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Hansen, Ulrich Elmer

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Ph.D. Thesis

Development of biomass power plant technologies in Malaysia: niche development and the formation of innovative capabilities

by

Ulrich Elmer Hansen

UNEP Risø Centre, Department of Management Engineering,
Technical University of Denmark

Main Supervisor: **Ivan Nygaard**
Senior Researcher, UNEP Risø Centre,
Department of Management Engineering,
Technical University of Denmark

Co-supervisor: Niels Fold
Professor, Department of Geosciences
and Natural Resource Management,
University of Copenhagen

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Preface

The preparation of this thesis has been an interesting, challenging and highly educational journey, and I am grateful to the UNEP Risø Centre for offering me the opportunity to go through it. Indeed, this thesis made me learn and experience much more than I could have ever imagined at the outset. In the following, I would like to thank a number of people who have helped me in different steps of the process.

First of all, special thanks go to my ever-enthusiastic Ph.D. supervisor, Ivan Nygaard for his truly exceptional support at all stages of my dissertation. I know that it is not inevitable that one receives so much constructive input and encouragement from a Ph.D. supervisor, so for this I am very grateful. Secondly, my co-supervisor, Niels Fold, also gave me very helpful feedback throughout the whole project, for which I am also very grateful. My colleagues at the UNEP Risø Centre were another important and great support. I would also like to thank colleagues at SPRU at the University of Sussex, especially David Ockwell for his interest in my research and for our fruitful collaboration, and Martin Bell, who provided substantial feedback on paper drafts, which was a highly educational experience for me. Important thanks also go to all of the interviewees in Malaysia and Denmark who took time out of their busy schedules to participate in my research.

Lastly, and most importantly, I would like to express my sincere appreciation to my wife Mie, who has put up with me during this long process, and also to my family for their support.

Contents

1. Introduction

1.1. Background and research objective

A number of countries in Asia have undergone a rapid and unprecedented economic process of development, which has increased their demand for energy and other resources to stimulate economic growth. With the increase in energy consumption and strong reliance on fossil fuels, the contribution of countries in developing Asia to climate change has increased significantly (Rock and Angel, 2005). The urgency of achieving a transition towards less carbon-intensive energy systems in Asian countries is therefore increasingly considered essential in global efforts to combat climate change (IEA, 2011).

The sustainable transition literature provides a useful perspective with which to address the topic of low-carbon technology diffusion, which is conceptualised as a niche development process that unfolds in opposition to a prevailing, resistant regime (Kemp et al., 1998; Geels, 2002; 2005; Schot and Geels, 2008). However, most studies conducted on low-carbon transitions have hitherto focused mainly on developed countries in which supportive environmental and industry policies have played a major role in promoting the diffusion of low-carbon technologies. According to Bai et al. (2009), Verbong et al. (2010) and Berkhout et al. (2011), more research is therefore needed to examine low-carbon transitions in developing countries that could provide valuable insights with relevance for policy and planning.

To promote low-carbon transitions in developing countries, the importance of facilitating the transfer of low-carbon technologies has gained much attention in international policy discussions, for example, within the United Nations Framework Convention for Climate Change (UNFCCC). This has resulted in a number of initiatives under the UNFCCC aiming to promote the transfer of low-carbon technologies, such as the Technology Needs Assessment (TNA) project, the Clean Development Mechanism (CDM) and the recent Climate Technology Centre and Network (CTCN). Yet, despite the wide recognition given to the importance of transferring low-carbon technologies in the climate change mitigation policy agenda, this issue has not received much attention in academic research until recently.

Most studies conducted thus far have analysed the role of CDM projects in stimulating the uptake of low-carbon technologies, with a primary focus on the transfer of physical hardware and patents (see e.g. De Coninck et al., 2007; Dechezlepretre et al., 2008, 2009; Seres et al., 2009; Hascic and Johnstone, 2011). A recent number of studies have adopted a technological learning and innovation-based perspective to analyse the transfer of low-carbon technologies, focusing more on the dynamics of technological capability building in developing countries (Ockwell, 2008; Doranova, 2010; Fu, 2011; Fu and Zhang, 2011; Watson et al., 2011; Ockwell and Mallett, 2012). These studies emphasize the centrality of knowledge transfer in contributing to broader processes of development along low-carbon trajectories. However, they only provide preliminary insights into the issues of low-carbon technology transfer, technological capability building, and innovation in developing countries.

The objective of this thesis is to contribute to advancing further this emerging research agenda on the subject of the transfer and diffusion of low-carbon technologies in developing countries by adopting a study of the development of biomass power plant technologies in Malaysia. Before proceeding, there is a need to introduce briefly some key concepts, as these will be addressed in the subsequent section. This thesis understands technology diffusion as a process involving the emergence of new technological innovations from experimentation activities in protected niches, which are gradually upscaled or aggregated towards broader and more widespread market applications in a national context (Hoogma, 2000; Raven et al., 2011). Moreover, following (Bell, 1990, 2012; Levin, 1997), in this thesis technology transfer denotes the exchange of knowledge through international inter-firm linkages, which contribute to enhancing the technological capability of the recipient firms, thus enabling them to engage in innovation.

The remaining synopsis is structured as follows. In the following sub-section 1.2., the main research questions guiding the analysis conducted in this thesis will be described. This is followed in Section 2 by a description of the conceptual framework used to examine the research questions. Subsequently, Section 3 presents the research methodology, and in Section 4, a description of the individual papers comprising this thesis is presented. Lastly, Section 5 provides the main conclusions and suggests areas of further research.

1.2. Research questions

As described above, this thesis is positioned within in a broader research field addressing the topic of the transfer and diffusion of low-carbon technologies to developing countries. This thesis focuses on the development of biomass power plant technologies in Malaysia, and the main research question guiding the analysis is formulated as follows:

-What have been the main factors influencing the transfer and diffusion of biomass power plant technologies in Malaysia?

In order to answer this main research question, it has been considered appropriate to address the issues of transfer and diffusion separately in a number of sub-research questions that are further explored in the individual papers of the thesis (see Table 1 below). First, the following three sub-research questions, which are analysed in Paper 1 and 2, have been formulated to address the issue of technology transfer:

-What role have Clean Development Mechanism (CDM) projects played in the transfer of new technology to Malaysia?

-To what extent has innovative technological capability been developed in the Malaysian biomass boiler and power plant equipment industry?

-What role have different learning mechanisms played in the development of technological capability?

Secondly, to explore the topic of the diffusion of biomass power plant technologies in Malaysia, the following two sub-research questions have been put forward, which are addressed in Paper 3 and 4:

-What have been the critical factors in the development of a palm oil biomass waste-to-energy niche in Malaysia?

-What role have donor interventions played in the development of a viable niche in Malaysia?

Table 1. Overview of papers presented in the thesis

Paper no.	Title	Authors	Status
1	An empirical case study of the transfer of GHG mitigation technologies from Annex 1 countries to Malaysia under the Kyoto Protocol's Clean Development Mechanism (CDM)	Ulrich Elmer Hansen	Published 2011 in *International Journal of Technology Transfer and Commercialization*, 10(1), 1-20
2	Learning and formation of innovative capability in clean tech industries in emerging economies: the case of the biomass power equipment industry in Malaysia	Ulrich Elmer Hansen and David Ockwell	Submitted to *Technovation*
3	Sustainable energy transitions in emerging economies: the formation of a palm oil biomass waste-to-energy niche in Malaysia 1990-2011	Ulrich Elmer Hansen and Ivan Nygaard	Submitted to *Energy Policy*
4	Transnational linkages and sustainable transitions in emerging countries: exploring the role of donor interventions in niche development	Ulrich Elmer Hansen and Ivan Nygaard	Revised and resubmitted to *Journal of Environmental Innovations and Societal Transitions*

Although the topics of technology transfer and diffusion have been separated to address the overall research question of the thesis, they may in practice be interrelated. Donor programs provide an illustration of this. Although conditions for the diffusion of low-carbon technologies locally or nationally are greatly influenced by national policies and institutional frameworks, factors operating outside national boundaries may also be important. International donor programs, for example, may play an important role in creating conducive conditions for the diffusion of specific low-carbon technologies by promoting supportive national policies or through more direct measures, such as investment subsidies and technical assistance to projects. Such donor programs may also facilitate the introduction of new technologies from foreign technology suppliers, for example, in the form of demonstration projects, with the aim of encouraging their subsequent diffusion, thereby acting as a catalyst for the transfer and further diffusion of low-carbon technologies. International governance frameworks, such as those under the UNFCCC, may potentially play a similar role.

2. Analytical frameworks

The thesis draws on two main analytical frameworks to examine its research questions. The first is based in the technological capability literature, which conceptualises the ability of developing country firms to engage in technological change as a process involving various types of learning mechanisms, with a particular emphasis on the role of foreign affiliates (Malerba, 1992; Ernst and Kim, 2002; Viotti, 2002). This literature provided a basis for analysing technology transfers and the development of technological capabilities in the Malaysian biomass boiler and power plant equipment industry. The second framework is founded in the sustainable transition literature, specifically the multilevel perspective (MLP) on socio-technical systems, which conceptualises the processes underlying fundamental transformations in the fulfilment of key societal functions such as energy, transportation, communication and housing (Geels, 2002, 2005). This literature is considered useful for conceptualising and analysing the diffusion of biomass power plant technologies in Malaysia as a niche development process.

The following two sub-sections 2.1. and 2.2. will provide a description and short discussion of the two analytical frameworks adopted, including key concepts and main theoretical propositions. Subsequently, some of the conceptual communalities pertaining to these analytical frameworks will be discussed in Section 2.3.

2.1. The technological capability framework

The process of building up technological capabilities is a longstanding topic in the literature on technological learning and innovation in developing country firms and industries. Starting with the early work by Jorge Katz and colleagues in the 1980s (see e.g. Dahlman et al., 1987; Katz, 1987; Lall, 1987; Amsden, 1989), this literature subsequently progressed in two subsequent phases during the 1990s (see e.g. Hobday, 1995; Lall, 1992; Kim 1997; Romijn, 1997) and 2000s (see e.g. Figueiredo, 2003; Marcelle, 2004; Tsekouras, 2006) (Bell, 2006). The main focus in this field of study has been on the processes whereby firms that arrive late on the world industrial scene progress in their level of technological capability in order to enhance their global competitiveness (Mathews and Cho, 1999). This interest in the formation of innovative capability is based in the recognition of the important

role of mastering technological innovation in a competitive global market. Studies have mainly focused on analysing the gradual building of a minimum base of technological knowledge in order for developing country firms to be able to carry out innovative activities (Dutrénit 2000, 2004). Different stages of technological accumulation have been identified, from the acquisition of foreign technology to the development of innovative technological capabilities, which allowed some firms to reach the technological frontier, and even to develop technological leadership in certain areas (see e.g. Kim 1997, 1998).

Firm-level technological capabilities are understood as the ability to generate and manage technical change (i.e. to engage in innovation activities) in process organisation, products and equipment (Bell and Pavitt, 1993, 1995). The accumulation of technological capability is considered path-dependant and highly firm-specific. A number of taxonomies to describe the achievement of different degrees of firm-level technological capabilities have been suggested in the literature. These typically elaborate a number of functions in the firm, such as process, product and investment-related activities, and various indicators are used to describe the levels of capability achieved within each of these functions (see e.g. Lall, 1992; Ariffin, 2000, 2010; Figueiredo, 2001; Ariffin and Figueiredo, 2004; Bell, 2007). The levels typically form the basic capabilities needed to use and operate existing production systems, at the lowest level, to the achievement of the capabilities needed to undertake advanced technical change at the highest level.

The formation of technological capability at the firm level derives from a complex process of learning, which comprises the processes by which additional technical skills and knowledge are acquired by individuals and through them, by the organisation (Bell, 1984, 2006). Rather than being an automatic and passive process accrued from the continuation of routine-based activities, learning is considered to demand active and dedicated investments with the aim of building technological capability. A main interest in this literature has therefore been devoted to understanding the nature and dynamics of the various learning mechanisms by which firms build up – or fail to build up – their level of technological capabilities over time. Thus, firms' paths of innovative capability-building and the underlying learning mechanisms (as sources of capabilities) are placed at the centre of those interests (Kim and Nelson, 2000; Dutrénit, 2004).

Much emphasis in the literature has been placed on the important role of learning from technology transfer relationships with foreign and more advanced technology

suppliers through different types of dyadic inter-firm linkages (Lee and Lim, 2001; Mathews, 2002, 2006; Bell and Figueiredo, 2012a,b). These linkages may, for example, be in the form of license agreements, parent-subsidiary relationships, joint ventures, technical assistance arrangements and strategic alliances (which are typically contrasted with purely transaction-based linkages, such as imports of and trade in goods) (Bell, 2007). Such inter-firm linkages may not necessarily or automatically increase the level of technological capability in developing country firms, as this will depend, among other things, on the intensity of efforts devoted to leveraging and exploiting the potential learning opportunities from these external sources. Studies have also emphasized the importance of learning through in-house technological efforts, such as internal training, various types of internal experimental activities and investments in formal R&D units (Lall and Latsch, 1998; Jonker et al., 2006). Similarly, the role of various forms of learning opportunities locally or regionally, such as engineering departments in universities, public R&D organisations, local spin-off ventures, strategic recruitment, intra-industry labor turnover and training institutes, have also been analysed (Malerba, 1992; Kesidou and Romijn, 2008).

With a basis in the framework presented above, Papers 1 and 2 conceptualise the transfer of biomass power plant technologies to Malaysia as part of broader learning and technological capability-building efforts by Malaysian boiler and power plant suppliers. This was based on a number of considerations. First, as noted by Ockwell et al. (2010) and Lema and Lema (2013), the dominant understanding in the existing literature on low-carbon technology transfer in the context of climate change (including in the policy arena) emphasizes the importance of the transfer of patents (and related intellectual property rights) and physical equipment. This understanding of technology transfer overlooks the centrality of the exchange of knowledge, know-how and accumulated experience and skills, especially the elements of knowledge that are tacit in nature and therefore difficult to transfer in patents and physical hardware (Lall, 2002). Conceptualising technology transfer in this thesis as an aspect of developing country firms' learning and technological capability accumulation efforts places greater emphasis on the development implications of technology transfer. This allows an understanding of technology transfer as having the potential to stimulate an additional learning process in recipient firms, enabling them to engage in further independent innovation on the basis of the acquired technology (Bell, 1990; Wei, 1995) .

Secondly, as mentioned above, the technological capability framework also highlights the important role of learning and technological capability-building through firms' internal technological efforts. Firms' own efforts to modify, adapt and further develop technologies acquired from foreign sources to suit new conditions may provide one example of this, which is widely recognised in the technological capability literature (Bell, 2007). While such efforts may often be of an incremental nature, they may nonetheless be an important stimulus to increase the level of technological capability in developing country firms. This is contrasted with the widespread understanding in the extant innovation literature that innovation is mainly conducted in developed country firms and subsequently transferred to developing country firms, for example, through license agreements or joint ventures. This greatly overlooks the additional improvement and technical change undertaken by developing country firms, which comprise more than the passive acquisition of imported technology (Bell and Pavitt, 1993, 1995).

While the technological capability framework was considered well-suited to addressing the topic of technology transfer in this thesis, one analytical weakness merits mentioning. As was shown above, in the literature the individual firm is ascribed a principal role in learning and technological capability formation, which according to Bell and Figueiredo (2012a; 19) reflects "]..the well-trodden assertion that learning in the sense of building and deepening capabilities to innovate is conscious, purposive and costly, rather than automatic and passive]". It may be argued, though, that this firm-centered perspective places too much emphasis on individual firms when compared, for example, to broader changes in the global division of labor and macro-political and economic structural conditions. It should be noted, however, that much research has addressed the role of industrial systems, national industrial policy and the regulatory environment on firm-level technological capability formation (see e.g. Figueiredo, 2008; Amann and Cantwell, 2012).

2.2. The multilevel perspective

The multilevel perspective (MLP) has been developed as a heuristic model for structuring analyses of socio-technical transition processes (Rip and Kemp, 1998; Kemp et

al., 1998; Geels, 2002)[1]. Studies adopting the MLP framework have mainly addressed the barriers and opportunities for the diffusion of technological innovations that may lead to wider sustainability transitions at a societal level. The MLP conceptualises how such transitions take place through the interaction between processes at three different levels of social aggregation, namely the socio-technical landscape, the regime and the niche level.

At the macro-level, the socio-technical landscape denotes the large-scale and exogenous structural context that influences dynamics at the regime and niche levels. Examples include global macro-economic conditions, international geopolitics, overarching global political discourses, demography, resource scarcities and changes in cultural and normative values. At the meso-level, socio-technical regimes comprise relatively stable configurations of institutions, techniques and artefacts, as well as rules, practices and actor networks that determine the 'normal' development and use of technologies. Regimes thus constitute the dominant and semi-stable institutional, regulatory and technological infrastructure that fulfils socially valued functions such as energy supply, transport, communication and housing. Sustainable transitions are understood in the MLP as changes in the manner in which existing regimes are configured to provide key social functions. At the micro-level, socio-technical niches constitute local platforms or incubation rooms from which new and alternative socio-technical trajectories may emerge to the dominating way of fulfilling functions within existing regimes. Niches play a central role in the MLP according to which the emergence of viable niches is understood as constituting a necessary but not sufficient condition for transitions (Hoogma, 2000).

As a result of stabilising mechanisms, regimes are characterised by path-dependency, structural lock-in and resistance to change (Raven, 2006). This proneness to inertia and stability is conceptualised in the MLP as effectively hindering alternative sustainable technological innovations from emerging and breaking through at the regime level (Unruh, 2000). In the energy sector, this could involve a situation in which the continuation of an incumbent fossil fuel-based energy system is stabilised by regulations, sunk investments in the infrastructure, subsidies, or the vested interests of incumbent actors such as utilities (Verbong and Geels, 2007; Rohacher, 2008). For a niche to evolve and

[1] The MLP may be considered part of a number of (related) analytical perspectives that address the overall issue of sustainable transitions, which also include the Transition Management and Technological Innovation Systems literatures (Coenen et al., 2010).

eventually progress towards large-scale societal transitions, a central assumption in the MLP is that niche proliferation is contingent upon destabilising tensions that open ‘windows of opportunity’ at the regime level (Verbong et al., 2008). Such destabilising tensions may arise from processes at the landscape level that provide opportunities for alternative practices and novel innovations to break through from niches. Whether such opportunities will be exploited, on the other hand, also depends on the viability of the niche in development.

According to the MLP, the viability of niches is influenced by three internal niche-level processes, which comprise: i) The shaping and alignment of expectations; ii) the formation of a social actor network; and iii) learning processes, which have been further elaborated in the literature on strategic niche management (SNM) (Schot and Geels, 2008). Increasing alignment of expectations involves niche-level actors increasingly sharing similar visions, beliefs, strategies, agendas and interests. Following Geels and Raven (2006), a high level of expectations is generally conducive for niche development, although the envisaged opportunities need to become more specific and to rely on positive tangible results. The second niche-level process concerns the formation of a social constituency behind a new or alternative socio-technical trajectory consisting of a network of engaged actors. It is generally assumed in the MLP that the formation of close social ties and regular interaction among actors stimulates niche development. Furthermore, the composition of the actor network plays a central role, and the involvement of a broader and more varied actor network also promotes niche development (Van der Laak et al., 2007; Coenen et al., 2010). Lastly, learning processes involve learning about the technological aspects of various niche-level experiments, including technical design, functionality and performance. Although the MLP accentuates the role of learning through techno-economic optimisation efforts, broader learning processes pertaining to the social embeddedness of these play an equally important role. The later involve various actors, and society at large, learning about many aspects of the technology, including regulatory conditions, user preferences, institutional, economic (e.g. business models, profitability and financing sources), infrastructure, socio-cultural and environmental aspects. Among the three niche-level processes there is a dynamic interplay, which may reinforce each other in a manner that is conducive to the development of a promising and viable niche. An initial ‘technological niche’ may therefore gradually evolve into a ‘market niche’ in which the technology in question becomes independently competitive and protection may be phased out (Raven, 2006).

With a basis in the framework presented above, Papers 3 and 4 conceptualise the diffusion of biomass power plant technologies in Malaysia as a niche development and up-scaling process. This was considered appropriate for a number of reasons. First, this framework understands technology diffusion as a non-linear process, which involves a multitude of interactive feedback mechanisms along the innovation–diffusion trajectory (Geels, 2002). This means that technology supply- and demand-side aspects are addressed simultaneously, although with a particular focus on technology adopters and user practices, which, according to Geels (2004, 2011), are often neglected in other related frameworks, such as the innovation system literature. Secondly, this framework also focuses on the broader institutional conditions for technology diffusion, including policies, regulations, culture and norms, social practices, industrial structures and supporting infrastructures, and markets dynamics. This multidimensionality involves consideration of a range of actors and processes at the landscape, regime and niche levels that indirectly and directly influence the diffusion process, which is contrasted with more technology-centric frameworks focusing exclusively on technology management in individual firms. Thirdly, following Markard and Truffer (2008), a main strength associated with conceptualising technology diffusion as a niche development process lies in the explanatory power of analysing the relative stability of an emerging niche relative to an existing regime. In this regard, according to Raven (2006), the greatest prospect for niche up-scaling may arise in situations with relative stability at the niche level in combination with a situation of relative regime instability.

Despite these merits, a number of drawbacks also pertain to this framework, which has been discussed in the literature (see e.g. Genus and Coles, 2008; Smith et al., 2010). As noted in Geels (2011), the MLP framework is a heuristic device that guides the analysis towards relevant questions and issues, and applications of the framework therefore require both substantive knowledge of the empirical domain and theoretical sensitivity (and interpretive creativity) to identify interesting patterns and mechanisms. Although the framework thus allows for interpretative flexibility, as a so-called middle-range theory (Geels, 2007) the lack of theoretical and conceptual rigidity is a main challenge in operationalisation and analysis. In addition, the MLP has been critisised for its inability to conceptualise the international dimension of niche development and transition studies, which have mainly been lumped together in the all-encompassing notion of the landscape concept (Geels, 2011). The framework has mostly been applied nationally, as the main

empirical boundary and studies have examined technology diffusion locally or nationally on that basis (Raven et al., 2012). This renders the framework less suited to addressing transnational linkages and the international dimension of niche development and transition process, which requires complimentary analytical perspectives to explore these issues.

2.3. Conceptual communalities

The MLP and technological capability literatures both have their basic origins in evolutionary theories of technical change, which since the 1980s have focused on the role of innovation in firm and industry-level competition (Nelson and Winther, 1982). Although these two literatures both have their foundational theoretical basis in evolutionary economics, they have moved in entirely different directions. The following will describe some of the shared conceptual communalities in these two bodies of literature.

In the literature on technological capability formation in developing country firms, the basic starting point is that firms cannot be assumed to be operating on a common production function since technological knowledge is not shared equally among them, nor is it easily imitated by or transferred across firms. Therefore, on the basis of differences in prior accumulated skills and various sources of knowledge inputs, firms in a given industry are likely to develop different levels of technological capabilities, which in turn translates into "]..different efficiencies in the innovative search processes]" (Dosi, 1988; 1156). This heterogeneity in technological capability accumulation, understood as the ability to implement technical change, is considered a main factor in explaining (intra-industry) variability in the competitiveness of firms (Lall, 1992). Firms in a particular industry do, however, share general routines, such as common cognitive search heuristics or engineering approaches, which reflect their bounded rationalities (Nelson and Winther, 1982). This influences learning and innovation in individual firms by structuring their technical search spaces in directions that are close to existing routines and competencies. This structuring comprises a technological regime, which according to Genus and Coles (2008; 1437) denotes "]..the beliefs and prevailing successful designs that predispose innovators in firms towards development of certain apparently marketable or feasible options and away from other less attractive options]".

In the MLP, the technological regime is conceptualised as playing an important role in hindering niche-level innovations from emerging due to lock-in and path dependence, as well as orientation towards incremental innovation along predictable trajectories. The understanding of technological regimes was developed further in the MLP from the original conceptualisation in Nelson and Winther (1982), which according to Geels (2004) over-emphasized technology design heuristics and cognitive rules within firms without giving due consideration to understanding technology and society as interrelated, co-evolutionary processes. This is reflected in Rip and Kemp (1998; 338), who suggest that a technological regime comprises "].. the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems – all of them embedded in institutions and infrastructures]".

Beside the technological regime concept, another conceptual communality in the MLP and the technological capability literatures is the importance of learning as a main condition for niche development and technological capability-building. Learning about technological aspects in niche development processes may, for example, take place as part of competition between private firms, labor turnover in a local industry, inter-firm technology cooperation or platforms for knowledge sharing. Similarly, such localised learning mechanisms may be equally important channels for individual developing country firms to acquire technological capability. As described above, the technological capability literature emphasizes the importance of access to technological knowledge from foreign, more advanced technology suppliers, and such external linkages may also play a role in niche development. For example, as part of learning from technology transfer in individual firms, potentially this may create broader learning opportunities in the maturation of technologies from experimentation activities in an evolving niche. This may take place through local knowledge spill-over from imitation and copying, although such issues have not been addressed to any great extent in the literature on niche development. Caniëls and Romijn (2008) do, however, note that the technological capability literature on learning mechanisms is similar to the conceptualisation of experimentation activities described in the sustainable transition literature on niche development.

While this brief discussion does not provide a full picture of the relationship between the MLP and the technological capability literatures, the two examples do illustrate that the analytical frameworks adopted in this thesis are not mutually incompatible or in conflict.

3. Research methodology

The following sub-section 3.1. describes the empirical context for the research conducted in this thesis. The second sub-section 3.2. describes the research method adopted to address the research questions put forward initially.

3.1. The empirical context

Malaysia has experienced remarkable economic growth in recent decades, which has lead to a concomitant increase in fossil fuel-based energy usage and greenhouse gas (GHG) emissions. Indeed, annual GHG emissions in Malaysia increased by around 8% in the period 1990-2006 and are expected to rise by 74% by 2020 from the 2005 level, which is mainly attributed to the continuing reliance on fossil fuels (NRE, 2011). Although still a small contributor to total emissions relative to, for example, China or the United States, this gives Malaysia one of the highest expected growth rates in emissions in the world.

However, with increasing environmental pressure, diminishing domestic fossil fuel resources, rapidly growing energy demand and a general increase in fossil fuel prices, renewable biomass energy has come to be seen as central to diversifying the energy system and reducing GHG emissions in Malaysia. This has led to the adoption of a number of energy policies in Malaysia, which, together with succeeding donor programs, have aimed at promoting renewable energy. These national energy policies and donor programs have particularly focused on the utilisation of palm oil biomass waste due to its availability in Malaysia (Shuit et al., 2009). However, limited studies have addressed the results of these policies and donor programs, as well as other factors influencing biomass technology development in Malaysia, although this may provide important insights with broader relevance for understanding the critical factors for low-carbon transitions in developing countries.

Moreover, since the 1990s different factors have contributed to creating conducive conditions for investments in palm oil biomass waste-to-energy plants in Malaysia. This attracted a number of Malaysian boiler companies to become engaged as technology suppliers to these power plants. In fact, most palm oil biomass waste-to-energy plants constructed in Malaysia were supplied by local boiler manufacturers. However, before their involvement in these plants, these local firms mainly supplied small-scale, inefficient industrial boilers to various industries and therefore had very limited experience in engineering or in the construction of large-scale, efficient biomass-fired power plants. They were therefore forced to engage in concerted learning and technological capability-building efforts in order to take advantage of these new market opportunities, which required new technological innovation compared to their existing boiler technologies. Some of these local boiler suppliers had established relationships with foreign technology developers, which provide a suitable context in which to examine the accumulation of technological capability and the role of technology transfer compared to other forms of learning.

3.2. Data collection methods and analysis

The research conducted for the four papers comprising this thesis draws on data collected during three successive periods of fieldwork undertaken in Malaysia in 2008, 2010 and 2011. The data collected during these extended periods of fieldwork mainly consisted of interviews, various sources of written material and observations at plant sites. The main research question addressed in the four papers concerns the main factors influencing the transfer and diffusion of biomass power plant technologies in Malaysia. The research methods adopted in order to examine this question in the individual papers will be described in the following.

Paper 1 investigated the importance of CDM projects in establishing new sources of technology and knowledge in Malaysia, while Paper 2 developed this analysis further by conducting a detailed study of the learning mechanisms underlying technological capability formation in the Malaysian biomass boiler and power plant supplier industry. These firms were identified on the basis of their involvement in palm oil biomass waste-to-energy plants in Malaysia. The data collected for these two papers primarily consisted of interviews with employees of firms in this industry and secondarily on written material. A key part of the

data collection process consisted of formulating interview questions in order to operationalise the key analytical concepts into data collection procedures (in interview guide questions). As Adcock and Collier (2001) describe, enhancing construct validity in this process of concept operationalisation essentially requires ensuring that observations meaningfully capture the fundamental ideas contained in the concepts. This was achieved by ensuring logical consistency between the conceptual constructs and the detailed interview questions, the aim being to obtain data about the key concepts of interest (Krefting, 1991). In order to operationalise the key concepts of learning mechanisms and technological capability formation, the interviewees were asked to describe the relative importance of various learning mechanisms with regard to the accumulation of technological capabilities throughout the firms' involvement in specific palm oil biomass waste-to-energy plants. The interview questions addressing the level of technological capability achieved by the individual firms drew mainly on a range of indicators from the literature. All interviews were digitally recorded and subsequently transcribed.

In order to increase the internal validity of Papers 1 and 2 concerning the role of CDM in technology transfer and the use of different learning mechanisms in technological capability building, two types of triangulation method were used to cross-examine and synthesise the data (Meijer et al., 2002). First, the triangulation of data consisted of interviews with current and former employees across different administrative levels and functions in the individual boiler supplier firms, and with local engineering consultants (with substantial industry experience), investors and plant operators. Moreover, since the data were collected over an extended fieldwork period of around three years, this allowed for some temporal spread in the data. Secondly, the application of triangulation by method involved the use of multiple sources of qualitative data in the form of interviews, different sources of written material and observations at plant sites. As suggested in Miles and Huberman (1994), the data analysis used the matrices method for data coding and interpretation procedures in order to identify regularities in the data. The analysis relied on pre-established coding categories based on the analytical framework adopted in the papers.

Paper 3 investigated the critical factors for the development of a palm oil biomass waste-to-energy niche in Malaysia. Building on this, Paper 4 focused on analysing the role of donor interventions in niche development, both of which were based in the MLP literature. Both papers used qualitative data, primarily in the form of interviews, and secondarily by

using different sources of written material, which included a comprehensive review of the academic and grey literature on the palm oil biomass waste-to-energy sector in Malaysia. A main objective of the data collection process conducted for the two papers was to illuminate previous and ongoing processes at the landscape, regime and niche levels. The interviews conducted with niche-level actors, such as boiler and power plant suppliers, engineering consultants, plant-level operators and investors, addressed the concepts related to niche development processes on the basis of semi-structured interview guides. Interview questions were therefore formulated to enable respondents to elaborate about different forms of learning processes, network formation and changes in levels of expectations. Interviews with regime-level actors were conducted with energy-related planners from governmental agencies, ministries and utility companies and donor program managers, as well as representatives of trade and industry associations and R&D organisations associated with the palm oil industry in Malaysia. Interviewees in the energy and palm oil regime were asked to elaborate about the existence of stabilizing factors at the regime level that were hindering niche development, such as the existence of infrastructural constraints, regulations and standards, sunken investments and vested interests, as well as destabilizing factors conducive for niche development, such as external pressures at the landscape level. The interview questions addressing the key concepts related to niche development and regime level dynamics were aligned in a logically consistent manner to ensure construct validity. All interviews were digitally recorded and subsequently transcribed.

In order to enhance the internal validity of Papers 3 and 4 with regard to the identification of critical factors for niche development and the role of donor programs, two triangulation methods were used to cross-examine the data. First, triangulation of data involved interviewing individuals from different firms and organizations that represented a variety of understandings and interests. Secondly, the application of triangulation by method involved the use of multiple sources of qualitative data in the form of interviews, different sources of written material and observations at plants sites. Data analysis followed the procedures described for Papers 1 and 2.

4. Paper summaries

The following section will provide a short summary of the four papers presented in this thesis, which will present the main findings and the contribution of the papers to the existing literature. Table 1 (in section 1.2) provides an overview of the four papers.

Paper 1 address the contribution of the CDM to the promotion of technology transfer to developing countries, a topic that has attracted increasing interest from scholars addressing the development impacts of CDM projects in host countries. Paper 1 contributes to this literature by analysing the role of CDM projects in stimulating the transfer of new technology and knowledge to Malaysia. Most studies within this field rely on project developers' own statements concerning technology transfer presented in official project documents. The extended fieldwork approach adopted in Paper 1 provides a more multifaceted picture going behind the 'official statements' found in project documents. Contrary to the general claims of project developers, the paper concludes that the CDM played a limited role in stimulating technology and knowledge transfer. On the other hand, CDM contributed to incentivizing the diffusion of existing technologies by reducing the payback period and improving the internal rate of return of projects.

Building on the analysis undertaken in Paper 1, Paper 2 addresses the topic of low-carbon technology transfer and technological capability formation in developing country firms. The existing literature on this topic has been dominated by industry-level studies and a conceptualisation of technology transfer as mainly encompassing physical equipment and patents. Previous studies have therefore neglected to examine the firm-level specifics of technological capability-building and overlooked the centrality of knowledge embodied in technology transfer. This paper contributes to addressing these gaps by utilising firm-level data to analyse the extent to which the use of different learning mechanisms can explain differences in the accumulation of technological capabilities. This is explored via an examination of eight firms in the biomass boiler and power plant supplier industry in Malaysia during the period 1970-2011. The paper concludes that differences in the level of technological capability achieved by individual firms were influenced by i) the specific combination of learning mechanisms employed by the firms; and ii) differences in the relative levels of resources dedicated to exploiting these learning mechanisms. It is found that firms relying on a combination of learning from foreign technology partners and

internal learning by planned experimentation make most progress in building technological capability.

Paper 3 addresses the issue of how transitions towards more sustainable development pathways may be achieved in Southeast Asia, a topic that has drawn increasing interest from a number of scholars within the socio-technical transition tradition. The paper contributes to this literature by examining the conducive and limiting factors for the development and proliferation of a palm oil biomass waste-to-energy niche in Malaysia during the period 1990-2011. The paper concludes that the niche development process has made only slow progress, despite a brief and momentary period of niche development during 2002-2006. The paper identifies reluctance in implementing energy policy, rises in biomass resource prices, limited network formation and negative results at the niche level as the main factors hindering niche development. The paper provide an empirical contribution to an understanding of the critical factors that may influence the development of niches from a single or a few isolated experiments to larger up-scaling in a developing country context.

The analysis undertaken in Paper 3 provides a basis for Paper 4, which explores the role of international donor interventions in the development of a palm oil biomass waste-to-energy niche in Malaysia. This paper responds to recent calls in the literature on socio-technical transitions for improving the conceptualisation and empirical assessment of transnational linkages in niche development and transition processes. It proposes adding a novel conceptual framework to the existing literature by drawing on the 'planned intervention' tradition to analyse the role of donor interventions as one form of transnational linkage in niche development. According to this framework, attention should be given to a focus on the analysis of interests, as donor interventions most likely open up new arenas of struggle over resources, interests and influence between various actors, rather than the execution of a specific plan of action. With regard to its empirical contribution, the paper concludes that the limited effect of twenty years of donor interventions on niche development was influenced by the following three factors: i) that advice and knowledge dissemination on energy policy had a limited impact, mainly due to strong opposing interests in maintaining the existing situation; ii) that creating the necessary conditions for transferring a private-sector model of electricity production to the Malaysia remained a challenge; and iii) that the short duration of each intervention and the

unpredictability of interventions generally can be seen as important impediments for programs to reach their objectives.

Beside these papers, four additional publications have been prepared in parallel with the preparation of this thesis. Although these four additional papers are not to be included as part of the assessment of the thesis, they are mentioned below in order to emphasise the relevance of the thesis with regard to the ongoing, practically oriented work in the UNEP Risø Centre on the transfer and diffusion of low-carbon technologies in developing countries.

1) Beniof, R., Coninck, H., Dhar, S., Hansen, U.E., McLaren, J., Painuly, J., 2010, Strengthening Clean Energy Technology Cooperation under the UNFCCC: Steps toward Implementation, Joint report by National Renewable Energy Laboratory (NREL), Energy Research Centre of the Netherlands (ECN), and UNEP Risø Centre.

2) Boldt, J., Nygaard, I., Hansen, U.E., Trærup, S., 2012, Overcoming Barriers to the Transfer and Diffusion of Climate Technologies, UNEP Risø Centre and Global Environment Facility (GEF).

3) Hansen, U.E, Olhof, A., 2009**,** Climate Change: The Current State of Knowledge, Part I in: Trade and Climate Change WTI-UNEP Report, World Trade Organisation (WTO) and United Nations Environment Programme (UNEP).

4) Haselip, J., Nygaard, I., Hansen, U., Ackom, E., 2011, Diffusion of Renewable Energy Technologies: Case Studies of Enabling Frameworks in Developing Countries, Technology Transfer Perspectives Series, UNEP Risø Centre.

5. Conclusion

5.1. Main findings

This thesis set out to explore the main influential factors for the transfer and diffusion of biomass power plant technologies in Malaysia. The following presentation of the main findings is organised around two overarching themes: i) slow niche development process compared to anticipations; and ii) firm-level learning and technological capability formation. These will be elaborated further below. Subsequently, areas of further research will be identified.

5.1.1. Slow niche development process compared to anticipations

The formation and up-scaling of niches typically takes place on a temporal scale of around 10-15 years, and studies generally find that niche up-scaling is a long-term, cumbersome and highly complex process (Hoogma et al., 2002; Raven 2005). Many studies also show that in many cases niche development does not even reach beyond the completion of a few isolated niche-level experiments (see e.g. Hoogma, 2000). Moreover, it is also uncertain whether the formation of a viable niche will eventually diffuse on a wider scale and create a transition at the regime level, which takes place on an even longer timescale. In correspondence with this understanding in the existing literature, this thesis found that the development of a palm oil biomass waste-to-energy niche in Malaysia only made limited progress despite a prolonged period of twenty years of niche formation.

The thesis identified reluctance in implementing an efficient (or necessary) energy policy as the main limiting factor for niche development in this case. Although a number of donor programs providing policy advice and knowledge dissemination advocated the adoption of a stronger enabling framework to support niche development, this only had a limited effect on policy development. When the government finally decided to improve the incentive structures through a reduction in fossil fuel subsidies and by introducing a feed-in-tariff system, these measures were only implemented about ten years after they had initially been suggested by donor programs. In addition, these measures were introduced at a time when the investment interest in palm oil biomass waste-to-energy plants in Malaysia

had slowed down significantly and therefore appeared to be having less effect on niche development than if they had been implemented earlier. The thesis finds that the limited impact of donor programs on policy development was mainly attributed to the strong opposing interests of key actors in maintaining the existing situation. Of particular importance was the limited support from the national electricity utility company in Malaysia, which over an extended period deliberately obstructed niche development because it was against its economic interests. Moreover, due to their short-term duration and instability of support, donor programs did not provide a sufficient level of continuity necessary to attract investors to engage in large-scale power plant projects.

The CDM played some role in supporting niche development by providing a financial incentive that improved the returns on project investments for project developers. However, many planned plants were never put into operation, and those that were constructed were substantially delayed and generally only had poor levels of performance. This may be acknowledged when considering the limited number of biomass CDM projects registered in Malaysia that have materialized into operational plants and issuing of carbon credits (UNEP Risø, 2013). The largely negative results from niche-level experimentation activities came to play an important factor limiting niche development since it significantly reduced the investment interest from palm oil companies, which increasingly considered palm oil biomass waste-to-energy plants a risky business venture compared to the continuation of their core business activities.

At the same time, a number of alternative usages of biomass waste attracted increasing commercial interest in the Malaysian palm oil industry, such as biofuel, pulp and paper and cardboards, which were considered more profitable compared to energy generation. Therefore, in combination with the generally high risk assessment of plant investments, palm oil companies became reluctant to invest in palm oil biomass waste-to-energy plants. This was at odds with the continued push from donor programs aiming to encourage palm oil companies to become power producers as part of promoting a private-sector model of electricity production in Malaysia. The growing interest in alternative biomass waste usages in the palm oil industry led to a substantial price increase for palm oil biomass waste. The perception of biomass in the palm oil industry therefore gradually changed from being considered an unproductive waste product to being an economically valuable resource. This meant that it became difficult to engage palm oil companies in long-

term biomass fuel contracts, which were needed for power plants investors relying on external biomass resources. This turned out be an important factor hindering niche development.

Finally, the thesis finds that, during the entire niche development process, a broader network linking actors together across the individual plants remained weak. The lack of inter-company coordination of activities and interaction in general was mainly attributed to longstanding rivalry among local boiler suppliers and a deliberate strategy of investors to prevent plant-specific knowledge from being disseminated. Formalised and coordinated knowledge sharing among these actors was therefore limited despite donor programs' efforts to establish a platform for exchanging experiences. The lack of knowledge sharing comprises another key factor limiting niche development. Yet, learning did take place in the niche development process, mainly in the form of unintended knowledge spill-over, such as imitation and copying, as well as in the individual projects.

5.1.2. Firm-level learning and technological capability formation

The transfer of technology is understood in this thesis as the exchange of knowledge through international inter-firm linkages, which contribute to enhancing the technological capability of the recipient firms, thus enabling them to engage in innovation. This understanding focuses on the importance of knowledge, including the elements that are tacit in nature, which is contrasted to the prevailing understanding in the existing literature that focuses on the transfer of physical equipment and patents. The learning and innovation-based perspective adopted in this thesis has provided a basis for analysing technology transfer and the formation of technological capabilities in the Malaysian biomass boiler and power plant equipment industry.

The thesis finds that firms that dedicate significant resources to a specific combination of learning from foreign partners and planned learning from their own experimentation made most progress in terms of technological capability. Firms using a combination of learning from imitating national competitor firms (which learned from interactions with foreign partners) and internal trial and error also made advances in technological capability although to a comparably lesser extent. The thesis also found that firms that rely on learning by imitating local competitors failed to take advantage of the

potential opportunities to learn from commercial interactions with overseas technology partners. This implies that a lack of technological capability-building through learning from foreign partners may be due to a lack of efforts devoted to exploiting such opportunities rather than a lack of an opportunity to do so. The implications of these findings suggest that a combination of specific learning mechanisms plays a significant role in technological capability formation in developing country firms.

The thesis also finds that CDM projects implemented in Malaysia played a limited role in stimulating the introduction of new technology and knowledge to Malaysian biomass boiler and power plant equipment supplier firms. Involvement in CDM projects did not add anything above and beyond what was already included in the existing relationships between the firms in question. The high level of optimism to be found in the international policy arena concerning the role of CDM in stimulating the transfer of low-carbon technologies to developing countries (see e.g. Grubb et al., 1999; UNFCCC, 2001) therefore did not materialize in the case of biomass power plant technology in Malaysia. These findings are interesting, as they challenge the over-optimistic view of the contribution of CDM to technology transfer in existing research and policy debates. This is particularly relevant as most of the project documents emphasized their influence on technology transfer, as did the institutional approval system in Malaysia. Yet, the limited role of CDM projects in technology transfer may not be that surprising given its main role as a financial mechanism.

5.2. Further research

Since research on the transfer and diffusion of technologies in developing countries in the context of climate change is very much in its infancy, four promising future research agendas could profit from the work undertaken in this thesis.

First, future studies are needed to explore further the topic of transnational linkages and the international dimension of niche development and transition processes. Previous studies in developing Asia have only described sustainable transitions in broad terms as part of ongoing globalisation processes (see e.g. Rock et al., 2009), but such analyses should become much more detailed regarding how global processes materialise in specific localities.

The work undertaken in Wieczorek et al. (2012) on the multilayerdnes of experiments and in Binz et al. (2012) on spatially coupled innovation systems are complementary to the work undertaken in this thesis, and could be further explored.

Secondly, and related to the above, technical change in developing countries is often driven by the acquisition, assimilation and further development of technologies obtained from foreign sources. As the literature on technological capability formation in developing country firms is particularly concerned with the importance of such external linkages with regard to learning and innovation, future research may tie this literature closer together with the socio-technical transition framework when applied in the context of developing countries (see e.g. Byrne et al., 2011). Particularly, additional studies could address the role of external firm-level linkages with regard to the maturation of technologies in an evolving niche, including their influence on learning and experimentation activities, actor-network formation and expectations for the niche. This is in line with the suggestion in Berkhout et al. (2011) to combine an analysis of global flows of knowledge and technology on localised niche development processes.

Thirdly, more research is needed to explore the role of firm-level technological capability formation in niche development processes. Since many developing country firms may only have developed limited technological capabilities, their ability to manage and generate technical change may be restricted, which may influence the niche development process. Although the technological capabilities of firms are considered an important part of the functioning of innovation systems, this issue has not been taken up in a developing country context to any great extent.

Fourthly, future research could address in greater detail the relative importance of different internal, local and foreign sources of learning, and their specific combinations, for the development of technological capability in developing country firms. This is not only relevant for studies examining low carbon technologies, but could also be explored in other industrial contexts. Important is however that the systematic collection and analysis of firm-level data should be an essential element of such research efforts. A topic of increasing importance in this regard concerns the recent growth of outward foreign direct investment from developing country firms in the form of mergers and acquisitions of firms in developed countries (UNCTAD, 2011). Since these outward investments are mainly motivated by the attempts of developing country firms to appropriate new technological know-how and

innovative competences, future research could address whether such sources of learning constitute a promising new avenue for technological capability building compared to other sources (Pradhan, 2010).

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Paper 1

An empirical case study of the transfer of GHG mitigation technologies from Annex 1 countries to Malaysia under the Kyoto Protocol's clean development mechanism (CDM)

Ulrich Elmer Hansen

UNEP Risoe Centre,
Systems Analysis Division,
Risoe National Laboratory for Sustainable Energy,
Technical University of Denmark – DTU,
Frederiksborgvej 399, P.O. Box 49,
Roskilde 4000, Denmark
E-mail: ulrich.hansen@risoe.dk

Abstract: This study assesses what role the CDM currently plays in relation to the transfer of GHG mitigation technologies from Annex 1 countries to non-Annex 1 countries. The study relies on multiple sources of qualitative data and is conducted as a case study of 13 CDM projects implemented in Malaysia. It focuses on the companies involved in the implementation of specific technologies in these projects and the channels that can facilitate the transfer process. In addition, the institutional CDM project approval process in Malaysia is taken into account. An analytical framework is put forward based on which it can be concluded that the CDM only plays a role in one out of the 13 projects examined. The study may contribute to provide a background for adopting future provisions concerning technology transfer in the CDM or other initiatives involving GHG mitigation activities in non-Annex 1 countries.

Keywords: Kyoto Protocol; KP; clean development mechanism; CDM; technology transfer; firm-level technological capabilities; Malaysia.

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Biographical notes: Ulrich Elmer Hansen received his MSc in Geography and Geoinformatics from the University of Copenhagen – Department of Geography and Geology. Currently, he works at the Danish UNEP Risoe Centre undertaking research on the Kyoto mechanisms, especially the CDM, technology transfer, sustainable development in developing countries and carbon finance. He has formerly worked in the Danish Ministry of Climate and Energy, also on matters relating to the CDM, and in the Ministry of Food, Agriculture and Fisheries in Denmark.

1 Introduction

The transfer of low carbon emitting technologies is an essential prerequisite in order to achieve significant greenhouse gas (GHG) emission reductions in developing countries. Given the rapid growth of emissions in these countries, technology transfer is needed to promote a more climate-friendly trajectory for economic development. The urgency of the matter can be affirmed when considering that the total projected level of GHG emissions for developing countries is expected to account for two-thirds to three-fourths of the global increase in emissions by 2030 (IPCC, 2007). Technology transfer from developed to developing countries has consequently and increasingly entered the top of the political agenda, especially concerning a post 2012 climate change regime following the first Kyoto Protocol (KP) period. The ongoing political negotiation process under the United Nations Framework Convention on Climate Change (UNFCCC), respectively under the Ad hoc Working Group of the Convention (AWG-LCA) and the KP (AWG-KP) have confirmed that technology transfer will constitute a cornerstone in a future climate change agreement. In this context, the KP's clean development mechanism (CDM) has played and continues to play a central role in these deliberations concerning effective mechanisms that can facilitate and promote the transfer of GHG mitigation technologies to developing countries (UNFCCC, 2009).

In spite of the above, a limited number of studies have undertaken empirical analysis of technology transfer occurring through the CDM (see Haites et al., 2006; de Coninck et al., 2007; Seres, 2007; Dechezleprêtre et al., 2008; Hoffmann et al., 2008). These studies, which apply similar methodological and analytical approaches, focus primarily on the arguments put forward concerning technology transfer in the CDM project design documents (PDDs), required for the process of project approval. A mainly descriptive approach has been adopted in these studies, although predominantly through regression analysis, they have also assessed whether technology transfer takes place and whether specific factors, e.g., project type or project size influence this. Notwithstanding the usefulness of these studies, they provide merely an overall picture or first layer of analysis on the issue at hand. An underlying weakness regarding the reliability of the results of these studies concerns their source of information, i.e., the PDDs, since the information herein is not evaluated or verified independently. The studies moreover focus narrowly on the origin of the technology, which may overlook the underlying arrangements and circumstances under which the technology has been supplied and implemented. Furthermore, owing to their research design, the studies do not further the understanding of the factors involved in the micro-level processes regarding technology transfer. These factors concern the nature of the relationship and interaction between the transferee and transferor parties in the projects (the receivers and providers of technology) and their respective strategic interests. In relation to this, the previous studies concentrate only to a limited extent on the nature of knowledge transfer-related activities, and thereby, contribute less to clarify the substance of this in the CDM. In contrast, the objective of this study is to assess what role CDM projects play in relation to the transfer of GHG mitigation technologies from developed countries (Annex 1 countries) to developing countries (non-Annex 1 countries) by focusing on the factors not addressed to any great extent in these studies. This study applies a different analytical approach and research design than the above-mentioned studies. This involves focusing more on the concrete actors, at the firm-level, involved in the technological aspects of specific CDM projects. As private companies predominantly have the ownership and legal rights over

various technologies and the diffusion of these occurs through markets, in which companies are key actors, this makes it relevant to focus on the company-level in the analysis. Hence, in order to conduct a more intensive and in-depth study of technology transfer at the micro-level and in a local context, a case study design was considered appropriate for this study. The study was performed as a multiple case study of 13 registered CDM projects implemented in Malaysia. Underpinning the selection of Malaysia was both a wish to reduce the interest sphere of the study and to address the issue in a country, which under its institutional CDM approval system has formulated detailed conditions concerning technology transfer. It could therefore be expected that this element would be an important part of the implemented projects, which render Malaysia suitable as a case for studying the associated processes. In relation hereto, the study also takes into consideration the country specific CDM-related institutional and regulatory arrangement. Furthermore, in Malaysia and in the Southeast Asian region, the number of CDM projects has been increasing and are expected to continue to increase (UNEP, 2008). Therefore, insights obtained from this study can provide valuable input into arrangements and configurations of similar projects in the future. It may also contribute to broader discussions on technology transfer provisions in the CDM or other initiatives involving GHG mitigation actions in developing countries.

The remainder of this paper is structured as follows. After the introduction, Section 2 will present the key concepts and notions that constitute the central elements of the analytical framework applied in the analytic process of this study. In Section 3, the methodological approach is described and Section 4 reports the results. This is followed in Section 5 by a general discussion of the findings. In Section 6, the conclusions drawn will be presented.

2 Key concepts and analytical framework

2.1 Conceptualisation of technology transfer

Most often, the transfer of GHG mitigation technologies denote the relocation of technology embodied in physical goods, instalations, industrial machinery and equipment, components, etc., which ultimately causes a net reduction in GHGs (IPCC, 2000). However, the concept of 'technology' has been defined in numerous ways and little consensus seems to have emerged concerning the meaning and content of the concept (Martinot et al., 1997; Müller, 2003). The various conventional definitions of technology can be categorised as representing three types of perspectives:

1 the technology as transformer perspective

2 the technology as tool perspective

3 the technology as knowledge perspective (Ramanathan, 1994).

The first perspective reflects the traditional understanding of technology as encompassing only the material side of production, i.e., the machines and equipment necessary to transform raw materials into finished products (Levin, 1997; Chandra and Zulkieflimansyah, 2003). The focus on tangible objects and artefacts also corresponds to the perception of technology as a 'black box' (Rosenberg, 1982). The technology as a tool perspective expands the concept to include man-machine interrelations by

emphasising the associated intangible factors, for example, the skills, methods and heuristic knowledge of humans. The third perspective opens up the technology black box further by understanding technology as a specialised body of knowledge which can take certain forms, e.g., tools, processes, techniques, machines, materials or procedures. This reflects the cognitive aspects of technology and encompasses both accumulated technical experiences, tacit knowledge and know-how, and the more complex scientific theoretical insights and expertise, involving more codified/formalised knowledge such as blueprints, patents and technical specifications (Jacot, 1997; Lorentzen, 1998). Ramanathan (1994) suggests a fourth eclectic form of technology understanding, which attempts to incorporate the different perspectives into an integrative technology concept. In accordance with this approach, technology is in this study understood broadly, encompassing both the tangible and intangible dimensions, which can be said to constitute or characterise a given technology (Sharif, 1994; Müller, 2003).

Table 1 The analytical assessment framework to assess the role of the CDM in relation to technology transfer

Factors taken into account	*Sub-issues related to these factors*
Transfer from Annex 1 countries to Malaysia in (and through) concrete CDM projects	• Identification of the technology-related transferee and transferor companies involvement of these companies in the projects • Characterisation of the CDM project-related internal arrangements relevant to the projects, which involve identification of the channels that facilitate transfer of technology and knowledge and the nature of the relations between the transferee and transferor companies • The previous CDM-related activities of the identified transferee companies in Malaysia • The transfer of main or core technological hardware components
Accumulation of firm-level technological capabilities in the Malaysian companies through CDM project involvement	• Technological learning process facilitated through interaction between the relevant companies involved in the CDM projects, including training activities, exchange of knowledge, e.g., through cooperation regarding implementation of the technology • Identification of the effects on the capability of the Malaysian companies (as a whole) to undertake new activities and/or to generate changes in the technology • The strategic interests of the relevant companies involved in and aspects relating to technology and knowledge transfer • The process whereby adaptation, modification, reconfiguration, redesign, development, etc., of the technological system pertinent to the CDM projects has taken place in order to overcome specific challenges, obstacles or barriers
CDM as an initiator – the historic account and background information on the activities of the Malaysian companies	• Historic assessment of the identified Malaysian (transferee) company, including the general company profile, its core business activities and project activities also before its CDM project involvement • The history and development of the relationship and interrelations between the Malaysian (transferee) company and the affiliated Annex 1 country (transferor) company

2.2 *Analytical framework*

An analytical framework was specifically developed for this study with the purpose to provide a thorough qualitative characterisation and assessment of technology transfer in the CDM. In Table 1, the framework is presented which comprise the three primary factors or criteria taken into consideration in the analysis of the specific CDM projects examined. These factors and related sub-issues will in turn be addressed in the following.

2.2.1 *Transfer from Annex 1 countries to Malaysia through CDM projects*

The transfer notion inevitably implies that at least two entities can be identified between which the transfer can occur. In this study, the relevant transferee and transferor agents of technology transfer are generally understood as the companies, with respective head offices located in Malaysia and Annex 1 countries which reasonably clearly can be identified as directly involved in the implementation of the technological systems in the CDM projects. In the Malaysian context, the *transferees* include the companies hosting the CDM projects, manufacturers, technology providers, consultant companies, licensees of Annex 1 country companies, joint venture companies and subsidiaries. These companies are included since they can directly influence and be influenced by technology transfer in the CDM projects. The technology *transferor* parties are understood as the Annex 1 country-based licensees, parent companies, joint venture companies and others, which provide, facilitate access to or enable the transferee companies to supply or implement technologies in the projects.

Different modes and mechanisms may facilitate technology and knowledge transfer. These includes FDI, joint ventures, licensing, fee and royalty agreements, turnkey projects, purchase of capital goods, technical agreements and various forms of cooperation arrangements (Bell, 1997; IPCC, 2000). At the company-level, these pathways appear to be especially relevant since they concern the commercial and technology-related relationships and ownership structures between the companies (Forsyth, 2005). The varying modes of transfer related to the CDM projects pertinent to this study are included as a central element of what is referred to as the project-related internal arrangements. These arrangements denote the internal structure of relations, interactions and ties between companies through which flows of technology and knowledge can be channelled. Therefore, this assessment factor also involves an identification of the CDM-related activities of the transferee company in order to address the existence or creation of these channels. Table 2 presents an analytic categorisation of the types of internal arrangements relevant for the specific projects and companies in this study. As appears, Table 2 establishes technology developer, technology producer and technology user companies as operational analytical entities according to their technology transfer-related characteristics. The developer companies encompass the relevant transferor companies in the Annex 1 countries, which develop and possibly produce core components of the technological systems implemented in the specific projects. The producer companies denote the non-Annex 1 country companies that owing to the relations with the former are able to manufacture and/or possibly implement the technology in question. The user parties are understood as the companies hosting the CDM projects, which in concrete terms utilise and operate the specific technologies. Figure 1 presents Table 2 visually, where the dotted line symbolises the boundary

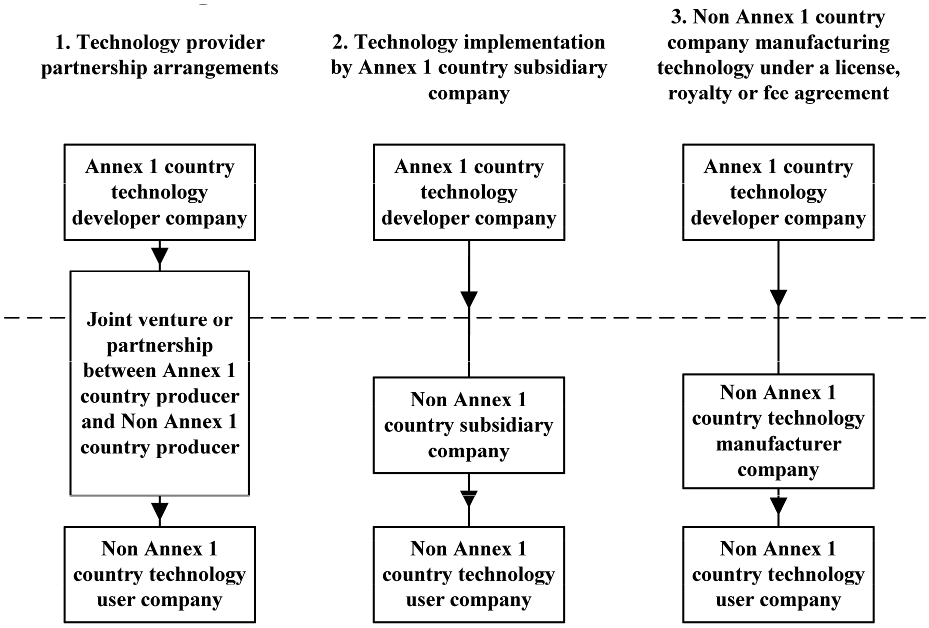
between the Annex 1 country transferor sphere (above) and the non-Annex 1 country transferee sphere (below).

Table 2 Analytic categories of the CDM project-related internal arrangements

	Modes and mechanisms of transfer	*Characteristics of the transferor and transferee companies*
1	*Technology provider partnership arrangements*	Transfer of technology and knowledge facilitated through joint venture companies or other partnership arrangements between an Annex 1 country technology developer company and non-Annex 1 country company manufacturer or other type of company that perform implementation of the technology, entailing also channels to the end-users of the technology
2	*Technology implementation by Annex 1 country company subsidiary*	The implementations of the technology or the technological system is handled, controlled and undertaken by an Annex 1 country company operating through its subsidiary company, which is based in the non-Annex 1 country. This implies channels to transfer of technology and knowledge from an Annex 1 country to a non-Annex 1 country albeit within the company and to the technology end-user companies of the technology.
3	*Non-Annex 1 country company manufacturing technology under a license, royalty or fee agreement*	Manufacture of technology by a non-Annex 1 country through a license, royalty or fee agreement with an Annex 1 country technology developer company, which thereby facilitate channels of technology and knowledge to the non-Annex 1 company and to the end-user companies of the technology

Source: Compiled from Kumar et al. (1999) and IPCC (2000)

Figure 1 Visual representation of project-related internal arrangements



Furthermore, as appears in Table 1, this assessment factor also takes into account the transfer of main or core technological hardware components. Yet, this aspect is primarily considered relevant insofar as the transfer process facilitates a possibility for the identified Malaysian companies to access valuable knowledge and obtain substantial insights into the hardware in question.

2.2.2 Accumulation of firm-level technological capabilities

Technology transfer can facilitate a possibility of tapping into the knowledge base of the external organisation and can thereby contribute to increase the human skills and organisational capital of the receiving company (Wei, 1995). A central element of the analytical frame, therefore, concerns an assessment of the technological learning processes and its effects on technological capability building of the Malaysian companies, resulting from its interactions with Annex 1 country companies involved in the CDM projects. The notion of firm-level technological capabilities is therefore used to characterise, conceptualise and qualify the knowledge dimension and the inter-organisational learning process of technology transfer (Levin, 1997). It should be remembered, however, that technology transfer also may have detrimental implications for the transferee parties, including reproduction of technology dependency, consolidate asymmetrical power structures and have socially damaging effects.

The concept of technological capabilities has since the 1980s become central to theories on engines of economic growth in developing countries (Lorentzen, 1998; Chandra and Zulkieflimansyah, 2003). The focus on technology transfer in this context has been to address the factors that lead to, stimulate and set into motion a continuing learning process in the receiving companies entailing, inter alia, further change and development of the initially acquired technology and existing technologies (Bell, 1997). The transfer of technology can, through facilitating a dynamic assimilation and learning process, contribute to develop the dynamic and innovative technological capabilities of the companies (Bell and Pavitt, 1993). Firm-level technological capabilities, thus, denote a company's ability as a whole to utilise technological knowledge efficiently to acquire, assimilate, use, replicate and generate changes in existent technologies and the ability to develop new technologies, products and processes. As organisations, firms can learn and accumulate knowledge over time, e.g., through technology transfer, which enables these to undertake new and progressively more demanding innovative activities. This process can be understood as gradual and evolutionary, and therefore, path dependent, in which sequential levels of capability accumulation can be identified (Müller, 2003; Dutrénit, 2004). In this study, the central aspect is that the identification of these capability levels can provide an understanding of the companies' competences regarding the specific CDM project-related technologies.

The characterisation and properties of the technological and organisational learning processes, relevant to technology transfer initiatives, have been considered in various ways in the literature on firm-level technological capabilities (Dutrénit, 2004). Common to these approaches are that the process of transferring knowledge which is accumulated in the transferor company that necessitates close interaction with the transferee company in order to facilitate access and insights into operation, maintenance, manufacture, implementation, design and development of the technologies in question (Lall, 2002; Müller, 2003). This technological knowledge, either tacit or codified in nature and possibly embodied in firm-specific routines and structures, may entail various forms of

interaction, including collaboration, instruction, supervision, training activities and more, to induce accumulation of technological capabilities in the transferee company. Different detailed taxonomic models to characterise and analytically operationalise the development and achievement of different capability levels have previously been advanced (Lall, 1992; Bell, 2007). Here, a simple model is adopted, and although inspired by the above-mentioned approaches, it will not contain as comprehensive information, especially regarding the company-related functions, as the above. Therefore, in this study, firm-level technological capabilities denotes the knowledge, including the coordinative, managerial and organisational capacity of the company as a whole, necessary to undertake certain activities regarding the technology in question. In Table 3, the model is presented, which features three levels of capabilities and the properties that characterise these levels. The model serves to provide an analytical basis for a qualitative assessment of the capability level of the Malaysian companies, both prior and subsequent to their involvement in CDM projects.

Table 3 The levels and properties of firm-level technological capabilities

Levels of capabilities	*Properties related to the levels of technological capabilities*
Basic (know-how)	• Capabilities to use, operate and maintain the technological equipment, devises, machinery, etc., subsequent to implementation of technology, including undertaking replacement and repair of minor components
	• The capability, primarily concerning the respective operators, to secure and maintain an efficient level of productivity (at best at its design levels of performance)
Intermediate (know-what)	• Capability to replicate and/or independently undertake complete implementation, including possible fabrication of technological components, technological subsystems or complete systems
	• The capability to independently undertake incrementally minor adjustments, modifications, improvements, optimisation, etc., in relation to specific application requirements and contexts
Advance or innovative (know-why)	• Capability to generate and manage more substantial changes and developments in the technological component, technological subsystem or complete system in question
	• The capability to undertake reconfiguration and redesign of the basic technology outlay, develop new designs or elements of the system or of the complete system including possibly to continuously optimise the system performance through engineering R&D-related activities

Source: Müller (2003) and Bell (1997, 2007)

This assessment factor also addresses the respective strategic interests of the companies involved in the process of, and aspects relating to, technology and knowledge transfer. In this regard, companies that develop technologies generally seek in different ways to retain strategic control over the core areas of their technology and tacit knowledge, through intellectual property rights (IPRs), patents and more, to hinder an uncontrolled dissemination of these aspects (Dicken, 2003). The ownership structure between companies, pertinent also to the rights of the technology, may constitute one opportunity for the technology developer companies to control their valuable assets in relation to activities and operations in other countries (Bell, 1997; Kumar et al., 1999; Forsyth, 2005). It has been suggested that a more integrated, binding and shared nature of

technology-related ownership relations between the companies involved imply increased incentives to exchange valuable knowledge (Hagedoorn, 1990). Relating hereto, the factors influencing the respective interests of the transferee and transferor agents, most important for the progress and outcome of technology transfer initiatives, have been summarised as capacity, opportunity and willingness (Kua and Ashford, 2004). For example, the needs and aspirations of the transferee company determine the envisaged opportunities and consequent willingness to actively engage in the process. The progress and outcome are, however, also contingent on the capacity of the transferee, the willingness to exchange valuable knowledge and the opportunities foreseen by the transferor.

Technology and knowledge transfer processes often involve an adaptation phase. This especially concerns the introduction of new technology in a company or country, since a different application context may imply challenges to the optimal performance of the technology. The technological system may therefore undergo changes to overcome the obstacles and different requirements (Lorentzen, 1998; Müller, 2003). If relevant, these adjustment processes to handle technological challenges or barriers will be taken into account.

2.2.3 The CDM as initiator of technology and knowledge transfer activities

This aspect of the analytical assessment framework concerns a historic assessment of the identified Malaysian transferee companies and focuses on the development, the company's core business activities and the general profile of the company. In this regard, the intention is also to address these companies' various project activities prior to the possibility of participating in CDM projects. This element, therefore, addresses the novelty of the specific technological systems implemented in the CDM projects, seen in relation to prior applications in Malaysia of the companies' technologies. Furthermore, the history and development of the transferee companies' affiliation with the identified Annex 1 country companies will also be taken into consideration. This assessment will address the nature of the relationship and interaction between these companies that has been evident prior to the CDM. Thereby, the analysis attempts to include the pre-existing engagements which may still be evident that facilitate transfer of technology and knowledge, in order to place the CDM within a historic context. The intention is thus to understand and assess whether the CDM initiates changes in the nature of the internal relationship and interaction patterns between the companies. Moreover, this also provides a possibility to understand whether the CDM essentially implies a continuation of the standard activities of the transferee company which implicitly have implications concerning the technological additionality of the projects.

3 Methodological approach

3.1 Projects and companies taken into consideration

As an initial data collection strategy, it was considered relevant only to include CDM projects registered by the clean development mechanism executive board (CDM EB), and published on the UNFCCC website, before the 1st of November 2007. The intention was thereby to focus on projects either implemented or currently in a final stage of

implementation. Among the 18 projects identified, 13 were chosen for further analysis since it was possible to obtain additional and sufficient information besides the official project documents concerning these projects and to establish contact to the relevant companies involved. Twelve of these projects involve the implementation of boiler technologies, which utilise biomass residues, inter alia from the Malaysian palm oil industry primarily empty fruit bunches (EFBs), to generate energy. One project concerns a landfill gas extraction and utilisation project. The project titles, project host companies and project numbers relevant to these 13 projects are presented in Table 4. The relevant companies referred to in the official PDDs and validation reports associated with these projects were consulted in order to identify additional technology supplier and facilitator companies. Each project, therefore, involves the participation of both Annex 1 country companies and companies based in Malaysia. The study is hence structured as a multiple case study, where each identified case describes the constellation of companies involved in the specific CDM projects. All projects taken into consideration claim to facilitate and result in technology transfer from an Annex 1 country to Malaysia in their PDDs and/or validation reports.

Table 4 CDM projects taken into consideration

CDM project title	*CDM project host company*	*CDM project no.*
Biomass Energy Lumut	PGEO Edible Oils Sdn. Bhd.	#249
Kina Biopower 11.5 MW EFB Power Plant	Kina Biopower Sdn. Bhd.	#385
Seguntor Bioenergy 11.5 MW Power Plant	Seguntor Bioenergy Sdn. Bhd.	#386
LDEO Biomass Steam and Power Plant in Malaysia	LDEO Energy Sdn. Bhd.	#395
SEO Biomass Steam and Power Plant in Malaysia	Sandakan Edible Oils Sdn. Bhd.	#402
Bentong Biomass Energy Plant in Malaysia	Pascorp Paper Industries Berhad	#501
ENCO Biomass Energy Plant in Malaysia	Kulim Industrial Estate	#502
Johor Bundled Biomass Steam Plant in Malaysia	WT Speciality Ingredients Sdn. Bhd.	#503
Jenderata Steam and Power Plant	United Plantations Bhd.	#558
Landfill Gas Utilisation at Seelong Sanitary Landfill Project	Seelong Sanitary Landfill	#927
Bandar Baru Serting Biomass Project	MHES Asia Sdn. Bhd.	#1091
Biomass Thermal Energy Plant – Hartalega Sdn. Bhd.	Hartalega Sdn. Bhd.	#1186
Mensilin Holdings Biomass Energy Plant Project	Mensilin Holdings Sdn. Bhd.	#1214

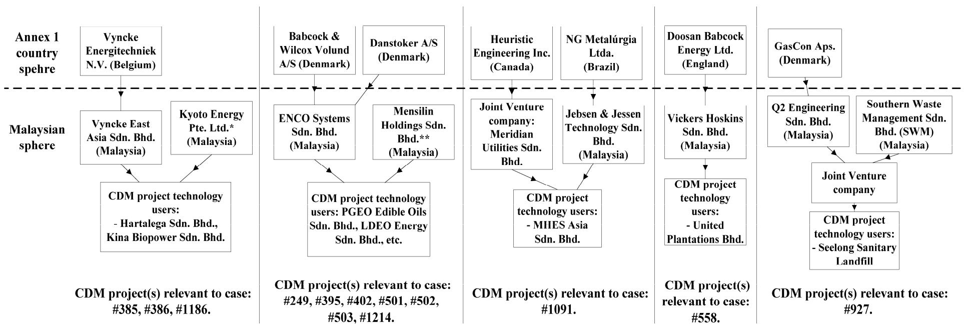
Note: See the http://www.unfccc.int web page for further information regarding these projects.

Source: UNEP (2008)

3.2 Sources of data and key informants

This study relies on multiple sources of qualitative data, primary relevance of the PDDs and to a lesser extent to the validation reports of the specific projects. The passages regarding technology transfer in these documents were assessed with the purpose to triangulate the information contained herein with other sources of data. Other documents obtained from company and project visits in Malaysia received by post from the companies and from the internet provides a further basis for understanding the activities of the companies involved. This includes company presentation papers, project descriptions, contractual agreements, technical documents and more. Moreover, a number of in-depth interviews with employees from the Annex 1 country and Malaysian-based companies involved in the identified projects constitute a central element of the data material of this study. The intention was to interview company representatives from both sides of the PDD's proclaimed technology transfer process, in order to reach a comprehensive understanding of their individual companies' history and development, internal relationship and concrete interaction throughout their CDM project involvement. The key informants identified have thus primarily been in higher and longer standing management positions within the various companies which enable these to provide such information. Interviews with key informants were of a semi-structured nature and were conducted both as telephone interviews and during personal meetings at the respective companies' head offices in Malaysia. Interviews were also conducted with official staff members of the Malaysian CDM-related regulatory system. Among the 16 interviews undertaken in total, two were performed with representatives of the institutional Malaysian CDM approval system and 14 with company representatives. All interviews in Malaysia were performed during a two-month visit in the spring of 2008. The interview discussions were structured on the basis of previously prepared categories of questions addressing each of the factors and sub-issues presented in the analytical framework (shown in Table 1).

Figure 2 The companies and projects constituting the five identified cases



Notes: *Kyoto Energy Pte. Ltd. was involved in CDM project no. 1186 as a carbon assest manager consultant for the project host company.
**Mensilin Holdings Sdn. Bhd. was both the project owner and technology end-user company in CDM project no. 1214.

Table 5 The summarised key findings regarding the analytical sub-issues addressed

Sub-issues / *Case no.*	*Project-related internal arrangement*	*Establishment of channels of transfer*	*Transfer of technological hardware from Annex 1 country*	*Implications of CDM involvement*	*Accumulation of firm-level technological capabilities*
1	• Vyncke operates as one company in Malaysia through its fully owned subsidiary company.	• The subsidiary company existed prior to the company's CDM involvement. • Establishes channels to technology and end-users	• There is transfer of technological hardware, but the CDM does not allow the technology end-users to gain substantial insights into this hardware.	• Vyncke essentially continues its previous activities in Malaysia by developing tailor-made boiler system solutions.	• Enablement of the relevant technology end use operators to carry out operation and maintenance of the technology
2	• ENCO produce boiler technologies under license and royalty agreements with Danstoker A/S and B&W Volund.	• ENCO was engaged in the royalty agreements before the company's CDM involvement. • Establishes channels to technology and end-users	• There is transfer of technological hardware, but the CDM does not allow the technology end-users to gain substantial insights into this hardware.	• ENCO continues its previous activities, which involves manufacturing and implementing boiler technologies.	• Enablement of the relevant technology end use operators to carry out operation and maintenance of the technology
3	• MHES formally implement the envirocycler technology under a joint venture agreement.	• The joint venture company existed prior the company's involvement in CDM projects.	• There is no transfer of technological hardware from an Annex 1 country company.	• MHES continues its previous activities in Malaysia concerning implementation and management of small power plants.	• Enablement of the relevant technology end use operators to carry out operation and maintenance of the technology
4	• Vickers Hoskins manufacture and implement boiler technologies under a license agreement with Doosan Babcock.	• The license agreement existed prior to the company's involvement in CDM projects. • Establishes channels to technology end-users	• There is no transfer of technological hardware from an Annex 1 country company.	• Vickers Hoskins continues its previous activities, although the company can subsequently implement the reconfigured boiler.	• Enablement of the relevant technology end use operators to carry out operation and maintenance of the technology
5	• SWN and GasCon Aps. jointly implement the landfill gas recovery technology under venture partnership.	• The initiation of the partnership was directly motivated by the possibility to venture into CDM projects involving landfill gas recovery and utilisation.	• There is transfer of technological hardware from an Annex 1 country company and the CDM allows SWM to gain comprehensive insights into this hardware.	• SWM is now, through the CDM, engaged in the implementation of landfill gas extraction and utilisation projects in Malaysia.	• Enablement of SWM, as a company, to carry out implementation of the technological system pertaining to CDM project #927

4 Results

4.1 Case studies

The study identified five cases in total, which each comprise the relevant companies and CDM projects constituting the case in question. The cases are presented in Figure 2, where the arrows represent linkages between relevant companies and thereby channels for technology transfer.

Furthermore, in Table 5, the sub-issues related to the factors taken into consideration in the analytical framework (see Table 1) have been addressed and the key findings regarding these elements pertinent to each of the five cases identified are summarised. These findings will be examined in more details in the following.

As appears in the first column in Table 5, different project-related internal arrangements, viz. the underlying formal organisational structures between the involved companies are evident in the five cases. The first case falls under the category of a subsidiary company facilitating technology implementation, whereas cases two and four are characterised by the manufacture of boiler technologies under a license and royalty arrangement. In cases three and five, the companies involved are engaged in joint venture partnership agreements.

Regarding case one, the Belgium company Vyncke Energietechniek N.V. has operated in Malaysia through its Malaysian-based subsidiary company Vyncke East Asia Sdn. Bhd. since the late 1980s. As a company, Vyncke specialises in the implementation of tailor-made boiler system solutions according to varying application contexts and can undertake all activities related to design, engineering, production, instalation and commissioning to training and after sale service. The activities of Vyncke in Malaysia and the Southeast Asian region have included numerous boiler system applications in different industries utilising various biomass materials. In case two, the Malaysian company ENCO Systems Sdn. Bhd. has manufactured and implemented boiler technologies in Malaysia respectively under a license and royalty agreement with the Danish-based companies Danstoker A/S since 1993 and Babcock & Wilcox Volund A/S since 1997. ENCO has implemented the companies' biomass utilising boilers in numerous cases in Malaysia. In the third case, the joint venture company Meridian Utilities Sdn. Bhd. was established in 2004 between the Canadian companies Heuristic Engineering Inc. and Northern Steel Ltd. and the Malaysian company MHES Asia Sdn. Bhd. As a company, Heuristic Engineering Inc. specialises in the development and application of biomass-fuelled combustion system technologies and has a license agreement with Northern Steel Ltd. to manufacture these technologies. Through the joint venture company, the purpose was to jointly undertake promotion, marketing, manufacture and distribution of Heuristic Engineering Inc.'s patented combustion technology (the so-called envirocycler) in Malaysia and the Southeast Asian region. Since the early 1990s, the Malaysian company Jebsen & Jessen Technology Sdn. Bhd. has under a partnership agreement undertaken sale, instalation and service of varying turbine systems in Malaysia for the Brazilian turbine manufacturer company NG Metalúrgica Ltda. Although Brazil is a non-Annex 1 country, the activities and relationship between these companies were taken into consideration in order to account for the implementation pathway of the turbine technology pertinent to CDM project no. 1091. Concerning case four, the Malaysian company Vickers Hoskins Sdn. Bhd. has since 1980, under a license agreement with the UK-based company Doosan Babcock

Energy Ltd., manufactured and implemented boiler systems in Malaysia. These boilers utilise various biomass materials as fuel source and they have been deployed extensively in Malaysia. In summary, as is evident from the above, the CDM did not establish new channels for technology transfer to other companies besides the technology end-user companies in the previously examined cases. In the fifth case, however, the initiation of a joint venture partnership between the Danish company GasCon Aps. (through its Malaysian-based company Q2 Engineering Sdn. Bhd.) and the Malaysian company Southern Waste Management (SWM) Sdn. Bhd. was primarily motivated by the possibility to venture together into CDM projects in Malaysia. Therefore, the activities of GasCon Aps. in Malaysia relating to landfill gas recovery and utilisation projects can be regarded as a direct consequence of or directly influenced by the CDM. The partnership also involved the completion of a small-scale demonstration project, co-funded by a Danish development fund, to explore the technical and financial viability of the ensuing large-scale CDM project at the Seelong Sanitary landfill (CDM project no. 927).

As can be seen in Table 5, the CDM projects in cases three and four did not involve the transfer of main technological hardware components from Annex 1 countries. In case one, the core components, i.e., the step grate combustion system, the heat exchanger system, the control and regulation system, etc., have in concrete terms been manufactured in Belgium and the Czech Republic (and in China) and transferred to Malaysia. However, Vyncke exercises a clear protective strategy to avoid an uncontrolled dissemination of information and knowledge concerning these systems in the Malaysian context. This has effectively hindered the end-user companies and other companies from gaining substantial insights into the various aspects of these systems. Regarding case two, the key hardware components, including the biomass shredding systems, ventilators, chippers, screening machines, separation systems and steam turbines, have been transferred to Malaysia from Annex 1 countries such as Sweden, Denmark, Germany, USA and others. As in the first case, ENCO strives to prevent other companies from gaining insights into the functionality, composition, outlay, arrangement and purpose of this hardware. In case five, a gas flaring system, gas analyser and automatic control system – constituting the main technological hardware components in CDM project no. 927 – were transferred from Germany, England and India. More importantly, GasCon Aps. allowed employees of the Malaysian company SWM to gain considerable and detailed insights into these systems during the transfer process.

As laid out in the fourth column of Table 5, Vyncke essentially continues its previous activities in Malaysia by implementing tailor-made boiler systems. For example, in CDM project no. 1186, Vyncke has supplied a boiler, which utilises EFBs, to generate energy. The company has independently handled the challenges or technological barriers associated with the combustion of this biomass material in their boiler system. The CDM has thereby increased the application volume of the Vyncke boiler system in Malaysia. A key factor to achieve this concerns the CDM-related revenue stream, obtained from the sale of certified emission reductions (CERs), which contribute to enhance the financial viability of such projects. Similarly, in case two, ENCO has through the CDM increased its boiler system application volume in Malaysia and has in this regard independently handled the appertaining challenges to an optimal operation. As it is the standard procedure of the company to manufacture and implement boiler systems utilising biomass materials, ENCO also continues its previous activities. Again, the CER revenue is a central factor for an increase in the volume of activities. Concerning case three, evidence seems to suggest that MHES Asia Sdn. Bhd. successfully has implemented the

envirocycler technology of Heuristic Engineering Inc. in CDM project no. 1091. Evidently, the company has not been in contact with its two Canadian partners since the commencement of the joint venture partnership and has therefore independently implemented the technology. In this regard, MHES Asia Sdn. Bhd. has utilised its previous extensive experiences in implementation and management of small power plants, as is the case in this CDM project, and has thereby continued and expanded its prior activities. The continuance of previous company activities also applies to the fourth case, where Vickers Hoskins Sdn. Bhd. has manufactured and implemented a boiler system utilising EFBs. However, a closer process of collaboration has been evident throughout the license partnership with Doosan Babcock Energy Ltd., which has involved assistance in solving various technical challenges in specific projects. This is also the case in CDM project no. 558, where the boiler system underwent reconfiguration to overcome the associated biomass-related challenges. Again, CERs have played a central role to further the volume of the company's boiler systems in Malaysia. In case five, SWM has not, prior to its involvement in CDM project no. 927 and concomitant partnership with GasCon Aps., been involved in undertaking landfill gas recovery and utilisation systems. The CDM project involvement has thereby stimulated SWM, as a concessionaire of a large number of landfill sites in Malaysia, to develop landfill gas projects through the joint venture company and/or independently.

In four out of five cases, the accumulation of firm-level technological capabilities has been limited to enable the relevant end use operators to carry out efficient operation and maintenance of the technologies in question. This has mostly been achieved through short training courses. Referring to Section 2.2.2, this corresponds to the lowest level of technological capabilities, which therefore suggest that the transfer of knowledge through the CDM has been limited. The Malaysian companies have therefore not undergone a process, through their CDM project involvement, which enable them to undertake other and more demanding activities. Yet, in the fifth case, the CDM project involvement has resulted in a substantial learning process for SWM employees throughout a close and mutually benefiting process between the involved companies. It appears that the CDM-related transfer of knowledge has significantly increased the technological capabilities of SWM to implement and handle gas recovery and utilisation systems. During all phases of the project, including the demonstration and feasibility study process, the companies collaborated closely and on a day-to-day basis. While working on site, GasCon Aps. utilised the company's comprehensive accumulated and tacit expertise in overcoming the instalation challenges. SWM, thereby, acquired familiarity with the methods and procedures of performing continuous system optimisation necessary to handle the implementation, and possibly further technology development, independently. The development of such capabilities, through the interaction process, has been strategically interesting for SWM, envisaged as involving future market opportunities, which has increased the willingness of the company to engage actively in the implementation process. GasCon Aps. has been willing to and interested in developing the competences of SWM in order to reach an equal project involvement and to streamline the process of jointly implementing highly efficient landfill gas recovery systems. However, GasCon Aps., also considers it necessary to retain some of the most essential information of the technology. This may point towards a possible underlying conflict of interest in relation to initiatives involving technology transfer. The cooperative and accommodating approach by GasCon Aps. may have been influenced by

requirements associated with the initially acquired Danish funds to engage in a long-term relationship augmenting the technological capacities of the local partner.

4.2 The Malaysian institutional CDM approval system

A CDM project host country needs to have a designated national authority (DNA) in place to be eligible to participate in CDM projects. In Malaysia, the DNA is located within the Ministry of Natural Resources and Environment. The role of the DNA is to ensure and approve that CDM project activities assists in achieving sustainable development for the projects to be registered by the CDM EB. A national committee on the clean development mechanism (NCCDM) and the Malaysian Energy Centre together with the DNA constitute the regulatory approval framework for CDM projects in Malaysia. It is the prerogative of the non-Annex 1 country in question to formulate and define the sustainable development criteria used to assess the CDM projects in the approval process. In this regard, Malaysia has included technology transfer as a key element of these criteria in its formal acceptance and approval modalities. In Table 6, these provisions are presented.

Table 6 The CDM-related technology transfer requirements in the Malaysian sustainable development criteria

Criterion 3 – projects must provide technology transfer benefits and/or improvement in technology
3.3.1 Interpretation
• Technology transfer and/or improvement in technology include both soft and hard elements of technology. • CDM projects should lead to the transfer of environmentally sound technologies and know-how. • Improvement in technology implies that the project applies a technology that is more efficient and less carbon intensive. • Technology transfer and/or improvement in technology should support the sustainable development objectives of Malaysia. • Technology transfer and/or improvement in technology should enhance the indigenous capacity of Malaysians to apply, develop and implement environmentally sound technologies.
3.3.2 Indicators – the relevant indicators should measure the following:
• Impact of the project on the indigenous capacity to apply, develop and implement environmentally sound technologies • Impact on increased use of renewable energy resources and/or increased energy efficient and/or reduction of GHG emissions • Demonstrations and replication potential of the technology • Impact on domestic energy-related industries and services (increased local content of skills and equipment in energy projects)

Source: Malaysia Energy Centre (2006)

It appears from Table 6 that technology transfer requirements in the CDM have been a central priority for Malaysia. In practice, however, the actual approval and assessment procedure adopted by the regulatory system under the DNA has been more straightforward and pragmatic. Indeed, technology transfer has in concrete terms been

interpreted to require only that the original technology design of the main components in a given implemented technological system must originate from an Annex 1 country company. Malaysian companies involved in CDM projects engaged in (previous) license, royalty and other agreements with Annex 1 country companies, therefore, per se involve technology transfer. Efforts have not been devoted to assess, in further detail, the concrete technology-related processes and interaction between the involved companies during the implementation of the CDM projects. The main reason for this approach is attributable to a wish to avoid upholding unnecessary barriers for CDM project developers to develop and implement projects in Malaysia. This may therefore suggest that more strictly enforced technology transfer requirements may constitute an obstacle to further the implementation of CDM projects.

5 Discussion

The CDM project assessment approach adopted by the Malaysian CDM approval system relates to a general discussion concerning how to conceptualise and operationalise technology transfer requirements. This concerns the different ways to formulate, assess, enforce, verify and implement technology transfer provisions and to integrate these aspects in an institutional and regulatory system. Recent discussions regarding technology support for nationally appropriate mitigation actions in developing countries and development of technology transfer indicator framework undertaken by the UNFCCC's Expert Group on Technology Transfer (EGTT) engages intensively with these elements. In relation to a follow-up period to the KP, it seems plausible that the CDM will continue to exist although most likely in a modified version. As mentioned, the subject of technology transfer from Annex 1 countries to non-Annex 1 countries has increasingly entered the top of the political agenda concerning a post 2012 climate change regime. Therefore, current debates in the negotiation process concern a possible integration of technology transfer requirements (for project registration and approval) in a reformed CDM or in other initiatives involving GHG emission reduction activities in developing countries. If technology transfer is to be a key priority, also taking the findings of this study into consideration, the provisions may require comprehensive assessments and accordingly allocation of resources to undertake the procedural activities associated herewith. However, a further complication of the CDM project cycle procedure may in this regard not be considered desirable for the CDM. Alternatively, the requirements may continue to exist as more non-binding and optional provisions, as this presently is the case under the regulatory system of the CDM EB. In continuation hereof, one possible politically acceptable approach may therefore involve adopting best available technology (BAT) requirements. In this regard, technology transfer as one objective ultimately needs to be balanced with other aims, including the aspiration to increase the volume of GHG mitigation activities, especially if technology transfer requirements potentially constitute an obstruction to further these activities. To agree upon relevant and verifiable technology transfer-related provisions which satisfy all relevant parties' demands may furthermore constitute a challenging or unfeasible task. A question also concerns which regulatory institutional body(ies), e.g., the CDM EB (or appurtenant panels), DNAs, designated operational entities (DOEs), etc., should be responsible for evaluating prospective technology transfer requirements. In addition, as

the CDM fundamentally is a market-based mechanism, it may not be considered politically appropriate to adopt too many restrictions which distort its functioning.

6 Conclusions

Although a formal priority of the Malaysian DNA, the study concludes that the CDM only plays a role in relation to the transfer of technology from Annex 1 countries to Malaysia in one registered and implemented CDM project in Malaysia – the Seelong Sanitary Landfill project. Among the 13 projects examined, this project stands out, as the CDM is the primary reason for an Annex 1 country company's engagement in a long-term, close and binding partnership with a Malaysian company, which facilitates substantial transfer of technology and knowledge. Through this project, the Malaysian transferee company gains access to comprehensive insights into fundamental aspects and principles of the technological system along with the methods and procedures for its continuous optimisation. The company, thereby, accumulates technological capabilities necessary to handle implementation, and possibly further development, of the landfill gas recovery and utilisation technology.

While transfer of technological hardware does take place in most projects, the transfer of knowledge through the CDM is considered limited. In fact, the process that takes place in the (12) remaining examined projects can essentially be characterised as the local diffusion of existing technologies. The Malaysian transferee companies' relationships with Annex 1 countries has existed before the companies' CDM project involvement and the capability to handle technology manufacture and/or implementation, including overcoming the specific instalation challenges, is already present. Therefore, the CDM does not, to any great extent, contribute to develop technological capabilities of these companies enabling them to take future responsibility for implementing or developing technological GHG mitigation solutions. Moreover, the activities of Annex 1 country companies in Malaysia may more appropriately be understood as an element of a general internationalisation of their economic activities, involving that these establish subsidiaries, joint ventures and license agreements, and more, in Malaysia. On this basis, the CDM have led to limited additional technology transfer, above and beyond what would have taken place as a consequence of other ongoing processes under the broad heading of globalisation. The CDM does, however, play a role as a financial mechanism to facilitate wider adoption and usage of the pre-existing technologies by making the project activities more financially viable.

Finally, companies do not engage in technology transfer activities as such, but instead in technology procurement, contracts, license, royalty and fee agreements, joint ventures and other company-related linkages. The extent to which these linkages, between the companies in question, are close and binding in nature seem to encourage the parties to exchange valuable technological knowledge. The character of the relationship, thereby, seems to play a role for the substance and quality of the technology and knowledge transfer process. It is suggested that the transferor companies may not necessarily have incentives to transfer substantial technological knowledge necessary to perform implementation and/or development of the technology in question. This may therefore constitute a potentially underlying limitation to the development of firm-level technological capabilities through technology transfer initiatives. Political deliberations addressing technology transfer and the CDM, including adopting relevant provisions post

2012, may therefore benefit from considering the various pathways or channels for technology transfer.

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Paper 2

Learning and technological capability building in cleantech industries in emerging economies: the case of the biomass power equipment industry in Malaysia

Ulrich Elmer Hansen[a]; David Ockwell[b]

[a]UNEP Risø Centre, DTU Management Engineering (Corresponding author)
[b]Department of Geography, University of Sussex

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Abstract

Low carbon technology transfer is fundamental to supporting lower carbon development trajectories in developing countries. But to have a long term impact technology transfer needs to support broader processes of learning and technological capability formation. Previous studies that look at this in the context of cleantech industries in emerging economies tend to overlook intra-industry differences and firm-level specifics. This paper contributes to filling this gap by utilising in-depth, qualitative firm-level data to analyse the extent to which the use of different learning mechanisms can explain differences in the accumulation of technological capabilities. This is explored via an examination of eight firms in the biomass power equipment industry in Malaysia during the period 1970-2011. The paper finds that firms relying on a combination of learning from foreign technology partners and internal learning by planned experimentation make most progress in terms of technological capability. Nevertheless, local spill-over effects were found to be important for some firms who learned principally from imitation of local competitors, although, significantly, firms learning from local spillovers failed to advance beyond extra basic operating technological capabilities. Those firms who proactively pursued learning from foreign partners, on the other hand, advanced further, reaching basic innovative levels of technological capabilities.

Keywords: Technology transfer; technological capabilities; indigenous innovation; climate change; biomass; renewable energy; palm oil; Malaysia

1. Introduction

There is often a tendency to think of sustainable development separately from processes of technological capability development in developing countries via the transfer/import of foreign technologies. For example, recent special issues of the development studies journal *World Development* dealt separately with the topics of "Sustainable Development, Energy and Climate Change" (Halsnæs et al., 2011) and "Foreign Technology and Indigenous Innovation in the Emerging Economies" (Fu et al., 2011). An emerging literature, however, is beginning to highlight how these issues are in fact inextricably linked and how an understanding of the latter might make a critical contribution to realising the former, i.e. sustainable development pathways that incorporate lower carbon energy technologies, contributing to climate change mitigation whilst simultaneously meeting critical development priorities (Mathews, 2007; Altenburg, 2008; Walz, 2010; Ockwell et al, 2010; Berkhout, 2012). But simply transferring lessons from research on conventional technology imports and indigenous innovation is not enough. Climate change and technologies for its mitigation or adaptation poses a range of unique challenges and considerations which are currently under researched and under theorised (Ockwell and Mallett, 2012). These include temporal concerns relating to the urgency of climate change mitigation (i.e. achieving extensive low carbon technology transfer as quickly as possible), the global good nature of the benefits of low carbon technologies which are not captured in the market (Mowery et al., 2010), ignored needs of the poorest people where market incentives are also lacking (Sagar, 2009), and the early stage of commercial development and adoption of many low carbon technologies, raising multiple risks to their commercial use and barriers to investment. However, despite the lack of an empirical or conceptual base upon which to build, in many development organisations, including donors, NGOs, and international development banks, the use of phrases such as "low carbon development", "climate compatible development" and "green growth" have become increasingly widespread and are shaping funding agendas. There is therefore an urgent need for empirically grounded research which explores theories of foreign technology and indigenous innovation explicitly within the context of low carbon energy technologies, and the contexts of climate change and development policy more broadly. It is within this context that this paper seeks to contribute.

A number of studies have recently begun to analyse how low carbon energy technology industries in emerging economies have evolved and proliferated in parallel with rapidly expanding renewable energy markets and overseas investments. A key question addressed in these studies is the extent to which foreign investment has increased indigenous capabilities in developing countries to engage in advanced product development (Brewer 2008; Altenburg, 2008; Lema and Lema, 2012). Existing work pays particular attention to the role of national political and institutional conditions for industry development (see e.g. Huang and Wu, 2007; Mathews et al., 2011; Pueyo et al., 2011; Walz and Delgado, 2012). A number of other studies use aggregate R&D and patent statistics both to assess the underlying processes of learning and whether innovative capabilities have developed at the industry level (see e.g. Walz et al., 2008; Tan, 2010; Walz and Weidemann, 2011; Dutch and Sharma, 2012; Wu and Mathews, 2012). This work therefore often misses potential intra-industry differences and firm-level specifics. Moreover, the economic indicators used only indirectly assess learning as an output of technological efforts. With notable exceptions, e.g. Lewis (2007, 2011), Mizuno (2007), Marigo (2009), Marigo et al.

(2010), few empirical studies based on firm-level data have undertaken in-depth, longitudinal studies of learning and accumulation of innovation capabilities in individual firms.

One important question concerns the critical factors that underlie differences in the accumulation of innovation capabilities at the firm level. This has critical implications for understanding how foreign technology imports, and interactions between indigenous firms and international technology owning firms, might contribute more broadly to building low carbon innovation capabilities in developing countries and thus how policy and practice might target such capability building. One potential factor that might underlie inter-firm variance in capability building is the nature of the learning mechanisms individual firms employ to develop their in-house technological capabilities. This paper therefore sets out to explore the extent to which the use of different learning mechanisms can explain inter-firm differences in the accumulation of technological capabilities. This question will be explored by examining the dynamics of firm-level learning in relation to boiler manufacturing in the biomass power equipment industry in Malaysia from 1970-2011.

The paper is structured as follows: Section 2 develops the conceptual framework. Section 3 sets out the methodology; Section 4 introduces the empirical context before the main findings are presented in Section 5. The paper concludes in Sections 5 and 6 with a discussion of the results and drawing some conclusions.

2. Conceptual framework

This paper draws on two key theoretical distinctions made within the innovation studies literature to guide its empirical analysis. The first theorises a continuum of technological capabilities in developing country firms, from productive through to innovative. The second theorises a twofold categorisation of different learning mechanisms that firms might adopt and which might explain the accumulation of technological capabilities. The latter also facilitates elaboration of the theoretical underpinnings of assessing the role different learning mechanisms play in technological capability formation.

2.1. Accumulation of technological capabilities in latecomer firms

This paper builds on the literature on technological learning and accumulation of technological capabilities in firms in developing economies – known as latecomer firms (see e.g. Amsden, 1989; Lall, 1992; Dutrénit, 2004; Bell, 2006). In this literature, firm-level “technological capabilities” are broadly defined as the resources needed to generate and manage technological change, including skills, knowledge, experience and organisational systems (Kim, 1997; Figueiredo, 2001). The accumulation of capabilities is thus conceptualised as a process whereby firms accumulate knowledge and skills over time that improve their ability to implement and handle technical change. Following Bell and Pavitt (1993), this paper makes a distinction between "innovation" capabilities and "production" capabilities. Production capabilities refer to the basic and routine-based capabilities necessary to produce industrial goods at different levels of efficiency, given various input combinations such as equipment, labour skills, product and input specifications, and the organisational methods and systems used. Essentially, such production capabilities represent the firms’ ability to use, operate, and make small productive efficiency improvements in existing technologies and production systems. Innovation capabilities, on

the other hand, denote the resources that firms need to create new, or to implement more substantial changes in products and product process organisation (Lall, 1992).

Production and innovation capabilities may according to Bell and Pavitt (1993; 1995) be considered to be at opposite ends of a continuum of sophistication of firms' innovative technological activities. Various studies have elaborated taxonomies to identify different degrees or levels of innovation capabilities of latecomer firms (see e.g. Katz, 1987; Lall, 1992; Ariffin, 2000; Dutrénit, 2000; Marcelle, 2004; Tacla and Figueiredo, 2006). These levels typically range from the basic operational production capability, at the lower end, towards more complex and advanced engineering and R&D-based activities, at the higher end, across various technical functions in the firm. As Bell (2007) and Plechero (2012) conceptualise, with an increase in innovative capability, firms are capable of mastering the generation of innovations with increasing degrees of novelty and complexity. At the lower end of the spectrum, innovations may be "new to the firm" and with increasing innovative capability, firms may generate innovations that are "new to the local industry" (or local market) and "new to the world" market (Fagerberg, 2005; OECD, 2005). It should be noted that in this context "innovation" can be taken to refer to both incremental and adaptive innovation, as opposed to simply radical (new to the world) type innovation. These former types of innovation, which may involve adapting technologies (including designs and organisational practices) to local contexts or incrementally improving technologies to move towards the technological frontier, are often of far more relevance in a developing country context (Mani and Romijn, 2004).

Building on this distinction between productive and innovative capabilities, a typology for assessing technological capability accumulation is presented in Table 1. It should be noted, however, that, as Bell and Figueiredo (2012) argue, the boundary between production and innovation capabilities is often fuzzy and not straightforward. Whereas other taxonomies, such as those elaborated in Ariffin (2000) and Figueiredo (2001), comprise indicators to assess the level of technological capability across a number of technical functions in the firm (such as process, product, equipment, or investment-related), this paper focuses exclusively on the product side. In the context of the case study of boiler manufacturing, this conceptualisation encompasses vital boiler and power plant components such as the grate, super-heater, economiser, fuel pre-treatment and fuel feeding system, as well as the complete power plant design and related engineering.

Table 1. Typology of levels of technological capabilities in boiler supplier firms.

Levels of technological capability		Product-related indicators
Innovative technological capabilities: Capabilities to generate and manage technological change	**(6) Advanced innovative capability**	-World leading in new boiler engineering and innovation based on cutting-edge research -Substantial number of highly specialised and internationally recognised R&D personnel -Systematic and continuous patenting of boiler design innovations that are "new to the world market"
	(5) High intermediate	-Own development of computer modelling and automation systems in project design engineering systems -Ongoing substantial independent R&D and engineering on new world class boiler system designs (close to the international innovation frontier) -Engaging in joint ventures and strategic alliances with leading foreign international firms and universities
	(4) Intermediate innovative capability	-Establishment of design engineering departments to undertake product-related R&D or substantial expansion of existing engineering staff -Product development certification (e.g. ISO 9001) or similar formalised qualifications -Continuous development of new product designs based on own research for local or regional markets -Establishment of collaborations with domestic research institutions and universities on basic R&D in new products
	(3) Basic innovative capability	-Systematic and planned routines to enhance boiler plant performance (improved project engineering design) with existing engineering staff -Acquiring designs that are new to the domestic market and using this to develop new products (e.g. from licensing new technology) -Significant modifications to existing designs and/or engaging in products that are completely "new to the local market and economy" -Generation of significant price-performance optimisation improvements compared to local/domestic competitors
Boundary between production and innovation capabilities		
Routine production capabilities: Capabilities to use and operate existing technology	**(2) Extra basic operating capability**	-Outsourcing production of key components and the integration of these in the overall boiler plant design outlay -Minor adaptation in existing design specifications and small incremental improvement in boiler performance -Modifications of existing designs to generate products that are "new to the firm"
	(1) Basic operating capability	-Manufacture of standardised boilers and small-scale power plants according to fixed design specifications -Routine quality and control to maintain existing standards (ongoing and final inspection) -Own production of vital boiler pressure part components (e.g. pre-heaters, economisers, grates, furnaces, tubes, etc.) -Awarded international certification (e.g. ISO 9002, ASME codes, LRQA, BS2790)

Source: Adapted from Lall (1992), Ariffin (2000, 2010), Dutrénit (2000), Figueiredo (2001), Viotti (2002), Ariffin and Figueiredo (2004), Tacla and Figueiredo (2006), Bell (2007).

2.2. Learning mechanisms

Bell (1984) distinguishes between two types of learning in relation to developing innovative capability in latecomer firms. The first type concerns doing-based learning that automatically and costlessly accrues from the continuation of well-established production activities, which through the implementation of minor changes may incrementally enhance the productive efficiency of a firm over time. Such efficiency improvements arise as passive

by-products over time from the execution of standardised production tasks (Malerba, 1992). According to Bell and Pavitt (1993), this mainly experience-based learning may enhance the firm's production capabilities, but provide limited stimulus to increase the innovation capabilities of the firm to manage technology and implement technical change. In contrast, the second type of learning is conceptualised as involving more active and purposive investments in learning activities that improve the ability of firms to carry out in-house changes in production process organisation and products (Scott-Kemmis and Chitravas, 2007). Learning in the second sense thus requires conscious, costly, and concerted efforts through the allocation of necessary financial and human resources with the explicit purpose of building innovative capabilities. Following Bell and Figueiredo (2012), this paper focuses on learning understood in the latter sense - as deliberate processes by which additional technical skills and knowledge are acquired by individuals, and through them by organisations, potentially varying according to how explicitly deliberate these processes are and how much time and money is invested in them.

Within this definition of learning, this paper makes use of the framework developed in Figueiredo (2001, 2003) to conceptualise different mechanisms through which such learning might be pursued, and to assess the role of these mechanisms in firms' accumulation of technological capabilities. While the sources firms actively utilise to acquire and generate new knowledge may take various forms, this paper conceptualises learning as the acquisition of knowledge from two distinct learning processes: intra-firm learning and externally-mediated learning.

Intra-firm learning processes involve the acquisition of new knowledge from various sources within the firm. These internal learning processes comprise formalised and purposive activities that take place by engaging in systematic and continuous improvements of production organisation, products, and equipment. For example, involvement in planned experimentation in new investment projects may give rise to "learning by changing" through the modification of equipment and machinery, particularly if this builds consecutively on accumulated experience obtained in different projects. Achieving the most effective learning outcomes in such new investment projects may, according to Kim (1997), be more likely if the learning process is proactively approached by conscious efforts to plan and manage how knowledge will be obtained and integrated into the organisation. Another example of intra-firm learning takes place in practical problem solving efforts in specific projects in the form of "trial and error learning". Different types of formal in-house training programmes, both course-based and on-the-job training of workers, supervisors, and managers (e.g. in product design routines) may also provide "learning by training" possibilities for employees. The generation of new knowledge may also derive from "learning by searching" activities through in-house technical efforts in firm laboratories, formal R&D divisions, design and engineering departments, and quality and control units (Jonker et al., 2006).

Externally mediated learning, on the other hand, involves a number of ways whereby knowledge is acquired and internalised into the organisation from sources outside the firm (Bell and Figueiredo, 2012). In this paper, particular attention is paid to learning processes facilitated through dyadic relationships between firms, as opposed to other types of external influences, such as linkages with local universities or recruitment of employees from sources outside the firm. These dyadic relationships may be through linkages with foreign firms in the form of licensing agreements, joint ventures, technology cooperation, technical assistance, strategic alliances, and other forms of commercial inter-firm

relationships that transcend the local economy. By facilitating the acquisition, assimilation, and possible improvement of foreign technologies, such transnational inter-firm linkages may comprise important sources of "learning by interacting" with foreign, more technologically advanced partners (Amsden, 1989; Hobday, 1995; Mathews, 2006). Another source of externally mediated inter-firm learning may take place when firms interact with local competitors either through formalised ventures, such as project partnering, or from non-formal channels such as "learning by imitation and copying" and local labour turnover. Such knowledge spillovers across firms in a local industry or economy may constitute a key (external) learning source for latecomer firms (Kesidou and Romijn, 2008).

This paper focuses on the extent to which firms make use of the different learning mechanisms introduced above in order to build innovative capabilities. Following Figueiredo (2001), attention is also paid to the *intensity* of management *effort* and financial commitment devoted to utilise a given source of learning, which Kim (1997) and Mathews (2006) also stress as an important determinant of technological capability building. These key characteristics of learning mechanisms, as operationalised in this paper, are illustrated in Table 2.

Table 2. Typology for assessing learning mechanisms utilized by firms in developing technological capabilities.

	Type of learning mechanism	
	Intra-firm	**Externally mediated**
Different learning mechanisms used by firms:	Presence or absence of processes for acquiring knowledge through internal activities	Presence or absence of processes for acquiring knowledge locally and/or abroad
Intensity of efforts devoted to utilise a given learning mechanism:	Level of persistence and human and financial resources devoted to leverage learning from in-house efforts	Level of persistence and human and financial resources devoted to leverage learning from external sources

Source: Adapted from Figueiredo (2001; 2003).

2.3. The importance of different learning mechanisms

Based on the conceptualisation above, one may distinguish between learning mechanisms that are either internal or external (local or foreign) to the firm (Bell and Figueiredo, 2012). Viotti (2002) stresses that technological learning in latecomer firms is largely confined to the absorption of existing technologies acquired from foreign, more technologically advanced firms. This recognition of the importance of external, foreign sources of knowledge is encompassed in various conceptual frameworks addressing the dynamics of technical change in developing countries. In the literature on capital investments by multinational firms in developing countries, for example, much effort has been devoted to analysing the knowledge spill-over effects of foreign investments in local industries (see e.g. Blomström et al., 2000; Saggi, 2002). In a related body of literature, the

dissemination of knowledge from multinationals to local producers inserted in global production networks has been extensively examined (Ernst and Kim, 2002). Similarly, the global value chain perspective has placed equal emphasis on foreign sources of learning, and devoted particular attention to understanding how lead firms govern the flow of knowledge and thereby the prospects for industrial upgrading amongst local suppliers (Gereffi, 1999).

With regard to local sources of learning, other analytical frameworks have accentuated the importance of local knowledge systems in latecomer firms' technological capability building (Bell and Albu, 1999). A lot of the literature on industrial clusters in developing countries, for example, addresses knowledge flows occurring, inter alia, through interactions among local competitors, user-producer relations, industry-university linkages, new firm creation, and labor mobility (Schmitz and Nadvi, 1999). In another body of the literature on innovation systems in developing countries, the main research interest concerns the institutional structures that enable knowledge flows among various actors at the national, sectoral, or regional level (Malerba and Mani, 2009; Lundvall et al., 2009).

Other frameworks have emphasised the important role of firms' internal strategic intent to invest in activities aimed at generating new knowledge from intra-firm sources (Xie and White; Scott-Kemmis and Chitravas, 2007). In the international business literature, for example, scholars adopting a resource-based view of the firm have focused on the essential role of increasing the internal human capital in latecomer firms as a central element of technological capability building (Mathews 2002). In a related literature addressing the development of absorptive capacity in latecomer firms, the key role of internal R&D investments and the cumulative nature of technological capability formation has been emphasised (Cohen and Levinthal, 1990).

While this short discussion by no means provides an exhaustive review of the treatment of the role of internal, local, and foreign sources of learning in various bodies of literature, it illustrates that these learning mechanisms are often treated separately. However, since it may be useful to consider these, at least potentially, as complementary (rather than alternative) sources of technological capability building, some recent studies have highlighted the importance of assessing how firms use different combinations of such learning mechanisms (see e.g. Giuliani et al., 2005; Kesidou and Romijn, 2008; Fu and Gong, 2011; Fu and Zhang 2011; and Li, 2011). Building on these studies, this paper examines which specific combinations of learning mechanisms firms utilise as complementary composites or bundles of learning mechanisms, thus providing a basis for examining the consequences of these firm-specific patterns for the levels of technological capability achieved.

3. Empirical context

Together with Indonesia, Malaysia is the largest producer and exporter of crude palm oil and derived products in the world. Since the 1970's, Malaysia’s production output and area under palm oil cultivation increased exponentially, leading to a concomitant increase in palm oil biomass waste. Compared to other residual biomass resources in Malaysia, such as rice husk or sugarcane bagasse, the electricity potential from utilising palm oil biomass waste is by far the largest - around 2700 MW in 2007 (Chua et al., 2011). Among these biomass waste by-products, empty fruit bunches (EFB) are the most abundantly available and lowest cost. At least until the beginning of the 1990's, this

resource was left largely unutilised in the palm oil industry except for mulching purposes. Owing to the anaerobic decay of EFB and palm oil mill effluent (POME), palm oil mills generate substantial methane gas emissions which have 20 times the warming potential of carbon dioxide as a greenhouse gas.

In palm oil mills, the usual waste management practice involved the utilisation of palm kernel shells (PKS) and mesocarp fibres in cogeneration plants to meet the internal process steam requirements owing to a higher calorific value compared to EFB. These conventional captive power plants were deliberately designed inefficiently in order to burn as much biomass waste as possible since the potential energy from utilising PKS, mesocarp fibres, and EFB was much larger than required by mills. Besides mulching, EFB was mainly left to decay in open landfills and stockpiles since it was difficult to utilise EFB directly in boilers owing to a high moisture, chlorine, and alkali (silica) content. Consequently, limited experience was generally accumulated in the local boiler industry with regard to utilising EFB efficiently for energy generation, particularly for modern, large-scale, and high-efficient combined steam and electricity power plants.

However, since the 1990's a number of factors contributed to conducive conditions for investments in renewable energy in general and EFB-fired power plants in particular (Hashim and Ho 2011). This created demand for EFB-fired power plants in Malaysia, opening new market opportunities for local boiler supplier firms. This market demanded fundamentally different products in terms of scale and efficiency than normally required in the conventional inefficient and small-scale cogeneration plants in palm oil mills. In contrast to the old, typically low pressure and low temperature palm oil mill boilers, the new market increasingly demanded efficient, high pressure and high temperature boilers in large-scale power plants. In order to compete in this market and meet this demand, Malaysian boiler supplier firms were, due to a lack of previous experience, forced to engage in concerted learning efforts and accumulate technological capabilities to improve their ability to implement technological changes. This dynamic setting thus provides a suitable context to examine the extent to which individual firms used different learning mechanisms and whether this influenced technological capability formation.

4. Methodology

This paper uses qualitative data from in-depth, semi-structured interviews with key employees in the eight Malaysian boiler and power equipment supplier firms which had achieved the strongest positions in the emerging market for palm oil biomass waste-to-energy power plants in Malaysia. Data was collected during successive field studies in 2007, 2010 and 2011 and supplemented with documentary material (such as archival firm statistics, firm websites, and industry reports). The eight firms were identified by consulting industry experts in Malaysia, and using a snowballing method to consult with competitors and customers, to ascertain which firms had supplied boilers to the majority of EFB-fired power plants constructed in Malaysia between 1990-2011. Key characteristics of these firms, which have been anonymised in this paper owing to confidentiality concerns, are presented in Table 3. Interviews were undertaken with lower and higher ranking employees with shorter and longer-lasting positions in each firm, including former employees. In total, thirty in-depth interviews were conducted and digitally recorded, transcribed and analysed. In advance of the data collection process, an identical interview questions protocol was prepared, which was used across the interviews conducted.

Table 3. Key figures on the firms analysed.

Firm	Production personnel	Engineering and Administration personnel	Year established	Ownership
Alpha	15	20	1975	Malaysian owned
Beta	0	30	1985	Foreign subsidiary
Gamma	40	50	2005	Malaysian owned
Delta	70	58	2005	Malaysian owned
Epsilon	40	20	1978	Malaysian owned
Zeta	80	15	1972	Malaysian owned
Eta	40	32	1993	Malaysian owned
Theta	12	25	1974	Malaysian owned

4.1. Concept operationalisation and data acquisition

4.1.1. Variety and intensity of learning mechanisms used by firms

To gain insights into the variety of learning mechanisms used by individual firms in their technological capability building efforts, interviews were conducted using the following guidance:

1. Interviewees were introduced to the conceptual distinction between external and internal types of learning mechanisms and given examples of these.
2. Interviewees were asked to use this categorisation throughout the interviews to elaborate which learning mechanisms, and specific combinations of them, they predominantly utilised during their involvement in EFB-fired power plants.
3. To guide their evaluation of learning mechanisms, interviewees were asked which learning mechanisms they considered most important in increasing their firms' ability to handle the engineering-related activities in the design and construction of EFB-fired power plants.
4. Interviewees were requested to substantiate the nature of identified learning mechanisms in further detail, including follow-up questions on what and how specific employees learned from different sources and how this learning process became manifested in concrete terms in the plants constructed.

This information fed into a subsequent round of interview questions that addressed the intensity of efforts devoted to utilise specific learning mechanisms using the following guidance:

1. Interviewees were asked to describe to which extent, and at which level of persistency, the management allocated financial and human resources to extract knowledge from a given source.
2. In interviews with firm managers, they were asked specifically about the level of attention and priority given to acquire new knowledge.
3. Additional probing questions were use to elicit detailed information, including the number of man-hours spent on intra-firm trial and error efforts (e.g. from on-site problem solving), internal R&D investments, and the level of continuity of resources devoted to searching for and leveraging knowledge from foreign technology suppliers and/or local competitors.

4.1.2. Levels of technological capabilities achieved by firms

Before conducting interviews in Malaysia, the levels and related indicators on technological capabilities detailed in Table 1 were first validated with firms in Denmark to see if they made sense to people working in the biomass boiler industry. Validation was based on consultations with five recognised Danish leaders in biomass boiler technology, Babcock & Wilcox Volund, Danstoker, Aalborg Boilers, SEM A/S and B&W Energy. This confirmed that the indicators in Table 1 made sense to people working in the industry and was therefore deemed appropriate for application in the fieldwork in Malaysia.

Interviews with the Malaysian boiler manufacturing firms applied the following guidelines to assess relative levels of technological capabilities:

1. Interviewees were first asked to elaborate on the technological milestones they considered most important during their firms' involvement in EFB-fired power plants.
2. To facilitate discussion interviewees were provided with examples that might have been associated with such milestones, such as the achievement of significant plant performance improvements, major design modifications, or specific landmark projects.
3. Interviewees were explicitly informed that these milestones should reflect a manifestation of their firms' increased level of skills to handle and improve their EFB-fired power plant technology.
4. Interviewees were subsequently shown an overview of the indicators described in the second column of Table 1 and asked a series of questions addressing the indicators in ascending order.
5. Using technological originality as a main indicator of the level of technological capability achieved by the firms, the interviewees were asked to describe which kinds of technical changes that they implemented during their involvement in EFB-fired plants, explicitly distinguishing between "no changes" from those that were "new to the firm", "new to local market", and "new to the world market". To obtain this information, interviewees were asked about the type of boiler technologies supplied by the firms, including when and if they introduced new

designs or products, and whether these were distinctly different from the existing ones in the local market.

6. As a secondary indicator, additional questions addressed whether the technical changes implemented by the firms were associated with relatively minor or more significant price/performance ratio improvements compared to similar plants constructed in Malaysia.
7. As a third indicator, interviewees were asked about product quality certifications acquired relating both to design and product standards.
8. To triangulate data on technological originality gathered from individual interviews, data were compared across interviewees and with other sources of data, such as firms' archival records and industry reports.

4.2. Categorisation of the firms

Data collected from the interviews were analysed in relation to two key issues identified in the literature reviewed in Section 2 above: I. Variety of learning mechanisms employed by the firms and the intensity of efforts devoted to leverage knowledge from these; II. Levels of technological capability achieved.

4.2.1. Variety and intensity of learning mechanisms used by firms

Learning mechanisms employed by the firms were categorised according to the importance ascribed to particular learning mechanisms by the interviewees in relation to their firms' technological capability building efforts. Explanations given by interviewees of the sources relied on to gain new technical insights and overcome concrete problems during involvement in successive projects provided evidence on the nature of intra-firm and externally mediated learning mechanisms employed. A given learning mechanism was interpreted as present if it was emphasised as having played an important role by the interviewees and was interpreted as absent if they did not ascribe importance to a particular learning mechanism.

The intensity of efforts devoted to different learning mechanisms were categorised based on interviewees' responses according to a continuum from short-term (one-off) efforts and the allocation of limited resources to utilise different learning mechanisms, to more persistent (longer-term) efforts with higher levels of devoted resources.

4.2.2. Levels of technological capabilities achieved by firms

Classification of technological capability used an analytical coding of interviewees' responses to questions on types of technical changes implemented during firms' involvement in EFB-fired power plants. Key indicators included level of originality (or novelty) of technological changes, which ranged from minor adjustments of existing boiler sub-components (possibly as part of repair and maintenance activities) towards more profound, and possibly entirely new, reconfigurations of the entire power plant design arrangement (involving new products and engineering solutions) (see also Plechero, 2012). A secondary indicator of changes in technological capability focused on price/performance improvements achieved. The coding process also applied the other indicators in Table 1.

Firms did not have to comply with all of the indicators to be placed within a given category level.

To illustrate the application of the coding process in practice, if interviewees stressed that they more or less continued to use their pre-existing boiler design drawings and standardised products without introducing any changes or achieving performance improvements, they were classified at the lowest level of technological capability, the "Basic operating capability" level in Table 1. Firms that had undertaken minor and incremental modifications to existing designs that were "new to the firm", including small improvements in plant price/performance ratios, were classified as having reached the "Extra basic operating capability" level. The "new to the firm" classification was interpreted as evident in cases where a firm introduced a new product or design that was already available from competitors in the local market. Firms that had introduced technical changes that were "new to the local market", including alternatives that were markedly different from existing designs used by their local competitors, were categorised as having reached the "Basic innovative capability" level. Another indicator used to determine whether firms achieved this level, involved assessing whether such changes encompassed significant plant price/performance ratio improvements compared to the plants constructed by their competitors.

4.3. Identification of patterns across firms

Following the analytical coding procedures related to the individual firms described above, subsequent analysis focused on identifying similar patterns across the firms in the variety and intensity of learning mechanisms used and the level of technological capability achieved. This employed cross-sectional analysis focused on identifying similarities in interviewees' responses within each of these themes using the tabular coding method suggested in Miles and Huberman (1994).

5. Results

The analysis led to the classification of the eight firms into the three main groups detailed in Table 4. Each group shared common features in terms of the learning mechanisms employed, the level and intensity of efforts devoted to leverage knowledge from these, and the levels of technological capability achieved. To provide a more detailed overview of the characteristics shared across these groups, a detailed description of one firm illustrative of each group is provided below – Alpha for Group 1, Epsilon for Group 2, and Zeta for Group 3.

Table 4. Key findings on learning patterns and levels of technological capability achieved.

	Intra-firm learning		Externally-mediated learning		Level of technological capability achieved
	Presence / absence	**Level of intensity**	**Presence / absence**	**Level of intensity**	
Group 1 (Alpha, Beta, Gamma)	"Learning through planned experimentation"	Significant	"Learning from interacting with foreign technology partners"	Significant	"Basic innovative capability"
Group 2 (Delta, Epsilon)	"Learning from trial and error efforts"	Low	"Learning from imitation of local competitors"	Significant	"Extra basic operating capability"
Group 3 (Zeta, Eta, Theta)	"Learning from trial and error efforts"	Low	Absent	Absent	"Basic operating capability"

5.1. Three illustrative firm representations

5.1.1. Representative illustration of firms in Group 1

Since its initiation in 1975, Alpha primarily installed and undertook service on imported industrial boilers and since 1992 manufactured and installed small-scale wood-fired and industrial gas/oil-fired boilers under a license agreement with the Danish company Danstoker A/S (Hansen, 2011). However, in 1998, Alpha decided to focus entirely on the emerging market for EFB-fired power plants. According to interviews with firm managers, one of the ambitious aims of Alpha was to become an energy service company (ESCO) supplying steam and/or electricity to industrial users from EFB-fired power plants. As the main investor and risk taker, Alpha had a strong strategic interest in continuously optimising their plants, which pushed the firm to devote sustained financial and human resources to their ongoing learning efforts.

Alpha proactively recognised a need early on to acquire new knowledge from different sources and paid particular attention to establishing relations with foreign technology partners. It engaged in a license contract in 1997 with the parent company of Danstoker at that time, Volund A/S, to manufacture and install a large-scale and high-efficiency biomass plant designed to utilise EFB and other fuels with high moisture content. According to interviewees, Alpha initially aspired to acquire access to the basic boiler design through the license agreement with Volund, which firm managers considered would address their limited technological expertise. As a main learning strategy, Alpha's management wanted to learn as much as possible from the relationship with Volund and accumulate knowledge over time through planned experimentation in successive plants on a project-by-

project basis. After engaging in its first EFB-fired power plant in 2000, in 2004 Alpha introduced a new vibrating and water-cooled (inclining) membrane grate system in an EFB-fired and grid-connected power plant in Malaysia under the license agreement with Volund. This type of system, which included fully automatic feeding, had not previously been constructed in Malaysia. Subsequently, Alpha sold around seventeen of these boiler units to customers in the palm oil industry in Malaysia and Thailand.

According to longstanding managers in Alpha, the license partnership with Volund enabled employees from Alpha to access a highly skilled pool of expertise and learn about critical elements of advanced boiler designs, including vital calculation methods. This externally mediated learning by interacting process occurred during on-site plant visits, overseas training, and through technical assistance. This learning process was particularly intensive in the period after the second plant was constructed in 2004 when the management in Alpha was committed to persistently devoting efforts and resources to leverage learning through regular interaction and communication between employees in the respective firms. Through this interactive relationship with Volund, Alpha's employees reached a sufficient level of knowledge to enable Alpha to subsequently manufacture, install, and further develop similar plants independently.

Regarding intra-firm learning, Alpha recognised a need for pre-treatment of EFB to reduce moisture content and fibre length, which were found to be critical determinants of boiler performance. To overcome this challenge, Alpha's learning strategy was to gradually develop a new EFB pre-treatment system through planned experimentation and learning by changing in successive plants. Alpha employees approached this learning process by continuously optimising plants by adding and replacing equipment (such as shredding and drying machinery) and subsequently integrating discovered solutions in new plants. This systematic experimentation process involved the introduction of a new automatic fuel feeding system, which was better suited to EFB than the original Volund design. Volund's design was evidently modified by Alpha in their efforts to utilise EFB, including introduction of a new furnace de-ashing system and a reconfiguration of the primary and secondary fans outlay. This pre-treatment system had not previously been used in Malaysia and was therefore new to the boiler industry and local market.

Owing to the low ash melting point of EFB, another persistent problem concerned formation of clinkers on heat surfaces in the boiler, a significant technical challenge which increased with utilisation of a higher percentage of EFB in the boiler. Attempts to circumvent clinker formation focussed on efforts to optimise the integrated furnace water cooling system. In addition, learning efforts were devoted to optimising the boiler control system by continuously adjusting critical parameters in plant performance, such as those related to air inlet velocity and fuel feeding operations. Throughout their engagement in EFB-fired power plants, Alpha persistently devoted significant financial and human resources to internal learning efforts in order to solve the multitude of challenges experienced. Thus, it appears that Alpha utilised a unique combination of (externally mediated) learning from interacting with a foreign technology partner and (intra-firm) learning by planned experimentation, both of which were characterised by a high level of intensity of efforts. The case of Alpha thus illustrates the complementarity between the use of specific types of external and internal learning mechanisms.

The interviews suggested the ability of Alpha to implement and handle technical change in EFB-fired power plants was significantly improved during their involvement with different plants. This resulted in substantial plant price/performance ratio improvements

over time compared to Alpha’s domestic competitors. In addition, Alpha's employees were independently able to design a fuel pre-treatment system that was new to the local industry and domestic market. With the introduction of a new automatic fuel feeding and optimised design outlay in this fuel pre-treatment system, Alpha was able to achieve a higher overall plant performance than by using the design initially acquired from Volund. This indicates that Alpha made some progress in moving from the basic level of routine-based production capabilities into more advanced stages of innovative technological capability. Based on the originality of the technical changes implemented by Alpha and the significance of the price/performance improvements made, Alpha could be considered to have progressed to the "Basic innovative capability" level in Table 1.

5.1.2. Representative illustration of firms in Group 2

Since its establishment in the late 1970's, Epsilon mainly supplied boilers to the palm oil milling industry and to a lesser extent small-scale packaged gas and oil-fired boilers to various industries. Over a period of more than thirty years, the firm was, according to the interviews, able to achieve a large share in the market for palm oil mill boilers in Malaysia (around 30% in 2011). Managers at Epsilon suggested this was an outcome of the primary and longstanding strategy of the firm, which was to secure and enlarge its market position. In 2002, however, Epsilon’s management decided to diversify activities and engaged in their first EFB-fired power plant at an existing palm oil mill in Malaysia. Subsequently, Epsilon was involved in the construction of five additional EFB-fired power plants.

At the outset of their engagement with EFB-fired power plants Epsilon apparently demonstrated limited recognition of a need to acquire new knowledge from different sources. During construction of the first plants, Epsilon’s managers considered the existing boiler technology design, which inter alia comprised a conventional step grate and water-tube system, to be sufficient for utilising EFB. This design had previously been used in Epsilon’s construction of boilers supplied for the palm oil milling industry, acquired initially in 1980 through a license agreement with a UK-based company. According to managers at Epsilon, the percentage of EFB utilised and the customer's required performance levels in the first EFB-fired power plants were both relatively low. Consequently, Epsilon only experienced minor operational problems in these plants. Later, Epsilon’s management found additional changes to the existing boiler design were necessary to utilise a higher percentage of EFB at higher efficiency and performance levels in order to compete in this market. This led Epsilon to search for new sources of learning during subsequent projects. In contrast to Alpha and the firms in Group 1, Epsilon did not actively promote EFB-fired power plants to new potential customers. The engagement in these plants was, according to the interviews, mainly driven by direct demand from specific customers and was therefore not, as in the case of Alpha, an outcome of a deliberate strategy to learn through planned experimentation in successive plants.

The main learning strategy pursued by Epsilon was to rely primarily on learning from their local competitors though non-formal channels and internal efforts by modification of their pre-existing boiler designs. To learn from competitors, Epsilon's employees devoted significant time and resources to searching for information about the technological solutions that led to performance improvements, mainly in the plants constructed by Alpha and the other firms in Group 1. This was achieved through plant site visits, communication with industry contacts (including former employees), relations with customers, and hear-say.

Apparently both plant owners and boiler technology suppliers attempted to prevent this information from being openly disseminated, for example by enforcing strict plant visiting regulations. According to interviews with firm employees, Epsilon's management came to the conclusion that EFB fuel pre-treatment systems, and, even more so, boiler water-cooling systems had contributed significantly to solving the clinker formation problem in other plants. Accordingly, employees from the engineering department in Epsilon concentrated efforts on developing a similar water-cooled grate system in an attempt to circumvent this generic problem. These internal efforts resulted in some learning through imitation, contributing to Epsilon subsequently developing a water-cooled grate design that was new to the firm. However, according to an interview with a representative of Epsilon's license partner, the design was relatively simple and did not work well. Epsilon's management also found that the design was not able to resolve the problems experienced and soon abandoned further development of this grate system. These relatively short-term internal efforts in Epsilon's engineering department were therefore undertaken with limited persistence.

Management subsequently decided to import a water-cooled vibrating grate from an internationally renowned supplier of biomass combustion technology (from the US) and to implement this system in later plants. Epsilon did not devote efforts to leverage learning through the establishment of a longer-term partnership or through closer interaction with this grate supplier company. Moreover, according to interviews with managers, Epsilon did not actively seek to utilise the relationship with its existing license partner in its learning efforts. Since it proved problematic for Epsilon to incorporate the vibrating grate in the firm's existing power plant design, some internal trial and error learning efforts were employed. These problem solving efforts concerned a number of issues related to malfunctioning of the draught fan systems and water feeding pumps. These challenges were more profound than initially foreseen and resulted in financial losses, so Epsilon was hesitant to engage in further EFB-fired power plants.

The case of Epsilon depicts a particular combination of the use of (externally mediated) learning by imitation and (intra-firm) trial and error efforts to develop and integrate a new grate system into their existing designs. This unique combination was different from the specific composition of internal and external learning mechanisms used by firms in Group 1. From interviews with Epsilon's managers, it appears that many problems remained unresolved during their involvement in EFB-fired power plants and Epsilon only recently made progress in overcoming some of these challenges. Epsilon was only able to achieve small price/performance ratio improvements through minor, incremental modifications to existing design specifications. Epsilon also managed to develop a water-cooled grate design that was new to the firm by imitating its domestic competitors, although this system did not perform well and further development was quickly abandoned. Thus, the ability of the firm to implement and handle technical change was only advanced to a limited extent commensurate with the second level of production capabilities (the "Extra basic operating capability" level in Table 1), but not to have progressed further into developing innovative capability.

5.1.3. Representative illustration of firms in Group 3

Zeta was established in 1972 and initially involved mainly in installation and servicing of imported boilers. From the late 1970's, Zeta began fabricating packaged fire-tube boilers

under a license agreement with a UK-based company and later in 1982 began producing water-tube (fixed grates) boilers for the palm oil industry under another license agreement. This mainly followed the general development of the Malaysian boiler industry. When demand for larger capacity boilers with higher levels of automation increased during the 1990's, Zeta developed a moving grate system to meet these requirements on the basis of their pre-existing boiler designs. Notwithstanding these minor incremental modifications, the basic boiler design in Zeta has remained largely unaltered over the last 15 years.

Zeta and the two other firms in Group 3 focused mainly on the market for conventional packaged gas and oil-fired boilers to various industries. However, according to interviews with managers in Zeta, management increasingly recognised a need to diversify activities to avoid becoming overly dependent on this market. This led to Zeta engaging in their first EFB-fired cogeneration plant in 2002 at an existing palm oil mill. The plant utilised a relatively low percentage of EFB in the fuel mix (around 30%) and the customer required a low performance level. The second cogeneration plant Zeta constructed was similar to the first, although it utilised a higher percentage of EFB in the fuel mix. In both plants, a boiler was used which had previously been supplied to customers in the palm oil milling industry. According to interviews with engineering employees at Zeta, these plants only gave rise to minor difficulties, which required some problem solving efforts at the plant sites. They attempted to circumvent these problems mainly through further modification of the moving (step) grate system via relatively short-term internal trial and error based learning efforts.

Zeta’s main learning strategy during involvement in these plants was to utilise their pre-existing boiler designs, which were considered suitable for a larger fraction of EFB than normally required in palm oil mills. Since the plants constructed by Zeta and the firms in Group 3 generally utilised a relatively low percentage of EFB in the fuel mix, typically around 30-40%, they were able to use the pre-existing conventional boiler designs without many problems and without much technical effort. In contrast to the plants constructed by firms in the other two groups, Zeta also only retrofitted existing steam generation plants in palm oil mills, not in plants primarily designed for electricity generation, which would have required additional design changes. Thus, Zeta did not recognise a need for new sources of learning in their efforts to overcome the minor challenges experienced. As an example, although an external engineering consultant provided some technical assistance to engineers in these projects, Zeta did not purposely seek to leverage learning from this source to any great extent. Zeta’s management also did not attempt to establish new relationships with external technology partners in their learning efforts.

Although Zeta experienced some minor problems during involvement in EFB-fired cogeneration plants, the challenges experienced were largely overcome by relying on their existing technology. The necessity of acquiring new knowledge and engaging in concerted efforts to overcome these problems were consequently limited, which resulted in the allocation of only a very limited amount of time and financial resources to problem solving. Essentially, therefore, Zeta continued to carry out their previous, routine-based production activities without many changes or additional learning efforts. Accordingly, Zeta did not achieve any price/performance ratio improvement. The manufacture of boilers and construction of power plants was undertaken according to pre-existing and standardised design specifications. Zeta can therefore be considered to have remained at the lowest level of technological capabilities, the "Basic operating capability" level in Table 1.

6. Discussion

6.1. Learning and technological capability formation

Existing studies of learning and technological capability formation in cleantech industries in emerging economies pay little attention to micro-level dynamics, despite the highly firm-specific nature of such processes (Lall, 1992). The analysis in this paper suggests that learning mechanisms employed by individual firms plays a critical role in the level of technological capability achieved. As illustrated through the case of Alpha, technological capability building was most pronounced where firms dedicated significant, sustained resources to a specific combination of learning from interacting with foreign technology partners and intra-firm planned experimentation activities.

These findings are consistent with previous studies on development of wind and solar industries in China and India, where foreign connections were also found to constitute important sources of learning (see e.g. Lewis 2007, 2011; Mizuno, 2007; Marigo et al., 2010). At a more general level, this supports the argument put forward in Kim (1997), Mathews (2002), and Bell and Figueiredo (2012) that significant advances in technological capability formation in latecomer firms is often related to learning through networks of foreign and more advanced technology partners. However, following Fu and Gong (2011), this also speaks to a broader discussion about internal (or indigenous) learning and innovation, on the one hand, versus foreign technology, on the other hand, as the main sources of technological capability formation in latecomer firms (see also Fu and Zhang, 2011). In this paper, Alpha and the firms in Group 1 were required to engage in concerted internal efforts to adapt and modify acquired foreign technology to improve its performance. Alpha, for example, not only devoted substantial resources to leverage learning from its foreign license partner, but also to its own efforts to engage creatively with the original design. Therefore, as Li (2011) argues, foreign sources of advanced technology will only enhance latecomer firms' levels of technological capability to the extent that simultaneous concerted investments are made in internal learning efforts. Thus, as the case of Alpha illustrates, and in line with Fu et al. (2011), rather than understanding technological capability formation as driven either by foreign or internal sources, these may more appropriately be considered as complementary drivers.

The more limited progress made by firms in Group 2 in building technological capabilities through a combination of imitating local competitors and internal (engineering) trial and error focused on modification of existing grate designs suggests at least three further insights. First, as Kesidou and Romijn (2008) note, learning opportunities available from local knowledge systems may provide an important stimulus for technological capability building in latecomer firms (see also Bell and Albu, 1999). Among such learning sources, Chen (2009) particularly stresses the role of inter-firm interactions in the form of informal knowledge spill-over among local competitors. As Mathews (2006) argues, however, since latecomer firms typically operate in isolation from world centres of science and innovation and sophisticated technology markets, the reliance on local learning sources may comprise a key barrier to technological capability building. This argument is further devolved in Plechero (2012), who emphasises that knowledge spill-over among local competitors may only enable firms to progress production capabilities - in order to reach more advanced levels of innovation capability, additional, complementary sources of learning may be required. As illustrated by Epsilon, the empirical findings of this paper

appear to corroborate this proposition since the firms in the Group 2 were not able to advance beyond the level of production capability. Notwithstanding this, owing to substantial resources devoted to imitating local competitors, the use of this learning mechanism did constitute an important stimulus for the technological capability improvement that did occur in the two firms in Group 2. However, the lack of resources devoted to engaging (concomitantly) in internal learning efforts may also have hindered the attainment of higher levels of technological capability.

Second, and relatedly, since the learning efforts of the two firms in Group 2 focused on imitation of plants constructed by firms in Group 1, this speaks to a broader discussion on local spill-over effects of technologies acquired from foreign sources (Fu et al., 2011). In the literature on inward foreign direct investments in emerging economies, the extent local firms benefit from knowledge spill-over effects is often discussed (Blomström et al., 2000). Benefits might be in the form of learning opportunities provided by exposure to new, more advanced technology and local diffusion of technological knowledge. As Saggi (2002) emphasises, technology owners often try to mitigate against unintended local spill-over of proprietary technological assets, which tends to reduce local knowledge diffusion. This paper corroborates this finding as firms in Group 1 strove to hinder knowledge from being openly disseminated, e.g. by enforcing strict visiting rules and regulations at plant sites. The diverging interest between technology owners and imitators may therefore comprise a central limitation in learning by imitation as opposed to learning through more formalised partnerships with foreign technology partners. It should, however, be noted that learning by imitation might be critical in the infant stages of technological capability building, but becomes less important as firms progress towards higher levels of innovative capability (Kim, 1997; Chen, 2009; Lema and Lema, 2012).

A third interesting finding concerns the nature of firms in Group 2's learning through relationships with foreign technology partners. As illustrated by Epsilon, although relationships were established with more advanced technology suppliers, limited efforts were devoted to leveraging learning from these sources. Epsilon could, for example, have achieved this by establishing a longer-term relationship with its water-cooled grate supplier and/or by extracting new knowledge from its established license partnership. As emphasised by Figueiredo (2001, 2003) and Mathews (2006), the extent to which such external linkages with foreign firms facilitate learning and technological capability building is strongly related to the persistence and resources (the intensity of efforts) devoted to utilising such learning opportunities. This paper seems to corroborate this argument.

The firms in Group 3 relied exclusively on internal sources in their learning efforts and, during their involvement with EFB-fired power plants, did not progress beyond the basic and lowest level of technological capability in Table 1. According to Edquist (1997), learning and innovation in firms rarely take place in isolation, but occurs through complex and varied interactions with the different actors and organisations in their external environment. Thus, as Bell (1984) argue, latecomer firms relying exclusively on their own resources and internal learning efforts are likely to have a hard time building technological capability. This is attributed, among other things, to the widespread absence, under-prioritisation, and/or understaffing of in-house R&D resources in many latecomer firms, especially small and medium-sized enterprises (Mani and Romijn, 2004). The case of Zeta seems to illustrate these limitations of relying exclusively on internal learning efforts in technological capability formation. However, Figueiredo (2001) emphasises the need not to underemphasise the importance of building a minimum level of technological capabilities

through internal efforts in latecomer firms. Cohen and Levinthal (1990) attribute this importance to the cumulative nature of technological capability building, which involves gradual increases in the efficiency of internal learning and associated increases in technological capabilities. Since the firms in Group 3 devoted very limited resources in their internal learning efforts, their ability and efficiency to appropriate additional learning remained limited (see Xie and White, 2004; Scott-Kemmis and Chitravas, 2007).

6.2. Reflections on technological capability building and low carbon development

As flagged in the introduction, an emerging body of literature seeks to develop theoretical contributions of past work on technological capability building in the context of specific challenges relating to low carbon technology transfer to developing countries to mitigate future development-related carbon emissions (e.g. Mathews, 2007; Altenburg, 2008; Walz, 2010; Ockwell et al., 2008, 2010; Berkhout, 2012). Research in this area is, however, very much in its infancy – there is a lack of empirical evidence and a distinct lack of any comprehensive attempt at theorising technology transfer and indigenous innovation as part of broader low carbon development pathways (Ockwell and Mallett 2012). There are a number of areas where this paper's findings on the role of learning mechanisms and technological capability building in a specific cleantech industry in Malaysia suggests broader implications for both theory building and future empirical research.

An initial focus for future research is to explore the applicability of the specific combinations and intensities of learning mechanisms identified by this and other papers within the context of other technologies, industries and countries. Low carbon energy technologies need to be researched across a spectrum of supply, network/infrastructure and end use technologies. But it is also important to explore them along the continuum of the innovation chain, from R&D, through demonstration, to widespread commercial availability. Specific risks and challenges apply at these different stages of maturity and their implications for learning and development need to be better understood (Ockwell et al., 2008). There is also a particular need to understand the role of learning mechanisms and technological capability development in lower and lower-middle income countries where existing levels of technological capabilities are likely to be low even for dealing with conventional energy technologies, let alone, newer, more efficient, low carbon technologies. This raises important questions as to what combinations of learning mechanisms are most appropriate in these contexts, and what firm based or public policy driven strategies are needed to encourage such learning and related capability building.

The internal efforts that firms employ to develop technological capabilities are currently understudied in existing studies on the evolution of cleantech industries in emerging economies (Mizuno 2007; Marigo, 2009). With notable exceptions (e.g. Lema and Lema, 2013), policy-oriented studies which have attended to the importance of technological capability building through low carbon technology transfer have also, to date, largely failed to analyse individual firm-level learning mechanisms, often relying on relatively crude typologies of technology transfer applied to large datasets of project proposals (Haites et al., 2006; Das, 2011). The historical, in-depth analysis applied in the current paper suggests one way of overcoming the methodological limitations of these other efforts. However, it raises difficult tensions with the urgency of providing sound empirical bases for designing climate and development policy.

Another weakness of the literature and policy thinking in this area is a tendency to conceive of technology transfer as constituting individual events, supporting the assumption that these events might somehow be scaled up to achieve more rapid diffusion of low carbon innovations in developing countries (Ockwell et al., 2010). This overlooks two important issues. Firstly, it fails to recognise the widespread adoption of low carbon technologies as the result of a *process* over time, involving both individual events of technology transfer and related processes of learning and capability building. As this paper demonstrates, this can involve both intra- and inter-firm learning and learning between foreign as well as national firms, with important implications for resulting levels of capability building. Secondly, a misleading distinction is implied between technology innovation and diffusion, viewing them as two separate activities and hence overlooking the additional creative engagement, improvement, and diversification of technologies acquired from foreign sources by latecomer firms. Creative learning and innovation efforts often continue during the diffusion process, which involves more than the simple and passive acquisition of imported machinery or product designs, and the assimilation of related operating skills (Bell and Pavitt 1993). In the current paper, for example, firms in Group 1 devoted substantial internal efforts to engage creatively with a technology design originally acquired from a foreign license partner, which contributed significantly to technological capability building. Subsequently, the firms in Group 2 combined internal efforts with imitative learning from their competitors in Group 1 and the import of foreign technology thereby became part of ongoing learning activities in the local economy. This implies a need for further research exploring the additional learning activities associated with technology diffusion and how this relates to technological capability building in cleantech industries.

An additional area to which this paper speaks and which warrants further attention is the widespread assumption that lower carbon development trajectories somehow necessitate the rapid introduction of "radical", or "disruptive", new-to-the world types of innovations. Such radical innovations are commonly identified as the main basis of correspondingly radical shifts towards more sustainable economic development. This understanding reduces the importance of incremental innovations which involve longer-term and gradual learning and experimentation efforts. Since such innovations are typically at the lower end of the spectrum of innovative novelty, such as being new-to-the firm or local market, they are often considered less important in the extant innovation literature (Fagerberg, 2005). These types of innovations may, however, be of equal, if not more importance in achieving low carbon development, not least because it is often incremental innovation that characterise the gradual development of technological capabilities in developing country firms (Bell, 2009; Ockwell and Mallett, 2012). In this paper, for example, incremental learning efforts were observed to enable some firms to gradually overcome technical challenges, which resulted in improvements in both performance and technological capabilities. There would therefore be value in additional research that explores in more detail the relationships between longer-term, incremental firm-level learning efforts and the development of relevant capabilities in relation to low carbon technologies at a regional or national scale. Indeed, the issue of scale is one which, to date, is surprisingly absent in existing studies and an area where engagement from the fields of economic and development geography could make important contributions to advancing the theoretical treatment of technology transfer and low carbon development more broadly.

Finally, most research in this field focuses on technology transfer and innovation in the context of potential or existing commercial markets in developing countries. As Sagar (2009) emphasises, there is also a need for research in the context of the development needs of poor people in the absence of commercial markets for relevant technologies or innovation efforts. This might also apply to examples where these market opportunities are nascent but could potentially be harnessed through new approaches to energy service delivery, such as emerging ideas around solar lighting provision via communal charging stations and mobile phone based hire-purchase agreements. This also alludes to a further emerging research area addressing the needs of marginalised groups and the radically different distributional implications of alternative low carbon development pathways (see e.g. Leach et al., 2010).

7. Conclusion

This paper's detailed, firm level analysis of the Malaysian biomass power equipment industry illustrates a range of inter-firm differences in the combination of learning mechanisms employed in making technological advances, as well as important differences in the relative levels of resources dedicated to exploiting these learning mechanisms. This suggests some important relationships between patterns and intensities of learning mechanisms and the level of technological capability building achieved by firms. In particular, firms that dedicated significant resources to a combination of learning from foreign partners and planned learning from their own experimentation were observed to have achieved most progress in terms of technological capability building. Nevertheless, important (albeit not as significant) advances in technological capability building were also made by firms who learned from imitating national competitor firms, the latter having learned from interactions with foreign partners. This suggests the role of local knowledge spillovers ought not be underestimated, although, significantly, firms learning from such local spillovers failed to advance beyond extra basic operating technological capabilities, as compared to those firms who proactively pursued learning from foreign partners who advanced to basic innovative levels of technological capabilities. Importantly, however, this paper found cases of firms who had tended to learn by imitating local competitors, but who had failed to take advantage of potential opportunities to learn from commercial interactions with overseas technology partners. This implies that in some cases a lack of technological capability building through learning from foreign partners is due more to a lack of intra-firm strategic decisions to dedicate resources to such learning than a lack of an opportunity to do so. Significant work remains to be done, both in terms of empirical research across different contexts and in terms of theory building, to make sense of these and other relevant insights on the role of learning and technological capability building in the broader context of sustained, low carbon development and technological change.

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Paper 3

Sustainable energy transitions in emerging economies: the formation of a palm oil biomass waste-to-energy niche in Malaysia 1990-2011

Ulrich Elmer Hansen[a]*; Ivan Nygaard[a]

[a]UNEP Risø Centre, DTU Management Engineering
*Corresponding author

Submitted to *Energy Policy*

Abstract

The economic development in emerging economies in Southeast Asia has significantly increased the use of fossil fuel based energy. This has severe implications for global climate change, and against this background, scholars within the sustainable transition tradition have taken an interest in addressing how transitions towards more sustainable development pathways in this region may be achieved. This paper contributes to the abovementioned literature by examining the conducive and limiting factors for development and proliferation of a palm oil biomass waste-to-energy niche in Malaysia during the period 1990-2011. Rising oil prices, strong pressure on the palm oil industry from environmental groups, and a persisting palm oil biomass waste disposal problem in Malaysia appear to have been conducive to niche proliferation, and on top of this national renewable energy policies and large-scale donor programmes have specifically supported the utilisation of palm oil biomass waste for energy. However, in spite of this, the niche development process has only made slow progress. The paper identifies reluctant implementation of energy policy, rise in biomass resource prices, limited network formation and negative results at the niche level, as the main factors hindering niche development.

Keywords: Biomass energy; Malaysia; Niche development

1. Introduction

A number of countries in Southeast Asia have undergone an unprecedented rapid economic development and industrialisation process during past decades. This has increased the demand for energy, and other resources, to stimulate their economic growth process. With the increase in energy consumption and strong reliance on fossil fuels, the contribution of Southeast Asian countries to climate change has increased significantly (Rock and Angel, 2005).

Against this background, a number of scholars within the socio-technical transition research tradition have recently taken an interest in addressing the question of how sustainable energy transitions take place, or may take place, in rapidly growing emerging economies in Southeast Asia (see e.g. Bai et al., 2009; Berkhout et al., 2009a,b; Rock et al., 2009; Berkhout et al., 2010; Patankar et al., 2010; Verbong et al., 2010; Romijn et al., 2010; Berkhout et al., 2011). A main topic of interest has been the role of emerging niches, comprising of alternative innovations (niche-level experiments) that lead to more sustainable trajectories for economic development.

Notwithstanding prior empirical studies conducted in Southeast Asia adopting the transition perspective, many aspects of niche development and transition processes in this region remain unexplored. As stressed in Bai et al. (2009), Raven et al. (2011), and Jolly et al. (2012), more knowledge of the conditions under which local niche-level experiments may evolve from a single or a few isolated instances to larger up-scaling and system-wide transitions is needed. The present paper contributes to this understanding by examining the development of a palm oil biomass waste-to-energy niche in Malaysia during the period 1990-2011. More specifically, the paper examines the extent to which a viable niche around palm oil biomass waste-to-energy has emerged in Malaysia; and identifies the conducive and limiting factors underlying the niche formation process.

During the last two decades, the palm oil industry in Malaysia has experienced a tremendous growth, which has led to an almost exponential increase in the biomass waste residues generated, and thereby created a substantial waste disposal problem for the palm oil industry. Concurrently, various overlapping national policies and international donor programme interventions have been implemented to enhance the utilisation of biomass waste for energy generation. Increasing oil prices and a growing pressure to reduce the environmental impact of the electricity generation system in Malaysia have, in combination with the waste disposal problem, contributed to creating conducive conditions for the formation and up-scaling of a palm oil biomass waste-to-energy niche in Malaysia.

So far, limited research has addressed the development of a palm oil biomass waste-to-energy niche in Malaysia. The few existing studies mainly rely on official records and typically highlight the general barriers for renewable energy in Malaysia (see e.g. Oh et al., 2011; Mekhilef et al., 2011). In contrast, this paper explores the niche development process through an empirically founded analysis of the progression of individual niche-level experiments and thereby fulfils the need for empirically based research in this area.

The paper is structured as follows. The second section presents the analytical framework adopted and the third section describes the research methodology - both of which are used to analyse the case study presented in section four. Finally, the conclusions are drawn in section five.

2. Analytical framework

This paper adopts the multilevel perspective (MLP) on systems innovations, which conceptualises how niche proliferation is influenced by interacting processes at the socio-technical landscape-level, the regime-level, and the niche-level (Kemp et al., 1998; Geels, 2002).

At the macro-level, the socio-technical landscape denotes the large-scale and exogenous structural context that influences dynamics at the regime and niche-level. Examples include global macro-economic conditions, international geopolitics, overarching global political discourses, demography, resource scarcities, and changes in cultural and normative values.

At the meso-level, socio-technical regimes comprise relatively stable configurations of institutions, techniques and artefacts, as well as rules, practices and actor networks that determine the 'normal' development and use of technologies. As a result of stabilising mechanisms, regimes are characterised by path-dependency, structural lock-in, and resistance to change, which effectively hinder alternative sustainable technological trajectories from emerging (Unruh, 2000). In the energy sector, this could involve a situation where the continuation of an incumbent fossil fuel-based energy system is stabilised by regulations, sunk investments in the infrastructure, subsidies, or vested interests of incumbent actors such as utilities (Verbong and Geels, 2007, 2010; Rohacher, 2008). Niche proliferation is therefore seen to be contingent upon destabilising tensions that open 'windows of opportunity' at the regime level (Verbong et al., 2008; De Haan and Rotmans, 2011).

At the micro-level, socio-technical niches constitute local platforms, or incubation rooms, from where new and alternative socio-technical trajectories may emerge to the dominating way of fulfilling functions within existing regimes. The MLP conceptualises niches as comprising distinct application domains that provide a time-restricted and protected space in which new practices and technological innovations can incubate and become viable through experimentation. The temporary protection of niches from the mainstream selection pressures in regimes is needed since new niche-level innovations may be unable to compete on purely commercial terms, due to initial low price/performance ratios (Smith and Raven, 2012). According to Schot and Geels (2008), the viability of niches is influenced by three internal niche-level processes, which consist of: 1) The shaping and alignment of expectations; 2) the formation of a social actor network; and 3) learning processes.

Increasing alignment of expectations involves that niche-level actors increasingly share similar visions, beliefs, strategies, agendas and interests. This is due to the important role of converging expectations in guiding individual actors towards a common direction. Following Hoogma (2000) and Geels and Raven (2006), a high level of aligned expectations is generally conducive for niche development although envisioned opportunities need to become more specific and rely on positive, tangible results.

The second niche level process concerns the formation of a constituency behind a new or alternative socio-technical trajectory consisting of a network of engaged actors. It is generally assumed in the MLP that the formation of close social ties and regular interaction among actors stimulates niche development. Furthermore, the composition of the actor network plays a central role and the involvement of a broader and more varied actor network also promotes niche development (Van der Laak et al., 2007). In addition to

technology actors, a broad network includes regulators, policy makers, scientists, societal groups, and others depending on the specific context (Coenen et al., 2010). Particularly with regards to the proliferation of renewable energy technology niches, the involvement of powerful actors in the established regime such as energy utilities is crucial (Smith et al., 2010).

Lastly, learning processes involve learning about technological aspects of various niche-level experiments, including technical design, functionality, and performance. Although the MLP accentuates the role of learning through techno-economic optimisation efforts, broader learning processes pertaining to the social embeddedness of these play an equally important role. The latter requires that various actors, and society at large, learn about many aspects of the technology, including regulatory conditions, user preferences, institutional, economic (e.g. business models, profitability, and financing sources), infrastructure, socio-cultural, and environmental aspects.

3. Data collection methodology

The present paper is informed by three successive empirical field studies undertaken in Malaysia during the period of 2008 to 2011 (see also Hansen, 2011). A main objective of the data collection process was to illuminate previous and ongoing processes at the landscape, regime, and niche level. The data collected identified all relevant palm oil biomass waste-to-energy plants implemented in Malaysia during 1990-2011 and their operational status. Although more was planned during this period, 39 plants had reached some level of progression from the initial planning stage towards full operation. All of these plants have been implemented as part of national and/or international programmes and thus within a protected space around the development of a palm oil biomass waste-to-energy niche in Malaysia. A sample of 12 of these plants were analysed in detail, which included plants that had been in operation for long and short-term periods, plants under construction, and abandoned plants. The analysed plants are located in Peninsular Malaysia and Sabah, respectively in west and east Malaysia, and include combined heat and power (CHP) plants, standalone grid-connected power plants, and off-grid steam generating plants for various industrial users (see a complete list of these plants in the Appendix).

Data collection mainly consisted of conducting interviews, gathering documentary material such as reports and statistical information, and observations at plant sites. In total, 40 formally planned and digitally recorded interviews were conducted during the field study period and around 10 additional non-formal discussions also pertained to the field work. Interviews were undertaken with representatives of private companies involved in specific niche-level experiments, which include boiler technology suppliers, investors, users, palm oil biomass waste suppliers, and consultancy companies. In addition, other people knowledgeable about specific plants but not directly involved in them, or with experience in the area of palm oil biomass energy generation in Malaysia, were interviewed. They include academics, private entrepreneurs, NGO representatives, private consultants, and others.

With respect to processes at the regime level, the study covered both the energy and the palm oil regime in Malaysia. Consequently, various representatives of institutions and organisations pertaining to both the energy and the palm oil sector were interviewed. This includes energy-related planners from governmental agencies, ministries, and utility companies, donor programme managers, as well as representatives of trade and industry associations and R&D organisations associated with the palm oil industry in Malaysia.

4. Development of a palm oil biomass waste-to-energy niche in Malaysia during 1990-2011

The main findings is presented as a historical narrative organised into three sections based on the three main time periods identified in the paper: The 'slow introduction' (1990-2001), the 'growth' (2002-2006), and the 'fragmentation' (2007-2011) phases. Within each time period the dynamics at the landscape, regime and niche level will be explored. A summary of the findings is presented in Table 1 in the concluding section five. It should be noted that it was not possible to identify any influential landscape factors of significance for regime and niche-level processes developed during the first phase.

4.1. The 'slow introduction' phase 1990-2001

4.1.1. Regime conditions

During the 1990's, the energy demand increased at around 8-10% annually and the key objectives of national energy policies focused on the provision of a sufficient and affordable supply of energy (see Fig. 1). To achieve these objectives, the government heavily subsidised the energy sector and focussed on utilising the indigenous oil, gas, coal, and hydro resources. The four fuel diversification policy, adopted in 1981, therefore aimed at reducing the reliance on a single source of energy, which proved to have negative impacts on the Malaysian economy during the global energy crisis in the late 1970's (Thaddeus, 2002). To increase the security of supply in the energy system, the four fuel policy continued to provide a dominating guiding principle for energy generation expansion plans throughout the 1990's.

Rapid depletion of indigenous oil reserves, frequent power outages - most notably in two substantial one-off blackout events in 1992 and 1996 - and the discovery of large natural gas resources in the early 1990's, entailed that the expansion of generation capacity was largely met by domestic natural gas (see Fig. 2). Consequently, the subsidies and priority given to natural gas provided the basis for continuing the fossil fuel-based energy regime. A formal renewable energy policy was also absent during this period. The energy sector was dominated by the state-owned utility company Tenaga Nasional Berhad (TNB) and the nationalised Petroliam Nasional Berhad (PETRONAS), which were vested with the entire oil and gas resources in Malaysia. Since 2005, TNB has owned around 60% of the generation capacity in the Peninsula and 55% in total in Malaysia. Electricity generation was liberalised during the 1990's, and this led to the inclusion of a few large-scale independent power producers (IPP). TNB has, nevertheless, remained by far the largest utility company with a monopoly on electricity transmission and distribution. TNB is also the major shareholder in the two main electricity utility companies Sabah Electricity Sdn Bhd (SESB) and Sarawak Energy Berhad (SEB) respectively in Sabah and Sarawak in east Malaysia.

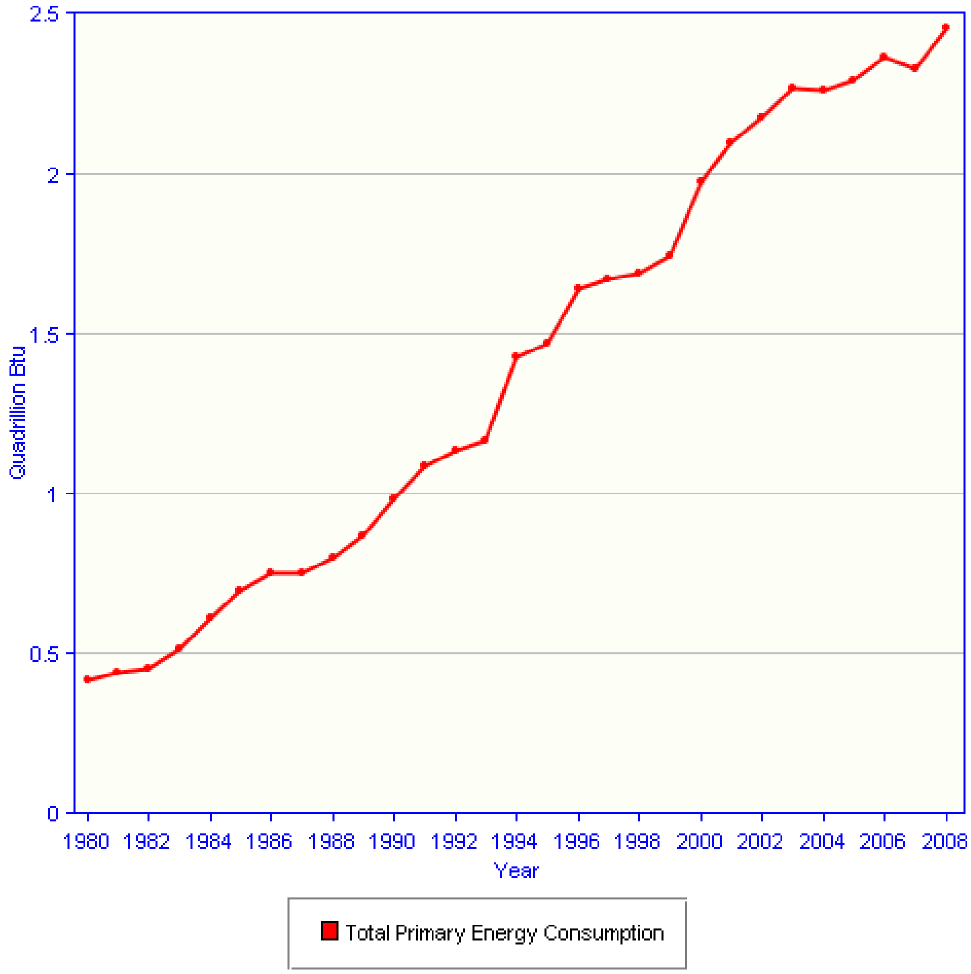

Fig. 1. Energy demand in Malaysia 1999-2010. *Source*: EIA (2012).

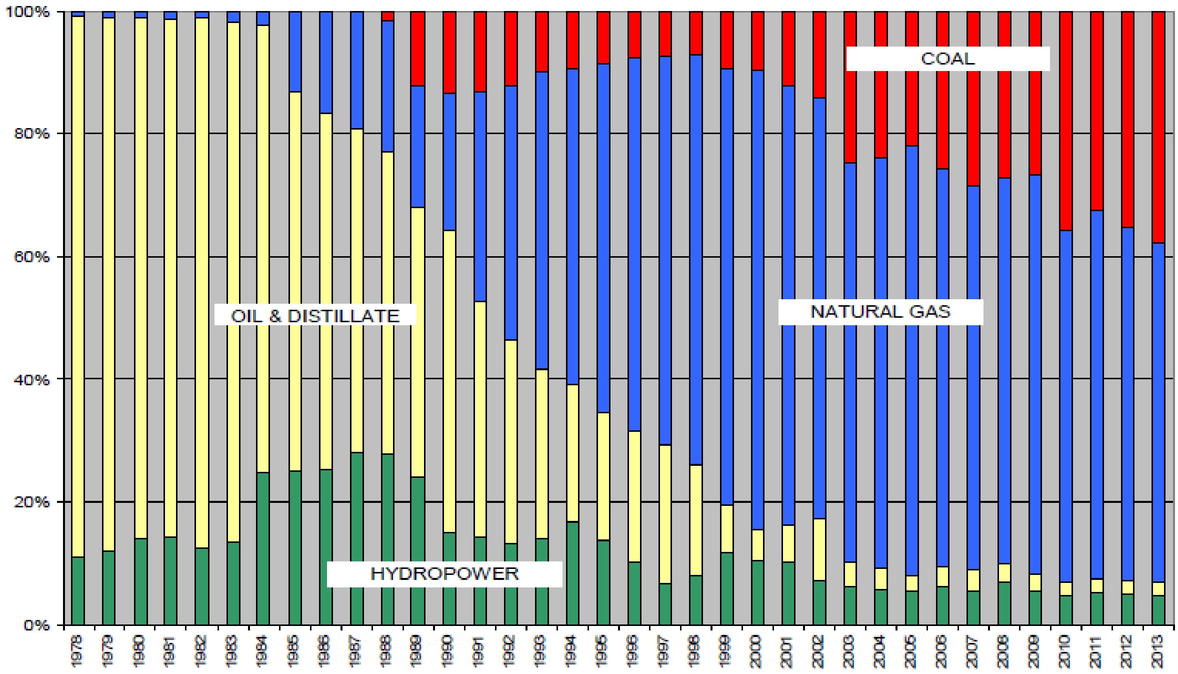

Fig. 2. Energy generation mix in Malaysia 1978-2013. *Source*: Oh et al. (2011).

Concerning the palm oil regime in the 1990's, the management of biomass waste in the upstream fuel supply chain was characterised by the longstanding and well-established practices in palm oil mills. The palm oil milling process generates three main fractions of solid biomass residues from the processing of fresh fruit bunches (FFB): Palm kernel shells (PKS), mesocarp fibres, and empty fruit bunches (EFB). The conventional practice in palm oil mills was to use PKS and mesocarp fibres, which had a high calorific value, for production of process steam and electricity for internal consumption. The energy demand in a standard size palm oil mill was, however, significantly lower than the potential energy from these waste resources, creating a substantial waste problem in terms of PKS, mesocarp fibres, and EFB. The amount of waste increased concurrently with the general rise in the annual production of crude palm oil in Malaysia, which increased from approximately 5 to 16 million tonnes in the period 1990-2001.

EFB is a fibrous and bulky material with a high water, chlorine, and soluble alkali content, and a low ash melting point. Compared to the other fractions, this rendered EFB less suitable as a fuel for energy generation (Menon et al., 2003). Therefore, EFB waste were mainly used as mulching and soil conditioner in plantations, dumped in open landfills, stockpiled in palm oil mill facilities, and burned in open incinerators - enabling the ash to be used as a fertilizer (Yusoff, 2006). In this regard, it should be noted that the anaerobic decay of EFB in landfills and stockpiles were associated with substantial emissions of methane, which is a highly potential greenhouse gas. Generally, the biomass waste was considered a disposal problem for palm oil milling companies due to high removal and transport costs, especially for EFB, and an absence of regulatory measures or incentives to circumvent this situation, including a lack of opportunities to sell surplus electricity to the grid (Evald, 2006). The power plants in palm oil mills were therefore deliberately designed to operate inefficiently so as to burn as much biomass residues as possible (Sulaiman et al., 2011). Consequently, during this period, the palm oil milling industry did not have incentives to invest in high-efficient EFB-fired energy generation plants.

A number of development assistance (donor) programmes were implemented in Malaysia during the 1990's with the aim to promote renewable energy. Among these, the EU–ASEAN COGEN 1 and 2 programme (1991-1994 and 1995-1998) and the Danish Cooperation for Environment and Development (DANCED/DANIDA)[1] programme (1994-2006) were particularly influential in creating conducive conditions for niche development (DANCED, 1999; Hezri and Hasan, 2006) (see Fig. 3). These programmes both provided technical assistance to energy sector and palm oil industry agencies and financial support to specific palm oil biomass waste-to-energy projects (Dewulf and Leelakulthanit, 1997; AIT, 2004). DANCED was also directly involved in the establishment of the Malaysia Energy Centre (PTM) in 1998 - an independent national energy research and information centre on renewable energy.

[1]The DANCED programme was in 2001 taken over by the Danish International Development Assistance (DANIDA). The programme is therefore referenced as the DANCED/DANIDA programme.

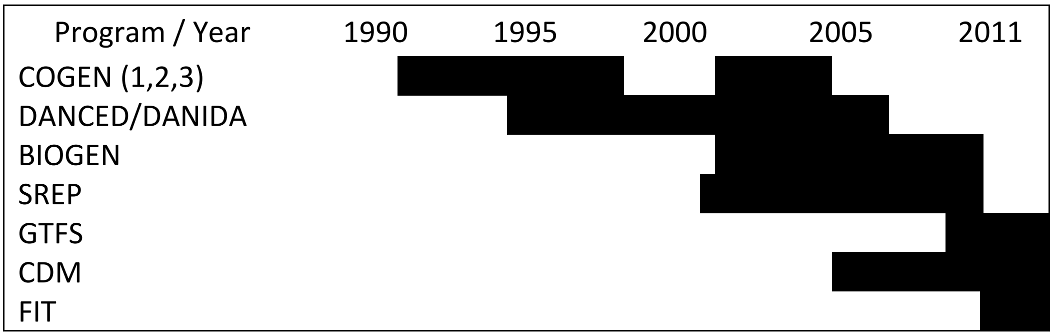

Fig. 3. Palm oil biomass waste-related national renewable energy policies and external support programmes in Malaysia 1990-2011.

4.1.2. Niche processes

Despite the need for expanding and diversifying the electricity generation capacity and in spite of the implementation of two international programmes aiming at promoting the utilisation of palm oil biomass waste for energy generation, only one cogeneration plant was constructed during this period. The plant was erected at an existing palm oil mill and was based on relatively simple and well-known technology using PKS and mesocarp fibres. The actor network formation and learning processes were therefore limited and at the end of the period the general familiarity with, and interest in, palm oil biomass waste-based energy generation was limited - both in the energy and palm oil regime.

4.2. The 'growth' phase 2002-2006

4.2.1. Landscape conditions

In this period, two factors at the landscape level contributed to generating tensions in the energy and the palm oil regime, which created opportunities for niche development. First, the rapid increase in crude oil prices and derived products such as gasoline, petroleum (including fuel oil), and diesel between 2001 to 2007, from around 30 to 70 US$/barrel, played an important role (IEA, 2011). This price increase provided an incentive for energy-intensive industries in Malaysia to utilise alternative and more cost-efficient sources of energy, such as palm oil biomass waste, to meet their heat and electricity requirements. As a result, palm oil biomass waste was increasingly utilised in the cement and rubber glove industry as well as in palm oil refineries and oleo-chemical plants relying on diesel and fuel oil-fired generators. Secondly, an increasing international environmental critique of the palm oil plantation expansion and production process put pressure on the palm oil industry to engage in an ecological modernisation process. In 2004, this led to the establishment of the roundtable on sustainable palm oil (RSPO), an international organisation aiming to promote and monitor sustainable palm oil production. This incentivised the utilisation of palm oil effluent and biomass residues to reduce the environmental impact from the palm oil production process.

4.2.2. Regime conditions

With a continued increase in the energy demand, recurrent power outages, and a rapid depletion of domestic natural gas resources, the pressure to expand and diversify the

energy supply created tensions in the incumbent energy regime (Shekarchian et al., 2011). The situation was especially urgent on the eastern coast of Sabah, which was plagued by aging, expensive, and unreliable power plants and transmission lines (Koh and Lim, 2010). Therefore, energy planning agencies in Sabah had a particularly strong motivation to enhance the reliability and sufficiency of the electricity supply. In response to these challenges, and given the low cost of coal, the energy authorities under the auspices of TNB continued expanding the generation capacity with mainly coal fired power plants in the first part of the period (Thaddeus, 2002) (see Fig. 2).

However, at the same time, political pressure to reduce the environmental impact of electricity generation in Malaysia, and a wish to diversify energy supply due to security reasons, spurred political action in promoting renewable energy. This was initially laid out in the Third Outline Perspective Plan (OPP3) in 2001, for the period 2001-2010, which specifically emphasised increasing the utilisation of biomass resources from the palm oil industry for electricity generation, and later reiterated in the Eight Malaysia Plan (8MP) adopted in 2001 (covering the period 2001-2005).

The 8MP gave renewable energy a strategic priority with the promulgation of the fifth fuel diversification policy. More precisely, a target was set by the government to achieve 5% of the total energy demand in 2005 to come from renewable energy, equal to around 500-600 MW additional generation capacity with a particular focus on palm oil biomass waste-based energy generation (EPU, 2001). This target was to be achieved through the government programme entitled “Small Renewable Energy Power Programme” (SREP), initiated in 2001, which applied various financial incentives to support grid-connected renewable energy. According to the programme, biomass-based generating companies were granted exemption of income tax on 70% of the statutory income for 5 years, or a tax allowance of 60% of qualifying capital expenditure incurred within 5 years. Additionally, import duties and sales tax exemption on energy conservation machinery and equipment not produced locally was granted as part of these financial incentives. Most significantly was the 21 years license period under a renewable energy power purchase agreement (REPPA) set up to provide project developers with long-term planning and investment security. These incentives contributed to creating opportunities for niche development.

Despite this, a number of policy design and regulatory aspects reduced the impetus from the SREP for niche development. First, SREP projects should be below a capacity of 10 MW and be situated within 10 km from the nearest grid-substation. Secondly, the project developer should bear the cost of new or reinforced interconnection lines including ancillary equipment, which in many cases comprised a substantial part of the total plant investments. These constraints made it difficult for developers to reach economies of scale and put additional pressure on project investment costs (Hashim and Ho, 2011). Thirdly, the REPPA contracts largely followed conventional independent power producer (IPP) contracts, which comprised unfavourable conditions for renewable energy, such as specified performance provisions and penalties for non-delivery (KETTHA, 2009). Last but not least, the REPPA contracts were not a feed-in-tariff with fixed tariffs and an obligation for TNB to purchase certain quantities of produced electricity. Rather, project developers and TNB were jointly responsible for negotiating a suitable REPPA agreement in the individual projects on a ‘willing buyer, willing seller’ basis. Due to the monopoly status of TNB, as the only power off-taker in Malaysia, this created an unequal bargaining position or power asymmetry in REPPA negotiations. The government did however in 2001 set out a negotiating range of the

tariff price level to be agreed under REPPA contract negotiations, which is shown in Table 2 below (Hashim and Ho, 2011).

The lacking obligation of TNB to buy electricity became especially important as subsidies to fossil fuel based electricity was maintained and thus contributing to the result that the levelised cost of electricity from conventional gas and coal-fired IPP plants was approximately half compared to that of renewable energy (Sovacool and Drupady, 2011). As the regulatory scheme did not allow TNB to transfer extra costs onto consumers, TNB would experience a serious loss in buying electricity form biomass waste-to-energy plants (Sansubari, 2010). Consequently, TNB only accepted the lowest possible tariff rate in REPPA negotiations and deliberately delayed and obstructed the project approval process, as it considered the SREP a threat to its revenue and profits (Sovacool and Drupady, 2011). Due to these reasons, many project developers found that project preparation and implementation were too complicated and time consuming, and that uncertainties and risk were too high compared to the potential profits with the envisaged tariffs, and consequently they did not proceed with project investments (Shafie et al., 2012).

Table 2. Changes in tariff price ranges for biomass projects under SREP 2001-2009.

Year	Price
2001	0.14-0.17 RM/kWh (0.043-0.052 US$/kWh)
2006	0.17-0.19 RM/kWh (0.052-0.058 US$/kWh)
2009	0.19-0.21 RM/kWh (0.058-0.064 US$/kWh)

Source: Chua et al. (2011).

In the palm oil regime, a ban on open burning of EFB was implemented by the government in 2000 owing to concerns about local health problems and complaints of black smoke in residential areas located close to palm oil mills. This effectively exacerbated the biomass waste disposal problem in the palm oil industry. The total volume of EFB generated in Malaysia increased from around 8.5 to 19 million tonnes, during the period 1998-2006 of which most was mulched, incinerated, stockpiled, or left to decay in open landfills (Ngadi and Mustapha, 2007; Shuit et al., 2009). In palm oil mills without their own plantations to dispose EFB, the situation became particularly problematic and the ban thus initiated a search for alternative waste management options including the utilisation of EFB for energy purposes. It should be noted however, that the regulatory enforcement of the ban was relatively weak in distant locations and palm oil mills that were in operation before 2000 were not obliged to comply with the regulation.

A second issue in the palm oil regime concerned dynamics set in motion by a rapid increase in the price of PKS, which began to materialise around 2003. This was a result of an increase in the demand for PKS, particularly from the cement and rubber glove industry in Malaysia, as a substitution for the use of fuel oil and diesel in processing facilities. Therefore, from effectively having no economic value at the beginning of the second period, the price of PKS increased to approximately 80 RM (26 US$)/tonne in 2006 (Dit, 2007), and continued to increase subsequently to reach around 180-200 RM (60-65 US$)/tonne in 2011. As a result, in fuel substitution and other types of palm oil biomass waste-to-energy plants, it became more economically viable to utilise EFB for which a market price did not develop (Evald, 2006). Consequently, from 2003 and onwards, the prospects for niche development became focused on the utilisation of EFB.

Lastly, two large renewable energy related donor programme interventions and the new financing opportunities through the Kyoto Protocols' Clean Development Mechanism (CDM) contributed to creating opportunities for niche development. The donor interventions were in the form of the EU-ASEAN COGEN 3 programme (COGEN 3) (2002-2004) and the Biomass-based Power Generation and Cogeneration programme (BioGen) (2002-2010) (from 2005) (see Fig. 3). The COGEN 3 programme continued the previous activities under COGEN 1 and 2, particularly the efforts to identify and mature specific projects (Lacrosse, 2004; COGEN3, 2012). The BioGen programme was funded by the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) and, among other things, provided direct financial support to specific plants, conducted training workshops, and undertook policy analysis on tariff structure revisions and REPPA agreement standards (Aldover and Yang, 2010). The financial incentive provided by the CDM, in the form of carbon credits, also contributed to creating more favourable investment conditions for palm oil biomass waste-to-energy plants in Malaysia (DANIDA, 2004; Hansen, 2011; UNEP Risoe, 2012).

4.2.3. Niche processes

Concerning the shaping and alignment of expectations, the second period from 2002 to 2006 was especially marked by the launch of the SREP, COGEN 3, BioGen, and the financial opportunities arising from the introduction of the CDM in Malaysia. These programmes contributed significantly to raise the level of expectations of various niche-level actors, such as technology suppliers, palm oil industry companies, investors, and project developers. This created a general hype around EFB-based energy generation and the interest to engage in niche-level experiments converged. Therefore, of the total 39 plants identified, 26 were planned, commissioned, and/or put into operation during this period as illustrated in Fig. 4 and the Appendix.

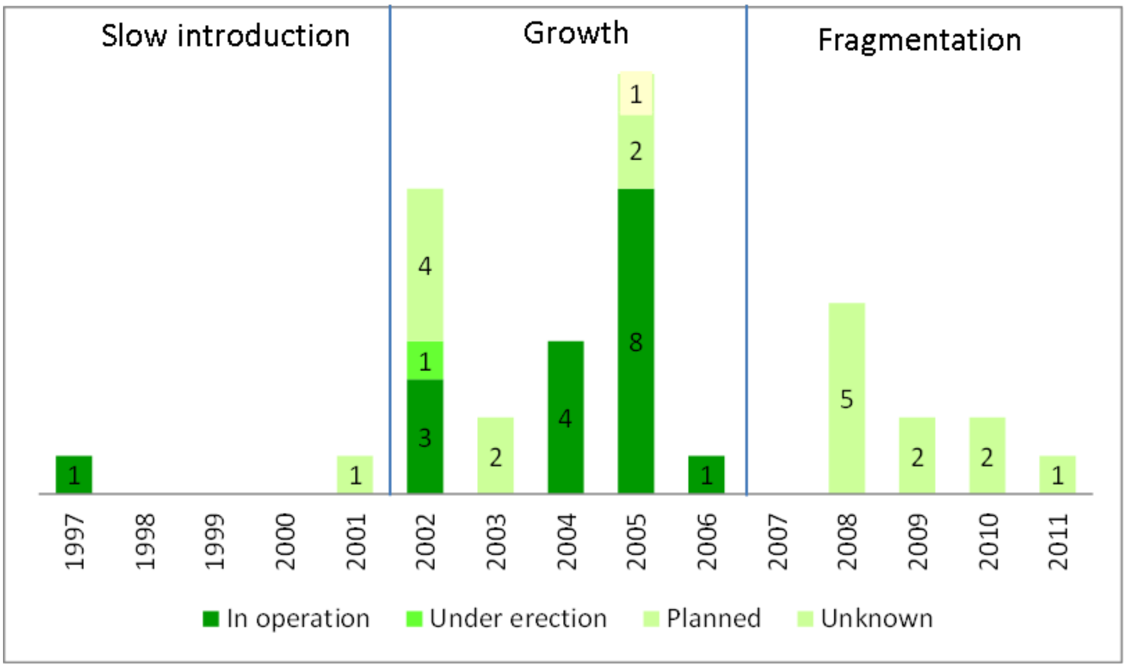

Fig. 4: Palm oil biomass waste-to-energy plants in Malaysia at various stages in project implementation. Status is based on information from 2011. The years in the table refer

to the date of obtainment of the necessary operational licenses of the individual plants (see Appendix). *Source*: Authors own elaboration based on various sources.

This has led some commentators to refer the 2002-2006 period as the 'bio-energy boom' in Malaysia (Aziz et al., 2011). This is also reflected in the large number of license applications submitted under the SREP programme. Apart from 5 plants, which mainly utilise PKS, all plants identified involve the utilisation of EFB as the main source of fuel for energy generation (see the Appendix). These plants vary in installed capacities from 1.2 MW to 23 MW and have primarily been implemented as cogeneration plants in palm oil refineries, in other industries, and as green-field grid-connected power plants. An overview of the status of the plants according to the categories above is shown in Fig. 5. It should be noted though that among the EFB-fired biomass projects that had been put in operation under SREP in 2005, only one plant had delivered electricity to the grid by the end of 2005 (EPU, 2006; Oh et al., 2011).

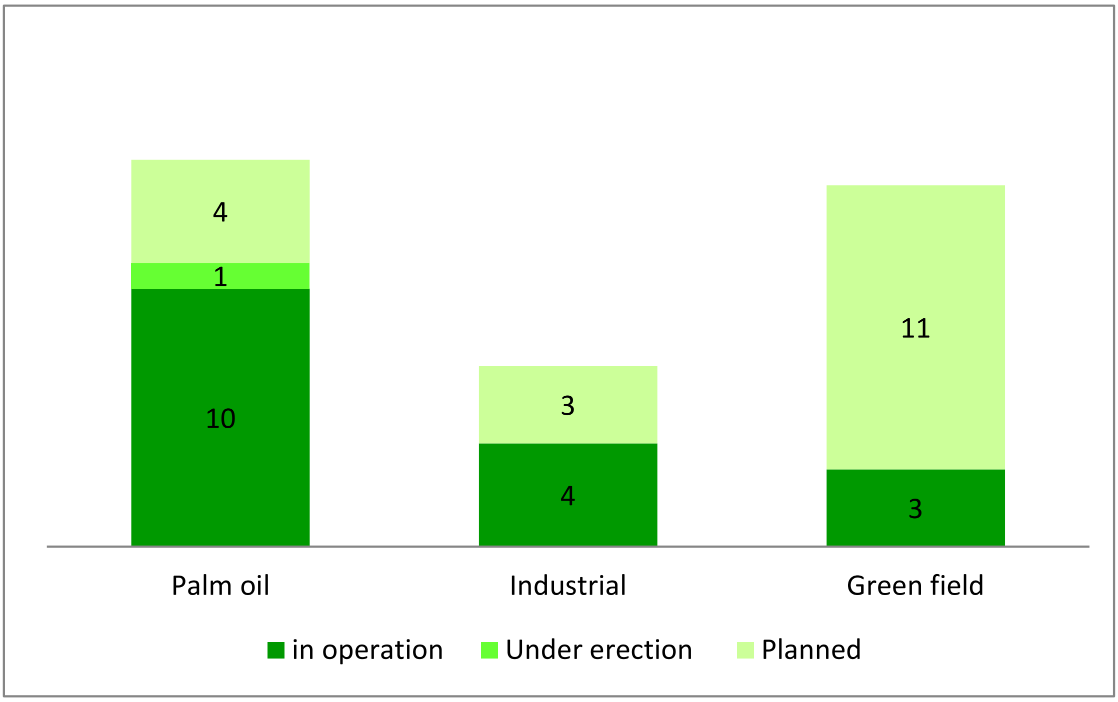

Fig. 5. Number of palm oil biomass waste-to-energy plants in Malaysia in palm oil refineries, in other industries, and as green-field grid-connected power plants by 2011. *Source*: Authors own elaboration based on various sources.

As mentioned above, for independent palm oil mill owners without plantations for mulching or disposal, the ban on open incineration in 2000 provided a strong incentive to consider alternative biomass waste management options, such as combustion of EFB. However, in spite of access to land for disposal, the ban on open incineration was also a motivating factor to invest in EFB-fired plants for the large-scale palm oil companies with upstream plantation and downstream processing facilities, such as palm oil milling and refining. According to plant owners, other motivating factors were: i) threat of increasing energy prices, ii) a need of reliable energy supply (especially in Sabah), and iii) an aspiration to improve their environmental profile. For some of the large-scale palm oil plantation companies, utilising EFB for energy generation was also considered a new potential business

area, and in spite of the ban on open incineration, high expectations to a profitable use of EFB for energy generation gradually changed the perception of EFB from being a waste product to being an economically valuable resource. In the boiler manufacturing industry, the expectations to the emerging market were high and a number of boiler supplier companies specifically targeted their activities towards the development of EFB-fired power plants. The strategy of these companies was to build a platform based on accumulated experiences, and from there move towards technological lead and a large market share. Despite limited experience with EFB combustion and the associated risks, many of these companies proved to be willing to invest both time and resources in aspiration to reap future benefits.

In parallel with the growing number of plants implemented since the first EFB-fired plant[2] was commissioned in 2001, the actor network gradually expanded during the second period. The network mainly included private companies directly involved in the plants either as suppliers of boiler technology and related ancillary components, energy consultants, investors, users, and suppliers of EFB. The evolving actor network was however characterised by a lack of relations linking actors together across the individual plants. The majority of the plants were implemented by a small group of local boiler suppliers, which were specialised in supplying boilers to the palm oil industry in Malaysia and in the Southeast Asian region since the 1970's, and according to the interviewed actors the high level of competition and rivalry among these suppliers was the reason behind very limited inter-company coordination of activities, cooperation, and interaction in general. Knowledge sharing among these actors was therefore limited.

Investors in the palm oil industry and other investors also saw a strategic interest in protecting plant-related information from being openly disclosed and they hindered third-hand parties from obtaining access to detailed information about the specific plants, with the result that formal sharing of lessons and experiences across industrial actors was largely absent. A concrete example of this was the strict visiting rules and regulations enforced at palm oil mills and refineries involved in various EFB-fired plants. In spite of support from the donor interventions to facilitate the establishment of an overarching body, which could stimulate an information sharing platform between niche-level actors, such efforts never materialised (Aldover and Yang, 2010). Consequently, the acquired knowledge remained concealed by the actors involved in individual plants.

Despite the limited interaction between niche-level actors, the network was broadened by the participation of a number of influential regime-level actors, most noticeably the Malaysian Palm Oil Board (MPOB) and the Palm Oil Industrial Cluster (POIC) in Sabah. In particular, the MPOB, a powerful state-owned palm oil R&D and innovation institution in Malaysia, became engaged in supporting niche development - although without actively engaging in specific plants. MPOB had a strong position in the Energy Commission that governed the SREP and was therefore able to influence the operational modalities of the programme. The POIC was set up in 2005 by the state government in Sabah to promote and provide favourable growth conditions for the palm oil industry in Sabah. A main purpose of the POIC was to support private investors in developing new palm oil biomass waste-based industries such as biofuel production, oleo-chemical, phytonutrient, and food industries, as well as palm oil biomass energy generation in Sabah. Among other things, MPOB and POIC were highly influential in the government's decision to

[2]The term 'EFB-fired plants' denotes biomass power plants that mainly, although to varying degrees, use EFB as the primary source of fuel input.

increase the negotiable REPPA tariff price range for projects under the SREP in 2006 and 2007 (see Table 2) (Sovacool and Drupady, 2011). A primary motivation for these palm oil industry organisations to push for a tariff increase was to improve the profitability of palm biomass-based energy generation to increase the commercial opportunities in utilising biomass waste resources in the palm oil industry. Other organisations, including the PTM, also encouraged a tariff increase on electricity from renewables (Aldover and Yang, 2010), but the achieved tariff rate increase only pertained to SREP projects on biomass and biogas and hereby favoured palm oil related energy generation compared to for example solar photovoltaic or hydropower. This result indicates the influence of the MPOB and POIC.

The plants implemented in this period from 2001 to 2005 gave rise to a number of important learning experiences at the plant level. First, an incremental and long-term techno-economic optimisation process occurred at the plant level throughout the period. The boiler suppliers and users were here pursuing a common interest. The users were generally interested in achieving the highest possible return on their investments by increasing the performance of the plants and the boiler suppliers were interested in enhancing the price/performance ratio of the technology to improve their competitiveness against competitors in the market. A characteristic feature of the learning and experimentation efforts undertaken in the individual plants was the absence of involvement from universities, R&D institutions and government-supported laboratories and testing facilities.

Initially, most of the plants used a boiler system similar to the conventional low-efficiency (and low cost) cogeneration boilers previously used in palm oil mills. As a result of the specific chemical and physical properties of EFB, this caused numerous problems in the combustion process. Especially the formation of clinker deposits on heat surfaces reduced plant performance substantially and required frequent shut downs for manual cleaning. This problem was addressed by adjusting and controlling the critical plant efficiency parameters such as air inlet levels and hereby achieving better control of temperatures in the boiler and by reconfiguration of and experimentation with new boiler designs, such as furnace grate systems. The fuel feeding system was not optimised to handle moist and bulky material such as EFB and therefore another feature of the learning and experimentation activities undertaken concerned the introduction of EFB pre-treatment systems and automatic feeding systems. The pre-treatment aimed at reducing the moisture and length of the EFB fibres, which was considered a particularly critical parameter regarding plant performance. With regard to operation and maintenance, interviewed users and suppliers claimed that lack of skilled and trained personnel in rural areas often led to sub-optimal operation and maintenance procedures, and limited the potential learning opportunities.

Another learning experience concerned the dynamics of user preferences and the profitability of various business models. During the second period, and subsequently, it became clear that the emerging market for EFB-fired energy generation became divided into a high-quality and low-quality segment. The users in the high-quality segment mainly preferred proven and reliable technology sourced directly from well-renowned international boiler supplier companies or indirectly through license agreements from local boiler companies. Although the total capital costs of plants in this segment were relatively higher, users generally appreciated a higher level of technical certainty and long-term operational durability to reduce the investment risks. An example of this involved two green-field grid-connected power plants erected only for the production of electricity and relying on external fuel supply sources. In order to increase the economic viability of such plants, users

in this segment valued a higher level of efficiency and plant performance. In the low-quality market segment, users tended to opt for larger risk-willingness by investing relatively less with the use of local boiler supplier companies working independently. The users in this segment focused more on reducing the upfront capital costs rather than securing the long-term financial viability of the plants, and were therefore more willing to accept a higher frequency of plant shutdowns and lower efficiency than the high-quality plant owners.

Lastly, critical learning experiences also pertained to fuel handling and management issues related to the organisation of integrated logistical systems to supply and utilise large amounts of EFB. The typical amount of EFB required to continuously and effectively operate a 10 MW power plant is around 150,000 tonnes of EFB/year or approximately 420 tonnes of EFB/day. The management of such large volumes of biomass required effective organisation for collecting, processing, and ultimately utilising EFB at the plants sites. This involved substantial challenges at most plants, but in particular at the large-scale green field plants relying predominantly on external fuel supply sources.

4.3. The 'fragmentation' phase 2007-2011

4.3.1. Landscape conditions

At the landscape level, the rise in crude oil prices culminated in a record high of over 140 US$/barrel in July 2008, and maintained the demand for relatively lower cost palm oil biomass waste-based energy generation (see also Romijn and Caniëls, 2011). After the global economic recession in 2008 and 2009, the price increased again and reached over 100 US$/barrel in 2011 (IEA, 2011). This provided a continuous impetus for niche development.

Moreover, climate change mitigation remained a key issue at the international level, which particularly attracted political attention in the lead up to, and during, the UN climate summit in Copenhagen in 2009. During the summit, the Malaysian government announced a commitment to reduce the national greenhouse gas emission intensity by 40% in 2020, compared to 2005 levels (Chua et al., 2011). This commitment was incorporated into the national energy policy with a focus on palm oil biomass waste-based energy, to help achieve this target. Renewable energy remained a key priority in the energy policy, and contributed to creating tensions in the energy regime.

The pressure on the palm oil companies from international environmental NGO's continued and was accelerated by criticism of the increasing biofuel production from the palm oil industry in Malaysia. This generated a strong push for reducing the environmental impact of palm oil-based biofuel, inter alia, by enhancing the utilisation of palm oil biomass waste residues.

Lastly, during 2006-2011 the crude palm oil price increased from 1,500 to over 2,500 RM (493-820 US$)/tonne, which made extraction of the residual oil in the milling process more profitable (Chandran, 2010). EFB residues thereby became more usable for various purposes such as energy generation, which incentivised alternative management practices in palm oil mills.

4.3.2. Regime conditions

The incessant power interruptions due to lack of capacity became more widespread compared to the second period, particularly along the eastern coast of Sabah, and it became clear that the continued increase in energy demand generated an urgent need for expanding the generation capacity in Malaysia. Because of the rapid depletion of indigenous natural gas reserves, it remained a priority for TNB to increase the security of energy supply by diversifying the energy sources (TNB, 2008). This was mainly achieved by constructing new capacity based on imported coal and consequently, the reliance of fossil fuels in the energy system increased (Shekarchian et al., 2011) (see Fig. 2).

Previous to the third period, the price of electricity and petroleum products were capped and the difference between world market prices and the caps were subsidised by the government. When the gap between world market prices and the price caps increased in 2008, the energy subsidies increased to around 14 billion US$ or approximately 4% of GDP (Aziz et al., 2008; TNB, 2008). The financial burden prompted the Malaysian government to review the energy subsidy policies (IEA et al., 2010), with the result that in 2008 the price of natural gas for power generation was raised by 124% in Peninsular Malaysia and the average electricity tariff for all sectors of the economy was increased by 24%. This reduction in subsidy on fossil fuels and adjustment to market costs contributed to creating more conducive conditions for renewable energy generation in Malaysia, which created an impetus for niche development.

When adopting the Ninth Malaysia Plan (9MP) in 2005, the 500-600 MW target set out in the 8MP was far from being reached. In fact only two grid-connected plants, with a combined capacity of 12 MW had delivered electricity to the grid in 2005 (EPU, 2006). Consequently the 9MP, covering the period 2006-2010, reduced the earlier target to 350 MW, comprising 300 MW renewable electricity generation capacities in Peninsular Malaysia and 50 MW in Sabah. While the SREP thereby continued to encourage niche development until its termination in 2010, the program remained in place without any additional specified roadmap and incentives, new strategic planning mechanisms and regulations, or revitalised institutional structure to achieve the target. Consequently, the problems pertaining to the configuration of the SREP explained previously, such as the unequal REPPA negotiating situation and unfavourable capacity and localisation constraints, remained intact (Sovacool and Drupady, 2011).

Other factors were more conducive for niche proliferation during the third period. Firstly, as in the previous period, the BioGen programme and the CDM continued to promote and incentivise palm oil biomass waste-based energy generation. Secondly, a 1.5 billion RM (0.48 US$ billion) green technology financing scheme (GTFS) was set up by the government in 2009 with the purpose to provide both users and producers of renewable and energy efficient technologies with financial support, primarily through soft loans (Hashim and Ho, 2011). Thirdly, and most importantly, a new renewable energy feed-in-tariff (FIT) system became operational in April 2011 following the Malaysian Cabinet's approval of a new national renewable energy policy in 2010. The FIT involved an obligation for the distribution companies (under the auspices of TNB) to buy specific quantities of electricity from biomass power plants at a fixed and significantly increased rate (see Table 2 and 3 for comparison). The agreement also introduced compensation to the distribution companies by allowing a general tariff increase of 1%. This reflected a larger political willingness to pass the cost of renewable energy generation onto consumers, and compared

to the second period, it reduced the losses for distribution companies in buying electricity from renewable energy.

Table 3. Tariff rates for biomass plants under the FIT system in Malaysia.

Capacity limit	**Fixed tariff price**
<10 MW	0.31 RM/kWh (0.10 US$/kWh)
>10 MW <20 MW	0.29 RM/kWh (0.09 US$/kWh)
>20 MW <30 MW	0.27 RM/kWh (0.08 US$/kWh)

Source: Hashim and Ho (2011).

In the palm oil regime, one factor was particularly influential regarding the prospects for niche development. This concerned the increasing interest in using EFB for various commercial purposes other than energy generation. Commercial interests were many. Firstly, researchers in various universities and R&D institutions in Malaysia showed interest in production of bio-fuel from EFB, and large-scale commercial production of both EFB-based biodiesel and second-generation bio-ethanol was established by large palm oil plantation companies (Shuit et al., 2009; Ng et al., 2012). Secondly, both research in and the commercial production of pulp and paper from EFB became a reality, and thirdly, a local industry emerged around the production of pellets and briquettes from EFB. Thirdly, EFB were increasingly used for a number of other purposes such as input material for wood-based products especially particle and fibre boards, composite panels, mattresses, animal feed, pyrolysis, composting in plantations together with palm oil effluent, and export for co-firing in power plants (Evald, 2006; Ngadi and Mustapha, 2007). The interest in EFB for competing usages increased the price of EFB from about zero at the beginning of the period to around 15-20 RM (5.0-6.6 US$)/tonne in 2011, and in some cases even up to 45-50 RM (14.8-16.5 US$)/tonne depending on the quality, localisation and site delivery (Chen, 2011). This situation opened opportunities for alternative biomass waste management practices in palm oil mills beyond the conventional mulching, landfill deposal and open incineration of EFB, but reduced the incentives for using EFB for energy generation.

4.3.3. Niche processes

At the niche level, the continuance of the SREP, BioGen and CDM, the introduction of the GTFS and the new FIT contributed to sustaining the general interest in palm oil biomass waste-based energy generation. Particularly influential was the FIT that introduced three new energy policy elements that were conducive for niche development: i) a raise in the tariff rate for biomass plants compared to the SREP (see Tables 2 and 3), ii) an obligation for distribution companies to purchase certain quantities of electricity from biomass energy plants, and iii) removal of some of the unfavourable capacity and localisation restrictions pertaining to REPPA agreements under the SREP (SEDA, 2013).

The influence of these initiatives on niche development is reflected in the continuance of EFB-fired energy plants applying for registration under the SREP, CDM, GTFS, and FIT (see the Appendix), and in the fact that a number of suppliers previously engaged in EFB-fired plants concentrated their activities around this market. Moreover, the interest

from various industrial users in Malaysia in using EFB as a substitution for diesel and fuel oil persisted and a number of large-scale foreign industrial investors also became active in the market for EFB-fired energy generation.

However, progress in EFB-fired power plants in the third period ended up being much lower than expected. At the end of the 9MP in 2010, only 62 MW of the planned additional 350 MW grid-connected renewable energy capacity under SREP was in operation. Of the 62 MW, three palm oil biomass waste-to-energy plants were responsible for around 30 MW in the period (about 30 % of total installed biomass capacity) while the remaining 32 MW came from mini hydro and biogas plants.

To through more light on the operational performance, the 17 plants in operation in 2011 were categorised into 5 levels of performance, defined by the author. The categorisation was based on interviews with plant managers, and in 9 cases interviews were conducted in a combination with field visits. Among the plants in operation, only smaller plants (total of 5 MW) using PKS and mesocarp fibres as fuel were in the category of high performing plants and only two plants (total of 24 MWe) relying exclusively on EFB were in the category of medium to high performance. The rest of the EFB-fired plants were performing either at the low level or at the low to medium level (see Fig. 6 and the Appendix).

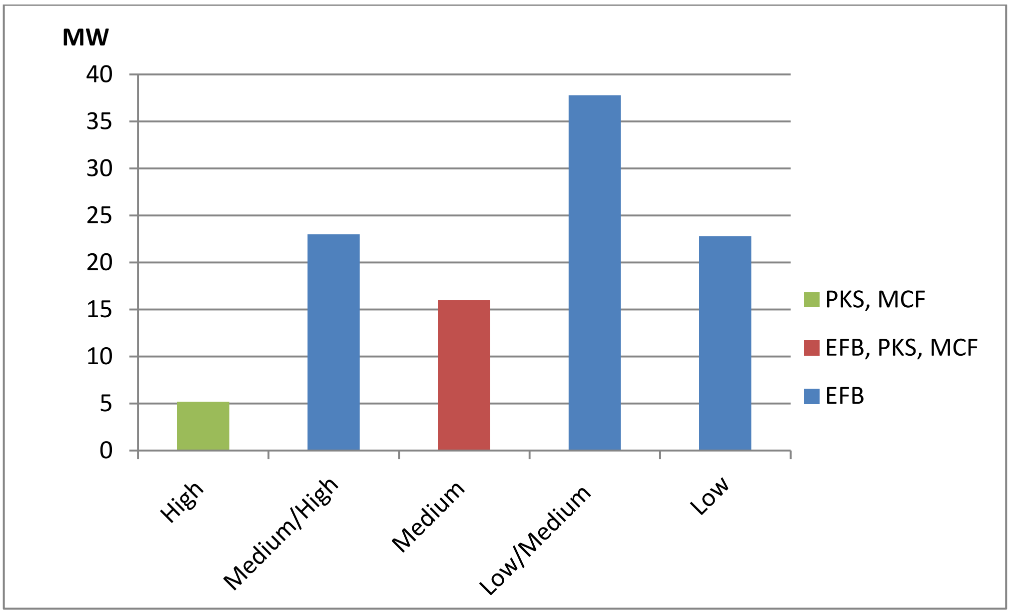

Fig. 6. Installed capacity of palm oil biomass waste-to-energy plants in operation in Malaysia at different performance levels. *Source*: Based on authors judgement of performance following interviews with managers and field visits in 2011.

This relatively poor performance in most of the plants, was as mentioned above, especially the result of problems related to formation of clinker deposits on heat surfaces and problems related to the fuel feeding system, which was not optimised to handle moist and bulky material such as EFB. Although techno-economic optimisation efforts continued in the already implemented plants most new plants were delayed in starting operation and performed substantially below design capacity levels. The plants were designed to produce process steam and electricity, but due to technical problems, the majority did not manage to produce electricity. Moreover, owing to the technical difficulties experienced, most

plants were not able to operate exclusively on EFB and were forced to add biomass with a higher calorific value such as PKS.

These operational problems resulted in substantially lower profitability than expected and these negative results became widely known (Shafie et al., 2012). According to investors, this reduced the general expectations to the commercial viability of using EFB for energy generation, with the result that the plants planned in this period were stalled and only previously commissioned plants were put into operation. It also became clear that the large palm oil plantation companies with own palm oil mills did not consider EFB-based energy generation part of their business activities. According to palm oil plantation companies, this was due both to the negative performance level of already established plants and the increasingly competitive alternative use of EFB. According to the smaller palm oil mill companies, most of them did not have an interest or the financial capacity to engage in large-scale EFB-fired plants and because of the competing commercial interest in EFB, they largely adopted a wait-and-see strategy, which made them hesitant to engage in longer-term contracts concerning the sale of EFB. As a result, contrary to converging expectations in second period, the niche level actors experienced a diverging interest in the third period.

The interaction and coordination between actors in the niche and linkages across various plants remained limited in the third period. However, in contrast to the second period, TNB became actively engaged in the niche as a main investor in two large-scale EFB-fired power plants (TNB, 2011). As a key regime actor, the direct involvement of TNB in niche development marked a new situation since TNB, in contrast to previously, initiated concrete actions to promote EFB-fired energy generation in Malaysia and invested in plants. Another factor that contributed to broadening the actor network during the third period concerned a large NGO coalition organised to campaign against a planned 300 MW coal-fired plant in Sabah (Green Surf, 2012). The substantial pressure from this campaign was highly influential in the decision of SESB in 2011 to withdraw from this coal plant and include renewable energy in future capacity expansion plans (McNish et al., 2010; Time, 2011). The actor network thereby became broadened to include civil society representatives in influencing niche development. Lastly, it should be mentioned that although the PTM, POIC, and MPOB continued to promote niche development, these actors increasingly supported diversifying the use of EFB.

With regards to the learning process, the techno-economic optimisation efforts continued as in the previous period. Although the results of these efforts were generally negative, as mentioned above, some price/performance ratio improvements were achieved in the individual plants. These performance improvements were mainly associated with additional efforts to optimise the EFB pre-treatment systems, which in most plants constituted a particularly laborious learning process. A main challenge was to reach a consistent size and moisture content of shredded EFB fibres since this was found to constitute a critical factor in the fuel feeding and boiler operation process.

Another central learning experience was that a reliable and affordable supply of EFB increasingly became a critical factor for plant operation and profitability. During the third period, EFB was mostly traded directly with palm oil mill owners on a non-contractual basis, which implied continuous negotiations regarding delivery, quality, price, and volume. Since all plants relied, to various extents, on external sources of EFB, this practice introduced a general risk to the profitability of EFB plants, and as palm mill owners were generally hesitant to engage in long-term fuel contracts, reliable and long-term EFB supply contracts

became a main hindering factor for financial institutions to provide loans to plant investors in this period.

5. Conclusion

This paper set out to explore the extent to which a palm oil biomass waste-to-energy niche was developed in Malaysia during the period 1990-2011 and to identify conducive and limiting factors underlying the niche formation process.

Regarding the development of a palm oil biomass waste-to-energy niche, the conclusion is that the niche has only made slow progress although some proliferation of the niche occurred momentarily in the period 2002-2006. Except in two cases, the performance level for plants using EFB was relatively low, and many planned plants were never put into operation and those that were constructed relying mainly on EFB were substantially delayed.

With regard to the conducive and limiting factors for the development and proliferation of a palm oil biomass waste-to-energy niche in Malaysia, the paper has identified the main influential factors at the landscape, regime, and niche-level involved in the niche development process in three distinctive periods. A summary of these factors is presented in Table 1 below.

In conclusion, rising oil prices, strong pressure on the palm oil industry from environmental groups, and a persisting palm oil biomass waste disposal problem in Malaysia have been some of the main conducive factors for the creation and proliferation of a niche over the three periods. These factors at the landscape level have in all three periods been supplemented by supportive regime level factors, such as policy measures in terms of national renewable energy policies and large-scale donor programmes interventions aiming at the development of the niche for renewable energy technologies in Malaysia. At the niche level, the momentary proliferation of the niche during the second period was strongly influenced by conducive niche level processes in the form of a high level of alignment of expectations and multifaceted learning processes.

Explanations as to why the niche did not develop as expected are many, and the present analysis is not able to provide any solid causal explanations to this complex question. Based on interviews with plant managers and observers in Malaysia and the analyses above, we would nevertheless points towards the following 4 hypothetical limiting factors:

5.1. Reluctant implementation of energy policy

As shown above, the policies for niche proliferation have gradually improved over time, but have been implemented, when it was too late as compared to the need (Sovacool and Drupady, 2011). Most prominently, the REPPA agreement developed under the SREP on a 'willing seller, willing buyer' basis, turned out to be costly for TNB, without providing a sufficient incentive for investors to engage in waste to energy cogeneration plants. The FIT, in contrast, comprising a higher tariff rate for project developers and giving compensation to the distribution companies through increased consumer tariffs was only agreed upon in 2011, when momentum was lost and the trust in high performance of EFB based power plants was heavily reduced. Moreover, subsidies on fossil fuel were maintained at a high level until 2008. If the fossil fuel subsidy had been reduced at an earlier stage, it would have

increased the competiveness for biomass based electricity so, as discussed in Oh et al. (2011), also this relevant policy would have benefited the niche development if introduced earlier. Both the FIT and the reduction of subsidies were well described incentives in the international literature since the late 1990s, see e.g. UNDP (2001), and with the high level of technical support in the Ministry of Energy, Green Technology and Water (KETTHA) from donor programmes, the late introduction was not due to lack of knowledge, but rather lack of political will.

5.2. Rise in biomass resource prices

The cost of the biomass waste increased over the period from being negative to reach a level of up to 45-50 RM (14.8-16.5 US$)/tonne for EFB and even higher for PKS and mesocarp fibres. This increase in price was due to two reasons: Firstly, increased oil prices made PKS and mesocarp fibres a competitive fuel for smaller industries needing process heat and was hence not available at a reasonable price for the palm oil industry, and secondly, increased palm oil prices changed the process at the palm oil mills, which made the EFB more usable for energy purposes but also for various other purposes, such as e.g. for biofuel, pulp and paper or cardboards. This reduced the pressure for combustion and increased the price of EFB. The rise in prices on EFB had an important side effect, as it raised expectations among the EFB producers, which in reality made it impossible to engage in long term delivery contracts and hereby hindering investment (see also Raven, 2005).

5.3. Limited network formation

During the entire niche development process, a broader network linking actors together across the individual plants remained weak. Apparently, a long standing rivalry among local boiler suppliers was the reason behind this very limited inter-company coordination of activities, cooperation, and interaction in general. Knowledge sharing among these actors was therefore limited. In addition, investors apparently saw a strategic interest in protecting plant-related information from being public and they hindered access to detailed information about the specific plants, with the result that formal sharing of lessons and experiences across industrial actors was very limited. This may also be seen as the main reason why involvement from universities, R&D institutions and government-supported laboratories and testing facilities were almost absent in the technological development. In line with Schot and Geels (2008), the findings of this paper points toward the lack of niche level network formation as a major reason of the limited learning results with respect to handling the challenging EFB fuel.

5.4. Negative results at the niche level

In combination with the factors above, the predominantly negative performances of the plants constructed, became the most important factor for the slow progress in niche development by 2011, when the research for this paper was concluded (see also Shafie et al., 2012). Despite the price/performance improvement achieved in some plants, the general picture was one of largely negative results at the niche level, which may be seen as a result of insufficient learning and innovation efforts. This may again refer back to limited strategic interest from investors and producers of equipment to engage in sufficient

investment, which can be the result of insufficient incentives. This paper thereby corroborates previous studies in the MLP literature, such as Geels and Raven (2006) and Van der Laak et al. (2007) that positive and tangible results from experiments at the niche level is an essential element of niche development.

Finally, the lack of alignment of the processes at the landscape, regime, and niche-level provide explanations of the relatively poor results in this case. The general hype and interest about biomass generation in the second period, was not aligned with sufficient incentives and the needed quality of plants to make them competitive. And when incentive structures became more adequate in the third period, the interest in investing had slowed significantly down, mainly due to the poor experiences. These findings hence support the general claim in the MLP framework that processes at the landscape, regime, and niche-level need to be aligned in order for a niche to flourish (see e.g. Geels, 2002).

Table 1. Summary of the main conducive and limiting factors in the development of a palm oil biomass waste-to-energy niche in Malaysia 1990-2011.

Phase	**Slow introduction 1990-2001**	**Growth 2002-2006**	**Fragmentation 2007-2011**
		Landscape conditions	
		-Rising oil prices -Environmental pressure on the palm oil industry	-Continued rising oil prices -Political interest in mitigating climate change -Sustained criticism of the palm oil industry -Palm oil price increase led to an upgrading of EFB residues
		Regime conditions	
Energy	-Rising energy demand and frequent power outages -Rapidly depleting oil reserves -High fossil fuel subsidies -Four fuel policy (focus on oil, gas, coal, and hydro) -Energy generation expansion largely met by natural gas -Lack of a formal renewable energy policy	-Continued rising energy demand and recurrent power outages -Rapidly depleting natural gas reserves -Sustained high fossil fuel subsidies -Fifth fuel policy and the SREP programme -Energy generation capacity expansion increasingly met by coal -Disincentive for TNB to engage in renewable energy	-Continued rising energy demand and power outages -Continued depleting natural gas reserves -Reduced subsidies on fossil fuels led to a general tariff increase -Continuation of the SREP. -Introduction of the GTFS, and the FIT -Continued generation capacity expansion mainly met by coal -Compensation for TNB to purchase renewable energy
Palm oil	-Stabilised waste handling practices in palm oil mills -Lack of regulatory measures or incentives to utilise waste	-Ban on open incineration of EFB -Rapid price increase for PKS (incentivises EFB utilisation)	-Increasing interest in EFB for competing use (EFB became an economically valued resource)
Crosscutting	-International programs (COGEN 1, 2 and DANCED/DANIDA)	-International programs (DANCED/DANIDA, COGEN 3, BioGen, and CDM)	-International programs (BioGen and CDM)
		Niche processes	
Expectations	-Limited interest in palm oil biomass waste-based energy generation	-High and converging expectations among niche actors	-Expectations raised due to new renewable energy policies -Expectations reduced from negative results in previous plants -Increasingly diverging expectations among various niche level actors
Actor network	-Limited actor network formation since only one plant was implemented	-Limited interaction among niche actors across experiments -Network became broader with the active participation of PTM, MPOB, and POIC	-Continued limited interaction among niche actors across experiments - Network was further broadened with the participation of TNB and NGO coalition
Learning	-Limited learning processes	-Techno-economic optimisation efforts focusing on plant performance -Learning about user preferences and various business models -Organising the logistical infrastructure around large-scale EFB-fired plants	-Mainly techno-economic optimisation efforts in existing plants -Difficulties in getting long-term EFB supply contracts hinders investment

Appendix. List of identified palm oil biomass waste-to-energy plants in Malaysia (1990-2011).

Name	Part of program	License date[1]	Current status (2011)	Operational performance	Fuel[2]	installed capacity (MW)	Analysed in detail in this study	Type[3]
Kilang Sawit United Bell Sdn. Bhd.	COGEN 2	1997	In operation	High	PKS, MCF	1.2	Yes	CHP in palm oil mill
Kim Loong Sdn Bhd	-	-	Planned not erected	-	-	14.0	No	CHP in palm oil mill
Bumi Biopower	COGEN 3, SREP, CDM	2001	Planned not erected	-	EFB, PKS, MCF	6.3	Yes	Greenfield power plant
Kalansa Energy Corporation Sdn Bhd	SREP, CDM	2002	Planned not erected	-	EFB	6.5	No	Greenfield power plant
Kogen Sdn Bhd	SREP	2002	Planned not erected	-	-	-	-	-
Palm Energy Sdn Bhd (Kwantas)	SREP, CDM	2002	In operation	Low	EFB	9.8	No	CHP in palm oil refinery
MHES Asia Sdn Bhd	Biogen, SREP, CDM	2002	In operation	Low	EFB (gasification)	13.0	Yes	Greenfield power plant
Sunquest Biomass project	SREP, CDM	2002	Planned not erected	-	EFB	6.5	No	Greenfield power plant
Golden Hope Plantations Bhd	SREP	2002	Planned not erected	-	EFB, PKS, MCF	-	No	-
IOI Bio-Energy Sdn Bhd project	SREP, CDM	2002	In operation	Low/Medium	EFB	15.0	Yes	CHP in palm oil refinery
Bell Eco Power	COGEN 3, SREP, CDM	2002	Under erection	-	EFB	10.0	Yes	CHP in palm oil mill
Potensi Gaya Sdn Bhd	SREP	2003	Planned not erected	-	EFB	7.0	No	Greenfield power plant
Alaf Ekspressi Sdn Bhd	SREP	2003	Planned not erected	-	EFB	8.0	Yes	Greenfield power plant
Sungei Dingin Palm Oil Mill project	COGEN 3	2004	In operation	High	PKS, MCF	2.0	Yes	CHP in palm oil mill
TSH Bio-Energy Sdn Bhd	COGEN 3, SREP, CDM	2004	In operation	Medium	EFB, PKS, MCF,	14.0	Yes	CHP in palm oil mill
Biomass Energy Plant-Lumut	CDM	2004	In operation	Medium	EFB, PKS, MCF	2.0	No	CHP in palm oil refinery
Lafarge cement project	CDM	2004	In operation	High	PKS	-	No	CHP industrial user (cement)
Naluri Ventures Sdn	SREP	2005	Planned not	-	EFB	12.0	-	Greenfield power

Bhd			erected					plant
Eko Synthesis Sdn	Biogen	2005	Planned not erected	-	EFB	-	No	CHP in palm oil mill
Bentong Biomass Energy Plant	CDM	2005	In operation	Low/Medium	EFB	1.2	Yes	CHP industrial user (paper mill)
LDEO Biomass steam project	CDM	2005	In operation	Low/Medium	EFB	1.2	No	CHP in palm oil refinery
SEO Biomass steam project	CDM	2005	In operation	Low/Medium	EFB	1.2	No	CHP in palm oil refinery
Kina Biopower Sdn Bhd project	SREP, CDM	2005	In operation	Medium/High	EFB	11.5	Yes	Greenfield power plant
Seguntor Bioenergy Sdn Bhd	SREP, CDM	2005	In operation	Medium/High	EFB	11.5	Yes	Greenfield power plant
The Sahabat EFB project	CDM	2005	In operation	Low/Medium	EFB	7.2	Yes	CHP in palm oil refinery
ENCO biomass project	CDM	2005	In operation	Low/Medium	EFB	-	No	CHP industrial user
Johor bundled project	CDM	2005	-	-	EFB	14.0	No	CHP in palm oil refinery
Jendarata Steam & Power Plant	CDM	2005	In operation	High	PKS, MCF	2.0	No	CHP in palm oil mill
Hartalega rubber glove project	CDM	2006	In operation	Low/Medium	EFB	12.0	No	CHP industrial user (rubber glove)
Bioenergy plant – Sawit Kinabalu	CDM	2008	Planned not erected	-	EFB	1.2	No	CHP in palm oil refinery
Eco Biomass (POIC) project	CDM	2008	Planned not erected	-	EFB, PKS	23.0	No	Greenfield power plant
FTJ Biopower	-	2008	Planned not erected	-	EFB	12.5	No	Greenfield power plant
FELDA and J-Power biomass plant	-	2008	Planned not erected	-	EFB	10.0	No	Greenfield power plant
Mini renewable energy plant	CDM	2008	Planned not erected	-	EFB, MCF, PKS	-	No	CHP industrial user (paper mill)
Pengkalan Chepa biomass plant	CDM	2009	Planned not erected	-	EFB, MCF, PKS	1.5	No	CHP industrial user (rubber

								glove)
G.B. Industries Biomass	CDM	2009	Planned not erected	-	PKS	-	No	CHP industrial user (rubber glove)
Cash Horse Sdn Bhd	CDM	2010	Planned not erected	-	EFB	12.0	No	CHP in palm oil mill
Maju Intan Biomass	CDM	2010	Planned not erected	-	EFB	12.5	No	Greenfield power plant
Agni biopower	GFTS	2011	Planned not erected	-	EFB	10.0	No	Greenfield power plant

Source: Own research.

Notes:

1) License date refers to the date of issuance of the earliest identified approvals from authorities given to the individual plants, such as business license from local authorities and generation or supply of electricity license issued by the Energy commission in Malaysia.
2) Abbreviations used: EFB = Empty Fruit Bunches, PKS = Palm Kernel Shells, MCF = Mesocarp Fibres.
3) Abbreviations used: CHP = Combined heat and power.

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Paper 4

Transnational linkages and sustainable transitions in emerging countries: exploring the role of donor interventions in niche development

Ulrich Elmer Hansen[a]*; Ivan Nygaard[a]

[a]UNEP Risø Centre, DTU Management Engineering
*Corresponding author

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Abstract

Recent studies have found that further development of the MLP is needed to conceptualise and empirically assess the role of transnational linkages in niche development. This paper explores the factors that may explain the effect of twenty years of donor interventions, as one form of transnational linkage, in promoting the development of a palm oil biomass waste-to-energy niche in Malaysia. The paper contributes to the existing literature by a conceptual and empirical examination of this research question. With regard to its empirical findings the paper concludes: i) that advice on energy policy had a limited impact, mainly due to strong opposing interests in maintaining the existing situation; ii) that creating the necessary conditions for transferring a private-sector model of electricity production to Malaysia remained a challenge; and iii) that the short duration and unpredictability of interventions generally can be seen as an important impediment for programs in reaching their objectives.

Keywords: Multi-level Perspective; Strategic Niche Management; donor programs; renewable energy; developing countries

1. Introduction

The multi-level perspective (MLP) on systems of innovation is a widely adopted framework for analysing stability and change in socio-technical systems. While most empirical studies using the MLP have been conducted in developed countries, a number of researchers have recently taken an interest in examining niche up-scaling and transition processes in emerging economies. These studies have mainly been undertaken in Asia owing to the increasing contribution of countries in this region to global environmental problems, such as climate change (Rock and Angel, 2005).

Previous studies adopting the MLP framework in Asia have found that further development of the framework is needed, especially for studies of niche development in developing countries (Romijn et al., 2010). In particular, the inability of the MLP both to conceptualise and assess empirically the role of transnational linkages in niche development and transition processes has been stressed (Bai et al., 2009; Rock et al., 2009; Berkhout et al., 2010, Romijn and Caniëls, 2011). Consequently, efforts to elaborate and further substantiate the nature of these transnational linkages have recently been incorporated into the MLP framework (see e.g. Binz et al., 2012; Coenen et al., 2012; Coenen and Truffer, 2012; Raven et al., 2012). Transnational linkages take various forms, such as relationships with foreign technical experts and inter-firm partnerships with foreign suppliers of technology. By facilitating a flow of knowledge, technological and financial resources, and organisational capabilities, such transnational linkages between actors and institutions may play a key role in niche development and transition processes (Berkhout et al., 2010)

Another prevailing transnational linkage is the technical and financial support to niche development from international donor interventions, as illustrated, for example, in Bai et al. (2009), Patankar et al. (2010), Romijn et al. (2010), Verbong et al., (2010), and Jolly et al. (2012). Although the effects of donor interventions were not specifically addressed in these studies, such interventions were generally assumed to have a significant and generally beneficial influence on niche development.

While the MLP literature has thus adopted a rather uncritical perspective on donor interventions, another body of literature rooted in development sociology and anthropology and often referred to as the 'planned development literature' has developed a critical approach to analysis of donor interventions over the past twenty years (see e.g. Olivier de Sardan, 2005; Long, 2001)[3]. This approach, which sees donor interventions as the result of a negotiation between various conflicting interests, has shed light on the complexity of donor interventions and illustrated how high levels of conflict and unpredictability in such interventions often lead to low levels of the fulfilment of stated objectives (Long and Ploeg, 1989; Mosse, 2005). This body of literature therefore contrast with the images of predictability, harmony and success which proliferate in the grey development literature, as a result of institutions continually searching for funding (see e.g. Nygaard, 2010).

The aim of this paper is to enhance the MLP framework by bringing in the critical perspective on donor interventions mentioned above as part of the analysis of transnational linkages. This goal of enhancing the MLP framework has been accentuated by a specific interest in understanding why more than twenty years of donor involvement in the

[3] This article draws on insights from two research traditions that have studied the ‘interface’ between development actors and beneficiaries. The two approaches, which have developed in parallel fashion in the French-speaking and Anglophone worlds, have been termed the ‘actor-oriented approach’ (Long, 2001) and the ‘entangled social logics approach’ respectively (Olivier de Sardan, 2005).

development of a palm oil biomass waste-to-energy niche in Malaysia has generated relatively limited results compared to the objectives set out in project documents, not least the widely published expectations following the launch of the programs.

In the present case of niche development in Malaysia, the amount of financial support, technical assistance, institutional capacity-building and awareness-raising campaigns channelled through donor interventions has been substantial, but as described in our recent paper (Hansen and Nygaard, 2013), despite a short and momentary period of niche development during 2002-2006, the level of niche development turned out to be far lower than expected. An analysis based on the traditional MLP approach to the niche development in Malaysia identified four main factors hindering niche development: i) a reluctant implementation of energy policy; ii) a rise in biomass resource prices; iii) a limited network formation; and not least iv) the low performance levels of implemented plants, but the paper did not analyse further the reasons behind the apparently limited effects of donor interventions, which were addressing these issues both directly and indirectly.

This paper intends to fill this gap by exploring the factors that may explain the low level of efficiency in donor interventions in the development of a palm oil biomass waste-to-energy niche in Malaysia. The contribution of this paper to the existing literature on sustainable transitions in emerging economies therefore consists in both its conceptual and empirical examinations of this question.

The paper in structured as follows. Section 2 presents the analytical framework, followed by a presentation of the research methodology in Section 3. Section 4 provides the main analysis. These results are discussed in Section 5, before the main conclusions are drawn in Section 6.

2. Analytical framework

2.1. The conceptualisation of transnational linkages in the MLP

The MLP currently conceptualises transitions as the outcome of interactions between three levels of social aggregation: regimes, niches and landscapes. According to the MLP, niche proliferation is conditional on destabilising tensions at the regime level, which opens windows of opportunity allowing for the proliferation of innovative niche-level experiments. Such tensions may arise from processes at the landscape level and/or from internal regime-level dynamics. In empirical studies, these three levels are often conceptualised using specific territorial boundaries: regimes tend to be depicted with national features, landscape dynamics with international features, and niches with sub-national or local features. Therefore, the role of transnational linkages and the global dimension of transitions have to a large extent been encompassed in the MLP's all-embracing notion of the landscape concept (Geels, 2011). However, as Raven et al. (2012) argue, there is no reason to conceptualise the MLP levels with specific territorial boundaries. Social networks in niches, for example, are not necessarily exclusively local, as sustainability experiments and niche-level actors are often embedded within global flows of knowledge, technology and financial resources (Rock et al., 2009; Coenen and Truffer, 2012). Likewise, regimes may also be transnational in their physical extent and may be influenced by global actor networks and institutional linkages that may either support or destabilise them (Smith et al., 2010). Thus, both regimes and niches may exhibit a similar form of multi-scalar layering in their spatial reach (Wieczorek et al., 2012). However, the

understanding of niche formation and transition dynamics as shaped by interactions between actors and institutions situated across different spatial scale has only recently been introduced in the MLP framework (Binz et al., 2012). This paper draws attention to the flows of resources facilitated through international donor interventions as one element in a transnational analysis of niche development processes.

2.2. A critical perspective on donor interventions

The term 'donor interventions' denotes planned development programs and projects that are funded either by multilateral organisations, such as the World Bank and agencies of the United Nations, or by bilateral donor agencies that distribute aid between countries. Using MLP terminology, donor interventions may influence regime-level dynamics and niche development processes in two distinct ways. At the regime level, donor interventions may provide policy advice, technical assistance and institutional support through training, capacity-building and techno-economic appraisals to government agencies, industry organisations and other key regime-level actors. Many donor interventions aiming to promote renewable energy in developing countries encompass such activities with the aim of inducing institutional changes at the regime level in order to create more conducive framework conditions for the development of specific niches.

At the niche level, donor interventions may support technological experimentation activities by providing direct financial support to specific niche-level experiments. This financial support is often provided to projects aimed at demonstrating the technological and economic viability of such experiments. As Byrne (2011) found, donor interventions can thus bear the main initial investment risk for private-sector project developers, and thus contribute to creating a protected space in which niche development processes, such as experimentation and actor network formation, take place (Smith and Raven, 2012). In many developing countries, this is particular relevant since the financial sector may have limited experience with regard to renewable energy projects, making it difficult for potential investors to obtain financing. Donor interventions may comprise a combination of various elements in 'packages' in the form of large-scale programs. Such programs can both target actors and organisations at the regime level and influence processes at the niche level through the provision of direct financial support and technical assistance to specific projects.

The analytical framework presented below is based on elements from the development sociology and anthropology literature, which provide a critical perspective to understanding the role of donor interventions in niche development.

2.2.1. Donor interventions as arenas of struggle and contestation

Many donor interventions are formulated as ideal-type models conceived as progressing from policy formulation to implementation, and resulting in a final stage after which ex post evaluations can be made about the extent to which the original objectives have been achieved. This implicitly entails that interventions are constructed to proceed in a linear fashion, involving a step-by-step series of activities from policy formulation to concrete and measurable outcomes. Such processes are often elaborated in standardised management models, such as the logical framework approach (LFA).

As part of these ideal-type constructions, donor intervention models encompass normative political and ideological views on desired outcomes, which are conceptualised as more appropriate alternatives to previous practices (Mosse, 2005). In relation to this, Kontinen (2004) argues that the legitimacy of donor interventions in promoting desirable goals rests on two main ideological premises. The first is that donor intervention objectives, whatever the prevailing interpretation of their 'right' social and economic contents, are thought to be achievable, desirable and beneficial to all. The second is the belief that a well-meaning, rationally constructed intervention in a social process will lead to such development and that it is in everyone's long-term interest to foster such interventions and development. However, these premises invite criticism for at least two underlying assumptions.

First, and according to Long (2001), from a practical perspective such ideal and rational planning model constructions are a gross oversimplification of how interventions typically proceed in reality, as there is a great deal of incremental 'muddling through' involved. Since interventions most often address highly complex and integrated social and economic problems, which involve numerous feedback interactions, achieving intervention objectives is not foreseeable or manageable in any straightforward manner (Olsen, 2006). This means that, rather than simply executing an already specified plan of action with expected behavioural outcomes, donor intervention agencies are often engaged in achieving what is pragmatically and practically realisable in the given context.

Secondly, such ideal-type (means-end) constructions obscure the more fundamental point that interventions should not be treated as a discrete set of activities taking place within a defined time-space setting. Rather, interventions should be considered to be one element of a continuous flow of social and economic life with on-going relations evolving between various social actors. Thus, following Long and Ploug (1989), interventions do not have sharp boundaries in time and space and are always part of an on-going, socially constructed and negotiated process. These on-going processes are occupied by social actors navigating a contested social field in which they exercise economic and political influence among various competing interests. The targeted 'recipients' or 'beneficiaries' of donor interventions are therefore not passive agents, as they actively interpret, react and position themselves in respect to the interests of other actors, including those of donor interventions (Arora and Romijn, 2012). In such contested fields, donor agencies may have limited operational control in steering processes in certain desirable directions owing to a lack of legitimacy, authority and bargaining power in relation to other influential actors. This means that the 'outcomes' that may be expected from donor interventions are greatly influenced by a variety of actors exercising and mobilising power in line with their heterogeneous interests and intentionalities (Grammig, 2002). In order to enhance their influence among the diversity of competing interests, donor agencies need to mobilise interests around their desired objectives. According to Mosse (2005), this requires donor interventions to engage in a struggle to persuade, negotiate and gain legitimacy from a supporting network of actors concerning these objectives. The perspective presented here assumes that donor interventions thereby open up new arenas of struggles over resources, interests, rationalities, interpretations and influence between various actors (see Nygaard, 2010). This follows the actor-oriented approach suggested by Long (2001), which, among other things, argues in favour of examining conflicts of interest and the contradictory motives and perceptions of various actors as a main element of donor intervention analysis (Bierschenk, 1988). An analysis of conflicts of interest between donor agendas and between influential

local actors will inform the analysis of why donor interventions in this case do not seem to have fulfilled their own objectives. It should be noted that this perspective does not direct attention towards actor interests at an individual level, but rather attempts to highlight the underlying systemic rationale of 'larger' actor logics (Long, 2001).

3. Data collection methodology

The present paper is part of a wider study of the development of the palm oil biomass waste-to-energy niche in Malaysia, which has included numerous plant visits and interviews with key niche-level actors (see Hansen and Nygaard, 2013). The paper focuses on three main donor-funded interventions that have been particular influential with regard to the development of a palm oil biomass waste-to-energy niche in Malaysia, respectively the COGEN program (1991-2004), the DANCED/DANIDA program (1994-2006) and the BIOGEN program (2002-2010). These interventions were studied by consulting palm oil biomass and energy-sector experts in Malaysia, as well as through a comprehensive review of the academic and grey literature on the development of the palm oil biomass waste-to-energy niche in Malaysia.

The primary data collected for this paper consists of thirty interviews with: i) former program managers of the three donor interventions, including expatriates and representatives of local implementing agencies and local consultants; ii) representatives of different energy-related governmental agencies; and iii) palm oil industry organisations in Malaysia. The interviews were conducted in Malaysia and Denmark in 2010 and 2011. The literature review comprises a substantial number of publicly available reports undertaken during the programs, such as barrier analysis, baseline studies and biomass resource inventories conducted by local and expatriate consultants. Added to this are various unpublished materials and internal documents, such as internal evaluation reports and technical reports (including market analysis and feasibility studies), collected through personal contacts with various actors involved in the programs. The overall approach highlighting the conflicting interests of key actors in the niche formation process guided the review process, with due attention being given to traditional 'source criticism' in analysing the various internal and publically available documents.

4. Presentation and analysis of twenty years of donor interventions

The twenty years of donor intervention aimed at enhancing the use of biomass waste for electricity production in Malaysia consists of three programs. The first program, the COGEN program, was a regional program targeting the Southeast Asian region, while the DANCED/DANIDA and the BIOGEN programs were national programs. All programs aimed at capacity-building, knowledge dissemination and improvement of the enabling framework for investments in biomass waste-to-energy plants, while the COGEN and the BIOGEN programs also provided economic support in terms of loan facilities and subsidies for investment. COGEN and BIOGEN started as short-term programs, but ended up being long-term interventions after subsequent phases were added or the first phase extended. The implementation periods of the different phases of the three programs are illustrated in Figure 1.

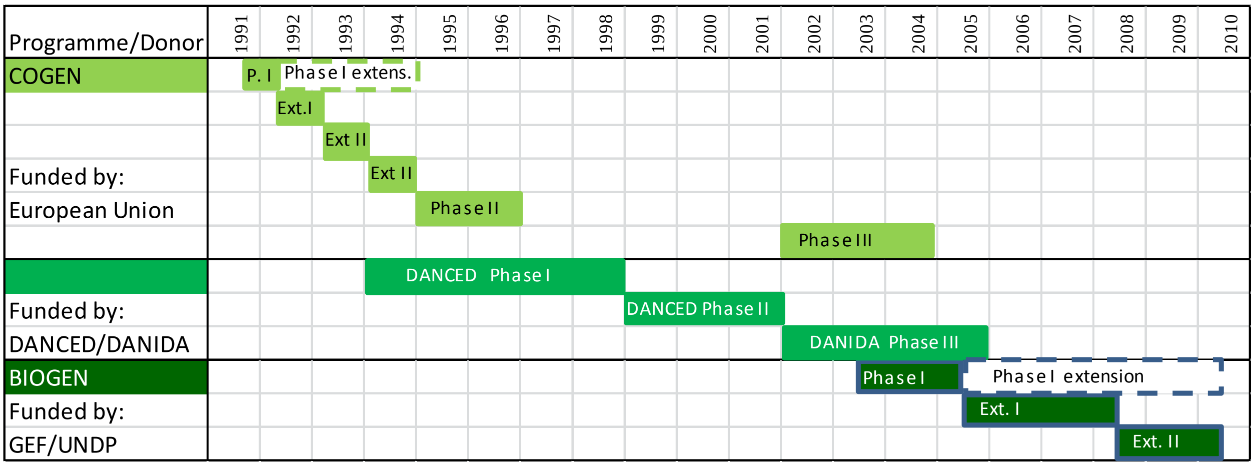

Fig. 1. Overview of the different phases of the three interventions.

This section provides a description of the main objectives of each of the three donor interventions and the measures adopted. This is followed by an analysis of the key issues that, according to interviews and reviews of evaluations, were ascribed particular importance in hindering the donor interventions in achieving their objectives. An analysis and discussion of the underlying factors shaping the outcome of the interventions is presented in Section 5.

4.1. The EU-ASEAN COGEN program

Within a long-term agreement to increase economic cooperation between the European Union (EU) and the Association of Southeast Asian Nations (ASEAN), the EU–ASEAN COGEN program was funded by the European Commission and completed in three phases in the period from 1991 to 2004. According to AIT (2004), the overall aim of the program was to promote proven and efficient biomass cogeneration technologies from European equipment suppliers to Southeast Asian countries, focusing primarily on agro industry-based energy generation. The COGEN program aimed at contributing to meet the growing energy demand in ASEAN countries by introducing more sustainable alternatives to the predominant fossil fuel-based energy systems.

In the first phase of the COGEN program (1991-1994), the main aim was to identify the biomass energy market potential and business opportunities for European equipment suppliers. A number of background papers, feasibility studies and market reports were produced, which often highlighted a highly promising potential in the ASEAN countries, particularly in the Malaysian palm oil industry (see e.g. Alanoca, 1993; DEA, 1993; Guillaume, 1993). This provided the basis for the European Commission's decision to proceed with a second phase of the program (1994-1997), which focused mainly on engaging European technology suppliers in full-scale demonstration plants (Dewulf and Leelakulthanit, 1997).

The COGEN 2 program provided financial support, in the form of a maximum grant of 15% of the total investment, and advisory services (such as feasibility studies and advice on financial models) for specific projects that were considered to have a high level of replication potential in the individual countries. During COGEN 2, the implementing agency in Malaysia, SIRIM Berhad, acted as a business partnership facilitator providing potential investors with product information and advice to facilitate their procurement process and

European technology suppliers with market information. The COGEN 2 program thereby served as a private sector-oriented export platform for European technology suppliers, by identifying possible linkages with potential investors and end-users in Southeast Asia. Various promotional activities in the energy and palm oil sector were also undertaken together with the provision of institutional capacity building and assistance to energy-related governmental agencies and palm oil industry organisations.

The COGEN 3 program (2002-2004) continued the promotional activities undertaken during COGEN 2, which included information and awareness-raising campaigns, training seminars, conferences, and plant visits for governmental agencies, project developers, potential end-users and financial institutions. A main objective of COGEN 3 was to implement a number of full-scale demonstration plants in Malaysia and other Southeast Asian countries. This was done by providing direct financial support covering up to 15% of the total investment costs (with a maximum amount of 400,000 Euros) and by offering technical and institutional assistance to project developers in plants that were considered eligible to receive support (AIT, 2004). The construction of these so-called 'flagship' plants was considered essential to convince potential investors and end-users of the financial and technological viability of palm oil biomass waste-to-energy plants (COGEN 3, 2012).

4.2. Main achievements of the EU-ASEAN COGEN program

By the end of the three COGEN program phases in 2004, only three palm oil biomass waste-to-energy demonstration plants had been constructed and put in operation in Malaysia, one implemented under COGEN 2 and two under COGEN 3 (Shuit et al., 2009). Although the COGEN program aimed at introducing new technology into ASEAN countries, two of these plants were constructed at existing palm oil mills and did not diverge greatly from the typical cogeneration plants being installed in the palm oil industry at that time (in terms of fuel source used and plant efficiency) (COGEN3, 2012). An official evaluation report of the COGEN program, undertaken by the European Commission in 2009, notes with some dissatisfaction that surprisingly little concrete output was achieved in terms of the number of installations in operation (EC, 2009). The role of the COGEN program in stimulating the sale of European equipment to ASEAN countries had consequently been limited. Since the construction of demonstration plants constituted a main purpose of both COGEN 2 and COGEN 3, the evaluators of the report concluded that the COGEN program had a "poor implementation ratio" (EC, 2009; 50). The internal evaluation report of the COGEN program conducted in 2004 also indicated that the high aspirations to be found in project descriptions were only reflected in activities on the ground to a very limited extent, which "with hindsight, was too ambitious" (AIT, 2004; 50). Owing to the limited number of plants constructed, actual private-sector business partnerships stimulated under the COGEN program were also limited, even though this had also been a main goal of the program (EC, 2009).

The evaluation reports assessed in this paper addressing the effectiveness of the COGEN program in achieving its goals identified the limited duration of the individual phases of the program as a main impediment to the lack of progress in terms of plants installed (AIT, 2004; COWI, 2006; EC, 2009). Due to the limited time available, the projects found eligible for financial support under COGEN 2 and COGEN 3 were either at a too early stage of maturation or simply could not meet the deadlines. Since the program was implemented over a twelve-year period, in principle this long period should have made possible a longer-

term planning period in which sustained efforts could be devoted to bringing specific projects towards the commissioning stage. Yet, as the program consisted of three consecutive phases, each lasting around three years, the short-term duration of these phases apparently worked against achieving the immediate goal of the program to achieve a high number of installations.

Interviews with former expatriate managers of the COGEN program pointed towards another issue which had influenced the limited number of demonstration plants constructed under the COGEN program. This concerned an apparent change in the European Commission's (EC) aspiration to provide direct financial support to demonstration projects. This change occurred from the late 1990s and was due mainly to increasing political concerns and criticisms about the indirect subsidisation of European technology suppliers through EC-funded donor intervention programs. These criticisms were raised internally in the EC, as well as by ASEAN country partners in the COGEN program, who argued in favour of redirecting these indirect subsidies towards providing institutional assistance. In response to this, the EC shifted the focus towards awareness-raising and institutional capacity-building, which led to a gradual reduction in the amount of financial support provided to individual projects under the COGEN program. This meant that the economic incentives given to project developers under the program were substantially reduced during the period between COGEN 2 and the implementation of COGEN 3. As an example of the low investment subsidy under COGEN 3, one of the plants constructed in Malaysia in 2004, for which the total investment amounted to RM 45 million (13.8 US$ million[4]), was awarded a RM 1.8 million (0.55 US$ million) grant corresponding to only 4% of the total investment.

Two former expatriate managers of the COGEN program also mentioned the widespread lack of support from Tenaga Nasional Berhad (TNB), the national utility company in Malaysia, as a main explanation for the limited number of demonstration plants constructed under the program. According to the managers, the TNB obstructed the implementation of the COGEN program during all three phases and showed very little, if any, interest in supporting the introduction of grid-connected renewable energy projects in general and biomass projects in particular. This understanding was confirmed during an interview with a representative of the implementing agency of the COGEN program in Malaysia. Program managers were therefore confronted with the challenge of achieving important donor objectives against the interests of powerful actors in the Malaysian energy sector.

Under the COGEN program, the level of awareness-raising campaigns, training and technical assistance, and capacity-building efforts conducted at various levels are reported to have been substantial (AIT, 2004), as were the amount of background reports, policy proposals and national strategy recommendations (EC, 2009). Yet, the evaluation reports emphasised that the lack of a supportive policy framework at the national level constituted a main obstacle to the construction of demonstration projects under the COGEN program. In EC (2009; 50), the evaluators stressed that "]..the lack of supportive policy environments at national level may have proved too large a barrier for fledgling cogeneration projects"]. Similarly, COWI (2006; 11) emphasised that the "]..lack of supportive national policy measures and economic incentives"] was a main barrier in achieving more installations under the COGEN program. These excerpts highlight the slow rate of implementations not

[4] Throughout this paper, an exchange rate conversion factor of 3.269 has been used to convert the Malaysian Ringgit (RM) to US Dollars (US$), which is based on a ten-year average exchange rate in the period 2000-2010.

only of installations but also of the policy seen as a precondition to make it happen, and they illustrate the high level of frustrations from the donor side when observing ‘good advice’ being neglected for political reasons that were not articulated.

4.3. The DANCED/DANIDA program

A main purpose of the Danish Cooperation for Environment and Development (DANCED) program (1994-2001) was to provide training and institutional capacity-building in national ministries and central government agencies in order to strengthen the environmental planning and management competence and to support policy and strategy formulation. In Malaysia, the DANCED program was implemented in two phases during 1994-1998 and 1999-2001. In 2001, due to a regime shift in Denmark, DANCED's activities were taken over and continued with some redirection by Danish International Development Assistance (DANIDA) in the period 2002-2006 (DANCED-EPU, 2001; Hezri and Hasan, 2006). During the late 1990s, the DANCED/DANIDA program contributed to establishing Pusat Tenaga Malaysia (PTM) (the Malaysia Energy Centre), an independent research institution set up to undertake policy analysis and energy planning and to co-ordinate various activities in the renewable energy sector. Throughout the DANCED/DANIDA program, various training and assistance activities were provided to employees at PTM, which, from around 2005, also focused on enabling PTM to become the secretariat of Clean Development Mechanisms (CDM) projects being implemented in the energy sector.

In the period 1998-2001, expatriate consultants from the DANCED/DANIDA program provided advice to relevant government agencies in the preparatory work for a new energy policy, which was adopted in 2001 under the 8th Malaysia Plan (covering the period 2001-2005)[5]. The new policy introduced renewable energy as a new strategic ‘fifth fuel’ resource under the country’s Fuel Diversification Policy and set a target of renewable energy to provide 5% of total electricity generation by 2005 (EPU, 2001). This target was to be achieved by different fiscal incentives to promote renewable energy projects, such as income tax exemptions of 70% on statutory income, investment tax allowances of 60% of capital expenditures, and import duty and sales tax exemptions on imported machinery and equipment. According to Kettha (2009), a report commissioned by the DANCED program in 1999 is considered to have been particularly influential in drafting this policy, and key elements from this proposal, such as a tariff for renewable energy and the removal of trade barriers, were subsequently incorporated into its final version. The DANCED report considered the utilisation of biomass waste from the palm oil industry to be the most attractive ‘low hanging fruit’, and the final energy policy accordingly focused mainly on palm oil biomass as a means of achieving the renewable energy target (DANCED, 1999).

4.4. Main achievements of the DANCED/DANIDA program

According to previous expatriate program managers and program evaluations (DANCED, 2001; DANCED-EPU, 2001), a main achievement of the DANCED/DANIDA program in Malaysia was considered to be the incorporation of key elements of the proposal on renewable energy into the energy policy adopted in 2001 under the 8th Malaysia Plan. Yet,

[5] This was prepared under the sub-component of the DANCED/DANIDA program entitled ‘Support to Development of a Strategy for Renewable Energy as Fifth Fuel in Malaysia’.

at the same time, the program managers also stressed that, subsequent to being processed during political negotiations concerning the financial budget in the national parliament, a number of important elements of the original and far more wide-ranging DANCED/DANIDA proposal were either excluded or watered down substantially. For example, two suggestions for establishing a renewable energy fund and for reducing the level of subsidies given to conventional fossil fuel-fired power plants were not included in the final energy policy. In addition, the tariff of 0.14-0.17 RM/kWh (0.043-0.052 US$/kWh) eventually offered under the SREP program was also much lower than had been suggested, but not least a regulatory scheme which would oblige TNB to purchase certain quantities of power from renewable energy was rejected. Rather, power-purchasing contracts were to be negotiated bilaterally between project developers and TNB on a 'willing supplier, willing buyer' basis. This created an unequal bargaining situation in power-purchasing contract negotiations, which largely favoured the interests of TNB. An earlier expatriate program manager emphasised that, mainly due to a lack of sufficient 'political support', the resulting policy turned out to be much less ambitious in terms of the regulatory framework that was drawn up to support renewable energy, leaving the full range of supporting instruments suggested in the DANCED/DANIDA proposal unexploited.

Continued resistance from TNB to support renewable energy was another main stumbling block, which contributed to reducing the impact of the DANCED/DANIDA program. Since TNB has a monopoly over electricity transmission and distribution, and owns around 60% of the overall generation capacity in Malaysia, support from this powerful actor in the energy sector was crucial. However, a former expatriate program manager explained that TNB was not willing to accept even the least problematic options. This included even apparently economically viable solutions such as co-firing of relatively small percentages of palm oil biomass waste in the existing conventional power plants. TNB claimed that it had limited incentives to purchase electricity from decentralised power plants since this would require investments in additional back-up capacity (Sansubari, 2010). In addition, due to a lack of experience in managing renewable energy in the energy system, TNB envisaged a number of difficulties, such as uncertainties in matching supply and demand, which made them react obstructively.

A main rationale underlying the promotional activities conducted under the DANCED/DANIDA program was to create awareness about the commercial opportunities of biomass waste-to-energy generation and thus encourage palm oil producers to become energy producers. This should have encouraged palm oil mill companies to venture into a new business area, enabling them to utilise their otherwise unproductive biomass waste as a new, valuable and profitable resource by providing them with an additional income from selling electricity. However, according to several previous program managers, the main 'program beneficiaries' in the palm oil industry did not see electricity production as one of their core business activities, and showed little interest in becoming independent power producers. According to consultancy reports conducted by expatriate and local consultants under the DANCED/DANIDA program, a main reason for this cautious attitude in the palm oil industry was the limited familiarity with power plant management and energy generation business in general, but also that energy generation was generally considered less commercially attractive than alternative biomass waste-utilisation options being investigated and tested at the time (Evald, 2005; 2006).

4.5. The BIOGEN program

The Biomass-based Power Generation and Cogeneration Project program (BIOGEN) was implemented by Pusat Tenaga Malaysia (PTM) in Malaysia in the period 2002-2010 and was funded by the Global Environment Facility (GEF) and the United Nations Development Program (UNDP). The overall objective of the BIOGEN program was to reduce the growth rate of greenhouse gas (GHG) emissions from fossil fuel-fired combustion processes in Malaysia by accelerating palm oil biomass-based power generation (GEF, 2001). This was to be achieved mainly through the provision of information and awareness enhancement campaigns, policy studies, institutional capacity-building and financial support to demonstration projects. The financial support was provided in the form of a RM 28 million (8.6 million US$) renewable energy fund, which would distribute soft loans to project developers. One of the ambitious aims of the BIOGEN program was to reduce GHG emissions from energy generation in Malaysia by 3.8% within the first five years of operation compared to a baseline without any interventions implemented (Aldover and Yang, 2010).

A main emphasis in the BIOGEN program was on establishing demonstration projects, which were considered to comprise a key catalyser for further project replications. As was laid out in the project description, these demonstration projects should not only demonstrate the technical and economic feasibility of palm oil biomass waste-to-energy plants, but also showcase a number of important components of the BIOGEN program, such as a viable business and financing model and a workable power-purchasing agreement standard (GEF, 2001; Aldover and Nethi, 2004). As in the COGEN program, the demonstration projects were therefore considered important in building confidence for potential investors in the palm oil industry. Financial support for demonstration projects was supplemented by promotional activities in the palm oil industry aimed to encourage palm oil companies to engage in energy generation.

4.6. Main achievements of the BIOGEN program

Among the main achievements of the BIOGEN program, the mid-term evaluation report conducted in 2004 (Aldover and Nethi, 2004) and the final evaluation report performed in 2010 (Aldover and Yang, 2010) found that the awareness-raising campaigns undertaken in the energy sector and palm oil industry had contributed significantly to increasing the familiarity with palm oil biomass waste-to-energy generation in Malaysia. The training and technical assistance provided under the program was also attributed an important role in increasing the capacity of relevant government agencies to conduct biomass energy-relevant planning and analysis. Furthermore, the policy studies conducted under the BIOGEN program were considered to have had an influence on the government's decision to raise the tariff level under the SREP in 2006 to 0.17-0.19 RM/kWh (0.052-0.058 US$/kWh) and again in 2009 to 0.19-0.21 RM/kWh (0.058-0.064 US$/kWh) (Aldover and Yang, 2010).

In spite of these achievements, however, the final evaluation report deemed the BIOGEN program to have been only "marginally satisfactory" in achieving the program objectives and noted that "]..the project results did not come out at the time and level as expected in project designs"] (Aldover and Yang, 2010; 10). A primary reason for this rather disappointing conclusion was attributed to the lack of progress made concerning the

construction of demonstration plants under the program. Despite the priority given to this program component, only one palm oil biomass waste-to-energy plant was constructed and put into operation as part of the BIOGEN program, and moreover the construction of this plant was substantially delayed and never reached continuous operation. Consequently, only RM 5 million of the RM 24 million made available from the renewable energy fund was used under the Biogen program's budget to support demonstration projects.

According to the final evaluation report and to representatives of the implementing agency of the BIOGEN program in Malaysia, a continuing lack of interest from the palm oil industry was a main impediment to achieving a higher number of demonstration plants. The lack of interest was described in terms such as "negative industry perception", due to a "]..lack of confidence in the feasibility of biomass power generation"] (Aldover and Yang, 2010; 15). The low feasibility also seems to have been acknowledged by the donors to a large extent. A report commissioned by the BIOGEN program in 2007 found the internal rate of return (IRR) of a 6MW plant with a total investment of RM 48.0 million to be as low as 4.08% (equivalent to a payback period of 12.4 years), which did "]..not show a very attractive return for power plant development in palm oil mills..], in which]..only a payback period of 3-4 years is considered attractive]" (Ngadi and Mustapha, 2007; 53). The final evaluation report resigned itself to stating that the resolution of this issue "]..is something that is not immediately within the control of program"] (Aldover and Yang, 2010; 15). The first phase of the BIOGEN program was initially planned to take two years, and was to have been followed by a second phase. However, due to the difficulties in identifying a host for the demonstration plants, the first phase was extended twice, and after the disappointing results achieved after seven years, the second phase was abandoned.

5. Discussion

As is evident from the analysis presented above, a number of objectives set out by the donor interventions to create conducive conditions for niche development were not achieved. While there may be many reasons for this, the discussion in this section will address the interests that may have constrained the fulfilment of these apparently well-conceived and important objectives. The discussion will focus on the reluctant implementation of energy policy, such as suppression of fossil fuel subsidies and the implementation of a feed-in-tariff, as well as on the related difficulties experienced in attracting investment interest from palm oil mill companies.

5.1. Suppression of fossil fuel subsidies

Fossil fuel subsidies are important barriers to the economic viability of renewable energy investments and, on top of the direct effect, eliminating such subsidies could in principle finance other incentives for energy production from biomass waste. Suppression of subsidies on fossil fuel was therefore a main element in the first proposal for an enabling policy for biomass waste to energy policy in 1999. This policy was only implemented some nine years later, in 2008. Throughout this period, the continuation of fossil fuel subsidies was seen as an obstacle by succeeding donor programs, and program managers explained this with reference to a lack of political will on the part of the government.

Addressing this phenomenon from an interest perspective shows that these difficulties may have been foreseen, as most groups of actors had an interest in maintaining

the subsidy. The industrial organisations representing the industry in general would have an interest in maintaining the subsidy in order to ensure low energy costs. The utility, which had a monopoly on electricity transmission and distribution, and which was not allowed to raise tariffs, also had an interest in maintaining the subsidy to reduce its losses (Sansubari, 2010). Even palm oil mill owners' organisations would be expected to be in favour of a generally low energy price for the sector rather than in uncertain future business opportunities as electricity producers. In fact, only the manufacturers of boiler and power plant equipment would have a clear interest in suppressing the subsidies, as they had a direct interest in an increased market for boiler equipment. Politicians, on the other hand, faced a dilemma: although fossil fuel subsidies weighed heavily on an already stressed state budget, they faced a general interest in maintaining the subsidy and thus keeping energy prices low. This would provide support from industry, but more importantly it would avoid unrest and political pressure from the population, who in a developing country context typically see increasing energy prices as a responsibility of the government.

Policy proposals from donor programs and expatriate experts were therefore not enough to convince national politicians to go in that direction, and apparently they maintained the existing subsidy levels until serious increases in oil prices forced the government to abandon a fixed energy price policy because it became economically impossible to maintain it with subsidies. This example illustrates that a policy that seems quite obvious from a northern and western perspective can be difficult to implement in another context, as in Malaysia, because strong groups of actors had an interest in maintaining the existing system.

5.2. Slow introduction of feed-in-tariffs

A feed-in-tariff (FIT) obliges electricity utilities to purchase certain quantities of electricity from renewable energy generators, usually in a given time period and at a fixed price set by the government. The cost of FITs is normally assumed by utilities and then passed on to consumers. In a number of European countries, the use of FIT has led to the widespread diffusion of renewable energy, which has created extensive political interest in its use as an appropriate model to support renewable energy deployment (Haas et al., 2011). This is not least the case for many donor organisations, for which FIT systems are congruent with the promotion of electricity sector reforms in developing countries in the direction of market liberalisation and support for private independent power producers (IPP) (Azuela and Barosso, 2011).

The introduction of a FIT to support renewable energy in Malaysia was also proposed early on, in 1999, as part of the DANCED/DANIDA program. This led to the adoption of a general power purchasing agreement (REPPA) comprising a minimum tariff for renewable energy as part of the national energy policy adopted under the 8th Malaysia Plan in 2001. The REPPA, however, was not a FIT per se, with fixed tariffs and an obligation for TNB to purchase certain quantities of produced electricity. Rather, project developers and TNB were jointly responsible for negotiating a suitable REPPA agreement and consequently, TNB only accepted the lowest possible tariff rate and deliberately delayed and obstructed the project approval process (Sovacool and Drupady, 2011).

Although two marginal tariff increases were made in 2006 and 2009, it was not until a 'real' FIT became operational in 2011 that the tariff for biomass energy was raised significantly from 0.21 RM/kWh (0,064 US$/kWh) to 0.31 RM/kWh (0.10 US$/kWh). The FIT,

which may partly be the result of advice and information provided through the three donor programs, also comprised an obligation for the utility to buy the produced electricity under transparent conditions. The tariffs under the REPPA and FIT are shown in Figure 2.

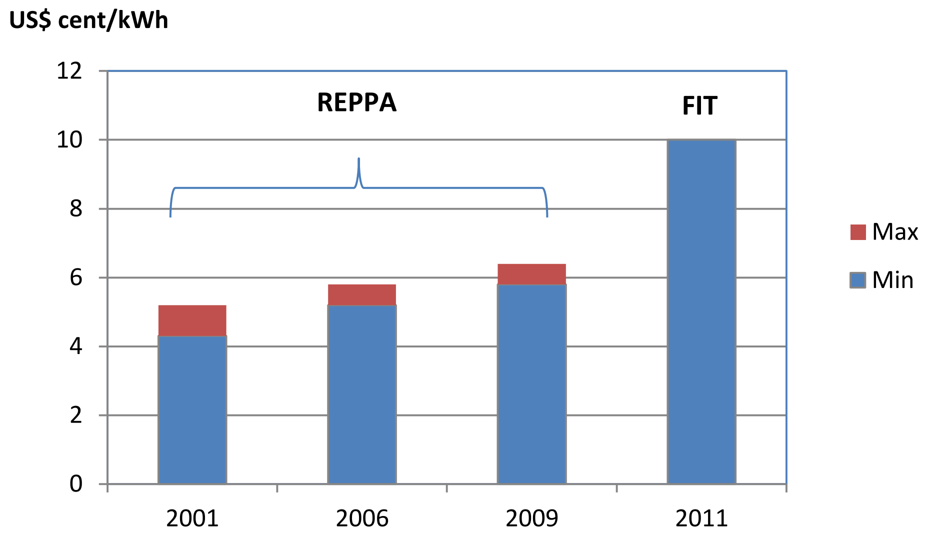

Fig. 2. Development of tariffs for IPPs to the national utility (by using an average exchange rate conversion factor of 3.269 in the period 2000-2010). The average inflation rate in the period 2000-2010 was 2.1%.

But how can it be explained that the FIT became operational only after twenty years of donor intervention in the area. Compared to the elimination of subsidies discussed above, which would increase energy prices for all actors, the FIT is a targeted measure, which would provide a financial viability to the industrial owners, with a smaller increased cost of electricity. This means that this measure could be expected to meet less resistance from the same main actors as the elimination of subsidies. On the other hand, the beneficiaries of the FIT – the palm oil mills and the local boiler and power plant equipment manufacturers – would be expected to be a strong proponent to this.

Palm oil industry organisations have an interest in a higher tariff for at least three reasons: i) to improve overall business opportunities for palm oil mill companies by providing additional income from selling electricity; ii) as a solution to the generic biomass waste-disposal problem in the palm oil industry; and iii) as part of supporting a broader ecological modernisation process of the palm oil industry (Hansen and Nygaard, 2013). Therefore, not surprisingly, these organisations were influential in promoting the tariff rise that occurred under SREP in 2006 and 2009 (Sovacool and Drupady, 2011).

On the other hand, from the perspective of the utility, paying a premium for renewable energy without being able to transfer this cost on to consumers would simply challenge its profitability. The obvious solution to balance this would be to abandon the fixed consumer tariff policy and finance the FIT by increasing the tariff by 1% (as was done in 2011). The politicians, however, were hesitant, maybe because they feared negative popular reactions even to a minor increase in consumer tariffs, but most likely because they were sensitive to the experiences from the electricity liberalisation process in the 1990s, in which private IPPs were given what were seen as very lucrative (long-term) power purchasing contracts by the government and which had led to widespread public criticism of the

government (Rector, 2005). According to McNish et al. (2010), the perceived risk of 'overpayment' for IPPs is therefore likely to have spilled over into political discussions about renewable energy tariffs, and apparently, according to the preparatory work for the FIT elaborated in Kettha (2009), only several years of practical experience of low investment interest, combined with pressure from donors and palm oil mill industry organisations, were finally sufficient to make it happen (see also Aldover and Yang, 2010).

5.3. Attracting investment interest from palm oil mill companies

The overall objective of the three donor interventions was to increase the use of palm oil biomass waste for energy in Malaysia. This could have been done by engaging the national utility in using waste resources in new power plants erected by the utility, as happened in Denmark during the same period (see e.g. Raven, 2005). In this case, however, being the producers of the waste, palm oil mill companies were expected to engage as investors in a new business area and produce electricity. This approach conformed with the dominant development discourse at the time, promoting IPPs as part of the privatisation and unbundling of the national utilities in developing countries (Wamukonya, 2003).

Palm oil mill companies' decisions on investing in biomass power plants are balanced between their interest in engaging in new high-risk investments and the continued expansion of their core business activities. Generally, palm oil mill companies had limited experience in energy generation, which had not been part of their core business (Evald, 2006). Therefore, to diverge from well-known business activities and become energy producers would require a considerably higher level of return from investments compared to what could be achieved in the expansion of their existing activities.

In addition, palm oil mill companies were concerned about highly uncertain aspects of biomass energy plant investments, such as technical performance, future biomass resource prices and future tariffs and regulations. At a late stage development of the niche, the largely negative performance of the plants actually in operation added to this concern about the high levels of risk (see Hansen and Nygaard, 2013). Therefore, compared to continuing and expanding core business activities, palm oil mill companies generally considered the large upfront capital investments needed in biomass power plants as a highly risky business venture, which could only be driven by high expectations to future profits (Aldover and Nethi, 2004).

Traditionally in the utility regime, power sector investments have been considered a long-term and relatively secure investment, with limited capital costs due to stable and increasing demand, well-known technology and security of fuel supply. However, in this case the expectations of high risk, the difficulties of access to capital and the likelihood of high profitability on alternative investments such as expanding existing core activities proved to require high expectations of profitability in order to attract investment. The 'necessary' level of return on investments required to attracting IPPs on conventional coal and gas technology seems to have surprised the proponent of private-sector engagement in the power sector in Malaysia in the 1990s, when the first IPPs achieved IRRs of up to 25% (Rector, 2005). Maybe unsurprisingly, this case illustrates that palm oil industry-based IPPs are equally concerned about the relationships between risk, profitability and alternative investments.

This example is hence adding on to a body of literature providing concrete examples of difficulties in attracting private-sector engagement in the power sector, especially in the

poorest developing countries (see e.g. Wamukonya, 2003). In this case it remains unclear to what extent the donor programs acknowledged from the beginning that the choice of private-sector involvement, benefitting from access to knowledge and capital, would also require much higher returns on investments than investment carried out by the national utility. This is doubtful, as it may be difficult for donor organisations to mobilise funds for investment support to large private companies while at the same time accepting expectations of very high profit rates (Smith, 2003). In this regard, there is a clash of cultures, expectations and interests, not only between the private sector, utilities and politicians at the national level, but also between private-sector support, the donor community and the donor constituency, which in practice makes investment support for private-sector engagement difficult.

6. Conclusion, policy and conceptual implications

In this case of support to niche development in Malaysia, the amount of financial support, technical assistance, institutional capacity-building and awareness-raising campaigns channelled through donor interventions has been substantial. Yet, as described in our recent paper, despite a short and momentary period of niche development during 2002-2006, the level of niche development turned out to be far lower than expected (Hansen and Nygaard, 2013). Our analysis, based on the traditional MLP approach to niche development in Malaysia pointed toward four main factors hindering niche development: i) the reluctant implementation of energy policy; ii) a rise in biomass resource prices; iii) limited network formation; and not least iv) the low performance of implemented plants.

This paper has explored the factors that may explain the low efficiency of donor interventions in terms of policy advice, and hence provide some insight into why the energy policy was only reluctantly implemented. The concluding remarks will address three crosscutting issues: i) the limited effect of advice and knowledge dissemination; ii) the challenge of transferring business models from developed to developing countries; and iii) the unpredictable and short-term donor interventions. Finally we will provide some reflections on how to address donor interventions as one of several transnational linkages in the MLP framework.

6.1. Limited impact of advice and knowledge dissemination

A large proportion of the twenty years of donor interventions has been dedicated to knowledge transfers, capacity building, feasibility studies and policy advice. The paper has shown that the three programs had high expectations regarding what could be achieved in terms of changes in enabling frameworks for private-sector engagement in energy production mainly by conveying the right information through short term programs. The governments' suppression of subsidies for fossil fuels and the implementation of a FIT were essential achievements, which to a large extent may be attributed to the activities supported by the three programs. However, these measures were implemented about ten years after they were first suggested, and this reluctance has been instrumental in the falling interest from both equipment manufacturers and palm-oil mills, which again to some extent may have spilled over to low plant performance. The discussion in this paper shows that 'facilitating' policy implementation by donor programs is difficult and takes time. This may to some extent be because national governments are reluctant to receive advice from

what could be seen as external interests, but as in this case it is mainly because of the relatively weak interest of any national actors in changing policy, and strong interest of institutional and political actors at both the niche and the landscape levels in maintaining existing policy. This shows that a proper stakeholder and interest analysis is important before any policy-related intervention, but it also calls for prudence regarding what can realistically be achieved by external interventions in this area.

6.2. The challenge of transferring private-sector models

The continuing lack of interest of private investors in investing in electricity production, as shown above, can to a large extent be seen as the result of the reluctant implementation of an energy policy providing the necessary incentives to invest, but it may also to be seen as a more profound challenge in transferring a private-sector model of electricity production from the EU to Malaysia. The analysis above shows that investment in biomass waste-to-energy production proved to be attributed a much higher risk in Malaysia than in Europe. This was due to greater uncertainty regarding a number of key factors linked to the sector, such as technical performance, fuel availability and future tariffs, but it was also to a large extent the result of the Asian financial crisis and the generally uncertain investment climate in Malaysia, which is typical for developing countries. This higher level of risk and its effects may not have been taken sufficiently into account in the first plans presented by donors, and interviews indicate that, even at a late stage in development, a large group of actors, including donors, utilities and government, were not prepared to support a sufficient risk premium in order to make this model attractive for private investors. This shows the difficulties involved in transferring a business model from a developed country context to a developing country context, and calls for serious caution in transferring experiences from one economic and political context to another, even when this is in conformity with the dominant development agenda at the time.

6.3. Unpredictable and short-term donor interventions

A final and overarching issue of importance for the effectiveness of donor interventions is their unpredictability. As outlined above, the COGEN and BIOGEN programs started out as short term (1-2 year) interventions, and turned into being long-term programs, with a number of extensions, and both foreseen and unforeseen subsequent phases. This shows the ability of donor programs to adjust to local circumstances, but it certainly also indicates that local actors should be reluctant to invest too much capital, interest and integrity in donor-related programs, as their futures are highly uncertain. Projects often have a quick turnover of managers, as in the case of the BIOGEN program, which had five chief technical advisors during seven years of implementation (Aldover and Yang, 2010). As in the case of DANCED/DANIDA, programs are committed in short phases of two to three years and subsequent phases are uncertain, and may be depending on political changes in donor home countries, new international agendas and new approaches in vogue in the donor community. This relates to a broader discussion about the volatility of aid channelled through donor programs, which may position 'recipients' as highly vulnerable to over-dependency of donor support (Bulíř and Hamann, 2001). While the precise effects of the uncertainty of donor programs are difficult to measure, the interviews underlying this paper strongly indicate that the short duration of each intervention and their

unpredictability can be seen as an important impediment to the programs in reaching their objectives. This call for better program preparation, followed by long-term interventions, which can create the necessary trust and stability.

6.4. Donor interventions, transnational linkages and the MLP framework

This paper is a response to a lack of conceptual and empirical focus on the role of transnational linkages in niche development and transition processes in the MLP framework. To establish greater understanding of these issues, the paper set out to explore the factors that may explain the limited influence of donor interventions in the development of a palm oil biomass waste-to-energy niche in Malaysia. In contrast to the images of planning, predictability, harmony and success often conveyed in the grey literature on donor interventions, this paper has been inspired by a perspective that assumes that donor interventions create new arenas for struggle over resources, interests, meaning, interpretations and rationalities between various actors. This approach has in our view provided interesting results and the paper thereby provides a conceptual contribution to the understanding of transitional linkages in the MLP. Some recent studies, such as Byrne (2011) and Arora and Romijn (2012), have tentatively explored these issues, which, together with this paper, could provide a starting point for such research endeavours in the future.

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Abstract

The objective of this thesis is to contribute to advance further the emerging research agenda on the transfer and diffusion of low-carbon technologies in developing countries by adopting a study of the development of biomass power plant technologies in Malaysia. The main research question addresses the main factors influencing the transfer and diffusion of biomass power plant technologies in Malaysia. This question is explored in the four papers comprising the thesis, which are based on analyses of qualitative data, mainly in the form of interviews, documents and observations collected during successive periods of fieldwork in Malaysia.

The thesis conceptualises the diffusion of biomass technologies in Malaysia as a niche development process and finds that the development of a palm oil biomass waste-to-energy niche in Malaysia has only made limited progress despite a period of twenty years of niche formation. The thesis identifies the reluctance to implement an efficient energy policy as the main limiting factor for niche development in this case. Although a number of donor programs have advocated the introduction of a stronger enabling framework for niche development, they have generally had only a limited impact on policy development. This was mainly attributed to the strong opposing interests of key actors in maintaining the existing situation, particularly the national electricity utility company in Malaysia, which deliberately obstructed niche development over an extended period because it was against their economic interests. When the government decided to improve incentive structures through a reduction in fossil fuel subsidies and by introducing a feed-in tariff system, the niche development momentum had already been lost because investors had limited confidence in project investments. Since many planned plants were never put into operation and those that were constructed generally showed only poor performance, the lack of investor confidence was due mainly to the largely negative results from experimentation activities in the niche. Moreover, a number of alternative biomass waste utilisation options gained increasing interest in the Malaysian palm oil industry, which were considered more commercially attractive compared to energy generation. On top of this, the increasing interest in these alternative usages of palm oil biomass waste led to a significant rise in biomass resource prices, which meant that it became difficult to negotiate long-term biomass fuel contracts. These factors turned out to be detrimental for niche development.

The transfer of technology is understood in this thesis as the exchange of knowledge through international inter-firm linkages, which contribute to enhancing the technological capability of the recipient firms, thus enabling them to engage in innovation. The thesis considers whether the use of different learning mechanisms could explain differences in the accumulation of technological capabilities in the biomass boiler and power plant supplier industry in Malaysia. It is found that not only is differences in the levels of technological capability achieved by individual firms influenced by the specific combination of learning mechanisms the firms employ, but also by the differences in the relative levels of resources dedicated to exploiting these learning mechanisms. Firms relying on a combination of learning from foreign technology partners and internal learning by planned experimentation make most progress in terms of technological capability. Firms using a combination of learning by imitating national competitor firms and internal trial and error also made advances in technological capability although to a comparably lesser extent. The thesis also finds that CDM projects implemented in Malaysia played a limited role in stimulating the introduction of new technology and knowledge to Malaysian biomass boiler and power plant equipment suppliers. Their involvement in CDM projects did not add anything above and beyond what was already encompassed in the existing relationships between the firms in question.

Dansk resumé

Formålet med denne afhandling er at bidrage til at øge forståelsen af teknologioverførsel og udbredelse af klimateknologier i udviklingslande ved at gennemføre en undersøgelse af udviklingen af biomassekraftværks teknologi i Malaysia. Afhandling forsøger at besvare det overordnede spørgsmål om hvilke faktorer der har haft betydning for overførsel og udbredelse af biomassekraftværks teknologi i Malaysia. Dette spørgsmål undersøges i de fire artikler, der udgør selve afhandlingen, som baserer sig på en analyse af kvalitativt data materiale primært i form af interviews, dokumenter, og observationer indsamlet under flere feltarbejdsophold i Malaysia.

Afhandlingen opfatter teknologiudbredelse som en niche udviklingsproces og finder at udviklingen at en palmeolie biomasse affald-til-energi niche i Malaysia kun har gjort meget begrænset fremskridt på trods af en niche udviklingsperiode på tyve år. Det påpeges i afhandlingen, at modvilligheden mod at indføre en effektiv energipolitik har været en central begrænsende faktor for niche udvikling. På trods af at en række internationale bistandsprogrammers advokerede for at indføre gunstigere rammebetingelser for at understøtte nichen havde dette kun en begrænset effekt på politik udvikling. Dette skyldes primært en stærk modvillighed fra en række hovedaktører, der havde større interesse i at opretholde den eksisterende situation, ikke mindst det nationale elselskab, som over en længere periode bevidst blokerede niche udvikling idet det var imod deres økonomiske interesser. Da regeringen besluttede at forbedre incitament strukturerne ved at reducere subsidierne til de fossile brændstoffer og ved at indføre et feed-in-tariff system blev disse iværksat på et tidspunkt, hvor nicheudviklingsprocessen havde mistet fremdrift på grund af investorernes manglende tiltro til rentabiliteten i anlægsinvesteringer. Idet mange planlagte anlæg aldrig blev idriftsat, og dem, der blev bygget generelt havde lave virkningsgrader skyldes manglen på investorernes tillid hovedsageligt de generelle negative resultater fra de idriftsatte anlæg. Desuden kom der stigende fokus i den malaysiske palmeolie industri på en række alternative anvendelsesmuligheder af biomasseaffald, som blev anset for mere kommercielt attraktive i forhold til energiproduktion. Oven i dette førte den stigende interesse for disse alternative anvendelser af palmeolie biomasseaffald til en betydelig prisstigning i biomasse ressourcen, hvilket betød, at det blev svært at etablere langsigtede biomasse brændstof kontrakter. Disse faktorer viste sig at være begrænsende for niche udvikling.

Teknologioverførsel opfattes i afhandlingen som udveksling af viden gennem internationale virksomheds relationer, som bidrager til at forbedre den teknologiske kapacitet i modtager virksomhederne som gør det muligt for dem at engagere sig i innovations aktiviteter. Afhandlingen analyserer, om brugen af forskellige læringsmekanismer har betydning for opbygning af teknologisk kapacitet i biomasse kedel og kraftværks leverandør i Malaysia. Det påvises, at forskelle i opbygning af teknologisk kapacitet i de enkelte virksomheder ikke kun er påvirket af den specifikke kombination af læring mekanismer som virksomhederne anvender, men også af forskelle i omfanget af ressourcer, der afsættes til at udnytte disse lærings mekanismer. Virksomheder som udnytter en kombination af læring gennem udenlandske partnerskaber og intern læring ved planlagte eksperimenter gør størst fremskridt i opbygning af teknologiske kapacitet. De virksomheder, der anvender en kombination af læring via efterligning af nationale konkurrenter og interne forsøg gør også gjort fremskridt i den teknologiske kapacitet, men i et sammenligneligt mindre omfang. Afhandlingen finder også, at CDM projekter implementeret i Malaysia spiller en meget begrænset rolle for indførelsen af ny teknologi og viden til malaysiske biomasse kedel og kraftværks leverandører. Deres engagement i CDM projekter tilføjer ikke noget ud over hvad der allerede var omfattet i de eksisterende relationer mellem de pågældende virksomheder.