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Biomass Energy Outlook in Malaysia using Functions of Innovation Systems

Bemgba Bevan Nyakuma[1,2]

[1]Centre of Hydrogen Energy, Institute of Future Energy,
Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Malaysia.
[2]Department of Chemical Engineering, Faculty of Chemical & Energy Engineering,
Universiti Teknologi Malaysia, 81310 Skudai, Johor Bahru, Malaysia.
Tel. +6(0)149890390; E-mail: bnbevan2@live.utm.my, bbnyax1@gmail.com

Abstract: Malaysia generates significant quantities of Oil Palm Wastes (OPW) which can be potentially valorised into sustainable bioenergy as envisaged by the National Biomass Strategy (NBS-2020). Despite significant investments, policy directives and government support, the valorisation of OPW into bioenergy has remained low exacerbating waste management challenges. Therefore, the strategies and impediments to the rapid bioenergy development and bioelectricity generation from OPW require practical assessment. Therefore, this paper examines the level of development and diffusion of the biomass innovation system in Malaysia based on the Functions of Innovations Systems (FIS) approach developed by Dutch and Swedish researchers. Furthermore, the key factors hindering biomass energy technologies implementation in Malaysia and potential solutions were identified, highlighted and examined. Based on the FIS analysis the functions; entrepreneurial activities, knowledge development, and resources mobilization functions are well established in the Malaysian biomass innovation system (BIS). However, the functions of guidance of search; creation of legitimacy; knowledge diffusion and market formation are underdeveloped resulting in the low penetration of bioenergy in Malaysia. Other factors include; fossil fuel subsidies, numerous or conflicting energy policies and weak collaboration between academia and the industry. The outlined challenges can be addressed by revising fuel subsidies, Feed-in tariffs, RETs implementation, roles of supervisory agencies, and bureaucratic procedures for access to funds for research and development of bioenergy in Malaysia.

Keywords: Biomass, Functions, Innovation Systems, Renewable Energy, Malaysia.

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1. Introduction

Energy is a crucial determinant of socio-economic growth and sustainable development [1]. Currently, the fossil fuels utilization comprises 82% of global energy mix with coal (64%), oil (19%) and natural gas (17%) accounting for the total economically recoverable sources of energy [2, 3]. Conversely, the International Energy Agency (IEA) predicts fossil fuel utilization will decrease by 2035 due to rapidly depleting reserves and growing concerns about environmental degradation and greenhouse gas (GHG) emissions [3, 4]. This has catalysed the search for alternative sources of low-cost, non-polluting, and renewable energy to supplement fossil fuels and ensure environmental sustainability [5, 6]. This will potentially stimulate growth in the development, diffusion and primary energy demand for renewables such as solar, hydropower, wind, ocean tidal, geothermal and biomass energy. As a result, the IEA projects that the global energy demand for renewables will be significantly influenced by emerging economies like China and India accounting for 90% of net energy demand growth by 2035 [7]. It is therefore envisaged that the utilization of RETs will critically influence the future dynamics of the global energy mix [8]. Similarly, the IRENA (international renewable energy agency) posits that the implementation of RETs will potentially account for 36% of the global energy mix by 2030. According to the report, biomass energy will account for the largest share based on soaring demand which is expected to exceed 108 EJ by 2030. This will potentially account for 60% of total RETs utilization around the globe [9].

Currently, biomass is ranked as the 4th largest global energy source comprising 10-14 % or 51 EJ of global energy supply [10-12]. The growing interest in biomass can be attributed to its wide global distribution, carbon neutrality and clean energy potential which results in zero CO_2 net emissions during conversion [13-15]. Biomass can be effectively converted into clean and renewable liquid, solid and gaseous fuels, energy and chemicals using a variety of feedstocks [16-19]. According to IRENA, the supply of biomass feedstock will exceed 145 EJ by 2030 with agricultural waste residues accounting for 37-66 EJ, energy crops 33-39 EJ and forestry residues 24-43 EJ particularly from developing countries in Asia [9].

Malaysia is the second largest producer and exporter of palm oil accounting for 31% of global output [20, 21]. Currently, oil palm (*Elaeis guinnensis*) is cultivated on over 5 million hectares of arable land production which yields 80 million tons of fresh fruit bunches (FFB) annually [22]. The FFB is typically processed into crude palm oil (CPO) and palm kernel oil (PKO) for utilization in the food, fuels, and chemical industries [23, 24]. This value creation process generates large quantities of lignocellulosic waste comprising empty fruit bunches (EFB), mesocarp fibre (MSF), palm kernel shell (PKS), palm fronds (OPF) and palm trunks (OPT) [25, 26]. The resulting solid oil palm waste (OPW) presents significant disposal and pollution management challenges for the palm oil industry [27-29]. Currently, the OPW in Malaysia is utilised for organic fertilizer, soil enhancement [30] and boiler fuel for the cogeneration of steam and electricity in oil palm mills (OPM) [31, 32]. However, large proportions of OPWs are simply dumped in open fields, indiscriminately burned or landfilled [33]. The inefficiency of these waste conversion techniques has exacerbated the rate of greenhouse gas (GHG) emissions, atmospheric pollution, and environmental degradation [34]. As a result, Malaysia is the 24th largest contributor to global GHG accounting for 250 million tons of CO_2. This arises from the 345% increase in CO_2 emissions recorded from 1990 – 2015 originating primarily from agriculture [35]. The underlying dynamics emphasize the urgent need for research into novel, low cost, and efficient technologies for the disposal, management, and valorisation of OPW.

Consequently, the Government of Malaysia (GoM) established the National Biomass Strategy (NBS-2020) in 2011 to address the challenges of OPW disposal and management [36]. The policy aims to valorise 20 million tons of dry biomass, reduce GHGs, generate renewable energy and create 66,000 jobs. One promising approach is to explore the conversion of OPW into clean, renewable and sustainable bioenergy and biofuels. However, the transition from fossil fuels to clean bioenergy in the Malaysian energy economy will require a paradigm shift from status quo, by addressing the numerous techno-economic and socio-political challenges hampering clean energy and power generation technologies in the country [36]. The challenges of developing and implementing RETs can be critically examined using sociotechnical analytical concepts such as the Functions of Innovations Systems (FIS) developed by researchers in the Netherlands and Sweden. This is an empirical concept designed to analyse and evaluate the societal subsystems, actors, and institutions that contribute to the development of an innovation. The concept can be used to analyse the performance of technological innovations systems using a set of "functions" called the "functions of innovation systems"[37]. An innovation system is the sum of all the hardware, software, institutions and economic structures that influence the rate and direction of socio-technological change [37, 38]. This is vital for assessing the level of sustainable economic growth and technological development in any society [39]. Furthermore, the approach avails researchers with tools to map, establish functional patterns and feedback loops between the various functions within an innovation system [40, 41].

The FIS concept can stimulate the creation of policy instruments aimed at meeting the targets of the innovation system through in-depth analyses of system determinants, performance, and failures [39, 42]. The practicality of FIS has been successfully demonstrated by its application to a number of sociotechnical and energy innovation systems around the world. The study by Kamp [43] examined the socio-technical dynamics, prospects, and limitation of wind power in the Netherlands and Denmark. Likewise the FIS approach has been applied to examine the prospects and challenges of biomass energy as an innovative RET. Negro *et al.* [44] examined the successes and failures of the biomass innovation system (BIS) in the Netherlands using FIS. A different study by Negro *et al.* [45] identified, highlighted and examined challenges of biomass digestion as an emerging innovation system in the Netherlands. Similarly, the success of biomass digestion as an emerging innovative renewable technology in Germany has been examined by FIS [46]. The results of the studies have demonstrated that FIS can be successfully applied to examine the level of development, diffusion, and utilization of biomass as an innovative RET. Furthermore, the FIS can present insights into the socio-technical dynamics, institutional framework and policy direction of energy systems. However, the FIS approach has never been used to analyse RETs or innovations system outside the European continent despite its success. Furthermore, there is limited knowledge on the status of biomass energy as described in Malaysia's energy policies such as the Fifth Fuel Policy (5FP) of the 8th Malaysia Plan (8MP) and the Renewable Energy Policy and Action Plan (REPAP) [47, 48].

Therefore, the FIS approach will be applied to examine the level of development and diffusion of biomass energy in Malaysia. It is envisaged that the concept will provide a systematic framework for examining biomass in Malaysia as an innovation system. Therefore, this study is aimed at identifying the key network of stakeholders, policies directives and innovative technologies that influence biomass energy in Malaysia through the set of 'functions' within Functions of Innovations Systems (FIS) approach. The study will also identify and highlight key sociotechnical and technological challenges hindering its implementation in Malaysia.

2. Functions of Innovation Systems (FIS)

The "Functions of Innovation Systems" (FIS) approach is governed by a set of "functions" namely; Entrepreneurial activities, Knowledge development, Knowledge Diffusion, Guidance of search, Market formation, Resources Mobilization, and Creation of legitimacy. This methodology can be used to identify the networks of key actors and institutions collectively known as "stakeholders" responsible for the development and diffusion of an innovation system. The stakeholders in any innovation system can be categorised into three broad groups [37]; Technology Producers, Technology Regulators, and Technology Users.

The technology producers consist of all the entrepreneurs, networks or clusters of technology companies within the innovation system. Conversely, the organisations, ministries and government agencies that oversee government policy directives and implementation guidelines are termed technology regulators. Finally, the end users of the products and spin-off technologies are referred to as technology users or consumers. Furthermore, the designated roles of the actors, network, and institutions in an innovation system are reinforcing and complementary, thus creating a network of activities that can be categorised into a stakeholder map [37, 49]. A stakeholder map of the biomass innovation system (BIS) in Malaysia is presented in Figure 1.

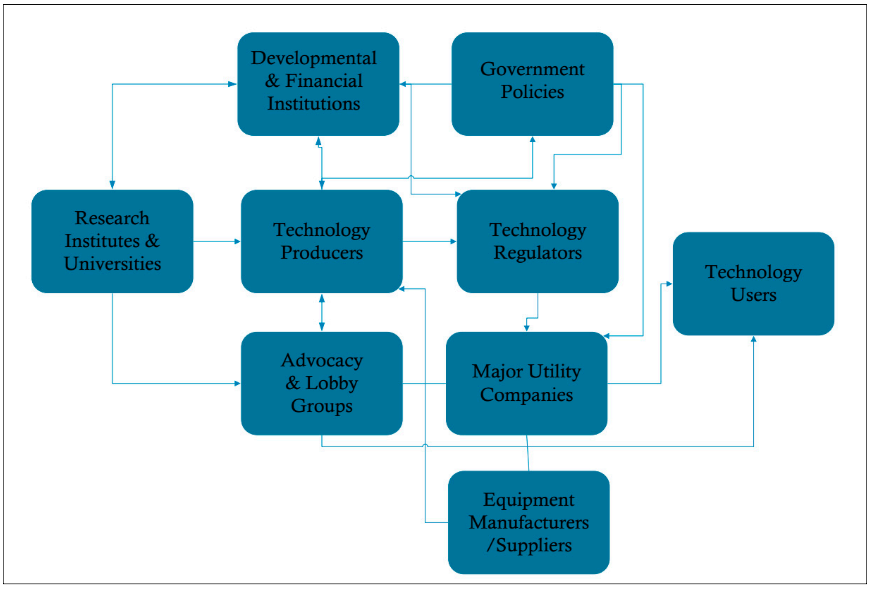

Figure 1. Stakeholder map for the Malaysian biomass innovation system.

The stakeholder map in presents an overview of the interdependencies between the major technological stakeholders comprising the producers, regulators, and users in innovation systems [49]. Based on this, the FIS will be employed to identify the key factors and stakeholders that influence the implementation of biomass energy technologies in Malaysia.

2.1 Entrepreneurial Activities

The entrepreneur plays a vital role in the success of an innovation system. The entrepreneur is responsible for conceiving and creating the innovative ideas that influence socioeconomic and technological change in any innovation system. The entrepreneur is also responsible for coordinating all the knowledge, networks and market potentials within an innovation system into business opportunities [37, 40]. In principle, entrepreneurs may either be new entrants looking to maximise the business potential of new technologies or established firms expanding their business portfolio. Essentially, entrepreneurs are risk takers involved in the development of new technologies [50]. Hence the success of an innovation system is greatly influenced by entrepreneurs and the network of functions within an innovation system [37]. Table 1 presents a list of the identified key actors notably entrepreneurs, organisations and government agencies in the biomass innovation system (BIS) in Malaysia.

Table 1. Key stakeholders in the Malaysian biomass innovation system (BIS).

Name of organisation, company or institution	Description	Role
Alaf Ekspresi Sdn Bhd	Private Energy Company	TP
Biomass Technology Group	Foreign Energy Company	TP
Bio-power Sdn. Bhd	Private Energy Company	TP
Bumi Biopower Sdn Bhd	Private Energy Company	TP
Chubu Electric Power	Foreign Energy Company	TP
Department of Environment	Government Ministry	TR
Department of Statistics	Government Ministry	OT
Genting Sanyen Power Bhd	Private Energy Company	TP
IRIS WRP Eco Power Sdn Bhd	Private Energy Company	TP
Jana Landfill Sdn Bhd	Private Energy Company	TP
Kemaman Biomass Power (M) Sdn Bhd	Private Energy Company	TP
Kina Biopower Sdn Bhd	Private Energy Company	TP
Malaysian Agric. Research & Dev Institute	Government Agency	OT
Malaysian Palm Oil Board	Government Agency	TR
Ministry of Energy, Green Technology & Water	Government Ministry	TR
Naluri Ventures Sdn Bhd	Private Energy Company	TP
Palm Oil Institute of Malaysia	Government Agency	OT
Petronas Group	National Energy Company	TP
Potensi Gaya Sdn Bhd	Private Energy Company	TP
Powertude Sdn. Bhd.	Private Energy Company	TP
Recycle Energy Sdn Bhd	Private Energy Company	TP
Sabah Electricity Sdn. Bhd	National Energy Company	TP
Seguntor Bioenergy Sdn Bhd	Private Energy Company	TP
Sarawak Electricity Supply Corporation	National Energy Company	TP
Suruhanjaya Tenaga	Energy Commission	TR
Sustainable Energy Development Authority	Government Agency	TR
Tenaga Nacional Berhad	National Energy Company	TP
TSH BioEnergy Sdn Bhd	Private Energy Company	TP

TP, TR, & OT represent Technology Producers, Technology Regulators, and Others respectively.

As observed, the key stakeholders serve as producers, regulators or users of biomass energy in Malaysia. The producers in the innovation systems is responsible for creating bioenergy from biomass utilization based on the lignocellulosic pathway of the National Biomass Strategy (NBS-2020) [36]. This is based on the long-term objective to generate 1,340 MW of bioelectricity from Oil Palm Wastes (OPW) and wood waste utilization in biomass power plants [51]. Table 2 presents an overview of the biomass power plants currently operated by various bioenergy companies in Malaysia.

Table 2. Key actors in the biomass innovation system (BIS) in Malaysia [52].

Plant owner/operator	**Location**	**Capacity (MW)**	**Technology**	**Fuel**
Alaf Ekspresi	Sabah	8	Steam turbines	Palm waste
Bumi biopower	Perak	6	Steam turbines	Palm waste
Jana Landfill	Selangor	2	Gas turbines	Biogas
Kina Biopower	Sabah	11.5	Steam turbines	Palm waste
Naluri Ventures	Johor	12	Steam turbines	Palm waste
Potensi Gaya	Sabah	7	Steam turbines	Palm waste
Recycle Energy	Selangor	8.9	Gas turbines	Biogas
Seguntor Bioenergy	Sabah	11.5	Steam turbines	Palm waste
TSH Bio Energy	Sabah	14	Steam turbines	Palm waste
Bentong Biomass Energy	Pahang	1.2	Steam Turbines	Palm waste/Wood
Mensilin Holdings	Selangor	1.2	Steam Turbines	Palm waste
SEO Energy Sdn Bhd	Sabah	1.2	Steam Turbines	Palm waste
LDEO Energy	Sabah	1.2	Steam Turbines	Palm waste
Kwantas Oil	Sabah	9.8	Steam Turbines	Palm waste
LH Kiln D Moulding	Johor	0.6	Steam Turbines	Palm waste
Total		**96.1**		

As observed, the current operations of the outlined companies involve the utilization of OPW and wood chips for generating biomass-based renewable energy using steam and gas turbines. The data in Tables 1 and 2 indicate that the BETs innovation system in Malaysia consists of a relatively large number of active stakeholders. According to Hekkert *et al.* [37], the existence of large numbers of entrepreneurs is a fundamental sign of a healthy innovation system as the nonexistence of entrepreneurs can lead to the failure of other functions in the innovation system. Furthermore, the success of an innovation system significantly depends on the networks formed by entrepreneurs and their ability to coordinate all the other functions of the innovation system [37].

Despite the healthy landscape of entrepreneurs, the biomass innovation system (BIS) is limited to 96 MW of installed and operational capacity. According to Oh *et al.* [53], Malaysia can potentially generate an estimated 1,340 MW of renewable electricity from biomass. This indicates that entrepreneurial activities in Malaysia are well short of the policy guidelines of the 5th Fuel Diversification Strategy of the 8th Malaysia Plan (8MP) aimed at generating 5% of the nation's electricity from RETs [54]. One potential solution will be to retrofit oil palm mills (OPM) operating in the country to generate bioelectricity for integration into the national grid [30, 55].

2.2 Knowledge Development

The development of scientific and technological knowledge base is fundamental to an innovation system in any modern economy. It refers to all the processes and mechanisms of learning which significantly influence the growth and development of innovation systems [56]. Hence, learning mechanisms are the heart of the innovation process particularly because they influence knowledge development through R&D. The learning process of FIS involves the learning by doing, interacting, searching and using; which emphasizes the importance of R&D to the success of an innovation system [57]. The study by Zangwill and Kantor [58], posits that the knowledge development function of an innovation system can be examined using three indicators namely; Patents, R&D projects, and R&D investments. Since R&D is vital to innovation, a comprehensive assessment of the patents and intellectual property rights in Malaysia is necessary to assess the knowledge development function. Table 3 presents a list of registered patents in science, technology, and engineering in Malaysia from 2006 to 2016 [59].

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Table 3. Technology Patents Granted in Malaysia from 2006-2016 [59].

YEAR	SECTION								TOTAL
	A	B	C	D	E	F	G	H	
2006	948	1,155	1,275	101	197	448	1,042	1,583	**6,749**
2007	1,179	1,213	1,748	109	221	407	883	1,223	**6,983**
2008	423	421	451	33	98	159	293	364	**2,242**
2009	656	633	837	53	119	185	488	497	**3,468**
2010	364	390	599	22	75	125	274	328	**2,177**
2011	404	402	693	28	90	126	283	366	**2,392**
2012	445	424	722	25	72	101	328	384	**2,501**
2013	523	393	840	36	98	108	315	378	**2,691**
2014	538	430	729	27	154	150	331	403	**2,762**
2015	542	494	642	25	161	198	352	494	**2,908**
Oct-16	537	359	881	30	129	127	213	360	**2,636**
TOTAL	**6,559**	**6,314**	**9,417**	**489**	**1,414**	**2,134**	**4,802**	**6,380**	**37,509**

Section A: Human Necessities; Section B: Performing Operations & Transportation; Section C: Chemistry & Metallurgy; Section D: Textiles & Paper; Section E: Fixed Construction; Section F: Mechanical Engineering, Lighting, Heating, Weapons & Blasting; Section G: Physics; Section H: Electricity.

The data presented indicates that the academia is actively involved in R&D and can potentially complement the biofuels and bioenergy industry in Malaysia. In addition to entrepreneurs, private institutions, academic institutions also play a vital role in the development of innovations systems. A list of academic institutions currently carrying out research into biomass-based energy technologies in Malaysia is presented in Table 4.

Table 4. Malaysian academic institutions conducting biomass research.

Institutions	**Abbreviation**	**Area of Research**
Universiti Kebangsaan Malaysia	UKM	Jatropha oil extraction, heterogeneous catalysis
Universiti Sains Malaysia	USM	Heterogeneous catalysis and Biodiesel from Jatropha
University Putra Malaysia	UPM	Biodiesel/Biofuels Research
University Malaya	UM	Biomass Conversion, Biodiesel/Biofuels Research
University Technology Malaysia	UTM	Biomass Conversion, Hydrogen, Fuel Processing
University Technology Petronas	UTP	Biodiesel/Biofuels Research
International Islamic University	IIU	Biodiesel/Biofuels Research
University Malaysia Sabah	UMS	Biodiesel/Biofuels Research

In addition to active university research, a number of institutes in the country are engaged in cutting-edge research in other RETs. In addition, the Malaysian government has been actively financing projects and providing policy guidelines for the development and diffusion of RETs in the country. A good example is the Feed-in Tariff scheme for biomass and other RETs managed by the Sustainable Energy Development Authority of Malaysia (SEDA Malaysia) [60]. Similarly, the Green Technology Financing Scheme (GTFS) is a funding scheme established in 2010 by the Government of Malaysian Prime Minister [61]. Other key policies for RETs development in Malaysia will be identified and highlighted in the Function: Knowledge Diffusion through Networks.

2.3 Knowledge Diffusion through Networks

The role of networks is to exchange scientific knowledge and technological information vital to the success of the innovation system [50, 62]. The knowledge diffusion function is an integration of technological insights, government policies, norms, and values – all referred to as 'learning by interacting'[37]. The integration of these networks not only augments the knowledge base of the innovation system but also the perception of what is possible and desirable in terms of future developments and investment choices [62]. Furthermore, the size of networks, extent of public-private collaborations, number of actors and stakeholders is evidence of the level of knowledge development and diffusion [37]. In Malaysia, biomass energy has been promoted by a number of key policies and regulatory guidelines aimed at stimulating the development and diffusion of RETs in the country. Table 5 presents a summary of the key laws, policies and implementation guidelines promulgated by the Malaysian government for RETs development over the years.

Table 5. Malaysian Renewable Energy Policies [47, 63, 64].

Policy Directive	**Year Established**	**Aim and Objectives**
National Energy Policy (NEP)	1979	Ensure an efficient, secure and environmentally sustainable supply of clean energy.
Four Fuel Diversification Policy (4FDP)	1981	Promote fuel diversification, reduce dependence on oil and increased emphasis on gas, hydro and coal.
Seventh Malaysian Plan (7MP)	1996	To achieve 5 % Electric energy demand from RETs by 2005 and promote energy efficiency.
5th Fuel Diversification Policy (FDP)	2000	Reduce overdependence on fossil fuels. Highlight the nation's biofuel potential and balance energy mix with RETs.
Renewable Energy as Fifth Fuel Policy	2000	To highlight the potentials of biomass, biogas and other renewable energy resources.
Energy Commission Act (ECA)	2001	To regulate the energy industry in Peninsular Malaysia and Sabah and ensure energy efficiency.
8th Malaysian Plan (8MP)	2001-2005	To promote sustainable development and achieve 5 % electricity from RETs.
Small Renewable Energy Power Program (SREP)	2001	Encourage the utilization of RETs for power generation and reduce overdependence on fossil fuels.

Renewable Energy Power Purchase Agreement (REPPA)	2001	To provide an equitable pricing policy for purchase of energy from RETs companies and integration of RETs into the national electricity grid.
9th Malaysian Plan (9MP)	2006-2010	Review electricity prices, fossil fuel dependency, increase the share of RETs in the energy mix, and access to funding for RETs.
National Biofuel Policy (NBP)	2006	To enhance extensive growth and development of the biofuels industry.
Malaysian Biofuel Industry Act	2007	Regulate, facilitate and develop the biofuels industry. Issue licences and reduce administrative barriers for growth in the sector
National Green Technology Policy (NGTP)	2009	Strengthen institutional framework, provide a favourable environment for green energy technology R&D and increase public awareness of RETs. Establish the Green Technology Financing Scheme (GTFS).
Renewable Energy Policy and Action Plan (REPAP)	2010	Promote the use of locally generated renewable energy, ensure energy security and fuel supply independence. Address market failures and policy inconsistencies and increase share of RE in the energy mix.
National Biomass Strategy (NBS2020)	2011	Promote the valorisation of oil palm wastes, reduce GHG emissions, meet RETs targets and generate 66,000 jobs.
Renewable Energy Act (REA)	2011	Ensure growth and development RETs in Malaysia, increase funds for RETs projects, reduce GHG emissions from fossil fuels use and electricity generation. Establish the Feed-in Tariff Scheme.
Tenth Malaysia Plan (10MP)	2011-2015	New policy directions, strategies, and programs to ensure knowledge abilities, innovation and sustainability.
Eleventh Malaysia Plan (11MP)	2016-2020	Promote the use of sustainable energy for growth and development in Malaysia. Ensure energy security and management of resources in the country by 2020.

The key policies and regulatory guidelines particularly the 8th - 11th Malaysia Plans outlined in Table 5 have been pivotal to RETs development in the country. In spite of the favourable environment, policy backing and government support, RETs diffusion into the Malaysia energy mix have remained low over the years. According to Strategy Paper 17 of the 11MP, the share of RETs has grown from 0.07% to 0.33% from 2006 – 2013 whereas that for biomass sparsely improved from 0.55% to 0.56% within the same period [65]. Similarly, the SEDA Agency reports that energy from biomass and solid bio-wastes account for 87.90 MW or 17.89% of the 491.12 MW of installed RETs capacity in Malaysia. As a result, Biomass and RETs still account for a small fraction (2.1% in 2015) of energy generation in Malaysia [65]. This is below the 5% RETs electricity target designated in 8th Malaysian Plan (8MP) which can be attributed to several factors [54].

The slow diffusion and development of RETs can be ascribed to the plethora of energy laws, and policies directives. The existence of which create conflicting roles for supervisory or implementation agencies involved in the development, diffusion, and administration of energy policies in Malaysia. For example in 2001 the ECA, 8MP, SREP, REPPA were established. As observed in Table 5 the objectives of the ECA, SREP, and REPPA are similar and can be merged into one encompassing law administered by the Ministry of Energy, Green Technology and Water (KeTTHA). Currently, KeTTHA, SEDA, and the ministries of Environment and Statistics are all charged with implementing RETs laws and policies in Malaysia. Likewise, the NBP, NGTP, and REA can be merged for more effective implementation of RETs directives with the proposed Energy Commission tasked with supervisory or implementation.

2.4 Guidance of Search

The guidance of search is an interactive process aimed at fostering the exchange of ideas amongst technology producers, technology users and other players such as advocacy or lobby groups, think tanks within the innovation system [37]. It emphasizes the need to set realistic targets and utilizing often limited resources to the most feasible technologies. The implementation of this function is the responsibility of individuals, government, and industry in the innovation system. The function also serves as a "selection process" aimed at creating high expectations and attracting future investments through effective resources utilization to create novel technologies and markets. Table 6 presents an overview of the governments RETs and GHGs emission targets by 2050. As observed in Table 6, the government plans to generate 11.5 MW of renewable electric energy by 2050 which serves to reinforce the government's commitment to the RETs sector. According to Hekkert *et al.* [37], such policy directives "helps to broaden the mental map" of the current and future expectations – a scenario that helps to reassure potential investors.

Table 6. Policy Directives of the Renewable Energy Act 2010 [47, 54].

Year	Cumulative Total RE (MW)	Share of RE (%)	Annual RE (GWh)	RE Mix (%)	CO_2 Reduction
2015	975	6	5,374	5	3,385,406
2020	2,065	10	11,227	9	7,073,199
2030	3,484	13	16,512	10	10,402,484
2050	11,544	34	25,579	13	16,114,871

2.5 Market Formation

Profit motivation is a key factor for introducing new technologies such as RETs. Hence markets, manufacturers, suppliers, and technology users are required for innovative technologies to thrive since novel technologies often experience competition from established technologies [37, 66]. Furthermore, the market availability supports the formulation and articulation of demand for new technologies. However, the diffusion of novel "niche" technologies such as RETs is a complicated process typically influenced by existing "regime" technologies such as fossil fuels. The regime technologies also called "prevailing technologies" are products of evolutionary improvements in terms of accumulated knowledge, capital outlays, infrastructure, and availability of skilled labour, production routines, social norms, regulation, and lifestyles [67, 68].

There are avenues available whereby the Malaysian government can support biomass energy technologies by either creating protective niche markets or instituting incentives and tax regimes. The introduction of more market-enabling policies such as Feed-in Tariffs (FiTs) and the Green Technology Financing Scheme (GTFS) will further catalyse RETs in the country. The FiTs scheme needs to be revisited as the rates have remained relatively stagnant at 0.27 – 0.31 RM per kWh from 2012 to 2017 [60]. Favourable rates will encourage OPMs, most of which already generate electricity from OPW biomass, to invest in retrofits for renewable energy production and integration into the national grid. Furthermore, financing for GTFS needs to be improved from its current level of RM 3.5 Billion to reflect the current economic climate.

2.6 Resources Mobilization

The allocation of funds and human capital is vital to the survival of new technologies within an innovation system [37]. This is vital to the process of knowledge development through the financing of long-term R&D programs, grants for universities and other research institutions within the innovation system. In Malaysia, the government has voted the sum of RM 1 billion (One Billion Ringgit Malaysia) towards its Renewable Energy Fund as part of the Renewable Energy Act established in 2010 [60]. Other sources of finance include loans from commercial banks, Developmental Finance Institutions (DFI), or equity financing from capital markets, angel investors, venture capital firms, technology manufacturers and suppliers.

2.7 Creation of Legitimacy

Incumbent technologies often possess the advantage of undergoing a process of increasing returns, thereby associating the new technologies with high price or low utility [50]. Therefore, niche technologies must liaise with lobby groups to counteract the resistance from incumbent regime technologies. In effect, the survival of new technologies significantly depends on the financial resources and advocacy campaigns of lobby groups [37]. In Malaysia, the interests of biomass energy companies are supported by organisations such as Palm Oil Refiners Association of Malaysia (PORAM), Malaysian Palm Oil Association (MPOA), Malaysian Palm Oil Board (MPOB), and Round Table on Sustainable Palm Oil (RSPO) [8, 69]. The role of these organisations is to promote the interests of the oil palm growers and stakeholders in Malaysia. However, none is responsible for promoting biomass power or electricity generation which effectively indicates that the lobbying and advocacy coalition activities of the biomass innovation system (BIS) are Malaysia is lacking.

3.0 Summary and Conclusions

The entrepreneurial activities, knowledge development, and resources mobilization functions are well established in the Malaysian biomass innovation system (BIS) as outlined by this study. The presence of a large number of actors, networks, and institutions is evidence of the success of these functions. However, the glut of entrepreneurs has prevented the formation of "prime movers"- actors with the technical, financial and political clout to significantly catalyse the emergence of novel technologies [50]. In addition, the increased competition in the network potentially shrinks the renewable energy market and in the long-term, the profitability of actors in the innovation system. This can discourage new entrants with novel innovation and ideas which can be an undesirable dynamic, particularly in the capital-intensive and high-risk RETs landscape. The learning methods outlined by Kamp *et al.* [57], are evident in Malaysian academia signifying the development of knowledge development function. The study reveals that numerous research groups are actively engaged in biomass energy technologies for power generation. Similarly, the government and related agencies are actively providing financial and infrastructural support through research grants and funding incentives for RETs research and development in Malaysia. This indicates that the resources mobilization function is also well established within this innovation system. However, the guidance of search, the creation of legitimacy, knowledge diffusion, and market formation functions are weak and lag behind the other outlined functions. In particular, the guidance of search and creation of legitimacy functions are not well developed in the biomass innovation system in Malaysia. Currently, advocacy efforts are primarily geared towards oil palm and palm oil products, ignoring the immense potential of diversifying their operations into clean power and electricity generation from the OPW generated in tow. As a result, advocacy or lobby groups in the innovation system (IS) need to intensify efforts in influencing government policy towards biomass energy technologies in Malaysia. Furthermore, the lobby groups need to redirect efforts and resources toward influencing related technology financing, environmental sustainability, biofuel subsidies, and tax exemptions for stakeholders in the BIS in Malaysia. This is corroborated by Ahmad *et al.* [70], who posit that RETs diffusion can only be achieved by reducing the cost of the technologies, related energy services and the removal of market distortions such as fuel subsidies. As pointed out earlier, the Feed-in Tariff for biomass and RETs needs to be reviewed. This will potentially encourage independent power producers such as oil palm mills to invest in the technologies for the production and integration of bioelectricity. Based on analysis of the BIS using the functions of innovation systems (FIS) approach, the authors have outlined the key factors hindering the BIS in Malaysia. These include; fossil fuel subsidies, inconsistent or conflicting policies, financing bottlenecks, a weak collaboration between academia-industry. However, the outlined challenges can be addressed by the gradual revision of current fuel subsidies, streamlining the RETs implementation and supervisory agencies, reducing the bureaucratic constraints hindering access to funds and hampering investments in RETs development and diffusion in the country. In addition, knowledge information centres (KICs) need to be established to foster the development of ideas, technical know-how and industry-based experience of RETs between the actors and networks in Malaysia. Lastly, lobby groups need to encourage and play a more significant role in policy formulation and creating greater awareness on the benefits of RETs in Malaysia.

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