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Energy & the Built Environment

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Abstract: This paper explores the critical role of energy in shaping the future of sustainable development, with a particular focus on energy transition in the built environment. As global energy consumption continues to rise, the shift from traditional fossil fuels to renewable sources becomes increasingly important to mitigate environmental degradation. The paper investigates various renewable energy technologies, such as solar, wind, and hydrogen fuel cells, and their potential impact on reducing carbon emissions in urban settings. Additionally, the research highlights the importance of energy efficiency measures, such as energy-saving buildings and waste-to-energy technologies. Through case studies and data analysis, the paper provides insights into the current challenges and opportunities for achieving a sustainable energy transition. Ultimately, it emphasizes the need for comprehensive policy frameworks and international cooperation to ensure the widespread adoption of renewable energy solutions for the built environment.

1. Introduction

Economic development in Malaysia is heavily dependent on energy, but traditional energy sources have led to severe environmental pollution and degradation. This paper explores the impact of energy transition on economic growth, social development, and sustainability. It is divided into three parts: The first part analyzes 45 years of energy consumption data, focusing on the built environment, transportation, and energy supply while considering population, economy, energy demand, and energy transition history. The second part discusses combining energy conservation and alternative energy sources to reduce energy consumption, ensuring sustainable development by minimizing carbon emissions and optimizing economic, environmental, and social outcomes. The third part offers suggestions for sustainable energy development, including environmental pollution control, economic growth, and energy structure optimization.

2. Understand Energy Use/Consumption And Emissions

Malaysia's fuel diversification policy has been evaluated since 1980, with oil, hydropower, natural gas, and coal as primary sources. By 2003, oil's share fell to 10%, and natural gas, coal, and hydropower increased their shares[1]. Non-renewable energy sources pose challenges due to limited resources and their contribution to greenhouse gas emissions. Malaysia signed the United Nations Framework Agreement on Climate Change and the Kyoto Protocol to reduce emissions.

Developing countries, especially in Asia, are major drivers of global energy demand, with Malaysia expecting annual growth rates of 5-6%. As a result, Malaysia’s government has shifted to

renewable energy, with 5% of electricity generation sourced from renewables by 2005[2].

2.1 Trends in energy supply consumption

As mentioned, Malaysia's current five-fuel diversification strategy has been implemented since 1999. In this strategy, Malaysia's energy mix consists of five important sources, namely natural gas, coal, oil, hydropower and renewable energy.

2.1.1 Trends in gas supply and consumption

Natural gas was discovered in Malaysia in 1983. Since then, the energy mix has changed and natural gas has become increasingly important. Today, Malaysia's gas reserves have grown to around 87 TCF, with proven reserves of 58 TCF, and it now has the largest gas reserves in Southeast Asia and the 12th largest in the world. Malaysia is also one of Asia's leading gas producers, producing 1 billion cubic feet of gas per day. Malaysia's reserve-to-production ratio of gas reserves is 87(assuming constant production).

2.1.2 Trends in coal supply and consumption

Coal has always played an important role in particular countries because it is the cheapest and most abundant fossil fuel[3]. Coal accounted for only 12% of Malaysia's energy mix in 2003, with coal reserves of about 1.712 billion tonnes of all types of coal, from lignite to anthracite, comprising 275 million tonnes of proven reserves, 347 million tonnes of confirmed reserves and 1.09 million tonnes of inferred reserves. As a result, the Malaysian government has ample coal resources, mainly from Australia, Indonesia, China and South Africa.

2.1.3 Trends in hydropower supply and consumption

Malaysia has significant hydropower potential of 29 gigawatts, but only 2 gigawatts are currently under development due to high investment costs and social, environmental, and political challenges. Developing hydropower stations involves complex issues beyond design and construction, including broader societal impacts. Coal reserves have become crucial for Malaysia's sustainable development. If all coal resources are mined domestically, they could meet annual demand for 285 years. As a result, Malaysia is likely to focus on sustainable development goals and ensure coal production adheres to environmental standards. Hydropower projects also contribute to economic development by improving infrastructure and providing benefits like flood control and rural electrification[4].

2.1.4 Trends in oil supply and consumption

The role of oil in the energy mix has been greatly affected by depleted reserves and high oil prices. Ten percent, down from 90 percent in 1980. As of 2003, Malaysia's proven oil reserves stood at 3 billion b/d, while production remained relatively stable at 700,000 b/d. If production remains at 250 million b/y, the ratio of stored oil to production is 12, which means Malaysia will run out of oil in 12 years. To sum up, except for power generation, oil is exported either as crude oil or downstream refined products.

3. Analysis

The five main energy sources in Malaysia's diversification strategy include natural gas, coal, oil, hydropower, and biomass. In addition, Malaysia is exploring alternative energy options such as

solar energy, hydrogen fuel cells, exhaust gas utilization, and municipal solid waste incineration.

3.1 Analysis of alternative energy sources: Hydrogen fuel cell

Hydrogen energy, considered the cleanest and most promising energy for the 21st century, offers high calorific value, non-toxicity, and low transport loss, making it a future replacement for fossil fuels. Recent advancements in hydrogen extraction and fuel cell technology have drawn global attention, with countries like the U.S., Japan, and Germany incorporating hydrogen energy into their national strategies. Malaysia's Petronas is investing in hydrogen as part of its carbon-free energy goals, alongside its focus on liquefied natural gas and renewables. CEO Tengku Muhammad Taufik Tengku Aziz emphasized growing demand in emerging Asia and Petronas' partnerships to develop hydrogen energy.

3.2 Analysis of alternative energy sources: solar

Solar or photovoltaic (PV) systems are estimated to be four times the world's fossil fuel resources. Malaysia, with its abundant sunshine year-round, is well-suited for solar energy development. Solar radiation in Malaysia ranges from 6.5 degrees/m ^{2}in January to 6.0 degrees/m ^{2} in August. Photovoltaic power generation converts light energy into electricity using the photogenerating volt effect on semiconductor devices. As a key renewable energy source, solar energy is growing rapidly due to its safety, resource abundance, and clean nature, playing a crucial role in long-term energy strategies. While Malaysia's photovoltaic development was initially slow, recent government policies and measures highlight its potential for future growth, positioning it as an important part of the nation's energy future.

3.3 Analysis of alternative energy sources: Waste gas

A fuel cell converts the electrochemical energy of a fuel into electricity, similar to a battery. A hydrogen fuel cell uses hydrogen as fuel and is more efficient than traditional engines, achieving efficiencies over 60%, compared to the 42% of thermal engines. Malaysia is prioritizing climate change and environmental pollution, with plans to implement a no-emission bus system using hydrogen fuel cells. In November 2018, Fast Cars signed a contract with Sarawak State Economic Development Corporation to launch Southeast Asia's first hydrogen fuel cell bus project. The pilot will see the supply of 10 hydrogen buses, with the first three shipped in April 2019.

3.4 Analysis of alternative energy sources: Incineration of municipal solid waste (MSW)

Municipal solid waste incineration (MSW) is an effective method for generating energy from waste. Companies operating waste incineration plants typically sign BOT or BOO agreements with the government to handle investment, construction, and operation. Revenue comes from government subsidies for waste disposal and electricity sales. The construction cost for new incinerators ranges from 400,000 to 730,000 yuan per ton per day for grate incinerators, and 230,000 to 370,000 yuan for fluidized bed incinerators. Government subsidies for waste disposal range from 60 to 100 yuan per ton, depending on the treatment scale and additional factors like fly ash and leachate treatment. Larger plants without these treatments receive lower subsidies, while smaller plants with higher treatment needs can receive subsidies above 70 yuan per ton.

4. Suggestion

4.1 Alternative governance

In Malaysia, solar hot water systems are widely used in hotels, small restaurants, and urban households. Around 10,000 residential heating systems rely on photovoltaic power[5]. However, the high cost and limited electricity generation from photovoltaics, particularly in remote areas, remain challenges. To address this, the Malaysian Energy Centre (PTM) launched the Integrated Utilisation of Photovoltaic Systems in Buildings Malaysia (MBIPV) project, aiming to reduce system costs by 20%. Malaysia is also focusing on hydrogen fuel cell vehicles. Companies in Sarawak are building hydrogen production plants and stations, marking the first hydrogen bus project in Southeast Asia, a collaboration between Fast Cars and SEDC. Malaysia, as a major oil and gas producer, is leveraging its hydropower resources to develop hydrogen energy. Additionally, the government is exploring waste-to-energy technologies to reduce municipal waste and generate energy, promoting waste incineration as part of its long-term energy strategy and encouraging local and foreign investments in this sector.

4.2 Economic mechanisms

At present, Malaysia's 10-year bond yield is between 3.4 and 3.5 percent, and GDP growth in 2011 is 5.1 percent. The economic situation is relatively stable. At the same time, the government has a special plan to provide financing and loans for green industry, GTFC, in which 60% of the loans are guaranteed by the government credit institution and the remaining 40% by financial institutions. However, because banks are still unfamiliar with green industry, the lending conditions are relatively strict. As a small net oil exporter, Malaysia not only needs to secure its domestic energy supply, but also needs to protect its exports from changes in international oil prices. In 2010, many scholars studied the relationship between energy consumption and economic growth in Malaysia and came to the following conclusion: Malaysia needs to combine labor, investment and energy utilization in the secondary substitution stage with energy development as the main body and the export-oriented economic liberalization stage[6].

4.3 Energy structures

The Sankey diagram for energy distribution in Malaysia involves five primary energy sources—raw coal, crude oil, natural gas, hydropower, and biomass—and three secondary energy sources: oil, liquefied natural gas, and electricity. The production of primary energy is shown in the energy supply link, while oil products, LNG, and electricity are part of the energy conversion link. The terminal consumption link includes sectors like agriculture, industry, commerce, transportation, and residential consumption, with sub-terminals for specific uses like air conditioning, lighting, refrigeration, and appliances. In industry, consumption is categorized into sectors like non-metallic minerals, chemicals, food, paper, and more. In transportation, engines such as gasoline, diesel, and natural gas are distinguished. Non-energy use is treated as a separate terminal. The diagram also tracks energy imports, exports, and inventory changes. Energy losses are not shown separately but are included in the total energy consumption by each sector. The diagram helps analyze the impact of energy consumption and conversion efficiency on Malaysia’s overall energy use.

5. Prove that suggestion

Selecting and implementing the right energy policy is complex, given the challenges of

incomplete information, political flaws, and diverse perspectives. An effective energy policy should address social, environmental, and economic needs for sustainable development. Malaysia, for example, has integrated renewable energy into its energy mix and launched projects to promote its use. Similarly, Nigeria's Ministry of Energy has established a task force to attract private sector investment in renewable energy.

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6. Conclusion

Malaysia still relies on non-renewable energy and contributes to greenhouse gas emissions. When realizing that the world (including Malaysia) is not ready Awareness of the importance of the role of renewable energy in sustainable energy systems has been increased through various policies and projects implemented by the Government of Malaysia in the context of replacing non-renewable energy sources with renewable fuels. More practical action must also be taken by ngos and the public, Adapting, promoting and using energy generated from renewable resources. In addition, close cooperation among countries in the region can further promote the use of renewable resources.

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