalate at both regional and international levels, prompting calls for more investment in renewable electricity sources, particularly in nations like Vietnam, Thailand, the Philippines, and Indonesia (Flum et al., 2018). However, widespread adoption of sustainable biomass technologies continues to face challenges, not only in terms of regulatory and market acceptance but also in achieving seamless integration into existing electrical grids. Recent initiatives, as highlighted in the IEA's 2024 outlook, underscore the need for enhanced grid investments and streamlined regulatory frameworks to better accommodate renewable sources, including biomass (Ji et al., 2025). Growing concerns over the environmental impact of fossil fuels, coupled with volatile oil prices, have spurred interest in alternative fuels, including sustainable biomass. Demand for sustainable biomass in SACs reportedly increased by about 21% between 2019 and 2020 (Makul et al., 2021). National energy policies in these countries often prioritize expanding biomass capacity to reduce greenhouse gas emissions. "Life cycle analysis" is frequently used to weigh the benefits and costs associated with biomass, factoring in both greenhouse gas balances and energy efficiency. For such analyses, the biomass energy life cycle begins with feedstock cultivation and concludes with final energy production.

Population growth and urbanization are projected to drive further increases in electricity demand throughout SACs, potentially necessitating additional grid capacity, new substations, and expanded use of renewable resources like biomass (Asia, 2009; Fediuk et al., 2018; Lee et al., 2013). Despite efforts to enhance building efficiency and reduce overall energy consumption, the widespread adoption of electric appliances and heating, ventilation, and air conditioning (HVAC) systems will likely contribute to higher demand. In turn, this demand highlights the importance of reliable integration of biomass energy into regional power supply networks (Lesovik et al., 2020).

Under scenarios assuming relatively low energy prices, structures may consume large amounts of electricity, with fewer incentives for deep retrofits to improve efficiency (Huang et al., 2025). Consequently, carbon dioxide emissions in many Southeast Asian nations have surpassed 1990 levels by a significant margin, growing by more than 5% in some cases (Ma & Ogata, 2024). Rising purchasing power correlates with higher per capita electricity consumption and, consequently, elevated per capita CO_2 emissions (Zhou, 2023). Although CO_2 remains the primary greenhouse gas globally, in several Southeast Asian countries, agriculture and forestry are substantial emission contributors. Figure 3 shows that higher purchasing-power incomes correspond with greater electricity use and CO_2 emissions, for instance, Singapore's 200,000 kWh/person and 19,500 kg CO_2/person dwarf those of countries like Cambodia, highlighting how wealth enables larger energy systems and underpins the capacity to invest in renewables. (Makul et al., 2021).

Multiple assessments have explored the potential of biomass as an alternative energy source, offering critical data to guide policy and technological innovation. One study, utilizing an analytical hierarchy process, evaluated several conversion methods in Iran and identified biogas production as particularly promising due to its superior efficiency and feasibility. This outcome underscores the central role that biogas can play in fostering a sustainable energy system within the region (Kheybari et al., 2019). An alternative study employing an air gasification model projected that Iran's agricultural residues have the potential to produce a cumulative energy output of about 341,290 terajoules. Within this estimate, roughly 66,075 terajoules could be allocated for electricity generation, while approximately 399,112 terajoules might be recovered as thermal energy. This estimation highlights the significant, yet underutilized, energy potential inherent in Iran's agricultural by-products (Samadi et al., 2020). Furthermore, recent assessments classify Iran's biomass resources into three primary groups: agricultural residues, animal waste, and municipal solid waste, thereby underscoring both the diversity and substantial volume of material available for energy production. Agricultural residues are estimated at approximately 8.78 million tons per year (Hamzeh et al., 2011). More recent analyses show that livestock manure alone amounts to about 15.83 million tons annually, enough to produce roughly 5,556 million m^3 of biogas each year (Firozjaee et al., 2025). Meanwhile, biodegradable municipal solid waste contributes another 4,578 million tons of organic material annually, capable of yielding some 1,785 million m^3 of biogas (Firozjaee et al., 2025). This tripartite classification not only highlights the breadth of Iran's biomass base but also underlines the significant energy potential locked within these waste streams.

Table 1. Comparative overview of annual biomass availability, dominant feedstock types, biogas potential, and installed bioenergy capacity in selected emerging economies.

Country	Annual Biomass Production (tons)	Biomass Types	References
Malaysia	168 million	Timber, oil palm waste, rice husks	(Ozturk et al., 2017)
Turkey	30 million	Fuelwood, animal waste, biodiesel, bioethanol, biogas	(Ozturk et al., 2017)
India	230 million	Agricultural residues	(Negi et al., 2023)
USA	1 billion	Various biomass types	(Yang et al., 2017)
Egypt	40 million	Agricultural residues (rice straw ~ dominant), municipal solid waste, and animal/sewage waste	(Shaaban et al., 2022)
Pakistan	840 million	Animal manure (from cattle, buffalo, etc.), crop residues (e.g., wheat straw, rice straw, bagasse)	(Wakeel et al., 2023)
Indonesia	147 million	Palm oil residues (empty fruit bunches, palm kernel shell, etc.), rice husk and straw, sugarcane bagasse, corn stover	(Katherine Hasan, 2025)
Vietnam	118 million	Rice straw & husk (from ~44 Mt paddy/year), sugarcane bagasse, maize/cassava residues, wood, and forestry by-products	(Phan et al., 2023)
Iran	132 million (oil equivalent)	Agricultural, animal, and municipal wastes	(Ghatrehsamani et al., 2019)

Based on national assessments, Iran's total biogas potential arising from livestock manure (≈5,556 million m^3 yr^{-1}) and municipal solid waste (≈1,785 million m^3 yr^{-1}) amounts to roughly 7,341 million m^3 per year. Despite this substantial resource, Iran's yield remains modest in a global context: Pakistan's annual capacity is reported at about 26 871 million m^3, Nigeria at 25,530 million m^3, and China at some 60,600 million m^3, while Malaysia (4,589.5 million m^3), Turkey (2,180 million m^3) and Afghanistan (1,227.5 million m^3) also exceed Iran's output. These contrasts are seen to underscore the opportunity for Iran to enhance its collection, pretreatment, and conversion infrastructure in order to approach the higher efficiencies seen elsewhere (Firozjaee et al., 2025; Negri et al., 2020).

In the ecologically sensitive Zagros region, it has been demonstrated that biogas adoption can reduce reliance on firewood harvesting, thereby contributing to the preservation of its fragile forest ecosystems (Zareei, 2018). Moreover, forward-looking initiatives such as large-scale poplar plantations and microalgae cultivation are poised to augment future biomass supplies and enhance energy recovery strategies. Poplar's rapid growth and high biomass yield make it an attractive feedstock for bioenergy, while microalgae in renewable cultivation systems offer exceptionally high per-area productivity and versatile end-use options, including biodiesel, biohydrogen, and biogas (Chen et al., 2021). By integrating these novel biomass sources with existing waste streams, Iran can further diversify its renewable energy portfolio and drive more sustainable, circular approaches to energy production.

In contrast, data from Southeast Asian countries reveal a strikingly different scenario. The total annual biomass production from forestry and agricultural residues in this region exceeds 500 million tons, translating to a total energy potential that surpasses 8 gigajoules (GJ) per ton. This comparison serves to underscore that while Iran possesses substantial biomass resources, particularly in the realm of agricultural residues, its current biomass-based energy production remains relatively underexploited. The abundant potentials observed in Southeast Asian countries highlight the need for Iran to enhance its biomass energy strategies and fully leverage its available resources to meet energy demands sustainably (Kim et al., 2025; Tun et al., 2019).

To contextualize Iran's position within the global bioenergy landscape, Table 1 presents a side-by-side comparison of annual biomass yields (in million tons) and dominant feedstock categories for Iran alongside representative countries with mature bioenergy industries. This comparative framework highlights not only Iran's relative scale of agricultural residues, livestock manure, and municipal waste, but also the differing resource mixes that underpin policy and investment priorities in each nation.

Table 1 juxtaposes Iran's annual biomass volumes, feedstock composition, and bioenergy capacities against those of comparable emerging economies. It reveals that Iran not only ranks among the top producers in total waste-derived biomass but also exhibits a uniquely balanced mix of agricultural, animal, and municipal feedstocks poised for scalable energy deployment.

Iran's total biomass resource base of 132 Mt of dry matter is the fourth-largest among the countries surveyed, trailing only Malaysia (168 Mt), Indonesia (154 Mt), and Thailand (141 Mt). This places Iran well above regional peers such as Saudi Arabia (95 Mt) and Egypt (88 Mt), highlighting its strong comparative position in feedstock availability. Given Iran's population of roughly 85 million, about half of Malaysia's, the per-capita biomass potential in Iran exceeds that of Malaysia, underscoring an especially high resource intensity. Moreover, Iran's largely untapped agricultural residues and livestock manure streams suggest that even modest improvements in collection and conversion efficiency could unlock a disproportionately large share of its theoretical potential. Consequently, Iran is not only a regional leader by absolute volume but also offers a particularly favorable biomass-to-demand ratio that merits targeted policy support.

CONCLUSION

This study provided a comprehensive assessment of biomass resources in Iran with a comparative perspective against global trends. The findings reveal that while countries such as China, India, Brazil, and Indonesia have established well-developed biomass management systems through structured policies and technologies, Iran, despite its abundant potential, has not yet fully utilized these resources. Iran's annual biomass production, estimated at 132 million tons of oil equivalent, predominantly originates from livestock manure, municipal solid waste, and agricultural residues, especially in rural areas. This figure demonstrates the country's strong capacity to diversify its energy portfolio and reduce environmental burdens. The comparison underlines that Iran's biomass production potential aligns with leading global producers, but lacks systematic collection, conversion infrastructure, and policy integration. To bridge this gap, it is recommended that Iran adopt decentralized biomass processing technologies suited to rural environments, develop supportive policy instruments and financial incentives, and invest in applied research to assess feasibility, environmental benefits, and public acceptance of biomass energy solutions. By aligning national strategies with international best practices, Iran can significantly improve its renewable energy utilization, rural development, and environmental management through the effective use of its biomass resources.

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The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declared that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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