International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.
© 2024 Scholar AI LLC.
https://ijpsat.org/
Vol. 48 No. 1 December 2024, pp. 436-450

Energy Transition Planning Modeling at Power Plants Using Renewable Energy in South Sumatra 2023-2040: Business as Usual (BaU) Scenario Using Low Emission Analysis Platform (LEAP) Software

Aranananda Dwi Putri[1], Nugroho Adi Sasongko[2], Donny Yoesgiantoro[3]

[1]Magister Program of Energy Security, Faculty of Defense Management Indonesia Defense University (IDU), Indonesia

[2]Magister Program of Energy Security, Faculty of Defense Management Indonesia Defense University (IDU), Indonesia

[3]Magister Program of Energy Security, Faculty of Defense Management Indonesia Defense University (IDU), Indonesia

Corresponding author: aranandadwi@gmail.com

(cc) BY

Abstract —This study aims to model the energy transition planning in power plants in South Sumatra using renewable energy from 2023 to 2040 with a Business as Usual (BaU) scenario using the Low Emission Analysis Platform (LEAP) software. This analysis uses macroeconomic assumptions, population growth, and energy demand based on the latest data from the Central Statistics Agency and PLN's Electricity Statistics. Using the LEAP model, this study projects the primary and final energy needs for major sectors such as industry, transportation, households, and others. The results indicate that without new policies, energy demand will continue to increase, driving the need to adopt renewable energy technologies to ensure sustainable energy supply. This study provides insights into the importance of effective energy policies and technological innovations to meet increasing energy needs while reducing emissions and enhancing energy security in South Sumatra.

Keywords—energy transition, renewable new energy, LEAP modeling, energy demand, South Sumatra.

I. INTRODUCTION

The continuously escalating regional energy demands, which increase annually, necessitate heightened attention and the formulation of energy policies aimed at substituting energy sources if the primary energy used is classified as polluting energy. The utilization of dirty primary energy contravenes national energy policies and the Paris Agreement, which are integral to Indonesia's transition towards the adoption of new and renewable energy sources[1]. Polluting energy generates greenhouse gas emissions; therefore, existing energy policies must be aligned with the government's commitments. This alignment is consistent with the vision of South Sumatra's renewable energy, which is "the creation of energy reliability and self-sufficiency by optimizing the utilization of local energy potential that is environmentally friendly and sustainable" [2]. In addition to greenhouse gas emissions, another critical factor that warrants attention is the availability of primary energy supplies within the country or region. These two crucial elements contribute to a region's robust and environmentally friendly energy resilience, aligning with the vision of South Sumatra's regional regulation (PERDA Sumatera Selatan) .

The demand for energy in South Sumatra Province's residential sector has been on the rise. This sector's energy needs include electricity which is generated from diesel power plants [3]. In response to the increasing final energy demand in the residential sector, it is necessary to develop policies that are beneficial for the region. One longstanding policy adopted by South Sumatra Province is the conversion of diesel-powered electricity generators into coal-fired steam power plants. The construction of these steam power plants was slated to commence in early 2018 and operate no later than 2022 [4] (PTBA, 2017). The plant only commenced operations in 2023, indicating a delay from the initial target [5]. While coal-fired steam power plants benefit from abundant coal availability, coal remains a polluting primary energy source due to its greenhouse gas emissions.

In Indonesia, energy demand is divided across several sectors, including residential, transportation, industrial, commercial, and others. In the residential sector, final energy consumption includes LPG, natural gas, kerosene, firewood, briquettes, and other fuels for cooking activities, while electricity is used for other activities. The demand for electricity in several sectors of South Sumatra Province has been increasing. According to the Statistics Indonesia (BPS) of South Sumatra, the demand for electricity in South Sumatra increased by 0.92% from 2021 to 2022. In 2023, there was a significant surge of 20.55%, amounting to 8,111.7 GW, compared to the previous year's 6,645.99 GW [6]. The demand for electricity in previous years is presented in **Table 1**, which shows data on electricity needs from 2016 to 2020.

Table 1. Final Electricity Consumption in Several Sectors [7] **(Central Statistics Agency, 2022)**

Type of Final Energy	2016	2017	2018	2019	2020
Electricity (GWh)	4.984,09	5.239,35	5.501,26	5.258,23	5.312,77

This study focuses exclusively in several sectors, examining the final energy consumption of electricity from fossil and renewable energy. These types of energy are projected to serve as an initial framework, illustrating the necessity of forecasting both final and primary energy consumption to ensure the long-term sufficiency of primary energy supplies. Such projections are also intended to guide regional or central leaders in making informed energy policy decisions. The LEAP (Low Emissions Analysis Platform) model [8] is employed to project energy needs, incorporating macroeconomic aspects such as Gross Domestic Product (GDP) and demographic factors like population growth rate, total population, and the intensity of electricity demand.

In the LEAP modeling framework, key assumptions involve two main aspects: demographic and macroeconomic factors. All known data from these aspects are input into the key assumptions module of LEAP using the BAU (Business As Usual) scenario to determine the final energy demand. The values of the macro assumptions for 2021, serving as the base year for simulating macro energy needs beginning in 2022 as the first scenario year, are presented in **Table 2.**

Table 2. Macro Assumption Data (Key Assumptions) for BAU (Business As Usual) Scenario in 2022

Key assumptions	Unit	Value	References
Population (2024)	People	8.837.301	South Sumatra Province Statistics in Figures 2024
Gross Domestic Product	Rupiah	2.767.669	South Sumatra Province Statistics in Figures 2024
Customer Growth Rate	%	1,26	Statistic of PLN's Electricity 2022
Number of Households	Unit	2.240.385	Statistic of PLN's Electricity 2022
Number of Industries	Unit	2.508	
Number of Commercials	Unit	69.953	
Number of Socials	Unit	45.067	
Number of Government Build	Builds	7.466	
Number of Public Street Lighting	Unit	7.199	

The data in Table 2 comprises macro assumptions to be inputted into the key assumption module. Additionally, the demand module requires additional data in the form of electricity consumption intensity for several sectors. This intensity is calculated by dividing electricity consumption by the number of households, industry, commercial and public for further clarification, refer to **Table 3.**

Table 3. Electricity Demand Data for BAU (Business As Usual) Scenario in 2023 [9]

Data	Consumption (Billion GJ)	Intensity (GWh/Building)	Intensity Growth Rate (%)
Household	10,74	1,332	4
Industry	0,014	1,607	5,7
Commercial	0,398	1,607	4,2
Social	0,072	0,778	3,4

II. LITERATURE REVIEW

A. Energy Transition

The global energy landscape is rapidly evolving towards more sustainable practices, driven by the pressing need to address climate change and reduce greenhouse gas emissions. This energy transition entails a shift from reliance on fossil fuels to the adoption of renewable energy sources. Renewable energy sources, such as solar, wind, hydro, and biomass, are pivotal in this transformation, offering the dual benefits of environmental sustainability and energy security. The integration of renewable energy into existing power systems is complex and requires sophisticated planning and modeling tools to ensure efficient and effective transitions [10].

B. Overview of The Low Emission Analysis Platform (LEAP)

The Low Emission Analysis Platform (LEAP) is a widely used tool for energy policy analysis and climate change mitigation assessment. Developed by the Stockholm Environment Institute, LEAP provides a comprehensive framework for evaluating energy systems and exploring future energy scenarios. Its versatility allows for detailed modeling of energy demand and supply, emissions, and economic impacts, making it a valuable tool for policymakers and researchers. LEAP’s scenario-based approach is particularly useful for comparing different pathways, such as Business as Usual (BaU) versus more proactive strategies aimed at increasing renewable energy uptake [8].

C. Existing and Renewable Power Plant in South Sumatera

South Sumatra is endowed with a wealth of renewable energy resources. The region's geographic and climatic conditions are ideal for the development of solar, wind, hydro, and biomass energy. Solar energy, for instance, benefits from high levels of solar irradiance, making photovoltaic systems a viable option [11]. Additionally, the abundant agricultural activity in South Sumatra generates significant biomass residues that can be harnessed for energy production. Studies have demonstrated the potential of these resources to meet local energy needs and contribute to the overall energy mix, reducing dependence on fossil fuels [12].

Table 4. Existing Power Plant Capacity in South Sumatera [13]

Power Plant	Total Units	Total Capacity (MW)	Net Generating Capacity (MW)	Generating Capacity (MW)
PLN				
▪ Diesel	2	25,0	19,0	20,0
▪ Gas	12	263,6	231,9	173,8
▪ Combine Cycle (Gas and Steam)	4	160,0	149,5	129,3
▪ Steam	4	260,0	200,0	196,7
Total of PLNs	**22**	**708,6**	**600,4**	**519,8**
IPP				
▪ Gas	2	23,4	23,4	22,0
▪ Combine Cycle (Gas and Steam)	6	279,4	279,4	299,3
▪ Gas Engine	2	22,0	22,0	19,4
▪ Microhydro	1	9,9	9,9	10,6
▪ Geothermal	1	55,1	55,1	55,1
▪ Solar	1	2,0	2,0	0.0
▪ Steam	10	1.007,0	1.007,0	1.072,3
Total of IPPs	**23**	**1.398,8**	**1.398,8**	**1.478,7**
Total	**45**	**2.107,4**	**1.999,2**	**1.998,5**

Table 5. Potential of Renewable Power Plant in South Sumatera [13]

Type of Power Plant	Capacity (MW)
Hydropower	36
Micro Hydropower	102,2
Geothermal	115
Biomass	34,9
Biogas	5
Waste-Fueled	24,5
Solar	27
Total	**344,6**

D. Business as Usual (BaU) Scenario

The BaU scenario represents a critical baseline in energy planning. It projects future energy consumption and emissions based on current trends and policies, assuming no significant changes or interventions. Understanding the BaU scenario is essential for benchmarking and evaluating the impact of alternative energy transition strategies. In South Sumatra, the BaU scenario helps illustrate the potential consequences of continuing with the current energy trajectory, including sustained reliance on fossil fuels and rising greenhouse gas emissions [14]

Modeling the BaU scenario in LEAP involves detailed data collection and analysis. Key inputs include demographic trends, economic growth projections, energy consumption patterns, and technological developments. Accurate assumptions about these variables are crucial to ensure the reliability of the model. In South Sumatra, data from national and regional statistical agencies provide the foundation for these assumptions. The integration of socio-economic and demographic trends is necessary to reflect realistic future conditions and to explore the implications of continuing current energy practices [15].

E. Application of LEAP in Regional Energy Planning

LEAP has been effectively utilized in numerous regional energy planning studies worldwide, demonstrating its adaptability and robustness. For example, Zhou et al. (2023) used LEAP to analyze energy transition scenarios in China, highlighting the tool's ability to incorporate local specificities into the modeling process [16] . Similarly, Handayani et al. (2022) employed LEAP to assess renewable energy potentials and emission reduction pathways in ASEAN[17]. These applications underscore LEAP's flexibility in handling diverse contexts and its effectiveness in providing actionable insights for regional energy planning.

F. Challenges in Implementing Renewable Energy in South Sumatera

Despite the significant potential for renewable energy development in South Sumatra, several challenges must be addressed to realize this potential. These include inadequate infrastructure, limited financial resources, regulatory barriers, and insufficient public awareness. Overcoming these challenges requires a concerted effort from government, industry, and civil society. Investments in infrastructure, such as grid modernization and expansion, are crucial to support the integration of renewable energy sources. Additionally, creating a favorable policy and regulatory environment is essential to attract investment and stimulate innovation in renewable energy technologies [18].

G. Opportunities for Advancing Renewable Energy in South Sumatera

The transition to renewable energy in South Sumatra also presents significant opportunities. Leveraging international climate finance can provide the necessary funding for large-scale renewable energy projects. Enhancing regional cooperation can facilitate knowledge sharing and joint ventures, accelerating the adoption of renewable technologies. Furthermore, fostering innovation in renewable energy technologies and business models can drive down costs and improve the efficiency of energy systems. Promoting public awareness and engagement is also vital to build broad-based support for the energy transition [19].

III. METHOD, DATA AND ANALYSIS

The Modeling Power Plant Planning using LEAP Software

In the context of energy projection modeling, various software tools can be employed depending on the type of data processed. In this case study, the modeling of energy demand projections in South Sumatera was simulated using the software known as the Low Emission Analysis Platform (LEAP). LEAP is a software tool designed to analyze energy policies, climate change, mitigation, and energy demand projections. Developed by the Stockholm Environment Institute, LEAP is currently utilized by several governmental agencies across various countries for energy analysis.

The LEAP software can be considered user-friendly due to its use of relatively simple parameters throughout its algorithmic processes. This simplicity enables efficient modeling of energy consumption, exploration and production of various resources, as well as analyzing the correlation between energy and the economy. Additionally, LEAP offers features for simulating renewable energy development and analyzing emission levels, pollutants, and short-lived climate pollutants (SLCPs) [8].

© 2024 Scholar AI LLC.

The analysis process using the trendline approach, econometric approach, and end-use approach methods will be simulated using the Long Range Energy Alternative Planning (LEAP) software. LEAP adopts an end-use simulation model, where essential data related to the growth of various parameters and the intensity of each demand unit are simulated [20] (Malka et al., 2023). In LEAP modeling, four main driver parameters are utilized for energy calculations and analysis. These primary driver parameters are: Key Assumption Parameter, Demand Parameter, Transmission and Distribution Parameter, and Resources Parameter [8]. Each of these drivers plays a distinct role in the energy calculation and analysis process. The following outlines the functions of these four driver parameters used in LEAP:

a) Key Assumption

This parameter is the most essential in the LEAP modeling process because the key assumptions provide the foundational data used for calculating subsequent driver parameters. Examples of data included in the key assumptions are population size, number of households, number of vehicles, among others. The data can be tailored to specific needs and is not rigid, but it is crucial that the data included in the key assumptions correlate with the case study.

b) Demand

The demand parameter complements the key assumption parameter, integrating data into the system that will be calculated in conjunction with key assumptions. This parameter encompasses various aspects related to the energy intensity used in a particular region. Data inputted into the demand parameter includes the level of energy activity, energy usage intensity, and the cost of energy requirements [8].

c) Transformation dan Distribution

This parameter functions to calculate energy supply sources. The data within this parameter is categorized into two types of energy: primary energy (such as crude oil and natural gas) and secondary energy (such as petroleum fuels, liquefied petroleum gas (LPG), and electricity) [8].

d) Resources

This parameter is divided into two types: primary energy and secondary energy, derived automatically from the data modeled within the transformation and distribution parameter. However, this data needs to be further refined by inputting parameters specific to each energy type used. The parameters to be included are: total resources (such as crude oil and natural gas) and the potential of other energy sources [8].

A. The Scenario

The process of modeling final energy demand projections using the LEAP software can be based on various scenarios tailored to the user's needs. LEAP includes several types of scenarios, such as the business-as-usual scenario, energy transition scenario, energy policy scenario, and various other policy scenarios. These scenarios in LEAP facilitate calculations by incorporating a range of complex and variable parameters for each desired scenario [21].

The case study for modeling energy demand projections in South Sumatera for several sectors will utilize a baseline scenario known as the Business as Usual (BaU) scenario. The BaU scenario is a fundamental scenario used in energy demand modeling, relying on various data parameters entered into the LEAP software's key assumptions. This scenario serves as a pure baseline without the influence or control of other parameters such as the economic conditions of the region, government policies, or other factors that might affect the BaU scenario [22].

This scenario depicts a development pathway where no mitigation strategies are implemented. The basis for this scenario is aligned with the definition of business-as-usual as described in the Indonesian NDC, which refers to a development trajectory that excludes mitigation policies. Under this scenario, the development of the power sector adheres to a cost-optimization principle, utilizing existing resources to generate electricity at the minimum cost. This scenario serves as a benchmark for the development of other scenarios and the calculation of baseline emissions.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.
© 2024 Scholar AI LLC.
https://ijpsat.org/
Vol. 48 No. 1 December 2024, pp. 436-450

B. The Structure of the Electricity Energy Demand Model

The demand for electrical energy is divided into several key sectors, each addressing different aspects of electricity consumption in society. The household sector includes residential use of electricity for various activities such as lighting, heating, cooling, and operating household appliances. This sector reflects the daily energy needs of individuals and families, impacting the overall electricity consumption pattern. The industrial sector encompasses the energy required for manufacturing and production processes, where factories and plants utilize substantial amounts of electricity to power machinery, equipment, and production lines. This sector plays a crucial role in supporting economic growth and development through its significant electricity demand.

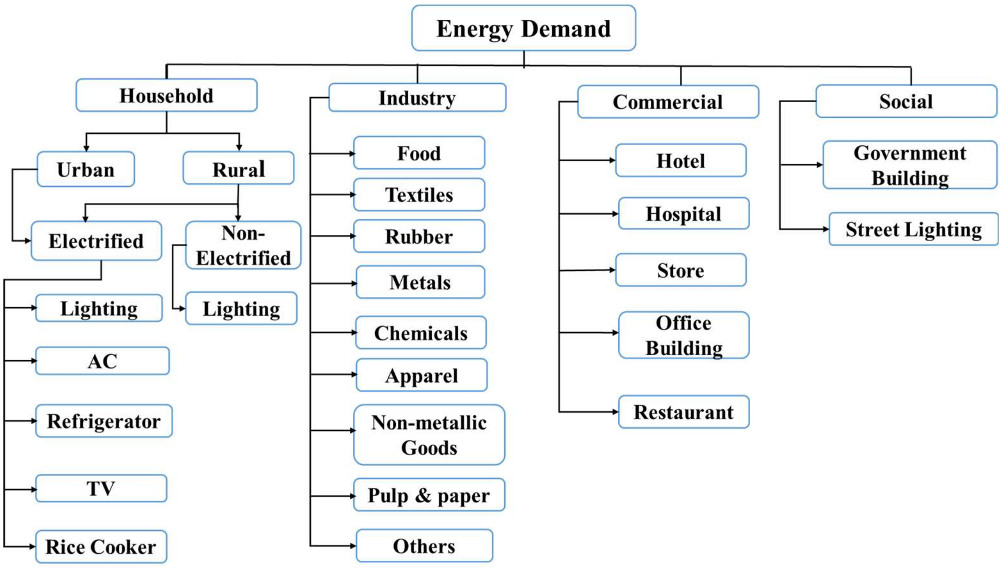

Figure 1. Modeling Energy Demand by Sector [23][24]

In addition to households and industries, the commercial sector covers energy consumption in businesses, offices, and service-oriented establishments. This sector's electricity needs include lighting, heating, cooling, and running various electrical devices and systems necessary for commercial operations. Furthermore, the social sector, which includes government buildings, public services, and street lighting, also contributes to the overall electricity demand. This sector ensures the provision of essential services and infrastructure, thereby enhancing the quality of life for the community. Each of these sectors has distinct electricity requirements, collectively shaping the patterns and trends of electrical energy consumption in society [25].

C. Structure of the Energy Model for the Household Sector

The energy modeling for the household sector is divided into two segments: urban and rural areas. Urban areas encompass only those regions that are already electrified, whereas rural areas include both electrified and non-electrified regions, as illustrated in Figure 1. The energy needs in electrified households are categorized by various uses, including cooking, lighting, air conditioning, refrigeration, television, and other appliances such as rice cookers, pumps, fans, and washing machines. It is important to note that not all families possess all of these energy needs, especially in terms of electricity requirements.

The lighting technology included for the household sector comprises fluorescent lamps (FL) with magnetic and electronic ballasts, compact fluorescent lamps (CFL), and LEDs. CFLs consume about 25–50% less energy compared to incandescent lamps, while LEDs consume up to 80% less energy than incandescent lamps [23] (National Energy Council, 2016). Air conditioning (AC) usage for cooling in the household sector is still limited to middle- to high-income households. Most households currently use standard split AC units, though the adoption of split inverter AC units, which are more energy-efficient, is gradually increasing. The types of televisions and refrigerators owned by households are often older technologies, such as cathode ray tube (CRT) or liquid crystal display (LCD) TVs and non-inverter refrigerators, both of which are inefficient in terms of energy use. It is anticipated that

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.
© 2024 Scholar AI LLC.
https://ijpsat.org/
Vol. 48 No. 1 December 2024, pp. 436-450

the adoption of energy-efficient LED TVs and inverter refrigerators will grow significantly, supported by policies promoting the use of these advanced technologies.

The projection of energy demand in the household sector is calculated based on the growth rate of the number of households and the energy usage rate, which is influenced by GDP growth. This energy demand encompasses cooking, lighting, and the use of electrical appliances. The energy usage rate varies depending on the household's per capita income and whether the household is located in an urban or rural area. Data from Susenas can be utilized to determine household income levels and fuel usage intensity.

D. Structure of the Energy Model for the Industry Sector

The modeling of the industrial sector using the LEAP software is illustrated in Figure 1. It shows that the industrial sector is categorized into nine subsectors: food, textiles, wood, pulp and paper, fertilizers and chemicals, iron and basic metals, cement and non-metallic minerals, machinery, and other industrial sectors. The industrial sector can also be classified into three categories based on energy intensity per unit [23] :

1) Energy-intensive manufacturing industries: This includes sectors such as food and beverages, pulp and paper, chemical fertilizers and rubber, cement and non-metallic minerals, and basic iron and steel industries.
2) Non-energy-intensive manufacturing industries: This includes textiles and leather goods, machinery and transportation equipment, and other processing industries.
3) Non-manufacturing industries: This includes wood and other forest products.

Currently, the energy demand in the industrial sector is predominantly driven by energy-intensive industries. Broadly, the technology for energy utilization in the industrial sector can be classified into four process technology types [23]:

1) Indirect process heating (boilers): Utilizing fuels such as oil, coal, natural gas, LPG, and commercial biomass.
2) Direct process heating (furnaces): Utilizing fuels such as oil, coal, natural gas, LPG, and electricity.
3) Process cooling (chillers): Using electricity.
4) Machine drives/motor-driven equipment (fan blowers, pumps, compressors): Using electricity.

E. Structure of the Energy Model for the Commercial Sector

The technology in the commercial sector generally pertains to applications in commercial buildings, including air conditioning, lighting, office equipment, elevators, and other electrical appliances. In this article, the energy demand in the commercial sector is differentiated between thermal equipment (e.g., in hotels and restaurants) and electrical equipment, as well as between private and governmental entities (refer to Figure 1). The level of activity in the commercial sector is measured by the floor area, calculated using approaches and assumptions due to incomplete or nonexistent data. It is assumed that electricity is consumed by both the government and private sectors, while non-electrical energy sources (such as oil, gas, and LPG) are consumed solely by the private sector. Commercial sector equipment consuming non-electric energy includes boilers or water heaters and kitchen equipment. The private sector includes offices, schools, hotels, malls, hospitals, and other private offices. Electrical equipment technology in the commercial sector can be categorized into four groups: air conditioning (AC), lighting, transportation (elevators), and other equipment (office equipment, pantry appliances, etc.) [23].

F. Structure of the Energy Model for the Social Sector

The energy model for the public sector includes social institutions, government buildings, and street lighting [3]. Social institutions encompass facilities such as hospitals, schools, and community centers that serve the public. These institutions often have specific energy needs related to lighting, heating, cooling, and specialized equipment, which are critical for their operation. Government buildings, including offices, courts, and administrative centers, require significant energy for daily operations, maintenance of electronic systems, and ensuring a comfortable environment for employees and visitors. Additionally, street lighting represents a crucial component of public infrastructure, enhancing safety and security in urban and rural areas. The model considers these diverse energy demands and integrates them to provide a comprehensive view of the public sector's energy consumption patterns.

In developing the energy model, various factors are taken into account, including the type of buildings, the intensity of energy use, and the specific needs of different public services. For instance, hospitals may have higher energy consumption due to the continuous operation of medical equipment and climate control systems, while government offices may have more predictable patterns of energy use tied to standard working hours. Street lighting energy needs are modeled based on the extent of urbanization, the density of street lights, and the efficiency of the lighting technology used. This comprehensive approach ensures that the energy model accurately reflects the public sector's energy requirements, aiding in the development of targeted policies and initiatives to improve energy efficiency and sustainability in public services.

IV. RESULT AND DISCUSSION

A. Projection of Electricity Energy Demand in South Sumatra Across Several Sectors

In this demand parameter, LEAP will perform modeling to determine the overall energy requirements. The demand value will be simulated based on key assumptions previously established. The parameter used for demand modeling involves calculating the energy intensity of each type of energy utilized by the population of South Sumatra province. Calculating the demand for South Sumatra province requires prerequisite data in the form of energy intensity for each energy type. The energy intensity values will then be modeled using various end-use methods, ultimately producing the main data component: annual electricity demand.

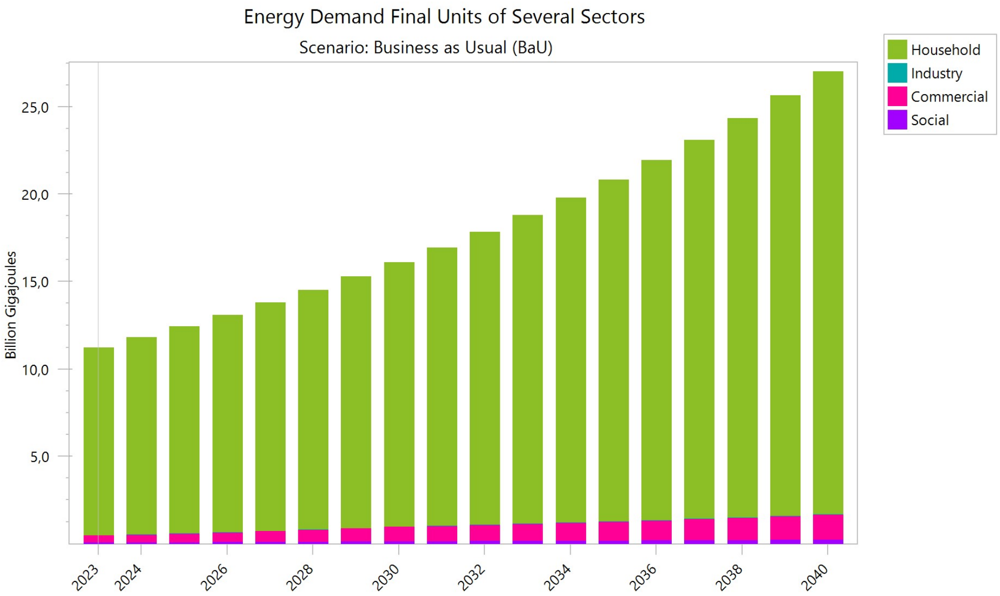

Figure 2. Energy Demand Unit of Several Sectors

The total energy demand exhibits a consistent upward trend from 2023 to 2040. The demand increases from approximately 12 billion gigajoules in 2023 to over 25 billion gigajoules in 2040.The electricity demand in South Sumatra is projected to continually increase, reaching a total of 324.53 billion GJ. The highest electricity demand is observed in the household sector, amounting to 305.10 billion GJ or 94.01% of the total demand. In contrast, the commercial, social, and industrial sectors account for 4.93%, 0.92%, and 0.13% of the total demand, respectively. The household sector's dominance indicates that residential energy consumption is the primary driver of overall energy demand. This could be attributed to population growth, increased household appliances and electronics usage, and overall lifestyle changes. Policies aimed at energy efficiency in households, such as promoting energy-saving appliances and renewable energy sources, could significantly impact overall energy consumption.

Table 6. The Simulation Results of The Final Electricity Demand for The Household Sector in South Sumatra Province for The Period 2023-2040

Year	Sectors (Billion GJ)				Total
	Household	Industry	Commercial	Social	
2023	10,74	0,01	0,40	0,08	**11,24**
2024	11,27	0,01	0,45	0,09	**11,83**
2025	11,83	0,02	0,50	0,10	**12,45**
2026	12,42	0,02	0,55	0,11	**13,10**
2027	13,04	0,02	0,61	0,12	**13,79**
2028	13,69	0,02	0,68	0,13	**14,52**
2029	14,37	0,02	0,75	0,14	**15,28**
2030	15,08	0,02	0,83	0,15	**16,08**
2031	15,88	0,02	0,87	0,16	**16,94**
2032	16,72	0,02	0,92	0,17	**17,84**
2033	17,61	0,02	0,97	0,18	**18,79**
2034	18,55	0,03	1,03	0,19	**19,79**
2035	19,53	0,03	1,08	0,20	**20,84**
2036	20,57	0,03	1,14	0,21	**21,95**
2037	21,66	0,03	1,20	0,22	**23,12**
2038	22,81	0,03	1,27	0,23	**24,34**
2039	24,02	0,04	1,34	0,24	**25,64**
2040	25,30	0,04	1,41	0,25	**27,00**
Total	**305,10**	**0,43**	**16,01**	**3,00**	**324,53**

Although the industrial sector shows an increase in energy demand, it does not grow as rapidly as the household sector. This may suggest that industrial energy efficiency improvements or shifts in the economic structure could be at play. The commercial sector's relatively smaller increase might indicate that while commercial activities are growing, their energy intensity might be lower, or they are adopting more energy-efficient technologies.

B. Primary Energy Demand from the Final Energy Transformation of Several Sectors

The total energy output shows a steady increase over the years, starting from around 13,000 million gigajoules in 2024 and reaching approximately 25,000 million gigajoules by 2040. The contribution from existing diesel and gas plants remains relatively stable throughout the period, indicating a continued reliance on these conventional energy sources. Existing Combined Cycle and Steam Plants show a slight increase in output, suggesting incremental improvements or expansions. Existing microhydro, solar, and geothermal plants contribute consistently, with a slight increase in output over time. There is a noticeable increase in the contribution

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.
© 2024 Scholar AI LLC.
https://ijpsat.org/
Vol. 48 No. 1 December 2024, pp. 436-450

from planned hydropower, minihydropower, geothermal, biomass, biogas, and MSW (Municipal Solid Waste) plants. These planned plants significantly boost the total energy output from renewable sources.

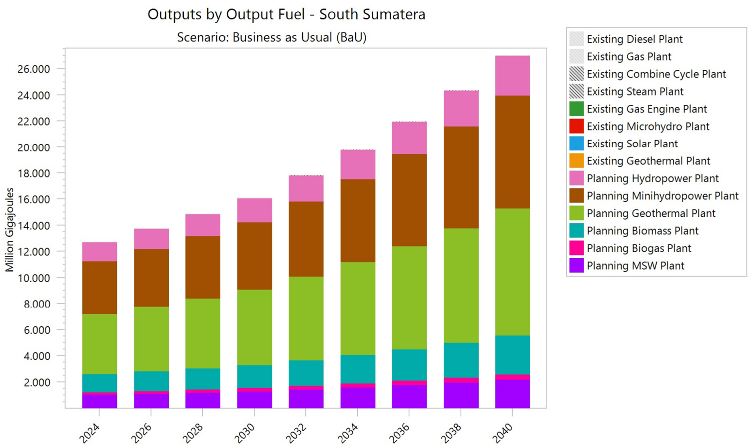

Figure 3. Output by Output Fuel

Table 7. Simulation Result of Output per Output Fuel (Existing) South Sumatera BaU Scenario 2023-2040

Year	Final Energy Demand (Million GJ)								Total
	Diesel	Gas	Combine Cycle	Steam	Gas Engine	Micro Hydro	PV	Geo-thermal	
2023	0,54	7,92	12,81	30,59	0,69	0,31	0,06	1,73	**54,66**
2024	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**12,731,77**
2025	0,25	3,32	5,36	12,82	0,29	0,13	0,03	0,72	**13.233,74**
2026	0,25	3,32	5,36	12,82	0,29	0,13	0,03	0,72	**13.757,70**
2027	0,25	3,32	5,36	12,82	0,29	0,13	0,03	0,72	**14.304,64**
2028	0,25	3,32	5,36	12,82	0,29	0,13	0,03	0,72	**14.975,58**
2029	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**15.471,62**
2030	0,25	3,32	5,36	12,82	0,29	0,13	0,03	0,72	**16.093,88**
2031	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**16.949,59**
2032	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**17.850,82**
2033	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**18.799,97**
2034	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**19.799,62**
2035	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**20.852,43**
2036	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**21.961,25**

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.
© 2024 Scholar AI LLC.
https://ijpsat.org/
Vol. 48 No. 1 December 2024, pp. 436-450

2037	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**23.129,05**
2038	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**24.358,96**
2039	0,25	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**25.654,30**
2040	-	3,32	5,36	12,81	0,29	0,13	0,03	0,72	**27.018,55**
Total	**4,53**	**64,32**	**103,97**	**248,4**	**5,6**	**2,55**	**0,51**	**4,01**	**316.898,14**

The most notable growth is observed in planned renewable energy plants, particularly hydropower and geothermal plants. This indicates a strategic shift towards diversifying energy sources and increasing the share of renewables in the energy mix. By 2040, the planned renewable plants contribute a substantial portion of the total energy output, reflecting efforts to meet growing energy demands sustainably.

The steady increase in total energy output aligns with the growing energy demand projected for South Sumatra. Meeting this demand requires both maintaining existing energy infrastructure and investing in new energy projects. The stable contribution from existing diesel, gas, combined cycle, and steam plants highlights the continued importance of conventional energy sources. While these sources remain a backbone of energy supply, their stable output suggests limited expansion, potentially due to environmental and sustainability considerations.

The substantial increase in output from planned renewable projects underscores a significant policy focus on expanding renewable energy capacity. This shift is critical for reducing greenhouse gas emissions, improving energy security, and promoting sustainable development. The planned hydropower and geothermal projects, in particular, indicate a strategic exploitation of South Sumatra's natural resources to enhance energy sustainability.

C. Allocation of Resources for Meeting Final Unit Energy Demand

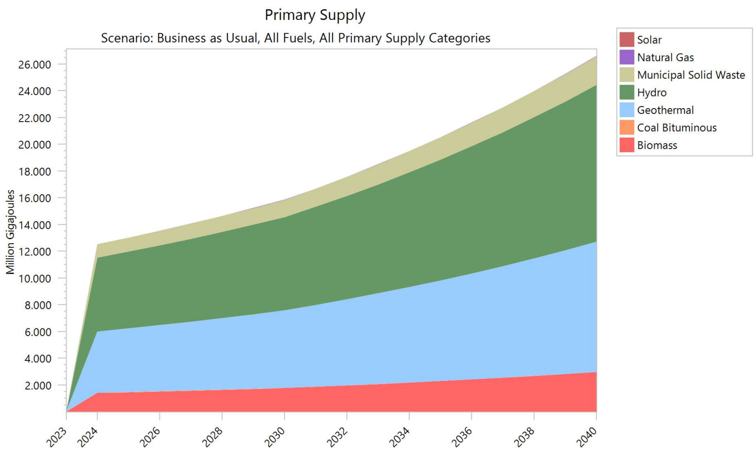

Figure 4. Allocation of Resources

LEAP allows for the assessment of various energy resources available for electricity generation. The resource categories listed are Biomass, Coal, Geothermal, Hydro, MSW (Municipal Solid Waste), Natural Gas, and Solar. The data presented in the graph depicts the projected primary resource consumption for a power plant between the years 2023 and 2040.

The graph shows a steady increase in the consumption of most resources over the given timeframe. Solar energy shows the most significant rise, with consumption nearly reaching 3.0 billion GJ by 2040. Coal consumption remains relatively flat, though there is a slight decrease projected by 2040. Natural gas consumption also shows a steady increase, reaching nearly 8.0 billion GJ by 2040. Total Consumption in 2040 reaching 26.60 billion GJ.

The graph suggests a potential shift towards renewable energy sources over the next two decades. Solar energy consumption is projected to rise significantly, while coal consumption is expected to remain flat or even decrease slightly. This trend aligns with global efforts to reduce greenhouse gas emissions and transition towards more sustainable energy sources. The continued use of natural gas is interesting to note, given its status as a fossil fuel. Natural gas consumption is also projected to rise steadily.

Table 8. Resources Primary in Billion GJ

Year	Biomass	Coal Bituminous	Geothermal	Hydro	MSW	Natural Gas	Solar	Total
2023	-	0,02	0,00	0,00	-	0,01	0,00	0,07
2024	1,39	0,02	4,77	5,51	1,02	0,01	0,00	12,54
2025	1,45	0,02	4,96	5,73	1,06	0,01	0,00	13,03
2026	1,50	0,02	5,16	5,96	1,10	0,01	0,00	13,55
2027	1,56	0,02	5,36	6,20	1,14	0,01	0,00	14,08
2028	1,63	0,02	5,80	6,44	1,19	0,01	0,00	14,65
2029	1,69	0,02	6,11	6,70	1,24	0,01	0,00	15,23
2030	1,76	0,02	6,78	6,79	1,29	0,01	0,00	15,85
2031	1,85	0,02	6,44	7,34	1,35	0,01	0,00	16,69
2032	1,95	0,02	6,44	7,73	1,43	0,01	0,00	17,58
2033	2,06	0,02	6,78	8,15	1,50	0,01	0,00	18,51
2034	2,17	0,02	7,14	8,58	1,58	0,01	0,00	19,49
2035	2,28	0,02	7,52	9,04	1,67	0,01	0,00	20,53
2036	2,40	0,02	7,92	9,52	1,76	0,01	0,00	21,62
2037	2,53	0,02	8,34	10,02	1,85	0,01	0,00	22,77
2038	2,67	0,02	8,79	10,56	1,95	0,01	0,00	23,98
2039	2,81	0,02	9,25	11,12	2,05	0,01	0,00	25,26
2040	2,96	0,04	9,74	11,71	2,16	0,02	0,00	26,60

V. CONCLUSION

The modeling of energy demand projections in South Sumatera using the LEAP software showcases its effectiveness in analyzing and simulating complex energy scenarios across various sectors. LEAP proves instrumental in integrating data from key assumptions, demand parameters, transformation and distribution parameters, and resource parameters to forecast energy requirements accurately. The software's user-friendly interface simplifies the modeling process, employing straightforward parameters to simulate energy consumption, resource allocation, and emission levels. This capability allows for detailed scenario analysis, including business-as-usual projections and alternative policy scenarios, crucial for strategic energy planning.

The results indicate a significant growth in electricity demand driven primarily by the household sector, reflecting population growth and increasing energy needs per capita. Meanwhile, the industrial and commercial sectors show steady growth but at a relatively slower pace compared to households. This disparity underscores the dominant role of residential energy consumption in shaping overall demand trends. Furthermore, the shift towards renewable energy sources is evident in the planned energy projects, particularly in hydropower and geothermal sectors. This strategic shift aims to diversify the energy mix, reduce dependency on conventional fuels, and mitigate environmental impacts, aligning with global sustainability goals.

Overall, LEAP emerges as a valuable tool for policymakers, energy analysts, and researchers in South Sumatera and similar regions, offering robust insights and projections essential for informed decision-making in energy policy and planning. Its ability to model various scenarios and integrate diverse data inputs positions LEAP as a cornerstone in sustainable energy management and policy formulation.

REFERENCES

[1] E. Hilmawan, I. Fitriana, and A. Sugiyono, "Outlook Energi Indonesia 2021," 2021.

[2] Perda Sumsel Perda No 4 Tahun 2020 Tentang Rencana Umum Energi Daerah Provinsi Sumatera Selatan 2020- 2050., *Perda Sumsel*. Indonesia, 2020.

[3] Dirjen Migas KESDM, "STATISTIK Minyak dan Gas Bumi STATISTICS Oil and Gas Semester I 2021 Directorate General of Oil and Gas Ministry of Energy and Mineral Resources," 2021.

[4] PTBA, "Bukit Asam Mulai Bangun PLTU Sumsel 8 Awal 2018.," 2017.

[5] CNBC, "Siap-Siap, PLTU 'Raksasa' Sumsel Bakal Beroperasi di 2023."

[6] BPS Sumatera Selatan, "Provinsi Sumatera Selatan Dalam Angka 2024," Palembang, 2024.

[7] Badan Pusat Statistik (BPS), "Statistik Indonesia Dalam Infografis 2022," 2022.

[8] C. G. Heaps, "Low Emissions Analysis Platform Training Exercises," 2020. [Online]. Available: https://leap.sei.orghttps//www.sei.org

[9] PT. PLN, "Statistik PLN," 2023.

[10] Q. Hassan *et al.*, "The renewable energy role in the global energy Transformations," *Renew. Energy Focus* , vol. 48, Mar. 2024, doi: 10.1016/j.ref.2024.100545.

[11] M. Dada and P. Popoola, "Recent advances in solar photovoltaic materials and systems for energy storage applications: a review," Dec. 01, 2023, *Springer Science and Business Media Deutschland GmbH*. doi: 10.1186/s43088-023-00405-5.

[12] H. Hou, W. Lu, B. Liu, Z. Hassanein, H. Mahmood, and S. Khalid, "Exploring the Role of Fossil Fuels and Renewable Energy in Determining Environmental Sustainability: Evidence from OECD Countries," *Sustain.*, vol. 15, no. 3, Feb. 2023, doi: 10.3390/su15032048.

[13] PT PLN, "RUPTL 2021-2030," 2021.

[14] S. Huang, C. Du, X. Jin, D. Zhang, S. Wen, and Z. Jia, "The Impact of Carbon Emission Trading on Renewable Energy: A Comparative Analysis Based on the CGE Model," *Sustain.*, vol. 15, no. 16, Aug. 2023, doi: 10.3390/su151612649.

[15] BPS - Statistics Indonesia, "statistik-indonesia-2020," 2020.

[16] K. Zhou, J. Yang, H. Yin, and T. Ding, "Multi-scenario reduction pathways and decoupling analysis of China's sectoral carbon emissions," *iScience*, vol. 26, no. 12, Dec. 2023, doi: 10.1016/j.isci.2023.108404.

[17] K. Handayani, P. Anugrah, F. Goembira, I. Overland, B. Suryadi, and A. Swandaru, "Moving beyond the NDCs: ASEAN pathways to a net-zero emissions power sector in 2050," *Appl. Energy*, vol. 311, Apr. 2022, doi:

10.1016/j.apenergy.2022.118580.

[18] A. B. Setyowati, "Mitigating inequality with emissions? Exploring energy justice and financing transitions to low carbon energy in Indonesia," *Energy Res. Soc. Sci.*, vol. 71, Jan. 2021, doi: 10.1016/j.erss.2020.101817.

[19] IRENA, *RENEWABLE CAPACITY STATISTICS 2020*. International Renewable Energy Agency (IRENA), 2020. [Online]. Available: www.irena.org

[20] L. Malka, F. Bidaj, A. Kuriqi, A. Jaku, R. Roçi, and A. Gebremedhin, "Energy system analysis with a focus on future energy demand projections: The case of Norway," *Energy*, vol. 272, Jun. 2023, doi: 10.1016/j.energy.2023.127107.

[21] E. Nur'aini, I. N. Darmawan, and M. A. Rayesa, "Long Term Projection of Electricity ... (Etika Nur'aini, et al.) LONG TERM PROJECTION OF ELECTRICITY GENERATION SECTOR IN WEST PAPUA PROVINCE: LEAP MODEL APPLICATION," 2020. [Online]. Available: http://journal.ugm.ac.id/index.php/ajse51

[22] L. Sani, D. Khatiwada, F. Harahap, and S. Silveira, "Decarbonization pathways for the power sector in Sumatra, Indonesia," Oct. 01, 2021, *Elsevier Ltd*. doi: 10.1016/j.rser.2021.111507.

[23] National Energy Council, "Indonesia Energy Outlook 2016 ," 2016.

[24] D. A. Zaman and C. Yong, "CAPACITY BUILDING ON DEVELOPING SDG 7 ROADMAP USING NATIONAL EXPERT SDG TOOL FOR ENERGY PLANNING," 2021.

[25] T. Nacht *et al.*, "Modeling Approaches for Residential Energy Consumption: A Literature Review," Sep. 01, 2023, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/cli11090184.