Overcoming the Energy Efficiency Gap: a Motivation, Opportunity and Ability Approach.

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Declaration

I hereby declare that this thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

Clément Baudelaire,
12 April 2014.

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Research is merely an individual adventure. This thesis is not an exception to the rule, and I want here to thank the people who made this study possible.

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En vérité, le chemin importe peu, la volonté d'arriver suffit à tout.

Albert Camus, *Le Mythe de Sisyphe*.

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Summary

In this paper we investigate the main barriers to energy efficiency in Singapore industries. Energy efficiency has been identified to be the most cost-effective and reliable way of addressing climate change issues. Yet its potential remains largely untapped. In order to understand the barriers that hinder its adoption we first build a theoretical framework based on the well-acknowledged Motivation, Opportunity, and Ability (MOA) theory, which is an original perspective for an energy-related study. Such an approach goes beyond the simple descriptive analysis of the presence or not of barriers in the given context and enables to test the impact of barriers – or drivers – on energy efficiency efforts. Besides, and to our knowledge, no study has considered the effects of performance measurement on performance itself and its determinants in the MOA framework. Hence we extend the latter by including the firm's ability to monitor energy efficiency outcomes as an exogenous moderating variable.

In order to test this novel framework we use the data collected from the Fifth Fuel Project. More than 150 questionnaires from various industrial sectors were obtained and used to compute the structural model, using a partial least squares method. The results show that the wish to cut operating costs and firm's know-how to implement energy efficiency have both a positive, statistically significant impact on energy efficiency outcomes. Know-how itself is driven by firm's know-what, which reflects the awareness and the fundamental understanding of energy efficiency. Interestingly, the ability to monitor energy efficiency outcomes moderates the impact of cost-driven motivation. By contrast, firm's corporate social responsibility, regulatory compliance, and opportunity to implement energy efficiency are found to have no significant effect on energy efficiency outcomes in the context of the study. Eventually, we discuss the implications to research of this work.

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Nomenclature

AVE	Average Variance Extracted
CM	Cost-driven motivation
CO_2	Carbon dioxide
CR	Composite Reliability
CSR	Corporate Social Responsibility
EE	Energy Efficiency outcomes
EI	Ease of implementation
GHG	Greenhouse gases
IB	Internal buy-in
KH	Know-how
KW	Know-what
LC	Legal compliance
MA	Monitoring ability
MOA	Motivation Opportunity Ability
PLS	Partial Least Squares
PNNL	Pacific Northway National Laboratory
SEM	Structural Equation Modeling
SME	Small and medium enterprises
USA	United States of America
VA	Voluntary Agreement
VIF	Variance Inflation Factor

1. Introduction

1.1. Context

Addressing climate change is a complex problem that inevitably calls for multiple solutions, originating from multiple sensibilities (e.g. science, economics, finance, management), undertaken at multiple scales (e.g. firm, state, or worldwide) and involving multiple stakeholders (e.g. politicians, institutions). Battling the increasing global green house gases (GHG) emissions – and especially CO_2 emissions, which were 65% higher in 2004 than in 1971 (Worrel, Bernstein et al., 2009) – is one of these solutions. Technological answers to this crucial issue are now identified: 1) foster the development of renewable energies, 2) capture and store the CO_2, and 3) improve the global energy efficiency, which is how much output one can produce with one unit of energy. If promising, the two first options are not economically viable at present stage and fossil fuels will still remain the main energy source to satisfy global energy demand. By contrast, energy efficiency addresses climate change issues without severely compromising the energy trilemma, that is, the need for a reliable, affordable, and clean energy. The benefits of energy efficiency even go beyond mitigating GHG emissions. They include reduced investments in energy infrastructure, lower fossil fuel dependency, improved competitiveness and increased consumer welfare (IEA, 2008). Hence, enhancing energy efficiency has became a major concern for policy-makers, resulting in large public investments and concrete energy targets to be reached in a narrow time window. As an example, the European Union's Energy Efficiency Directive, supported by a 265 million euro-funds, is aiming to cut 20% in Europe annual primary energy consumption by 2020. These ambitious targets are in fact reasonably aligned with the colossal, albeit largely untapped, energy efficiency potential. As an example McKinsey & Co. (2010, p. 4) estimated that the United States could save more than a trillion dollars in energy savings by 2020 if substantial efforts were made for energy efficiency.

Needless to say, the industry sector has a major role to play in the seek for energy efficiency since it consumes nearly one third of total global primary energy supply and 38% of energy related CO_2 emissions (IEA, 2007) (see Figure 1). Even for this highly-consuming sector, energy management is not fully prioritized (Thollander et al., 2010) and there is still a great improvement potential demonstrated by many studies (Caffal, 1995; Neelis and Pouwelse, 2008; Christoffersen et al., 2006; Rohdin and Thollander, 2006; Thollander et al., 2010). As an example, the IEA (2006, p. 386) found that the "energy intensity of most industrial processes is at least 50% higher" than the theoretical minimum given by thermodynamic laws. Likewise, two US studies conducted by the Energetics Team and Pacific Northway National Laboratory (PNNL) have revealed a waste heat recovery potential exceeding 1.6 quadrillion Btu per year (about 1.6% of US total energy consumption in 2006) (Energetics 2004; PNNL, 2006). For developing countries in which industry drives much of the economy, resulting in high energy intensity levels, restraining global consumption to meet energy targets may seem challenging. Yet energy efficiency is an effective way to solve the complex equation of competitiveness, rising energy prices, and stringent energy consumption targets imposed by governments. Given the particular interest of the industry sector in the seek for energy efficiency, this study will stick to this sector. More precisely, the scope of our research focuses on Singapore-based industries. The city-state is a place of special interest for an energy-related study since it has no significant natural resources to tap on and since its open economy is inevitably prone to energy prices fluctuations. This very situation makes it the "third-most expansive destination for utility costs" in the world (The Economist, 2014, p. 1). Embarking on energy efficiency is therefore crucial for Singapore since such policies would help it reduce its dependence on foreign energy supplies and mitigate carbon emissions associated with energy use.

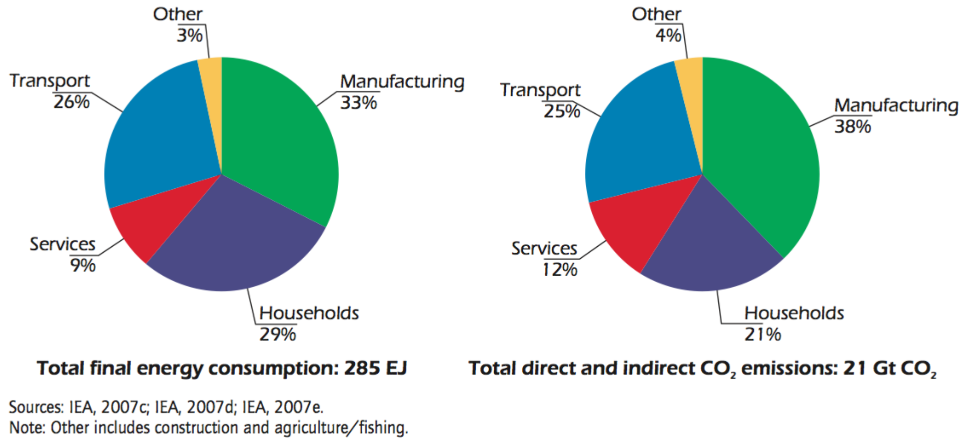

Figure 1 - Shares of global final energy consumption and CO2 emissions by sector, 2005.

Much of the academic and policy research about energy efficiency have addressed the latter by understanding the "energy gap", that is, the "paradox of gradual diffusion of apparently cost-effective energy efficient technology" (Jaffe and Stavins, 1994). Weber (1997) first proposed the idea of the existence of energy efficiency barriers that hamper energy efficiency implementation. Three non-exclusive broad categories are introduced to better apprehend them: barriers are economical, behavioral and/or organizational. Sorrel et al. (2000) further broke down these categories and highlighted, among other barriers, the presence of hidden costs, access to capital issues, imperfect information, adverse selection, split incentives or principal-agent relationships problems. Despite the multidisciplinary nature of energy efficiency-related studies, energy barriers are, in essence, mainstream economics concepts, and consist, for example, in market failures – that is, the deviances from the assumptions of perfect markets – and non-market failures. Most studies dealing with energy efficiency adopt a descriptive approach in which barriers relevant to the context are identified, then scored according to the respondents' perceptions of barriers' importance. The higher the score, the most present is the barrier, and implicitly, the more the barrier hampers energy efficiency efforts. If empirically identifying barriers in different contexts is far from straightforward, these studies, as a matter of fact, test only half of the energy barriers concept since they do not statistically examine the causal link between barriers and energy efficiency attempts. That is, among identified barriers, which are the ones that have a real impact on energy efficiency initiatives? Arguably, investments for energy efficiency would better pay off it they are targeted on the very barriers – or drivers – that affect the most energy efficiency. This lack of understanding is an important research gap that need to be addressed.

1.2. Research question

In order to fill the research gap identified earlier, this work endeavors to understand the mechanisms underlying an industry's energy efficiency outcomes and their obstacles from a different perspective than the mainstream economics angle. Based on the Motivation, Opportunity and Ability theory we aim to examine the impact of energy efficiency antecedents.

1.3. Main contributions

This study provides three main contributions to the energy-related knowledge.

First, we use a novel, parsimonious framework to better understand how barriers – and drivers – affect an industry's energy efficiency outcomes. We believe our framework, based on the Motivation, Opportunity and Ability (MOA) theory, can aid industries implement more effectively their energy efficiency projects. Grouping barriers into broader concepts – namely, M, O, and A – gives a clear and parsimonious view on the impact of fundamental barriers which aids the interpretation of the findings. Further, we believe that the founding principles of the MOA theory, that mostly lie in management science, give a fresh perspective on energy efficiency matters. These principles are also well suited to address the management realities that encounter industries when they implement energy efficiency. Previous studies have indeed extensively used mainstream economics concepts, such as split incentives or adverse selection, to understand how energy barriers act. As a result, and to our best knowledge, no real theoretical alternative has been suggested to tackle energy efficiency issues. This study is one answer to this absence.

Second, going further than identifying key barriers in our research context of Singapore industries, we examine the nature of the relationships between some of these barriers and we discuss their impact on firm's energy efficiency outcomes. Studies that both identify barriers and test their impacts are notably scarcer than studies that stick to the first stage. As a result, links between barriers and energy efficiency implementation remain much less understood than the question of existence of these barriers.

Third, we expand the traditional MOA model by adding a monitoring ability variable as an exogenous moderator and statistically test its effect. Despite an extensive literature on the role of performance measurement in organizations, no MOA-based study has ever discussed the importance of this factor on performance. Likewise, when looking at energy efficiency-related works, we find that few studies have stressed the relevance of energy monitoring, and none has attempted to quantify its impact. Our work discuss how this variable can be incorporated in the traditional MOA framework and how it affects an industry's energy efficiency outcomes.

1.4. Outline of the thesis

This study consists of six chapters. A brief description of each chapter is listed as follows:

Chapter 2 – literature review. In this chapter we identify the solutions that an industry may use to improve its energy efficiency. If these means are now well-identified, energy efficiency is overall seldom embraced. This infamous paradox, referred to as the "energy efficiency gap" has been explained by the existence of "energy barriers" that impede the adoption of energy efficiency. We analyze the nature of these barriers and describe how previous studies have used them to understand the mechanisms that prevent energy efficiency implementation. This review is followed by a discussion of the limitations of previous studies. variable.

Chapter 3 – hypotheses development. In this chapter we first present the general MOA theory, its origins and its applications in past academic research. Then after we point out an important gap in the model, namely the absence of a performance measurement. We then detail the concepts and the variables that are used in the theoretical framework. The MOA model is specified within the context of energy efficiency. Based on the extensive literature review made in Chapter 2 and on the fundaments of the MOA theory we then establish the set of hypotheses that are proposed of empirical testing. Direct effects as well as one moderating effect are discussed.

Chapter 4 – survey instrument development and implementation. A large-scale survey is chosen as a research methodology to verify the hypotheses expressed in Chapter 3 and the unit of analysis consists in Singapore industries. In this section we first explain the data collection process, analyze the sample of the respondents and test for any non-response bias. We then detail how we operationalize the theoretical constructs with measurable items and how these items are adapted from the mainstream literature and from preliminary interviews with industry executives. We take special care in clarifying which constructs are reflective and which are formative since incorrect model specification can inflate Type I and Type II errors risk.

Chapter 5 – data analysis and results. Following the procedures established in Chapter 4, a total sample size of 143 industries from various sectors and with completed data is used in our analysis. We first test the measurement model by performing a confirmatory factor analysis in SPSS for the reflective constructs and a factor weight analysis in SmartPLS for the formative ones. We then test the hypotheses regarding direct effects in the model through Structural Equation Modeling (SEM). For certain reasons expressed in Chapter 3 we use a Partial Least Square

(PLS) approach. Finally the hypothesis regarding the moderating effect is examined by performing a linear regression.

Chapter 6 – discussion and conclusion. In this chapter we sum up the research findings corresponding to the hypotheses we proposed in Chapter 3. We also present and discuss the possible explanations of these results. Contributions and implications of our work are addressed to researchers. Eventually we discuss the limitations of our study and suggest possible future research orientations.

2. Literature review

In this chapter we first provide some insights about how industries may practically implement energy efficiency. We show that these systematic solutions are now well-identified and well-understood. Yet the huge potential of energy efficiency is scarcely exploited. Section 2 introduces the theory of energy barriers to explain this paradox known as the "energy efficiency gap" and extensively describes these barriers based on past literature. This section shows that despite numerous attempts to (re)classify energy barriers into pertinent groups, nothing appreciably new has been said about their nature. In section 3 we give a fresh perspective on energy efficiency and present the Motivation, Opportunity and Ability theory upon which we build the research model. Eventually, we express our research questions.

2.1. Energy efficiency implementation

Industries are fundamentally given with three technical ways to embrace energy efficiency. First, they may simply evaluate their energy consumption and identify the energy wasted in the production process. The Table 1 below (McKinsey & Co., 2010) gives a possible classification of wastes types. Alternatively industries may optimize the energy integration in heating and cooling processes (e.g. proper use of insulation and utilization of exhausted heat from one to another process). Finally, industries may adopt more energy-efficient technologies.

As an alternative approach, Herrmann and Thiede (2009) suggest that improving energy efficiency can be operationalized at three different layers in the industry: 1) production process and machine (e.g. efficient shutdown procedures), 2) production system (e.g. minimizing waste or using opportunities of time and location shifting, such as producing at night to save costs) , and 3) technical building services (e.g. avoiding of unnecessary demand).

As it can be seen, the two approaches described below somehow overlap, and the industrial processes advocated by researchers to implement energy efficiency tend to converge to the same fundamental ideas (see also Müller et al., 2009).

Table 1 - Type of wastes.

Types of waste	Definition	Example
1 *Overproduction*	Producing excess energy	Venting excess steam
2 *Waiting*	Consuming energy while production is stopped	Laser welding line on standby still consumes 40% of maximum energy
3 *Transportation*	Inefficient transportation of energy	Leaks and heat radiation in steam network
4 *Overspecification*	Process energy consumption (deliberately) higher than necessary	Blast furnace operating at 1,100°C instead of the required 1,000°C
5 *Inventory*	Stored goods use/lose energy	Crude steel cools in storage, is then reheated for rolling
6 *Rework/scrap*	Insufficient reintegration in upstream process when quality is inadequate	Re-drying polymer lines that did not get coagulated in drying process
7 *Inefficient processes*	Energy-inefficient processes	Excess oxygen in steam boiler
8 *Employee potential*	Failure to use people's potential to identify and prevent energy waste	Employees not involved in developing energy savings initiatives

2.2. Energy efficiency gap and barriers

As mentioned above, the methods to implement energy efficiency are now well identified. Moreover, the energy efficient technologies in which an industry may invest to improve its energy efficiency are mature and already available on the market. Further, improving energy efficiency seems appealing for industries since, among other things, it may help them reduce their production costs. Nevertheless, empirical studies lead to the conclusion that what is now referred to as the "fifth fuel" remains largely untapped. This paradoxically slow diffusion of energy efficient technologies has been coined "energy efficiency gap" by Jaffe and Stavins (1994) and acts as a justification for policy intervention. This "gap" has been traditionally explained by listing and describing the numerous "energy barriers" that could refrain industries from implementing energy efficiency (Sorrell, 2000) and that are defined as the "postulated mechanisms that inhibit investment in technologies that are both energy efficient and economically efficient" (Sorrell et al., 2004). Therefore, overcoming these barriers becomes a priority to achieve the aforementioned energy efficiency potential for the policy-markers.

If energy efficiency have been studied by a wide range of scientific disciplines, such as economics, organizational or behavioral sciences, energy barriers remain for a large part a mainstream economics concept. In a much-cited review, Sorrell (2000) distinguishes four non-exclusive groups of barriers, namely, market failures, non-market failures, behavioral and organizational barriers. In what follows, we develop some of the key barriers found in Sorrell taxonomy and reported in Table 2.

Market failures typically involve *imperfect* or *asymmetric information* issues. The energy service market does not deliver enough quality information about the energy performance and opportunities of different technologies, leading to cost-effective decisions being missed and sub-investment in energy efficiency. Product labeling is one solution to practically address this issue. Further, asymmetric information difficulties happen when the seller of a technology does not disclose some information about the product to the buyer. Such information retention by the seller is known as *adverse selection*, and is a market failure. In a different context that energy efficiency, one famous example of adverse selection is given by Akerlof (1970) with the market for second-hand cars. In such a market, buyers face difficulties assessing the quality of the good, so sellers are incentivized to market goods at lower-than-average quality. Further, embracing energy efficiency involves buying new, unfamiliar technology for the firm, dealing with multiple intermediaries and suppliers. As Sorrel et al. (2011) remarks, purchases are infrequent because of equipment's long lifetime, technical change is quicker than purchasing flow, and therefore, asymmetric information issues are continuously occurring.

Risk has also been recognized to put a strain on energy efficiency efforts. Risk is a multicomponent barrier and may include, for example, the risk regarding economic trends (inflation, interest rates), financial risks, or technological risks. Albeit mature and reliable, new, unfamiliar technologies may cast doubts on the buyer, who anticipates that costs associated with breakdowns or maintenance will overweight the cost reduction potentials. *Perceived* ease of use and *perceived* usefulness are here more relevant than the intrinsic technical capabilities of the equipment, as the widely accepted Technology Acceptance Model (Davis, 1989) recalls.

The other frequently identified market failure is the presence of *hidden costs*. This typically occurs when engineering-economic studies fail to account for either the reduction in utility associated with energy efficient technologies, or the additional costs associated with their use (Nichols, 1994). The direct consequence of such costs is the overestimation of energy efficiency potential. Hidden costs may refer to the costs of energy management (costs of specifically trained employees, of metering and analyzing energy data, of auditing), the costs involved in individual technology decisions (costs of disruption, of additional staff for maintenance, etc.), or the loss of utility resulting from energy efficiency-related decisions (degradation of working conditions, lower reliability, etc.) (Sorrel et al., 2011).

As Hirst and Brown (1990) have pointed out, the *lack of access to capital* is another major obstacle in the seek for energy efficiency. This is typically relevant for SMEs, which have low internal capital capabilities and are subject to high interest rates. Other capital investments may be perceived as more important and requirement for short payback periods illustrate how lack of access to capital can manifest itself. DeCanio (1998) analyses company-level data from the United States Environmental Protection Agency's Green Lights program in the industry sector. His study shows that, among other things, a set of organizational and bureaucratic barriers control firms' investment behaviour.

The existence of these barriers is now widely recognized and serves as a starting for many studies dealing with energy efficiency. In addition to the traditional economic, behavioral and organizational pattern used by Sorrell, some authors from various fields of research have developed new systematic taxonomies to classify barriers. The rationale for such studies is that sorting out barriers aids the understanding of barriers and drivers, as categories may be even more relevant for policy-making than the barriers themselves. Liu et al. (2013) split drivers for energy savings activities into external and internal ones, the external drivers beings coercive, normative, or mimetic and the internal ones being the energy saving strategy orientation, the top management support, and the learning capacity. In their study, Vine et al. (2003) showed that the identified barriers could be classified into 1) a lack of information about energy use, 2) a lack of access to information about financing investments in general and 3), a low importance given to energy efficiency in decision-making. Watson et al. (2012) come up with five categories: financial/cost, cultural, technical, institutional/regulatory, and ability (skill). As a last example, Sudhakara Reddy (2013) distinguishes micro, meso and macro-level barriers. If taxonomies labels vary across studies, it appears that these categorizations do overlap since the key barriers remain the same. As Sorrell et al. (2004) remarks, categories of barriers are often non-exclusive, and barriers may co-exist and interact. Further, the existence of multiple frameworks make comparison of studies results ticklish.

Some authors have also tried to estimate the relative importance of the barriers identified in the given unit of research, typically a region (e.g. UNEP 2006) or a country (e.g. Nagesha and Balachandra 2006; Rohdin and Thollander 2006; Thollander and Ottosson 2008; Wang, Wang et al. 2008). These descriptive approaches typically consist in computing a score of relevance for each of the identified barriers based on interviews and/or surveys; alternatively, they advocate how great is the fraction of respondents who agreed on the presence or the absence of a given barrier.

Table 2 - Energy barriers

Category	Theoretical barriers	Comment
Market failure/market imperfection	Imperfect information	Information imperfections, for example, lack of information, may lead to cost-effective energy efficiency measures not being undertaken
	Adverse selection	If a seller knows more about the energy performance of a technology than the buyer does, the buyer may select goods on the sole basis of price or visible aspects such as color and design
	Principal– agent relationship	Strict monitoring and control by the principal, since he or she cannot observe what the agent is doing, may result in the overlooking of energy efficiency measures
	Split incentives	If a person or department cannot benefit from an energy efficiency investment, the most likely outcome is the nontake-up of the measure
Nonmarket failures/non-market imperfections	Hidden costs	Hidden costs include overhead costs related to the investment, cost of collecting and analysing information, and production disruptions
	Access to capital	Limited access to capital may inhibit cost-effective energy efficiency measures from being implemented
	Risk	Risk aversion may result in cost-effective energy efficiency measures not being undertaken
	Heterogeneity	A technology or measure may be cost-effective in most locations but not in others, leading to excessive potential being claimed for the technology
Behavioral barriers	Form of information	Research has demonstrated that to increase the diffusion and acceptance of information on cost- effective energy efficiency technologies, the information should be specific, vivid, simple, and personal
	Credibility and trust	The source of information must be considered credible and trustworthy by the receiver in order to successfully deliver information about cost- effective energy efficiency technologies
	Values	Energy efficiency improvements are more likely to be of interest if the organization consists of individuals with real ambition
	Intertia	Individuals are often hesitant to change, which may, in turn, result in the overlooking of cost-effective energy efficiency measures
	Bounded rationality	Instead of being made based on, for example, perfect information and complete rationality, decisions are often made in constrained environments that result in limited, or bounded, decisions, i.e., nonoptimal from a fully rational point of view
Organizational	Power	Low status of energy managers may lead to energy issues being assigned a low priority in industrial organizations
	Culture	Over time, organizations may encourage energy efficiency investments by developing a culture characterized by environmental values; for example, the core values of an industrial organization may inhibit or promote energy efficiency

To our knowledge few attempt to describe the possible relationships and interactions between these barriers. Few also, have tried to answer the next central question, which is, once the barriers are identified and *perceived* as relevant in the context of the study, what barriers have the most significant impact on energy efficiency efforts. Arguably, the identified barriers in the context of the study are not all equal in their impact on energy efficiency. Further, efforts to alleviate these barriers would better pay off if they are targeted on barriers that affect the most energy efficiency initiatives. Eventually, such descriptive studies often fail to prioritize these efforts to provide effective policies. As a result, the effects of barriers remain much less understood than the existence of these barriers.

Addressing this important issue requires more quantitative methods. One way to examine a possible correlation between barriers – or drivers – and energy efficiency, consists in testing an econometric regression in which the dependent variable that measures energy efficiency efforts is a linear combination of self-assessed barriers and control variables, such as firm size or share of energy costs in total costs. The regression coefficients are then computed, their significance is discussed (e.g. Sardianou, 2007). Based on theory, significant correlations may indicate a significant causality.

The results of all these descriptive and predictive studies greatly vary with the context of research. As an example, technical risk of production disruption has been found to be a serious barrier to energy efficiency investment in foundry industry (Rohdin et al., 2007) and in Swedish pulp and paper industry (Thollander and Ottosson, 2008) but insignificant for German SMEs (Fleiter et al., 2012). Lack of capital is often identified as a key obstacle (e.g. Velthuijsen, 1993; Anderson and Newell, 2004; Thollander et al., 2007; Trianni and Cagno, 2012; Fleiter et al., 2012), which indicates that initial expenditure needed for energy efficiency projects are determinant but there are notable exceptions (e.g. Harris et al., 2000). Eventually, lack of information is pointed out as a key barrier in several studies (e.g. Schleich and Gruber, 2008; Kostka et al., 2011). Along with barriers, Fleiter et al. (2012) point out that the intrinsic characteristics of energy-efficiency measures themselves may also help explain low diffusion rates of energy efficient technologies.

If energy barriers are relevant to understand the fundamental mechanisms that may hinder or foster the adoption of energy efficiency at the macro-level, such an approach is less suited to describe what happens at the firm level. Most of concepts related to energy barriers, such as market failures or uncertainty, may not be adequate tools to help CEOs and executives adopt energy efficiency in their factories. Besides, a more firm-centered theory may contribute to design better energy efficiency policies at the macro-level. These kind of approaches are scarce in previous extensive literature about energy efficiency and motivates this study based on the Motivation, Opportunity and Ability theory.

3. Research model and hypotheses development

In this chapter we first present the MOA theory on which we base the theoretical framework used in this study. We then define the independent, dependent and moderating variables used in this study. Next, we present the research model framework and the hypotheses that will be empirically tested. The last section is dedicated to the hypotheses development.

3.1. The Motivation, Opportunity and Ability theory

The Motivation, Opportunity and Ability (MOA) theory was first established by Blumberg and Pringle (1982) and finds its founding principles in both industrial and social psychology (e.g. Lawshe, 1945). The authors' aim was to understand job performance's drivers in a parsimonious manner, which could encompass the numerous antecedents for performance previously identified in literature, such as leadership, job satisfaction, or job attitudes, as well as the observations the authors made while studying coal mines workers. The MOA theory identifies three fundamental determinants in the performance of a given individual (an employee for example) or organization (a firm or a state), which are, precisely, the motivation, the opportunity and the ability of this individual or this organization. The more they are motivated, the more there are opportunities to perform, and the more they are capable, then the more they are likely to perform. This framework has been used in various fields of research, such as entrepreneurship (Davidsson, 1991), firm-level decision-making (Wu et al., 2004), marketing (Clark et al., 2005), behavior in information systems research (Hughes, 2007), or knowledge sharing (Siemsen et al., 2008).

The three components of the MOA framework are related constructs (Blumberg and Pringle, 1982). To illustrate this, let's think about a talented employee who has no opportunity to perform, say, because of a stressful environment within the company. It's likely that our employee will not perform, however talented she may be. Therefore, the correlation between motivation, opportunity and ability may have to be tested in our study. However, it has been usually hard to confirm empirically this supposed complementarity (Terborg, 1977). As an example, Siemsen et al. (2008) have shown that the addition of two-way interactions terms between motivation, opportunity and ability does not improve much the fit a simple linear model that accounts for the direct effects only. In addition to the interaction between the three dimensions of the framework, performance in turn can also affect the levels of motivation, opportunity and ability by creating a positive feedback. For example, *evidence* of performance is likely to motivate employees to perform again, and *acted* performance is likely to increase their ability since they are more experienced.

To our knowledge, no study has emphasized the importance of performance measurement within the MOA framework, and how, in turn, these measures affect the direct effects of motivation, opportunity and ability on performance. Yet these questions have been widely addressed in business research. Folan et al. (2007) argue that the measured entities must be relevant to the given context, keeping in mind that the choice of energy indicators is always subjective since the whole spectrum that defines performance can't be totally captured. In their study, Hyland et al. (2007) break down the function of performance monitoring as follows: performance evaluation; support for determining suitable rewards; motivating desirable behavior; communicating expectations; identifying performance gaps; support for decision making; providing goals against which progress can be measured; providing data for seeking appropriate courses of action; providing data for planning strategic decision. This list suggests that performance monitoring as a variable should be exogenous to the MOA framework rather than incorporated into, for example, ability, since monitoring by itself has no direct impact on performance. Moreover the "Motivating desirable behavior" function in particular let us consider an interaction between performance measurement and the motivation variable of MOA theory.

3.2. Definition of variables

Since the MOA framework is *meta-theory* (Gregor, 2006), which has enabled its application across various fields of study, its dimensions do have to be specified within the current context of research. Hence motivation, opportunity and ability have to be defined within the context of energy efficiency implementation.

Based on literature review and interviews conducted prior to this study with executives in the industrial sector in Singapore we first observe that the cost-saving potential of energy efficiency motivates industries to implement it. This source of motivation is especially high in the industrial sector since the energy costs represent a high share of the total production costs. Further, we identify two other sources of motivation: the Corporate Social Responsibility-driven motivation and the Legal compliance. The wish to implement energy efficiency may indeed arise from an industry's green corporate policy to embark on environment preservation practices. Alternatively, energy-related regulatory pressure exerted on industries represents should drive the implementation of energy efficiency projects. Ability wise, we distinguish firm's Know-what and Know-how. Their impacts are discussed below in the hypotheses development. Eventually we observe that firm's Internal buy-in and Ease of implementation are two critical components of firm's Opportunity to embrace energy efficiency. These two important criteria determine whether of not the implementation of energy efficiency will be successful or not. The sub-dimensions of each construct and their definitions are summarized in the Table 3 below.

Table 3 - MOA components and definitions.

	MOA components	**Definition**
Motivation	Cost-driven motivation	The extent to which energy costs reduction motivates efficient efficiency implementation.
	Corporate Social Responsibility (CSR) motivation	The firm's commitment in building a greater society.
	Legal compliance	The extent to which law and regulation pressure motivates energy efficiency implementation.
Ability	Know-what	The extent of firm's understanding of energy efficiency-related matters.
	Know-how	The extent of firm's technical skills and proficiencies to implement energy efficiency.
Opportunity	Internal buy-in	The extent of firm's commitment of production and quality departments for energy efficiency projects.
	Ease for energy efficiency implementation	The extent to which energy efficiency can be easily implemented.

In addition to the M, O, A antecedents we label the dependent variable "energy efficiency outcomes" and define it by being *the extent to which energy efficiency projects deliver*. Eventually, we define the monitoring ability by being *the extent of firm's ability to monitor the results of energy efficiency implementation at both physical and financial levels.*

3.3. Hypotheses development

3.3.1. Direct effects of Motivation

Motivation is empirically well driven by the wish to reduce energy costs. If a company's energy costs represent a high proportion of its total costs the firm is likely to be more motivated to cut off them by reducing its overall energy consumption, that is, being more energy efficient (de Groot et al., 2001; Schleich and Gruber, 2008; Schleich, 2009). The rationale is that energy efficiency investments compete with other investments and even profitable energy efficiency investments may be discarded because some other investments appear to be more profitable (de Buck et al., 2010). Further, high energy cost share can also trigger top-management support for energy efficiency (Cooremans, 2011). On the other hand, if the firm's energy costs are not significant in its total costs, which are the case for the service sector for example, it is likely to be less concerned and motivated to reduce them. In other words, cost savings do not have a strong strategic relevance for the company. Further, energy costs are often the only cost component that can be reduced internally by the industry itself, unlike raw material costs for example, which call for negotiation with different external suppliers. These observations can be summed up in our first hypothesis:

H1: A company's energy efficiency initiatives outcomes increase with its motivation for energy costs savings.

But cost-motivation is not the only source of motivation. Corporate Social Responsibility (CSR) plays also an important role, as more and more industries are now committed to embark on environment preservation practices. Going further than simply complying with current legislation requirements, these industries adopt proactive, voluntary positions in order to alleviate their environmental impact. CSR itself is driven by a wide range of more fundamental sources of motivation, such as the mean to satisfy or increase customer's demand for green products, the wish to enhance corporate reputation, the desire to build employee/leadership capabilities, or to differentiate from competitors (McKinsey & Co, 2008). Building a CSR typically involves transforming the management system, the operations system and the commercial system (Gonzalez-Benito et al., 2005). Some authors however - including Nobel price economist Milton Friedman - have questioned the idea of engaging in CSR for it may be inconsistent with the business's obligations of maximizing wealth for the firm's stockholders. Yet once an industry has decided to embark on such environmental practices, mitigating overall energy consumption, and, en route, embracing energy efficiency are on the agenda. de Groot et al. (2001) for instance have shown empirically that the green image of a company has a positive impact on energy efficiency efforts. Eventually we can hypothesize the following:

H2: A company's energy efficiency initiatives outcomes increase with its motivation to be a socially responsible corporate.

Motivation can also find its sources outside the company. Energy-related regulatory pressure on firms – which began in the 1970s with the energy crisis – is also likely to make them implement energy efficiency through energy taxes, cap-and-trade systems, tax credits for efficient systems, product labeling, or direct regulatory limits on the energy consumption of products (Sachs, 2012). The National Academy of Sciences (2001) has shown that without the regulatory pressure on cars and light trucks in the USA (known as CAFE standards) and the tax on inefficient "gas guzzlers", the USA would have consumed an additional 2.8 million barrels of gasoline per day as of 2000. Minimum efficiency standards have been proven to be a very powerful tool to achieve energy efficiency, especially when they are regularly updated (Heller et al., 2006). As a striking example, in 2009 the United States saved more energy from refrigerators efficiency standards alone than they produced from wind and solar power together (Biello, 2009). These macro-level observations of the effects of legal compliance on energy efficiency efforts are arguably still valid at the firm level. Moreover, even though energy efficient systems adoption may represent a high initial cost for an industry, this cost may be lower than the cumulative penalties or sanctions that the company has to pay if it does not abide by the law. Hence we can express hypothesis 3:

H3: A company's energy efficiency initiatives outcomes increase with its motivation for legal compliance.

3.3.2. Direct effects of Ability

Based on knowledge management literature we distinguish in this study two forms of abilities, namely know-what and know-how, also referred to as declarative knowledge and procedural knowledge (Singley and Anderson, 1989). These two types of abilities are both important for the long term development of firms (Leonard Barthon, 1990) and differ in their nature. Know-what is facts, description, information, that is, in our case, a certain awareness of the benefits – in terms of energy savings for the company for example – to embrace energy efficiency. Know-how deals with how to be able to do something (Kogut and Zander, 1992), that is, in our case, how to technically implement energy efficiency, for example, how to set up new, efficient machinery and maintain it over time. Arguably, firms may have a high level of know-what but a level of know-how; the contrary, however, is not true. Many authors (e.g. Bohn, 1994) have argued that know-what allows better development or implementation (i.e. how-how). In other words, know-what works as a proxy for know-how.

Know-how is a different story. Embracing energy efficiency often implies the adoption of new, unfamiliar and complex technologies, which generally speaking require higher knowledge and skills for the company to be implemented (Dewar and Dutton, 1986). As a consequence, lack of qualified employees might hamper energy efficiency initiatives (e.g. Sardianou, 2008) and is regarded as a transaction cost for the firm. Big companies often have a technical staff dedicated to energy efficiency but they may also tap on knowledge from overseas experts to complement their intern expertise. On the other hand, as they have limited resources, SMEs are less likely to rely on intern experts to help energy efficiency adoption, and may instead use external expertise, expressed through benchmarking or energy audits. Energy audits are indeed a crucial instrument to achieve energy savings since they evaluate the current energy consumption and point out the range of energy savings opportunities (Fleiter et al., 2012). They should lead to technical, concrete saving measures for the management, such as insulation of piping or leaking prevention. Further, energy audits enable industries to prioritize and rank the identified energy efficiency opportunities. Overall, energy audits help industries overcome the information gap (Palmer et al., 2013), which has been identified as a key energy barrier. For all these reasons, we can express the two following hypotheses:

H4: A company's energy efficiency know-how increases with the company's know-what.

H5: A company's energy efficiency initiatives outcomes increase with the company's know-how.

3.3.3. Direct effects of Opportunity

A company's implementation of energy efficiency projects needs the close cooperation from its internal staff and, as many studies highlighted it, top-management support is often crucial. For example, strong resistances from production and quality departments, possibly due to fear of disruption to production and fear of risks to product quality respectively, could severely hinder the implementation of the energy efficiency projects. Resistance to change may also explain a lack of internal buy-in. Thus, companies with high internal buy-in should be able to achieve better energy efficiency initiative outcomes. We therefore hypothesize the following:

H6: A company's energy efficiency initiatives outcomes increase with the company's internal buy-in.

Implementing energy efficiency projects implies stopping the plant that often runs twenty-four/seven with few periodic maintenance shutdowns, which is problematic in most cases. The rationale for this is that stopping a continuous production line entails substantial technical risks (Thollander et al., 2008), especially if the energy efficiency-related operations are involved in the core production processes of the firm (Anderson and Newell, 2004; Dieperink et al., 2003). These risks in turn, are linked with the technical ease (in terms of time needed for example) to shut down the different machines in the plant. Physical constraints such as lack of space may also hinder the ease of implementation. Overall, easy-to-stop systems and absence of physical constraints enable a good ease of technical implementation, open up the window opportunity, which then acts as a driver for the firm's energy efficiency outcomes. Thus, we hypothesize the following:

H7: A company's energy efficiency initiatives outcomes increase with the ease of implementing the energy efficiency projects.

3.3.4. Moderating effects of Monitoring Ability

Within the context of energy, performance measurement can be seen as a component of a broader concept known as *energy management*. John (2004) lists out some strategic energy management practices: collect data, fix efficiency targets, and communicate on-going energy performance to stakeholders in the company. Further, Backlund et al. (2012) argue that data gathering and analysis aid investments in energy efficient technology by providing information about energy flows and potential savings, as well as identify faulty machinery, optimize firm's energy system and energy performance. Reporting and monitoring are also key requisites in voluntary agreements (VA) to fix energy targets. Yet Rezessy et al. (2011) consider these requisites are the weakest points of VAs et suggest to rely on an independent third party to verify data and reports. These considerations show how crucial energy performance monitoring is when embracing energy efficiency. Yet to our knowledge very few energy-related studies other than the aforementioned ones have examined its impact on energy efficiency implementation (one notable exception is Sivill et al., 2012) . We attempt to do so by adding this variable in the MOA model.

Companies with a stronger monitoring ability are likely to have a better understanding of their energy assumption issues, and thus, are more prepared and motivated to engage in energy efficiency projects Monitoring ability would involve both low and high level sub-metering and a thorough evaluation of consumption trends over time. Otherwise, the industry will lack feedback on the effects of its energy efficient technology investments, with the consequence that energy consumption will be somewhat opaque (Hewett, 1998). Further, as Hyland et al. (2007) recall, one fundamental function of performance measurement is to "motivate desirable behavior". Thus, companies with strong monitoring ability may be more easily motivated to achieve their energy efficiency initiatives. Thus, the extent of a company's monitoring ability on energy efficiency may moderate the positive relationship between a company's certain motivations and its energy efficiency initiative outcomes. In the context of our model, cost-motivation appears to be the most relevant source of motivation that can interact with firm's monitoring ability. Indeed, proper CSR should be intrinsic source of motivation, whose intensity on the energy efficiency outcomes does not vary in presence of energy consumption results. Regulatory compliance should also not be affected by firm's monitoring ability, since law pressure comes from outside the firm's environment However, the presence of energy performance results may affect firm's cost-driven motivation, and, then the impact of the latter on the energy efficiency outcomes. That is, monitoring ability moderates the relationship between cost motivation and energy efficiency outcomes. We therefore hypothesize the following:

H8: The positive relationship between a company's cost-motivation and its energy efficiency initiative outcomes will be stronger if the company has a stronger monitoring ability.

3.4. Research model

The hypotheses and the proposed research model are shown on Figure 2. This suggests than both firm's motivation (i.e. Cost motivation, CSR, and Legal compliance) and opportunity (i.e. Internal buy-in and Ease of implementation) can influence its energy efficiency outcomes. Firm's ability can also influence these outcomes through its know-how, which is driven by itself by its know-what. Eventually, firm's Monitoring ability of its energy efficiency projects is hypothesized to moderate (doted line) the effect of cost motivation on the energy efficiency outcomes.

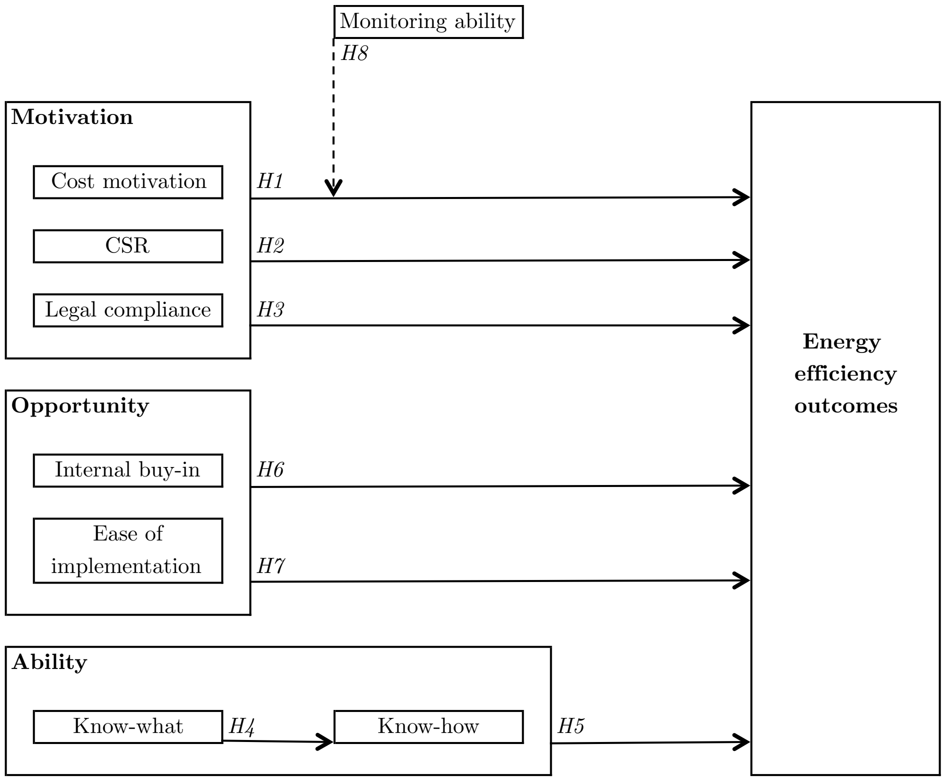

Figure 2 - Proposed research model.

4. Research methodology

4.1. Data collection

Data collection started in 2010 and was part of the "Fifth Fuel Project", a large-scale study on energy efficiency in Singapore funded by the Energy Studies Institute. The survey data was collected by the NUS Management of Technology division as follows. First a mailing list was obtained from One Source, a commercial company that sells databases containing company contact information (available to NUS students/staff). A hardcopy survey (in color) was then post to Singapore's industrial companies by post. Finally, a Dillman's multiple-contact point system was adopted in the administration of the survey (Dillman et al. 2009):

- Week 1 – pre-notice letters sent to the companies;
- Week 2 – questionnaire, together with cover letter & pre-paid postage envelope sent to the companies;
- Week 4 – the first reminder letter sent to the companies;
- Week 5 – the second reminder letter sent to the companies;
- Week 6 – follow-up calls made to randomly selected companies to urge a response in the case of non-response.

4.2. Sample analysis

Survey questionnaires were sent out using the mailing list and no sampling was performed. The sectors that were not significantly represented because of a low number of responses or a low percentage response rate were discarded from the data set and were not used in further analysis. The remaining sectors after this selection process were SSIC 10, 20, 24-25, 26 and 28, where SSIC stands for Singapore Standard Industrial Classification 2010. 143 usable questionnaires have been received. The Table

4 below defines these sectors and presents their response rates.

Table 4 - Non-response rate analysis.

	SSIC 10 Manufacture of food	**SSIC 20** Manufacture of chemicals and chemical products	**SSIC 24-25** Manufacture of basic metals and fabricated metal products	**SSIC 28** Manufacture of machinery and equipment	**SSIC 26** Manufacture of computer, electronic and optical products
Total mailed	586	749	1010	1850	1032
Undelivered /unusable	217	442	592	728	537
Declined	11	53	63	104	72
Balance	358	254	355	1018	423
Usable	18	28	27	47	23
Overall response rate	5.03%	11.02%	7.61%	4.62%	5.44%
Total response rate			**6.10%**		

The total response rate is in the low range. However, most of respondents were directors, general managers of CEOs (together they represent 57% of respondents), which adds credibility to the answers.

4.3. Non-response bias

This low total response rate may also introduce some non-response bias, and this bias has to be tested since, as Armstrong says "if persons who respond differ substantially from those who not, the results do not allow to say how the entire sample would have responded" (Armstrong et al., 1977). We use a wave analysis technique to test the non-response bias, and compare the means of a given question across three groups: 1) firms which responded before the first reminder, 2) those which responded after the first and second reminders, and 3) those which responded late. This mean comparison was performed using a one-way analysis of variance (ANOVA) in SPSS 21.0, which computes a F-test, F being the ratio between the mean square within groups and the mean square between groups. We test the null hypothesis that all means are equal across the groups against the alternative hypothesis that at least two means differ from each other. The satisfaction with firm's energy efficiency efforts was used to compute the means. The results are given in Table 5.

Table 5 - Non-response bias test.

	Sum of squares	dof	Mean square	F	p-value
Between groups	3.046	2	1.523	.554	.576
Within groups	332.632	141	2.749		
Total	335.677	143			

For a protection level alpha = .05, and the p-value being .576, we fail to reject the null hypothesis that all means are equal across the three groups, that is, there is no evidence of difference among the different respondents' answers. These analysis shows that there is little or no bias in the responses.

Data analysis was performed using Partial Least Squares (PLS), in SmartPLS 3.0. PLS is a structural equation modeling technique that uses a principal-component-based estimation approach (Chin, 1998), which has the following benefits: 1) it does not suffer from indeterminacy problems like other causal modeling techniques using a covariance-based approach; 2) it is a nonparametric technique and, therefore, does not assume normality of the data; 3) it does not require as large a sample size as other causal modeling techniques; and 4) it can be used to estimate models that use both formative and reflective indicators. Because our sample size of 143 respondents is relatively small and because the proposed model includes both formative and reflective indicators, a PLS-approach is suitable for our study.

Sample size requirements for PLS stipulate that there should be at least 10 respondents per predictor in the most complicated regression of the model. Since our dependent variable has 7 predictors, a sample size of 70 is adequate. Our sample size satisfies this condition (143 > 70).

4.4. Construct operationalization

Our model consists of both formative and reflective constructs. Proper model specification is essential since it can induce Type I and Type II errors (Petter et al., 2007). Items of formative construct refer to items that top in different concepts, each item contributing to a specific dimension of the construct,. Reflective constructs on the other hand are made by items originated and affected by the same concept (Jarvis et al., 2003). The items of reflective constructs are parallel, and should covary. In our study, Cost motivation, Legal compliance, Know-how and Ease of implementation are formative, while the remaining constructs are deemed reflective. Items measuring constructs are based on both extensive literature review and interviews conducted by the NUS Management of Technology division with Singapore industries. The items are shown in Table 6.

Cost motivation is operationalized by three formative items based on interviews.

CSR. Items measuring the CSR are based on interviews with the local Singapore firms, and the study of Benito 2005, and are affected by the same environmental concept. CSR is therefore deemed reflective.

Legal compliance is operationalized based on the interviews, and the items designed each contribute to a specific dimension of the construct, including the legal infrastructure and the severity of the penalties. These dimensions are not interchangeable. Therefore, this Regulatory Compliance should be formative construct.

The *Know-what* items are based on interviews and Singapore industry energy data, and all originate from the same knowledge/awareness about the energy efficiency and address the same dimension of the construct. Thus, Know-what is a reflective construct.

The *Know-how* is measured by items adapted from Luken, Rompaey and Zigova 2008 & Kammerer 2009. Since these items top in different concepts (e.g., internal technical capability and external expert connection), the Know-how construct is deemed formative.

Monitoring ability. The operationalization of Monitoring Ability was based on interviews and Energy Efficiency Survey Project, International Finance Corporation, World Bank group, 2010. The items share the same common core, and are all related to the objective monitoring of both physical and financial characteristics of energy consumption. Monitoring ability therefor is a reflective construct.

Internal buy-in. Both items of internal buy-in address the departmental acceptance of energy efficiency. If there is any change in the overall internal buy-in of a company, this change will affect energy efficiency acceptance of both the production and quality departments. Therefore, internal buy-in should be a reflective item.

Ease of implementation. The two items measuring the ease of the energy efficiency implementation address two different challenges: the easiness to stop the current production & the physical constrains faced by the company. As the items contribute to different dimensions of ease of energy efficiency implementation, the ease of implementation is a formative construct.

The items of *Energy efficiency initiatives outcomes* share the same common core: the proper implementation of the energy efficiency projects. Any proper energy efficiency project of a company must be on schedule, within budget, and generate satisfactory outcome. Therefore, all the items are expected to covary. For example, the overdue of a project often involves additional expenses, which in turn reduces the overall satisfaction of the project. Thus, the energy efficiency initiatives outcomes is a reflective construct.

Table 6 - Constructs and items.

Construct	Items	Sources
Cost motivation	CM1: Reducing energy cost can lower my company's overall production cost substantially.	From interviews
	CM2: My company implements energy efficiency practices and technologies so as to reduce energy costs.	Gonzalez-Benito 2005
	CM3: Energy efficiency implementations tend to increase our costs of business due to costlier processes and materials and more compliance.	From interviews
CSR	CSR1: My company is concerned and cares about the environment.	From interviews
	CSR2: My company is committed to reducing our impact on natural environment, even if this entails lower productivity and higher operating costs.	Gonzalez-Benito 2005
	CSR3: My top management views environmental issues seriously.	From interviews
Legal compliance	RC1: There is NO comprehensive set of law and regulations on energy management by the national authorities (reverse)	From interviews
	RC2: There is a strong penalty by national regulators if we do not adhere to rules and regulations of energy consumption.	From interviews
Know-what	KW1: My company is aware of the opportunities improvement for energy efficiency.	From interviews and Singapore industry energy data (Singapore Economic Development Board)
	KW2: My company understands energy costs well as we have data.	
	KW3: My company knows the best practices and technologies to reduce energy consumption for our processes.	
Know-how	KH1: The engineers and technicians in my company have the technical knowledge to implement energy efficiency practices and adopt energy efficient technologies.	Kammerer 2009
	KH2: My company can easily access external experts who can help us in conducting energy audits and implementing energy efficiency improvements.	Luken, Rompaey and Zigova 2008
	KH3: My company knows exactly who to approach to learn about energy efficiency improvements.	Luken, Rompaey and Zigova 2008
Monitoring ability	MA1: In my company, energy savings from projects can be verified objectively.	From interviews
	MA2: My company uses an automated metering & control system (real-time) to track energy consumption.	Energy Efficiency Survey Project, International Finance Corporation,World Bank group, 2010
	MA3: Energy savings from energy efficiency projects is monitored quantitatively in financial and physical units.	From interviews
Internal buy-in	IB1: My company's production department resists energy efficiency improvement projects for fear of disruption to production and delivery schedule.	Murillo-Luna, Garces-Ayerbe and Rivera-Torres 2011
	IB2: My company's quality department resists energy efficiency improvement projects for fear of risks to product and process quality.	Murillo-Luna, Garces-Ayerbe and Rivera-Torres 2011
Ease of implementation	EI1: In my company, production can be stopped easily in order to carry out energy efficiency improvement activities (e.g. upgrading of electric motors).	Murillo-Luna, Garces-Ayerbe and Rivera-Torres 2011
	EI2: My company faces physical constraints (e.g. lack of space) to implement energy efficiency improvements. (reverse)	From interviews
Energy efficiency initiatives outcomes	EE1: Overall, our energy efficiency projects are on schedule.	From interviews
	EE2: Overall, our energy efficiency projects are within budget.	From interviews
	EE3: The outcomes of our energy efficiency projects meet our expectations.	From interviews
	EE4: Overall we are satisfied with the returns of our energy efficiency projects.	From interviews

5. Data analysis and results

In this section we first test the effects of industrial sectors and firms' size on the dependent variable. Then we check the reliability of the measurement model, the common method bias. Eventually we present the results of the structural model.

5.1. Sector invariance

We first control for the industry sector by performing an ANOVA in SPSS. We examine whether or not respondents' answers vary across the industrial sectors that are represented in our sample. We look at all items that measure the energy efficiency outcomes (EE1 to EE4). The results are shown in Table 7 below.

Table 7 - ANOVA for sector invariance.

		Sum of Squares	df	Mean Square	F	Sig.
EE1	Between Groups	9,035	4	2,259	0,808	0,523
	Within Groups	310,275	111	2,795		
	Total	319,31	115			
EE2	Between Groups	13,869	4	3,467	1,27	0,286
	Within Groups	303,165	111	2,731		
	Total	317,034	115			
EE3	Between Groups	11,521	4	2,88	1,028	0,396
	Within Groups	311,031	111	2,802		
	Total	322,552	115			
EE4	Between Groups	17,733	4	4,433	1,617	0,175
	Within Groups	307,036	112	2,741		
	Total	324,769	116			

All p-values being above the protection level alpha = .05, we fail to reject the null hypothesis that all means are equal among sectors. In other words, there is no significant difference in respondents' answers between industrial sectors. One interpretation of this result is that industries in Singapore represent a very homogeneous sample in which industries have similar practices, in particular in the domain of energy efficiency. Liu et al (2013) find a comparable invariance in their study, and argue that this could be due to the small geographic area where the survey was conducted. In such a limited area, respondents tend to have similar levels of energy savings, regardless of their industrial sector.

5.2. Firm's size invariance

The following histogram shows the repartition of firms' size in our sample. It is strongly left-skewed towards industries with less than 50 employees. This is desirable since a more even repartition in our sample allows us to examine it as a whole. In other words, the consistency of the distribution adds credibility to our analysis. We also perform an ANOVA to test whether firms' sizes explain differences in the answers. Again, all items measuring the energy efficiency outcomes are used in the analysis. The results are shown in Table 8.

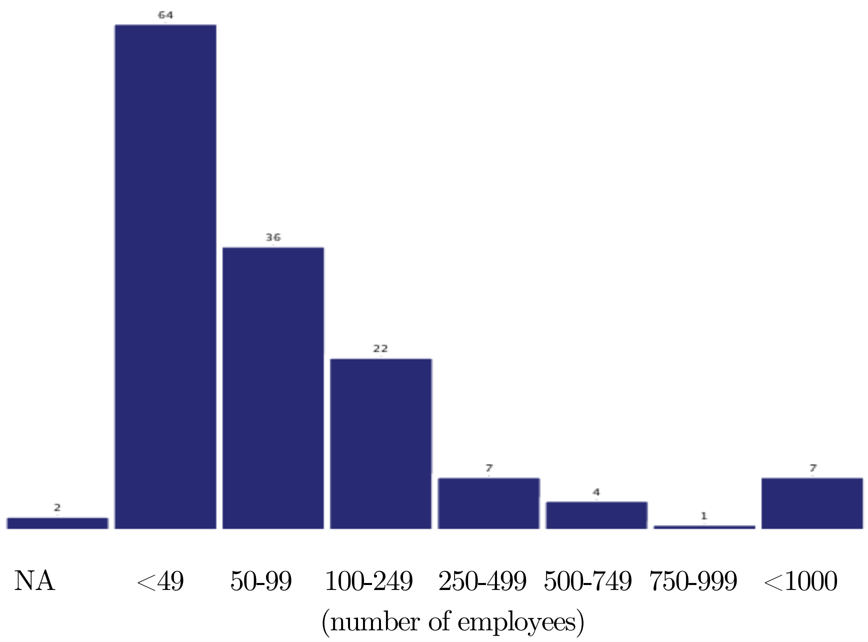

Figure 3 - Firms' size distribution.

Table 8 - ANOVA for firms' size invariance.

		Sum of Squares	df	Mean Square	F	Sig.
EE1	Between Groups	10,103	7	1,443	0,481	0,846
	Within Groups	350,729	117	2,998		
	Total	360,832	124			
EE2	Between Groups	15,031	7	2,147	0,724	0,652
	Within Groups	347,097	117	2,967		
	Total	362,128	124			
EE3	Between Groups	3,894	7	0,556	0,188	0,988
	Within Groups	346,794	117	2,964		
	Total	350,688	124			
EE4	Between Groups	9,359	7	1,337	0,455	0,865
	Within Groups	346,799	118	2,939		
	Total	356,159	125			

Again, all p-values are above the protection level alpha = .05. Hence we fail to reject the null hypothesis that all means are equal among firms' size groups. That is, we show the invariance in respondents' answers among groups of firms' size. One the one hand, this invariance further strengthens the homogeneity of our sample in terms of firms' size. One interpretation is that the strongly left-skewed distribution shown in Figure 3 may not have enough variance to produce significant differences across different industry sizes. Arguably, more larger firms in our sample would have made the ANOVA results significant but would also have compromised the homogeneity of our sample, which is not desirable. In that case, indeed, it would not have been possible to treat our sample as a whole. One the other hand, such an invariance contrasts with some studies (e.g. Aramyan et al., 2007; Hofer et al., 2012; Schleich, 2009) – but not all (Fleiter et al., 2012) – that tend to show that bigger companies are more likely to better implement energy efficiency. Likely though, industry size effects are partially captured by some of the other variables. As an example, big companies tend to have more technical personnel to implement energy efficiency projects, that is, they should have a better Know-how.

5.3. Test of measurement model and common method bias

In order to assess to validity of the measurement model we examine reliability, convergent validity, and discriminant validity of the items, keeping in mind that formative and reflective items need to be treated differently as explained in what follows (Petter et al., 2007).

Regarding the reflective items, we examine the reliability by computing at Cronbach's alphas coefficients. All constructs show satisfactory scores, exceeding the threshold of 0.70 (see Table 11). We then test the convergent validity by looking at items loadings, composite reliability (CR), as well as average variance extracted (AVE) for each latent variable (see Table 11). All constructs show adequate item loadings (> 0.70), CRs (> 0.70), and AVEs (> 0.50). This indicates sufficient convergent validity. We further assessed discriminant validity by performing an explanatory factor analysis in SPSS 21.0 (in which the number of extracted factors is fixed to 5), and a comparison of the constructs correlations and the square roots of their AVEs. Factor analysis shows that all items are loading significantly on their intended constructs (see Table 9) and construct correlations are lower than their respective AVEs' square roots, confirming satisfactory discriminant validity (see Table 10). To test whether there is any multicolinearity issue we compute the variable inflation factor (VIF) using the factors scores provided by the SmartPLS for a linear regression in SPSS. The VIFs are in the range 1.035 and 2.147, far below the stringent 3.3 cut-off value for multicolinearity issues.

In the case of formative measures, instead of examining the factor loadings, we examine factor weights (see Table 12) – which represent a canonical correlation analysis and provide information about how each indicator contributes to the respective construct (Mathwick et al., 2001). Formative items' weights are usually smaller than reflective items' loadings. The PLS method optimizes the items' weights to maximize the explained variance of the dependent variables in the model. Hence, a formative construct's rather small absolute weights do not mean a poor measurement model (Chin, 1998). If these weights are not significant, they may be considered for elimination, keeping in mind that the remaining items still should cover all aspects of the construct domain (MacKenzie et al., 2011). Multicollinearity among the items is a concern with formative measures (Mathwick et al., 2001), since it can produce unstable estimates. If there is evidence of multicollinearity, the problematic, non-significant items should be discarded. Hence, we performed a collinearity test by regressing the formative factors' scores against the dependent variable; the results showed minimal multicollinearity, the VIFs of all items being far below the stringent 3.3 cut-off value again. Hence, we do not discard the formative items that are not significant.

Before examining the structural model we compute a Harman procedure to test if there is any evidence of common method bias in our data set. We perform a factor analysis in SPSS for all reflective constructs and fix the number of components extracted to one. If this component explains the majority of the total variance, this suggests a presence of common method bias. The test shows that the extracted component explains 46% of the variance, which shows that there is no or little common bias in the sample.

Table 9 – Factor analysis (rotated matrix).

Constructs and items	CSR	KW	MA	IB	EE
CSR motivation (CSR)					
CSR1	**0,877**	0,169	-0,044	-0,084	0,172
CSR2	**0,712**	0,117	0,330	0,120	0,084
CSR3	**0,803**	0,354	0,110	-0,037	0,206
Know-what (KW)					
KW1	0,331	**0,786**	0,186	0,144	0,205
KW2	0,130	**0,855**	0,176	0,007	0,286
KW3	0,316	**0,728**	0,305	0,052	0,288
Monitoring ability (MA)					
MA1	0,054	0,061	**0,869**	0,019	0,203
MA2	0,181	0,324	**0,732**	0,077	0,378
MA3	0,164	0,386	**0,721**	0,027	0,217
Internal buy-in (IB)					
IB1	0,006	0,065	0,016	**0,942**	0,130
IB2	-0,013	0,050	0,058	**0,948**	-0,006
Energy efficiency initiatives outcomes (EE)					
EE1	0,181	0,223	0,278	0,012	**0,846**
EE2	0,084	0,213	0,168	0,082	**0,906**
EE3	0,159	0,221	0,150	0,072	**0,916**
EE4	0,166	0,163	0,222	0,032	**0,900**
Variance (%) (without rotation)	**11.2**	**12.5**	**8.40**	**5.89**	**46.3**

Table 10 – Construct correlations versus square root of AVE.

	EE	CSR	MA	IB
EE	**0.952**			
CSR	0.408	**0.863**		
MA	0.573	0.419	**0.876**	
IB	0.157	0.037	0.137	**0.943**

Table 11 – Item loadings of reflective constructs.

Constructs	Item	Loading*	t-value
CSR motivation (CSR)	CSR1	0.876	20.362
α = 0.812 ; CR = 0.889 ; AVE = 0.730	CSR2	0.790	13.779
	CSR3	0.919	53.187
Know-what (KW)	KW1	0.908	46.341
α = 0.891 ; CR = 0.932 ; AVE = 0.821	KW2	0.893	36.090
	KW3	0.917	56.928
Monitoring ability (MA)	MA1	0.819	15.282
α = 0.849 ; CR = 0.908 ; AVE = 0.768	MA2	0.932	88.541
	MA3	0.874	25.560
Internal buy-in (IB)	IB1	0.987	5.338
α = 0.896 ; CR = 0.941 ; AVE = 0.889	IB2	0.897	5.093
Energy efficiency initiatives outcomes	EE1	0.939	62.136
(EE)	EE2	0.949	78.886
α = 0.965 ; CR = 0.975 ; AVE = 0.906	EE3	0.968	135.919
	EE4	0.951	76.762

*All item loadings are significant at p<0.001

α = Cronbach's alpha; CR = Composite Reliability; AVE = Average Variance Extracted

Table 12 – Item weights of formative constructs.

Constructs	Item	Weight	t-value
Cost motivation (CM)	CM1	0.209	1.231
	CM2	0.840***	7.240
	CM3	0.284*	2.315
Legal compliance (LC)	RC1	- 0.567	0.869
	RC2	0.977	1.426
Know-how (KH)	KH1	0.889***	5.644
	KH2	0.129	0.837
	KH3	0.068	0.418
Ease of implementation (EI)	EI1	0.988**	3.062
	EI2	0.101	0.231

* Item significant at p<0.05

** Item significant at p<0.01

*** Item significant at p<0.001

5.4. Test of structural model

Testing interaction effects in a formative model requires caution. As Chin explains "since formative items are not assumed to reflect the same underlying construct (i.e., can be independent of one another and measuring different factors), the product indicators between two sets of formative indicators will not necessarily tap into the same underlying interaction effect" (Chin et al. 2003, Appendix D). Hence, instead of computing pair-wise items products in PLS and looking at the significance of the paths of the product terms, we use a two-step procedure suggested by Chin et al. (2003). First the direct effects of the independent variable on the dependent variable are tested in SmartPLS, using a case-wise elimination for missing values. Then the corresponding factors scores are saved and used for to build the interaction terms by multiplying the scores pair-wise. Eventually the interaction terms and the factor scores serve as independent variables in a multiple linear regression against the dependent variable. During this process, all items need to be standardized (or centered) for an adequate interpretation of the interaction terms (Chin et al. 2003). The results are shown in the Table 13 below.

Table 13 – Results of structural model.

Without interaction effects	**Path coef.**	**t-value**	**Result**
Dependent variable: EE			
(R_1^2 = .454)			
Cost motivation (CM)	.325***	3.473	**Significant**
CSR motivation (CSR)	.016	.179	Not significant
Ease of implementation (EI)	.009	.127	Not significant
Internal buy-in (IB)	.056	.577	Not significant
Know-how (KH)	.211*	2.146	**Significant**
Monitoring ability (MA)	.254**	2.718	**Significant**
Legal compliance (LC)	-.056	.675	Not significant
Dependent variable: KH			
(R^2 = .448)			
Know-what (KW)	.669***	12.735	**Significant**

With interaction effects	**Path coef.**	**t-value**	**Result**
Dependent variable: EE			
(R_2^2 = .473)			
CM	.369***	3.746	**H1 supported**
CSR	-.019	-.203	H2 not supported
EI	.004	.051	H7 not supported
IB	.051	.713	H6 not supported
KH	.239**	2.451	**H5 supported**
MA	.215*	2.133	**Not hypothesized**
LC	-.021	-.268	H3 supported
CM.MA	.149*	2.021	**H8 supported**

* Item significant at $p<0.05$
** Item significant at $p<0.005$
*** Item significant at $p<0.001$

5.5. Results

5.5.1. Direct effects model

Cost motivation ($t = 3.47$, $p < 0.001$) and Know-how ($t = 2.15$, $p < 0.05$) have both a significant effect on energy efficiency outcomes. Know-what works as a significant proxy for Know-how ($t = 12.73$, $p < 0.001$). We also test the direct effect of Monitoring ability on the dependent variable before adding the interaction term in the second model as it is required when examining moderation effects. Surprisingly, Monitoring ability is found to be significatively and positively correlated with energy efficiency outcomes ($t = 2.72$, $p < 0.005$). This observation is discussed later on.

5.5.2. Interaction model

The moderating term (Cost motivation x Monitoring ability) is then added to build the interaction model. The significant effects in the previous model are still significant in the interaction model: Cost motivation ($t = 3.75$, $p < 0.001$) and Know-how ($t = 2.45$, $p < 0.005$) have both a positive impact on energy efficiency outcomes. The correlation between the moderator Monitoring ability and the dependent variable remains also significant in the second model ($t = 2.13$, $p < 0.05$). Moreover, the moderating term is found to be significant ($t = 2.02$, $p < 0.05$). Recall that "a significant interaction term *X.Z* indicates that the effect of *X* on *Y* differs across the range of the moderator variable *Z*' (Dawson and Richter, 2006, p. 917). In other words, a high Monitoring ability reinforces the effect of Cost motivation on energy efficiency outcomes. According to the directives of Cohen and Cohen (1983) we plot the dependent variable for two levels of moderator and two levels of Cost motivation (see Figure 4 below).

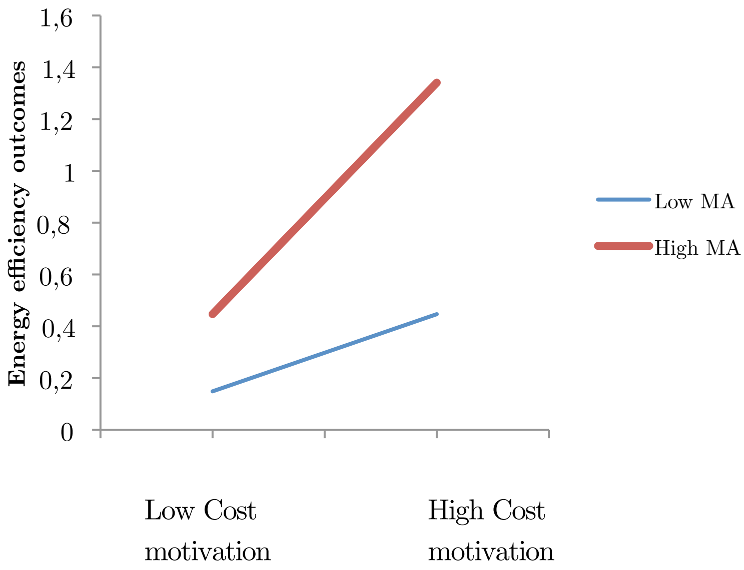

Figure 4 - Moderation effect of Monitoring ability.

Overall, hypotheses *H1*, *H4*, *H5* and *H8* are supported. This is represented in Figure 5 below. The interaction model improves the overall fit (R_2^2 = .473) compared to the direct effects model (R_1^2 = .454). This improvement can be quantified by computing the effect size $f^2 = (R_2^{2} - R_1^{2}) / R_1^{2}$ (Handbook of Partial Least Squares, 2010). The effect size here is f^2 = .0419 which indicates a small to medium effect (Cohen, 1998).

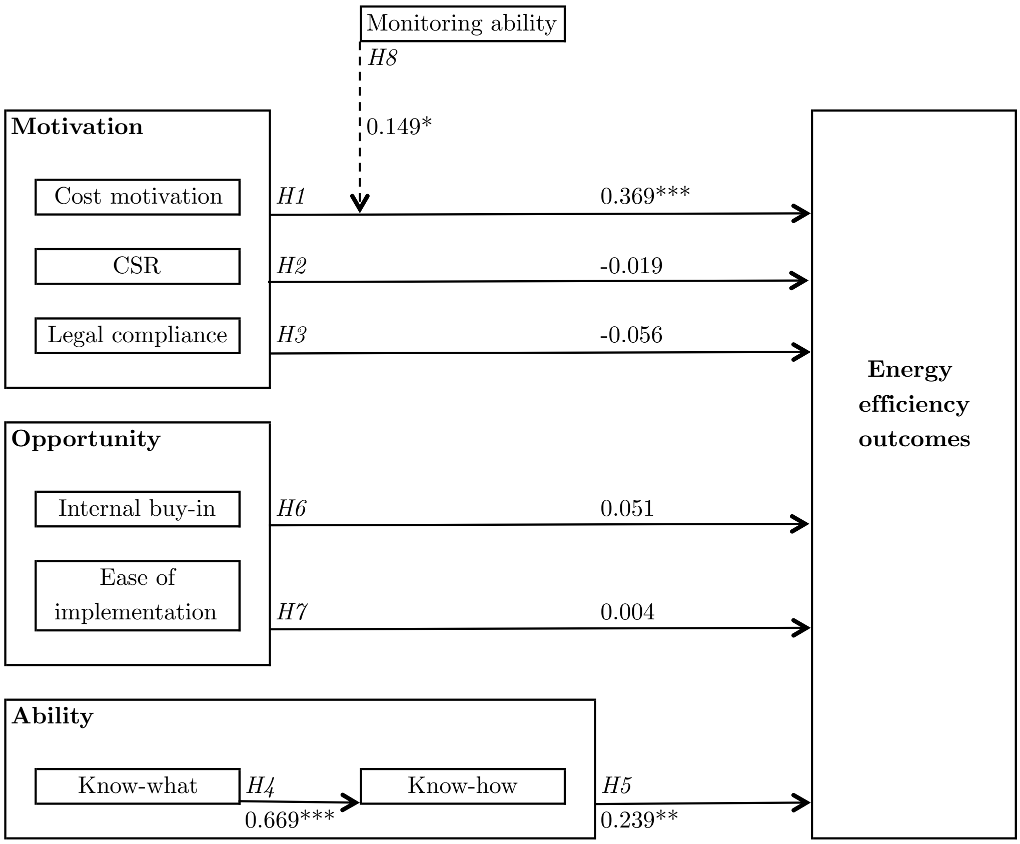

Figure 5 - Supported hypotheses

6. Discussion and Conclusion

In this section we first summarize and discuss the research findings corresponding to the hypotheses we proposed in Chapter 3. We give possible interpretations to these findings and to why certain hypotheses are not supported in our context. Then after we detail the implications of our results for energy-related research. Eventually we discuss the limits and the future work of our study.

6.1. Discussion

Cost motivation has the highest impact (standard path coefficient = 0.37 in the interaction model) on energy efficiency outcomes. This can be interpreted as a consequence of the firm's bottom-line to increase its profits by cutting down its operation costs. As explained in the hypotheses development section, energy costs often represent of non negligible part of an industry's costs. In Singapore especially, high energy prices are likely to further strengthen firm's wish to lower its operating costs. The relation between energy prices and savings has been reported by several authors (Boonekamp, 2011; IEA, 1997; De Buck et al., 2010), which reinforces our intuition. Further, energy-related costs can be effectively reduced internally, unlike costs of raw materials, logistics or marketing that are often intertwined with external factors that are beyond firm's control. Therefore, our results confirm that energy efficiency projects that have a substantial reducing effect on energy costs are more attractive to firms, in comparison to those projects that offer no significant advantages on energy costs. Overall, this finding supports the results by de Groot et al. (2001), Hasanbeigi et al. (2010), Schleich and Gruber (2008), Schleich (2009) and Velthuijsen (1995). Overall we suspect than the effect of Cost motivation on energy efficiency outcomes will strengthen over the years as resource prices are expected to rise in coming years (Berger, 2009).

The second largest effect on energy efficiency outcomes is driven by firm's Know-how (standard path coefficient = 0.239 in the second model). When reversed, this result confirms that the lack of qualified personnel is a serious energy barrier, as several studies have shown it (e.g. Prindle, 2010). Such a barrier can be seen as a transaction cost for the industry. Whatever the path taken by an industry to implement energy efficiency (evaluation of energy wastes, optimization of heating and cooling processes or adoption of new technology), all these processes call for certain skills and competencies. As argued in the hypotheses development, embracing energy efficiency often implies the adoption of new, unfamiliar and complex technologies, which generally speaking require higher knowledge and skills for the industry to be implemented (Dewar and Dutton, 1986). The level of this knowledge is even more critical when changes affect the core processes of the industry (Anderson and Newell, 2004; Dieperink et al., 2003). Our results confirm these considerations, and stress out the importance of Know-how when implementing energy efficiency projects. Further, these significant results reinforce the importance of energy audits that are captured in the measurement model for the Know-how variable. Overall, these audits are a good way to overcome imperfect information barriers. Further, and as a complementary finding, the quality of energy audits (in terms of satisfaction with audits) is also found to be significant in Fleiter et al. (2012).

One other remarkable result is that Monitoring ability moderates the effect of Cost motivation on energy efficiency outcomes. Recall that Monitoring ability is *the extent of firm's ability to monitor the results of energy efficiency implementation at both physical and financial levels*. This is an important factor that has been neglected both in MOA-based studies and to some extent in energy efficiency academics. The significant moderation effect of this variable shows that a strong ability to precisely *show* and *demonstrate* the benefits of energy efficiency investments in terms of energy savings further intensify firm's motivation to cut down costs and, in the end, the extent to which energy efficiency projects deliver. As a contrasting example, lack of monitoring abilities makes the identification of faulty, energy-intensive machinery almost impossible. As a result, motivation to embrace energy efficiency remains low, especially when the machinery can still perform its task. One typical attitude that illustrates this phenomena is: "if the machine works why change it?" – which is also related to the resistance to change and the fear of disruption. In this case, lack of monitoring capabilities hides the fact that this functional machine consumes lots of energy, which in turn does not encourage any replacement. Besides, one interpretation of this moderation effect is that as long as industries can see financial benefits from energy efficiency projects, they are likely to carry on their energy savings efforts. Bunse et al. (2011) give some key needs for proper energy monitoring system. These needs include, among other things, "More integration with systems using real-time data for operational monitoring and facilitating strategic decisions regarding energy efficiency", "Production line performance system to monitor energy consumption" or "Sensor technology for monitoring and transmitting production asset energy performance".

As mentioned in the results section (5.5.), Monitoring ability is itself significatively correlated with the extent to which energy efficiency projects deliver, which is something we have not hypothesized since a causal link between the two phenomena seems rather unlikely. In other words, setting up a sophisticated energy monitoring system cannot by itself lead to energy savings, which are rather driven by all the sub-dimensions of motivation, ability and opportunity. Yet this setup is likely to motivate an industry to embrace energy efficiency as discussed above. One possible way to interpret this correlation though is to notice that high capabilities to monitor the results of energy efficiency projects correspond to industries that have achieved a certain level of energy efficiency. Indeed, at the first stages of energy efficiency implementation, priority is to buy new energy-efficient equipment, hire competent personnel to install these machines, and so on. Tracking the results of such efforts then come next on the agenda. Therefore, firm's Monitoring ability can be seen as a good indicator of its level of energy efficiency implementation. If it is low, it is likely to be at the early stage of energy efficiency adoption. If it is high, the industry is likely to have already implemented some energy efficiency projects.

If our study shows than industries themselves can greatly benefit from an efficient monitoring system, it is also likely than the adoption of such systems will be fostered by policy-makers and governments in the future. Indeed, micro-level energy data provided by firms is a prerequisite for building macro-level indicators that are more available, precise and comparable across countries. In turn, these "energy indicators can play an important role in supporting energy efficiency policy development and evaluation" (IEA, 2008, p. 10). Designing these indicators presents some challenges. In non-IEA countries for example, "little or no detailed data [is] available for most countries" (IEA, 2008, p. 76), which makes the need for a proper monitoring system even more critical. As a response, some of these countries take part into programs that help them develop new energy indicators. The IEA, for instance, together with the World Bank, is aiding organizations in Mexico, China and South Africa design these indicators. Further, energy performance measurement and monitoring at operating levels are only now early-stage concepts (Sivill et al., 2013). The availability of data is not the only concern. Some other obstacles, like confidentiality of the data provided by firms or anti-trust legislation also make the aggregation of micro-level energy data problematic.

The supported hypotheses provide us with some key insights when an industry embarks on energy efficiency. Yet some hypotheses remain not validated.

First, Legal compliance is found to have no effect on energy efficiency outcomes. This surprising result can be observed in other studies. One very relevant example is found in Liu et al. (2013), in which the "regulative pressure" does not drive the "total energy savings activities" despite the high "regulative pressure" perceived by the respondents. As mentioned in the Literature Review, this example shows how much great care researchers should take in making conclusions about barriers that have a high score – that is, a barrier that is perceived to be present by most respondents: highly-scored barriers may well not have any statistical effect on energy efficiency outcomes. In the context of our research the absence of effect of Regulatory compliance suggests that older laws regulating energy efficiency at the time of the survey were not sufficient to affect firm's motivation to embrace energy efficiency. Although the respondents may represent Singaporean energy-intensive firms, the questionnaires were sent out two years before Singapore energy efficiency related laws like the Energy Conservation Act which introduces minimum energy management standards for large energy users (more than 15 GWh per year) from fiscal year 2013. As a consequence, the effectiveness of this mandatory policy in enhancing energy saving practices of companies could not be observed in this survey. Keeping track on behavioral changes of industries on energy efficiency in response to the implementation of related policies would be useful for understanding the appropriate and effective policy direction.

Contrary to hypotheses, CSR is also deemed to have no serious effect on firm's energy efficiency outcomes. One interpretation of this result is that this absence of effect is somehow related to the non-effect of Legal compliance discussed above. Indeed, firm's CSR policy can be seen as a way to anticipate future energy-related laws. If law pressure exerted on industries remains low, then adopting a proactive position in terms of environment preservation may not be a priority. In other words, Legal compliance can be seen as an antecedent for firm's extrinsic CSR. When law pressure is low, firm's CSR is mostly intrinsic.

Eventually the Opportunity variables, namely Internal buy-in and Ease of implementation, are found to be not contingent upon energy efficiency outcomes as hypothesized. In other words, the overall Opportunity does not explain the extent to which energy efficiency projects deliver in our research context. This result deviates from previous findings on barriers such as risk of disruption and resistance to change that are in essence captured in the items measuring Opportunity sub-dimensions. The Opportunity dimension also reflects transaction costs issues, such as the time needed to implement the energy efficiency decision. This absence of effect can be interpreted as the proactive attitude of Singapore industries when a decision is taken. Further, this result can be imputed to the small size of our industries sample. In SMEs, the hierarchical ladder is somehow both shorter and narrower than in big companies, which tightens top-management executives and operators together. In such organizations, top-management executives are even more influential in the decision-making process; decisions flow more rapidly in the company, which gives more opportunity to implement them. These ideas are confirmed by Velthuijsen (1995), who shows that larger companies face slow decision-making processes, which in turn delays the adoption of energy efficiency projects.

6.2. Implications to research

This study makes four major contributions to the existing literature.

First, we attempt to use test a novel framework on energy efficiency-related issues. Arguably, the understanding of energy efficiency adoption does benefit from alternative theories to mainstream economics which constitute the theoretical base for the energy barriers concept. Indeed, neo-classical economics usually treat firms as "black boxes" in which managerial realities are hardly taken into account. As Stiglitz (1991, p. 15) recalls, "if economists wish to understand how resources are allocated, we must understand what goes on inside organizations". The variables used in our framework, namely, Motivation, Opportunity, and Ability, illustrate our willingness to penetrate these "black boxes".

Second, we refine the traditional MOA theory by adding an external moderator, namely the Monitoring ability. Future MOA-based studies can greatly benefit from testing the effects of a performance tracking variable on their research questions. This performance measurement variable has to be specified within the particular context of research. In the case of energy efficiency, we see two major areas that are relevant to build the construct: energy metering or energy savings tracking and financial monitoring. Our findings suggest that, albeit different in their nature a priori, both dimensions are merged into a same variable by respondents – see factor analysis – and that this variable has important effects on energy efficiency outcomes by moderating firm's Cost motivation.

Third, our study mainly focuses on the effects of barriers on energy efficiency outcomes rather than identifying them. Energy barriers are now a well-established concept and there are now numerous studies that attempt to discuss their presence in a specific context. Less though try to investigate about the other side of the energy barriers coin, that is, do the identified barriers really affect energy efficiency outcomes? As a result, this question remains unclear. Researchers should now mainly focus on links between barriers and energy efficiency, or even between barriers or groups of barriers (e.g. Chai et al., 2012). Again, we should emphasize that a barrier that is perceived to be important by respondents is not necessarily deemed to affect energy efficiency efforts. Energy barriers theory argue so, but empirical evidence is still required to prove it. Generally speaking, we believe that more empirical studies should be beneficial for the understanding of energy efficiency-related matters. As Trianni and Cagno (2012) observe, there is indeed a "huge" amount of theoretical contributions on barriers in academics. Empirical investigations are scarce, though. Ultimately such studies would help better energy policy making.

6.3. Limits and future work

Our study has several shortcomings. First, we rely on subjective answers of respondents to evaluate their perceptions of energy efficiency matters within their industry. Second, this study would have benefited from a broader spectrum of industry sectors and industry sizes since this would have had more generalizability to our findings. Eventually, we believe that collecting panel data would worth the effort for the understanding of energy efficiency issues. Among others things, such an approach would be extremely beneficial to track the causal relationships between energy efficiency efforts and its determinants over time.

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