Investigating the Feasibility of Distributed Production of Electricity and Heat from Two Renewable Energies (Geothermal and Biomass) on a Local Scale in Iranian Cities

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Abstract

In this study, the consequences of global population growth and increasing energy demand were investigated, highlighting the importance of sustainable development and the use of renewable energy. Given the challenges in providing sustainable energy, this study examined the energy situation in Iran and the rising intensity of energy consumption in the country. Additionally, the environmental and economic effects of carbon dioxide emissions were analyzed, emphasizing the need to modify energy consumption patterns across various sectors. Finally, this article explored the feasibility of distributed production of electricity and heat from renewable energies, specifically geothermal and biomass, on a local scale in Iranian cities, examining the benefits and challenges of utilizing these resources.

Keywords: Sustainable development, renewable energy, energy consumption, geothermal energy, biomass.

Introduction

According to forecasts, by the end of this century, the planet's population will increase dramatically, exceeding 13 billion people. This growth will have significant consequences for humanity and the planet (Hoornweg & Pope, 2017). The increasing global population has dramatically heightened the demand for energy. As the level of well-being rises and people seek better lives, the use of more appliances and services requiring energy consumption grows. Estimates suggest that global energy demand will double in the 21st century, presenting several challenges for sustainable and reliable energy supply worldwide (Minelli et al., 2014). Today, sustainable development is a key concept in policies and macro-planning globally, with energy production and consumption playing a vital role. In 2017, investments in the renewable energy sector accounted for about 13% of all energy production investments worldwide. This figure underscores the growing attention to renewable energy and its increasing importance in sustainable development (Edenhofer et al., 2011). The significant growth in investment in renewable energy from 2004 to 2011 demonstrates the global commitment to sustainable development and addressing environmental challenges. In 2004, investment in clean energy production was approximately $54 billion, which rose to $260 billion in 2011—a fourfold increase. This growth reflects the increasing importance and confidence in the sustainability and cost-effectiveness of renewable energies, indicating a global effort to invest in energy sources based on sustainability and economic efficiency (Anderson, 2018).

Despite its vast oil and gas resources, Iran faces a serious energy crisis. The inappropriate conditions of energy production and consumption in the country exacerbate its critical energy situation (Najafi et al., 2015). Ministry of Energy statistics show a significant increase in energy consumption intensity in Iran from 2000 to 2005. During this period, the intensity of energy consumption in Iran increased by 30%, rising from 41% to 71%. Meanwhile, Europe saw a 10% decrease in energy consumption intensity, reducing this ratio from 29% to 19% (Afsharzade et al., 2016). With energy consumption intensity ten times that of the European Union, seventeen times that of Japan, four times that of Canada, and twice that of China, Iran is the world's most consuming country in this field. According to the US Energy Information Administration, Iran was the 19th largest consumer of electricity in the world in 2007 (Conti et al., 2014). Statistics indicate that nearly 80% of the energy produced in Iran is wasted in the upstream oil and power sectors. This inefficiency reduces power plant efficiency to about 36% and the amount of energy recovery to 26% (Afsharzade et al., 2016). Energy consumption statistics in Iran for 2012 show an unbalanced distribution across different sectors. The industry sector accounts for the largest share of energy consumption at 29%, followed by the household sector at 25%. The agricultural, transportation, commercial, and general sectors also hold significant shares with 13% and 12%, respectively. Internal consumption of power plants accounts for 4% of total consumption, with other uses making up 2%.

This distribution, coupled with high losses, indicates potential for improvement in energy management and optimal use, as 15% of produced energy is wasted before reaching consumers (Najafi et al., 2015). In 2015, Iran produced about 611 million metric tons of carbon dioxide, resulting in adverse environmental and economic consequences.

The sources of carbon dioxide emissions in Iran are as follows: power plants play a key role, contributing 33% of the emissions; the domestic consumption sector accounts for 25%, highlighting the need to modify energy consumption patterns; transportation contributes 23%, reflecting the impact of vehicle emissions on air quality in major cities; the industrial sector accounts for 17%, indicating a need for technological updates; and the agricultural sector contributes 2%, necessitating improved agricultural methods. The social cost of releasing each ton of carbon dioxide is $12, resulting in an annual loss of $7.3 billion for Iran, with $2.419 billion attributable to the power plant sector (Ahmad & Du, 2017). Given the destructive consequences of fossil fuels and the environmental pollution they cause, the use of renewable and sustainable resources, such as geothermal and biomass, has become essential.

Geothermal energy, being native, clean, non-polluting, sustainable, and renewable, has the ability to attract domestic and foreign investment. It is considered cost-effective in the long term and is utilized in many countries, including Iceland, Italy, Russia, the United States, China, Japan, the Philippines, Turkey, Australia, the United Kingdom, South Korea, the Netherlands, Sweden, and Norway (Tsai et al., 2014). Additionally, geothermal energy is used for tourism purposes due to the presence of hot springs (Srinivasan et al., 2012).

Biomass is a form of solar energy because plants absorb the sun's energy and perform photosynthesis. The chemical energy in plants is absorbed by humans and animals that consume them. Vegetable fuels derived from forest residues and agricultural products are the largest source of solar energy storage and can potentially provide energy equivalent to 70 billion tons of crude oil annually, which is ten times the world's annual energy consumption. An important aspect of using this resource is that the carbon dioxide produced by burning biomass is reabsorbed by new plants, having no net effect on the greenhouse effect and global warming.

Investigating the feasibility of local renewable energy production is the first step toward achieving defined goals in this field. This research explores the feasibility of distributed production of electricity and heat from two renewable energy sources—geothermal and biomass—on a local scale in Iranian cities.

Geothermal Energy

Geothermal energy is the internal heat energy of the Earth, which is independent of the Sun's energy (Stober & Bucher, 2013). It represents the heat within the Earth, a large percentage of which is related to the decay of nuclei and unstable atoms. This means a substantial amount of heat is stored in the planet, and human activity cannot deplete this energy reservoir.

Consumed energy is replenished by the Earth's internal activities, making geothermal energy a sustainable resource. The sustainable use of renewable energy sources implies that the amount of consumed energy is equal to or less than the renewable energy. Geothermal heat recovered from various depths below the surface offers unique and diverse possibilities for use. Consequently, geothermal heat utilization is divided into near-surface geothermal systems and deep geothermal energy systems (Stober & Bucher, 2013).

Geothermal energy, the heat stored deep in the Earth, can be used as a clean, renewable, and sustainable source of electricity and heating. The concept of geothermal energy was introduced by Muffler and Cataldi in 1978, who defined this source as heat that can be extracted at a future date at a cost competitive with other forms of energy (Muffler & Cataldi, 1978). Geothermal energy sources are naturally found in areas of the Earth's crust where the heat flow is greater than in surrounding areas. In these regions, water in permeable rocks (reservoirs) at depth is heated and turns into steam. This hot steam is pushed to the Earth's surface under pressure and can be used to turn turbines to generate electricity or to heat homes and buildings. Geothermal activity in a region indicates that the subsurface rocks are hotter than usual. The source of this local heat can be boiling magma with a temperature of 600 to 1000 degrees Celsius, which has penetrated several kilometers from the Earth's surface. Geothermal activities are not limited to areas with recent shallow magma intrusions. Geothermal fields can also form in regions without active magma nearby, where geothermal heat is provided by other processes such as tectonic plate movement, natural rock radioactivity, and warm underground fluids. Areas of abnormal heat flow may result from specific geological conditions, such as thinning of the continental crust, bringing the crust and mantle closer together and significantly increasing the deep Earth's temperature.

Discovering a thermal anomaly in an area is only part of locating a productive geothermal source; it also requires the presence of a reservoir. This reservoir must consist of a significant body of permeable rock at an accessible drilling depth. The reservoir must carry a substantial volume of water or steam to transfer heat to the Earth's surface. The rocks of the reservoir absorb heat from deep within the Earth and transfer it to the fluids inside. The flow of hot fluids within the reservoir also transfers thermal energy to the Earth's surface. In the geothermal life cycle, the recharge zone, comprising cooler rocks, allows rainwater to seep underground and reach the warmer reservoir rocks to be heated. The heated water then returns to the Earth's surface, continuing the cycle. Cracks and seams in rocks play a key role by providing pathways for rainwater to penetrate deep into the Earth and reach the hot reservoir, facilitating heat transfer from the reservoir to the surface.

Water in geothermal reservoirs is an irreplaceable means of heat transfer, utilizing density changes caused by temperature and the convection process. This method of heat transfer is more efficient than heat conduction, ensuring the temperature of the upper parts of the reservoir remains nearly as warm as its depths. Geothermal reservoirs have the lowest geothermal gradient among normal permeable rocks, highlighting the unique efficiency of convection in these reservoirs. Additionally, primary heat in geothermal reservoirs is transferred through heat conduction from magma to permeable reservoir rocks. The hot rocks heat the fluids inside the reservoir, initiating the convection process. Finally, hot fluids in the reservoir naturally tend to escape to the Earth's surface, signifying geothermal activities in various parts of the world (Barbier, 2002).

Geothermal fields stand as silent witnesses to the Earth's fiery heart. This phenomenon is commonly found in young tectonic and volcanic areas, typically less than 65 million years old. The active boundaries of tectonic plates provide an ideal environment for this phenomenon to manifest (Figure 1). Volcanoes and hydrothermal systems represent two sides of the same coin in regions where magma intersects with groundwater. This fascinating dance unfolds exclusively at active tectonic intersections and hotspots (Barbier, 2002).

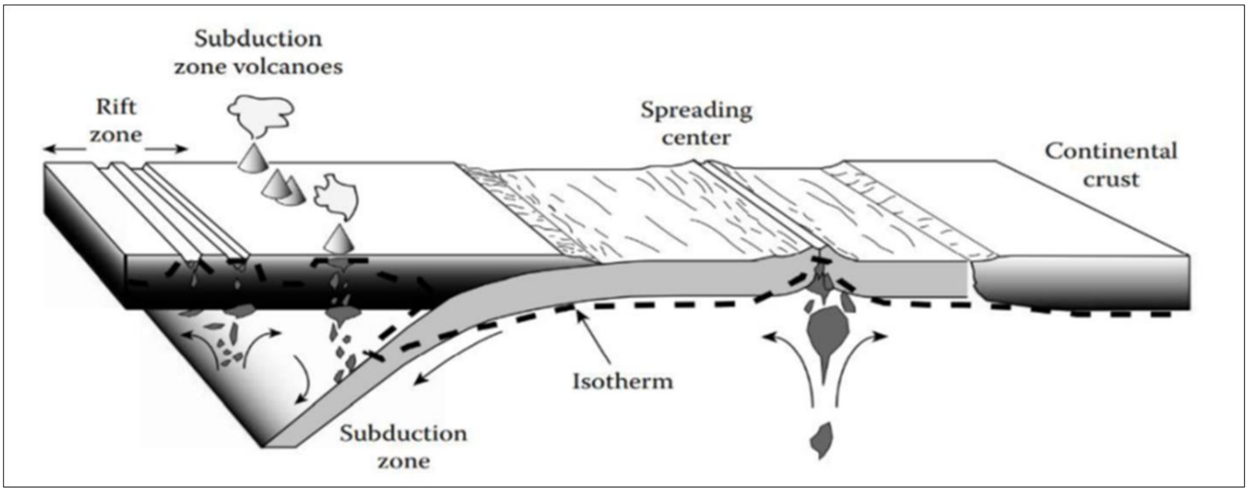

Figure 1: Configuration of plate tectonic structures (Glassley, 2014)

Investigation of Geothermal Resources in Iran

In 1975, ENEL published the first geothermal prospect map of Iran, which was later completed in 1998 by SUNA-CRERA. This map served as the primary basis for initiating all exploration activities in the geothermal field in Iran (Figure 2). Fotouhi and Noorollahi (2000) elucidated the origin of hydrothermal fluid units in underground sources by mapping hydrothermal ore deposits along the volcanic belt of Iran (Fotouhi & Noorollahi, 2000).

Yousefi et al. (2007) subsequently updated the Geothermal Potential Map of Iran using Geographic Information System (GIS) and existing digital data layers (Yousefi et al., 2007). These layers comprised geological (volcanic rocks, craters, and faults), geochemical (hot springs and acid hydrothermal alteration zones), and geophysical (seismography and shallow intrusions) information.

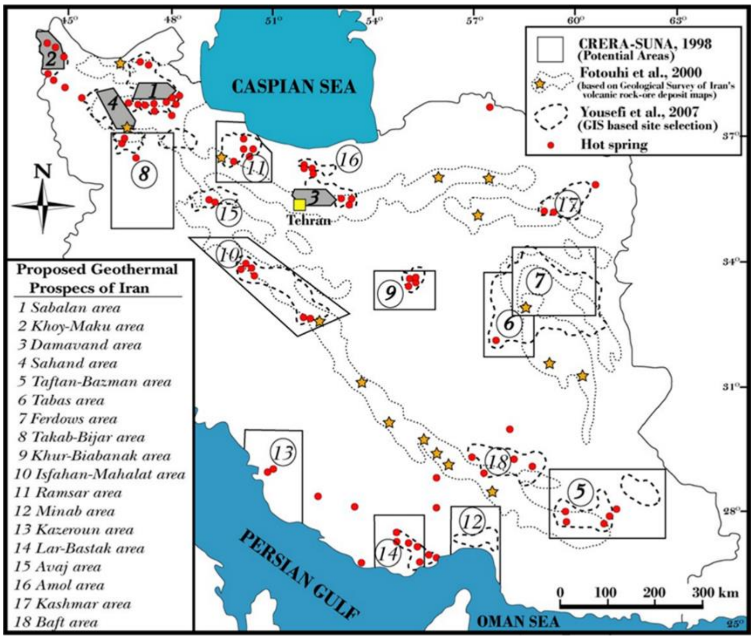

Figure 3: the geographical distribution of regions exhibiting potential for geothermal energy within Iran (Torbehbar & Liseroudi, 2015)

Iran, as part of the western segment of the Alpine-Himalayan orogenic belt, exhibits a complex structure characterized by significant geotectonic diversity. This diversity is evident in the presence of various crustal series, tectonic blocks, and distinct structural zones. Multiple lines of evidence, including seismic activity, volcanic eruptions, coastal uplift, and salt dome formation, underscore the geodynamic evolution of Iran's crust and its ongoing dynamics. The tectonic history of Iran reflects a series of changes over time, with the phases of Alpine orogeny from the late Triassic to the Late Cretaceous playing a pivotal role in shaping the current characteristics and morphology of the country. Presently, the region experiences tectonic stresses induced by the expansion of the Red Sea and the Indian Ocean, as well as the northward movement of the Arabian plate, resulting in various tectonic movements across Iran. These stresses manifest as activity along major faults and the occurrence of frequent earthquakes. The clustering of epicenters of 20th-century earthquakes along these major faults indicates their continuous activity and underscores the high seismicity of Iran (Aghanabati, 2004).

Methods of Producing Electricity and Heat from Geothermal Energy

Generating electricity and heat from geothermal energy stands as one of the most crucial and widely adopted methods for producing clean and renewable energy. This process harnesses underground heat sources to generate heat, subsequently utilized to rotate turbines and generate electricity. Three main methods are employed for this purpose:

- **Dry Steam System:** In this system, hot, pressurized water steam naturally extracted from geothermal reservoirs at temperatures above 150 degrees Celsius is utilized. The steam is circulated to turn turbines and generate electricity. This method boasts high efficiency, converting thermal energy into mechanical energy with notable effectiveness. Moreover, the technology involved is relatively straightforward to implement, potentially reducing costs and technical complexity. However, its reliance on high-temperature geothermal reservoirs presents a significant challenge, along with the production of minor pollutants that necessitate careful management to mitigate environmental impacts.

- **Flash Steam System:** Medium temperature geothermal hot water is utilized in this system. The hot water is transferred to a tank under low pressure, where a portion is converted into steam and subsequently transferred to turbines via a heat exchanger. Despite its relatively simple infrastructure and ability to use medium temperature reservoirs, this method exhibits lower efficiency compared to the dry steam system. Some heat is retained as cold water due to the use of hot water with low pressure, reducing the overall efficiency. Availability of suitable geothermal sources with medium temperature may also pose limitations in certain areas.
- **Double Cycle Systems:** This method employs a fluid with a lower boiling point than water, such as isobutane or pentane, as the working medium. The fluid flows in a closed cycle and serves as a heat exchange medium. Geothermal hot water is first transferred to the working fluid in a heat exchanger, causing it to turn into steam and circulate through a turbine to produce mechanical energy. The converted steam then transfers its heat to another fluid in a heat exchanger to return to its liquid state. While this method enables the use of lower temperature reservoirs and achieves relatively high efficiency, it requires more sophisticated technology and involves higher investment costs due to technical complexities and the need for precise management.
- **Geothermal heat pump systems:** This method represent one of the most prevalent methods for transferring heat from the ground to buildings or heating systems. These systems utilize geothermal heat sourced from beneath the earth's surface, collected by a carrier fluid, typically water or glycol, and transferred to a heat pump. The heat pump elevates this heat to a level suitable for transfer to the building's heating system or another system operating in reverse mode. Notably, this method boasts high efficiency and environmental compatibility by harnessing renewable and sustainable energy from the earth, thereby avoiding the combustion of fossil fuels. Consequently, it mitigates greenhouse gas emissions and air pollutants, contributing to environmental health. Nevertheless, challenges and limitations accompany this method, including the requisite for substantial space for system installation. Adequate space is necessary for the construction of pipes and equipment essential for heat collection and transfer to heating systems, presenting occasional challenges. Additionally, high initial investment costs may hinder broader adoption of this method. However, despite these obstacles, geothermal heat pump systems are recognized as a dependable solution for heat transfer and providing heating and cooling in buildings.

In selecting the appropriate method for electricity and heat production from geothermal energy, several factors must be considered, including the temperature of the geothermal reservoir, the demand for electricity or heat, and the geological and economic conditions of the region. Iran, with its abundant geothermal resources, offers the potential for employing various methods of this energy source. However, making the optimal choice necessitates conducting detailed studies and weighing diverse factors.

Investigating the Feasibility of Scattered Production of Electricity and Heat from Geothermal Energy

The utilization of geothermal energy in Iranian cities offers several fundamental advantages. Primarily, it leads to a substantial reduction in greenhouse gas emissions and air pollutants, thus serving as an environmentally friendly alternative to fossil fuels. This transition significantly enhances air quality and mitigates the adverse impacts of climate change. Additionally, distributed electricity and heat production from geothermal energy diversifies energy sources, bolstering energy supply security, especially in regions with limited access to the national power grid or prone to power outages. Furthermore, the development of geothermal resources generates new employment opportunities across various sectors, including exploration, mining, power generation, and auxiliary services, thereby fostering employment and economic growth within cities. Consequently, the adoption of geothermal energy as a sustainable energy source contributes to sustainable urban development by curbing pollution and enhancing social welfare.

The feasibility assessment of distributed electricity and heat production from geothermal energy in each city hinges on several factors, including geothermal resource potential, energy demand, and geological and economic conditions. The feasibility study comprises several key steps. Initially, geothermal resources are identified through comprehensive geological, geophysical, and geochemical studies. Subsequently, the potential of these resources for electricity and heat production is evaluated through detailed studies and exploratory well drilling. Estimation of the city's electricity and heat requirements follows, accounting for factors such as population, economic activities, and energy consumption patterns. Lastly, the geological and economic conditions of the region are scrutinized to assess the technical and economic feasibility of scattered electricity and heat production from geothermal energy.

The selection of the appropriate method for distributed electricity and heat production from geothermal energy in each city is influenced by various characteristics, including geothermal resource potential, energy demand, and geological and economic conditions. Location-specific constraints, such as insufficient geothermal resources, may limit method selection in certain cities. Moreover, investment costs play a pivotal role, as high exploration, extraction, and production costs may render the implementation economically unfeasible. Environmental considerations, including greenhouse gas emissions and noise pollution, must also be factored in, although their impact is generally lower compared to fossil fuel-based energy generation.

Dispersed electricity and heat production from geothermal energy offer numerous benefits for Iranian cities. However, before embarking on investments in this domain, a comprehensive feasibility study is imperative. Iran, endowed with significant geothermal resources, holds promise for the widespread adoption of this renewable energy source for scattered electricity and heat production across numerous cities. Through meticulous studies and consideration of all pertinent factors, this clean and sustainable energy source can be effectively harnessed, contributing to the sustainable development of cities.

Biomass Energy

Biomass energy, heralded as a sustainable energy source, derives from organic materials such as plants, residues, and animal waste. Various processes, including biological decomposition and thermal conversion, extract energy from these materials. The manifold benefits of biomass energy encompass reductions in air pollution, employment generation, diminished reliance on non-renewable resources, and environmental preservation. Given the burgeoning global population and escalating energy demands, the imperative of utilizing biomass energy as a sustainable and dependable solution has intensified.

Biomass Resources

Biomass, as a pivotal energy source, is categorized into distinct types, each comprising specific biological components. According to the EC77/2001 directive of the European Union, biomass encompasses "biodegradable components of agricultural products, residues, and wastes, including plant and animal materials, forests, related industries, as well as degradable industrial and municipal wastes." Biomass sources encompass five primary categories: agricultural and forest residues, solid waste, municipal wastewater, wastewater from food industries, and livestock waste. Each of these categories contributes uniquely to energy production and warrants brief elucidation for clarity.

Agricultural and Forest Residues

This category encompasses a broad spectrum of materials, including sugar, starch, cellulose, and lignocellulosic materials. Combustion technology is applicable to all these materials, with superior efficiency and performance observed in materials with lower moisture content. Thermochemical technologies find utility in wastes with low moisture content, with cellulose and lignocellulosic materials proving particularly advantageous. Conversely, materials with high moisture and low lignin content are amenable to digestive technologies. Various methods of alcohol production technology find application, primarily for sugary and starchy materials, and secondarily for cellulose and lignocellulosic materials.

Solid Waste

Solid wastes comprise residues from commercial, administrative, domestic, and some industrial activities. These wastes necessitate treatment before conversion to gas, electricity, heat, or methane. The method of purification is contingent upon energy market dynamics. Notably, a significant portion of these wastes can be repurposed as raw materials for energy production, recycled materials, or fertilizer. Gas derived from rural solid waste sources can also fuel energy production. The calorific value of household waste exhibits regional disparities. Advanced utilization methods include fertilizer production, recycling, incineration, and various conversion processes. However, the complexity of urban waste combustion poses environmental challenges due to the diversity of materials. Pollutants generated from solid fuel combustion include sulfur, chlorine, fluorine derivatives, nitrogen compounds, chlorinated hydrocarbons, and heavy metals (Xiaodong et al., 2002).

Direct combustion technologies for rural waste encompass bulk waste incineration and burning of processed waste using waste-derived fuel. Thermochemical technologies such as fracking and gasification have been trialed with waste-derived fuel, with oxygen gasification achieving operational and commercial viability. Anaerobic digestion technologies find application through landfill digestion and digestion in anaerobic tanks for municipal waste.

Municipal Sewage

Liquid wastes from human settlements, including sewage, harbor substantial energy potential and can undergo anaerobic fermentation to produce methane gas, akin to animal wastes. Anaerobic fermentation of sewage has a long history, with historically produced gas utilized in electric motors and illuminating roadways. Presently, sewage gas primarily serves as heating for digesters in refineries (Deublein and Steinhause, 2011). Anaerobic digestion technology is employed through treatment plant sludge digestion and direct wastewater digestion, with methane gas as the energy output.

Industrial Wastewater

Anaerobic digestion technology finds application in treating industrial wastewater. Through various reactors, decomposable organic materials in wastewater undergo conversion into methane. The resultant methane can then power generator engines to produce electricity required by the facility.

Animal Waste

Anaerobic digestion also serves to convert animal waste into biogas. While traditional rural communities often directly burn animal excreta, scientific literature less frequently mentions energy production through direct combustion of such waste.

Biomass Energy Extraction Technologies

Bio-waste energy production technologies facilitate the conversion of bio-waste into energy and energy-generating products. Each technology within this domain comprises distinct processes ultimately leading to energy production. These technologies are primarily categorized into five main groups: direct combustion, pyrolysis, gasification, anaerobic digestion, and alcoholic fermentation. Furthermore, energy production technologies from biomass are classified into two main groups: thermochemical technologies and biological technologies. These methodologies enable the production of energy and energy products from biological waste, significantly contributing to sustainable energy provision and reducing reliance on non-renewable sources.

Direct Combustion

Direct combustion stands as one of the fundamental applications of biomass energy. Relative to other biomass utilization methods, direct combustion boasts several advantages, chief among them being the rapid conversion of latent energy in biomass sources into thermal energy. Additionally, its technology is generally simpler and more practical than other methods, suitable for all types of solid fuels. Dating back to ancient times, direct combustion represents humanity's oldest method of converting chemical energy into thermal energy. The range of methods within this technology spans from rudimentary to highly advanced and efficient.

Primitive combustion methods remain prevalent in many developing villages and communities, primarily serving heating and cooking purposes. In direct combustion, biomass undergoes combustion directly exposed to sufficient air, with the energy released utilized for various applications such as heating and steam generation. This process encompasses various approaches, with each method applicable under different conditions. Limitations inherent to each method include economic, technical, and yield constraints. Traditional fuel combustion methods typically exhibit low efficiency, often below 10%. Consequently, recent scientific and industrial efforts have focused on enhancing combustion efficiency. Small-scale developments, such as stoves and heaters in regions like China, boast higher efficiency rates, around 25%, and emit fewer pollutants. Direct combustion generally occurs in two states: fixed feed and liquid feed, further categorized into subgroups (Amin Salehi, 2012).

Excavation Technology

Combustion is a process in which organic matter decomposes under heat in the absence of oxygen and water vapor, yielding new gases, volatile substances, tar, and coal. Hence, it is also termed "destructive distillation". The primary products of combustion technologies encompass coal, liquid fuels, and synthetic gases. Several significant fire excavation methods have been explored, including:

- Fast Fire at Normal Pressure (AFP)
- Pyrolysis at High Pressure and Relatively Low Temperature (Hydrogenation)
- Incineration with Hot Steam (Hydropyrolysis)
- Direct Thermal Firefighting
- Excavation with Methane Gas

In this technology, biomass reactions initiate at temperatures ranging from 300 to 375°C. Coal, organic liquids, gas, and water are yielded in varying proportions, dependent on operational parameters such as temperature, heating rate, retention time, raw material type, and moisture content (Kirk-Othmer, 2007). Higher temperatures and prolonged residence times yield more gas, whereas lower temperatures and shorter residence times favor coal and liquid production. Solid byproducts of this process include activated carbon and ash. The resulting liquids comprise organic compounds with lighter molecular weights than the raw material, including acids, alcohols, aldehydes, ketones, esters, and cyclic compounds. The gas produced contains carbon monoxide, carbon dioxide, methane, ethane, ethylene, water vapor, and other hydrocarbons. The coal obtained from pyrolysis is significantly more active than conventional coal, offering advantages such as activated carbon production for water purification and refining processes. At lower temperatures (300-500°C) and shorter residence times (seconds), charcoal production efficiency increases, a process also known as "charring" or "carbonization". Laboratory experiments have demonstrated enhanced coal production efficiencies exceeding 50% through pressurization and inert gas filling within the reactor (Grassi & Bridgewater, 1991).

Various reactor designs have been developed for fire excavation, including:

- Fixed Feed Reactors
- Mobile Feed Reactors
- Suspended Feed Reactors
- Fluid Feed Reactors
- Static Reactors with Vertical Stationary Feed
- Rotating, Inclined Greenhouses
- Horizontal Greenhouses

Accumulated experiences and research findings indicate that:

- Coal production and low-calorific-value gas production exhibit less complexity and higher reliability.
- Liquid fuel production necessitates more equipment and precision but yields higher value products.
- Wood and forest residues are optimal raw materials for fire cultivation technology, followed by lignocellulosic agricultural residues.
- Urban waste demonstrates limited performance due to compositional diversity and textural heterogeneity. In the United States, only one waste incineration unit operated until 1992 (Tchodanoglous et al., 1993).

Hydrogenation

Hydrogenation through high-pressure melting is a process that yields organic liquids and oily fuels by heating organic materials between 250 and 400°C under very high pressure (100 and 250 atmospheres). The resulting fuel contains more stable compounds and a lower oxygen percentage. However, the technical requirements of this process are quite demanding and specialized, thus hindering its widespread adoption compared to other thermochemical technologies (Amin Salehi, 2012).

Gasification

Gasification is a process akin to fire excavation, wherein emphasis is placed on gas production, and the heating process persists until maximal destruction and decomposition of raw materials are achieved. An additional substance, termed the gasification agent, is introduced into the reactor. This agent may comprise air oxygen, water vapor, methane, or helium. Biomass gasification methods can yield three primary types of synthetic gases:

- Gas with Low Calorific Value (LTV)
- Gas with Medium Calorific Value (MTV)
- Gas with High Calorific Value (HTV)

In air gasification, the amount of air introduced is deliberately less than the theoretical requirement for complete combustion of raw materials. A lower ratio of incoming air to required air results in higher calorific value gas production. Typically, this ratio falls between 0.2 and 0.3. Acidic gases are absorbed by molten materials possessing alkaline properties, trapping ash within. The molten material undergoes continuous refinement, with impurities removed before its return to the reactor (Kirk-Othmer, 2007).

Biological Technologies

Within these technologies, energy producers arise from products generated through the metabolic processes of living organisms, utilized as fuel owing to their high calorific value. Methane gas and ethyl alcohol (ethanol) stand as the most significant outputs. Methane gas results from anaerobic digestion, while ethanol derives from alcoholic fermentation (Amin Salehi, 2012).

Alcoholic Fermentation

Alcohol is procured through the fermentation of carbohydrates. The simplest process involves fermenting glucose with specialized yeast, yielding ethanol. Ethanol can exist as pure ethanol with a concentration of 95% (medical alcohol) or as industrial ethanol. Industrial ethanol production proves more cost-effective due to lower impurity separation thresholds.

Biomass Resources in Iran

In recent years, the utilization of agricultural products as a renewable energy source has garnered significant attention. These products encompass woody plants, annual and perennial herbaceous plants, sugar and starch plants, and oilseeds. Among these, crops such as corn, cotton, poplar, sorghum, sugarcane, bamboo, eucalyptus, and oil palm are commonly employed in the bioremediation process. The concentration of renewable power plants is notably high in central Iran, as illustrated in Figure 4.

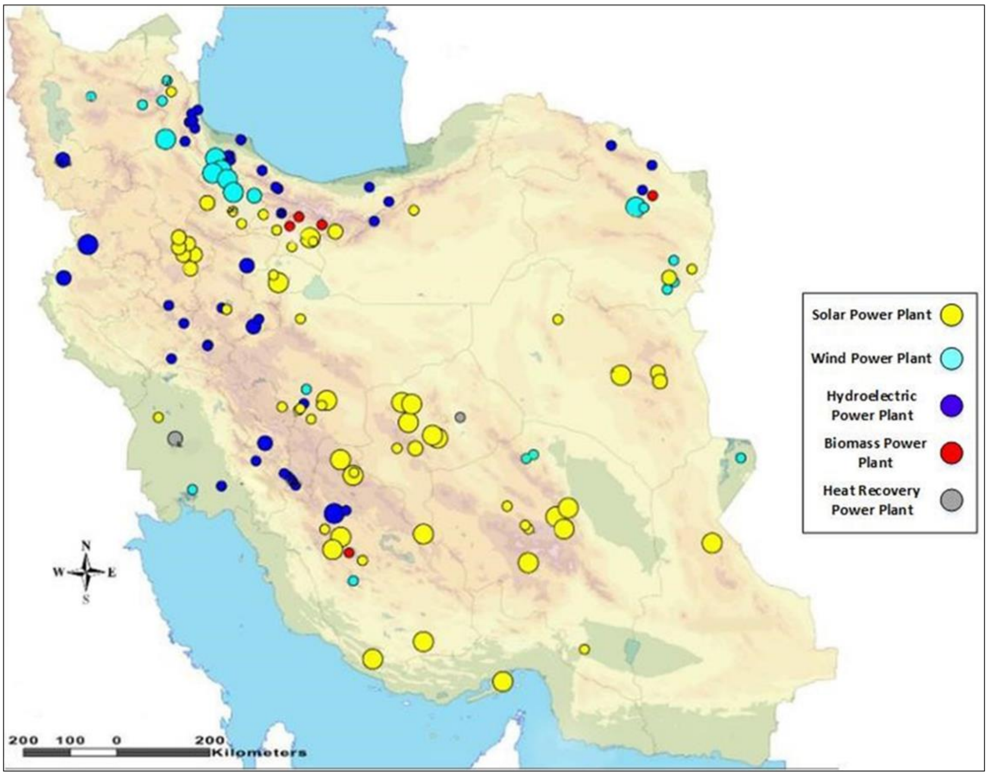

Figure 4: Distribution of renewable energies in Iran (Jorjani et al., 2021)

Agricultural waste, including straw and other plant residues unsuitable for market sale, accumulates to over 200 million tons annually in Iran. This substantial volume of waste contributes to fulfilling 10-15% of the country's energy requirements. Wood fuel encompasses all fuel types derived from forest waste, serving as raw material for energy production in power plants. Iran's forests possess the potential to annually produce a considerable biomass volume, and with the establishment and enhancement of biofuel power plants, this energy reservoir can be effectively harnessed. Furthermore, the extensive cultivation of agricultural products across Iran's farmlands constitutes another significant biomass source. These resources exhibit a higher density in the northern and western regions of the country compared to other areas (Jorjani et al., 2021).

Wood fuel, comprising various fuels derived from forest resource waste, wood, and paper industry waste, alongside processing facilities adjacent to forest areas, serves as a primary raw material in power plants and related industries for energy provision. Notably, wood fuel production in Iran has witnessed a decline from 2010 to 2019 (Jorjani et al., 2021).

Forests, particularly in the northern region of Iran, represent the primary source of forest biomass in the country. The biomass potential in this area is estimated between 6500 and 7200 tons, significantly higher than in other parts of the west and northwest of Iran.

Biomass power plants hold the capacity to contribute to the nation's energy demands and address significant environmental crises stemming from household waste and various organic pollutants, both solid and liquid. Such initiatives can lead to notable economic benefits for the nation. The dispersed generation of electricity and heat from biomass presents several advantages, including reduced energy losses as generation occurs near points of consumption, thus minimizing energy loss. Moreover, distributed generation aids in grid stability, mitigating blackout risks, and curbing air pollution by reducing reliance on fossil fuels. An additional benefit lies in the generation of employment opportunities in rural areas, fostering new job prospects. However, distributed biomass production also presents challenges. High initial investment costs for establishing scattered biomass power plants and accessing sufficient biomass sources pose significant hurdles. Advanced technologies are imperative for efficient electricity and heat production from biomass, and mismanagement can lead to water and soil pollution. Despite these challenges, access to energy resources remains a critical challenge in Iran's biomass power plant research and development endeavors. While bioenergy offers environmental benefits and employment opportunities, natural gas and oil remain predominant energy sources in Iran (Jorjani et al., 2021).

Investigating the Feasibility of Scattered Production of Electricity and Heat from Biomass Energy

As highlighted, Iran possesses significant potential in biomass production, thereby enabling its utilization as a renewable energy source for decentralized electricity and heat generation within urban areas. The adoption of distributed generation technologies for electricity and heat production from biomass encompasses gasification, direct combustion, biogas, and pyrolysis methods. Gasification involves the conversion of biomass into gas under high temperatures and limited oxygen, suitable for electricity and heat generation. Conversely, direct combustion entails burning biomass directly in a furnace to produce steam and subsequently electricity. Additionally, the biogas process decomposes biomass anaerobically to yield methane gas, serving as a viable energy source for electricity and heat generation.

In the pyrolysis method, biomass undergoes decomposition at high temperatures and in the absence of oxygen, yielding various products such as coal, gas, and oil, all of which can be harnessed as energy sources. The adoption of these technologies represents a sustainable and economically viable approach to energy production in Iran, fostering local development and reducing reliance on non-renewable energy sources.

Scattered production of electricity and heat from biomass offers significant advantages. It aids in reducing energy losses by generating electricity and heat near consumption points, thereby mitigating energy wastage. Furthermore, distributed generation contributes to grid stability, averting blackouts, and curtails pollutant emissions compared to fossil fuel-based electricity generation, consequently mitigating air pollution. Moreover, this approach facilitates job creation in rural areas, thereby stimulating economic growth. However, the decentralized generation of electricity and heat from biomass presents challenges, including the high initial investment costs associated with establishing scattered biomass power plants. Additionally, some regions may face challenges in accessing sufficient biomass sources, necessitating the development of advanced technologies for efficient electricity and heat production from biomass. Improper management of scattered biomass production can also result in water and soil pollution.

Despite these challenges, decentralized electricity and heat production from biomass holds promise in advancing sustainable energy and development in Iran. With governmental support, private sector investment, and technological advancements, these challenges can be surmounted, enabling the full realization of the benefits offered by this renewable energy source.

Conclusion

This study delved into the current state and future outlook of energy production and consumption globally, with a specific focus on Iran. The burgeoning population and escalating energy demands pose formidable challenges to ensuring stable and reliable energy provision. Moreover, the study underscores the pivotal role of sustainable development and the imperative of renewable energy adoption in addressing these challenges. It scrutinized Iran's energy production and consumption landscape, highlighting its adverse implications and advocating for a shift towards cleaner, renewable energy sources.

The findings unequivocally advocate for sustainable development and a reduced reliance on fossil fuels, advocating for the utilization of renewable energy sources such as geothermal energy and biomass. Leveraging Iran's abundant renewable energy potential necessitates strategic investments, technological advancements, and a paradigm shift in national consumption patterns. Ultimately, concerted efforts aimed at achieving sustainable development and mitigating adverse environmental impacts promise a brighter future for succeeding generations.

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