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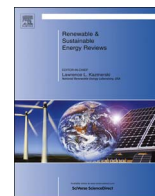
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# LED standardization in China and South East Asia: Stakeholders, infrastructure and institutional regimes



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## ABSTRACT

LED is now becoming the new standard in lighting solutions in developed countries. However, in developing countries, it is not yet used on a large scale. One of the reasons is a lack of established regional standards for LED. An institutional infrastructure for standardization is one of the essential elements for the establishment of common standards. We examine the institutional infrastructure for LED lighting in China, the Philippines, Thailand, Vietnam, and Indonesia by conducting a stakeholder analysis. Although many stakeholders are involved in LED standardization in these countries, each country has a distinct standardization process. We argue that the institutional environment in these countries influences the role of stakeholders in the standardization process. We distinguish these five countries in terms of their standardization regime shaped by political, professional, and business interests, which are represented by the stakeholders involved in the standardization process.

## 1. Introduction

Climate change is a severe threat to global development and a priority on the international agenda. In order to fight climate change, reducing greenhouse gas emission is essential. Taking into account that energy consumption is the main cause of greenhouse gas emission, energy efficiency plays an important role within the international debate on climate change. Within this context, LED lighting, as one of the existing energy-efficient technologies [1], provides a lighting solution which uses less energy than most other types of lamps.

However, before LED lighting can be widely adopted, standards for e.g. lighting quality need to be developed. Standards can lead to reduced production costs and lower prices, thus increasing the installed base for products that implement LED technology [2]. Indeed, such standards are widely available in developed countries. The International Electrotechnical Commission is the main international standard setting institute involved in LED standardization. LED standards activities also take place at a regional level. For example, in 2013, the European Commission identified the need for LED standardization and issued a mandate addressed to the European Committee for Standardization, the European Committee for Electrotechnical Standardization and the European Telecommunications Standards Institute (the three official European standardization organizations) to develop LED standards in 20 areas

including luminaire lifetime, power consumption over the lifetime, and light metric definitions [3]. Furthermore, national standards organizations such as the Japanese Standards Association, the American National Standards Institute, the British Standards Institution, the Canadian Standards Association, and the German Institute for Standardization are also developing LED standards. Finally, many companies from developed nations are involved in standards consortia such as ASTM International and the Global Lighting Association. In conclusion, the main drivers for standardization in the western world include firms, national, regional and international standards organizations, and governments. These institutions are all actively involved. Over the years, more than 160 standards have been developed for different aspects of LED [4].

Developing countries also stimulate the adoption of LED lighting as they acknowledge that this can contribute to reducing greenhouse gas emissions [5]. However, although standards are available in developed nations, regional standards for LED lighting do not exist in most developing countries. In order to stimulate the transition to LED lighting (and thereby reducing greenhouse gas emissions), a proper stakeholder infrastructure for standardization is required. However, in developing countries, numerous national and international organizations, governments and associations are involved in the standardization process each with their own interests, complicating standard setting. Due to the great differences among developing countries in

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terms of local industry and institutional conditions, it is difficult to develop one overall standard that can be accepted in all these countries.

The objective of this paper is to explore the stakeholder infrastructure for standardization in developing countries. Specifically, we aim to study the relevance and importance of stakeholders involved in the standardization process in the Asian region. The analysis of transnational standard setting of LED in Asia gives us insight into the process of standardization and contributes to the growing academic interest in standardization in the Asian region. Research in the field of standardization in this geographical area is limited [6]. We raise two questions. First, are Asian developing countries involved in LED standardization and if so what is their level of involvement? Second, how does the institutional and industrial environment influence the standardization process of LED lighting in developing Asian countries? In order to answer these questions, we conducted a case study analysis of various Asian developing countries including China, the Philippines, Thailand, Vietnam, and Indonesia.

We use both theory on standardization and stakeholder theory to identify and analyze the actors that are involved in the standardization of LED lighting in Asian developing countries. Taking into account that the world has become increasingly interconnected and that the transition to LED lighting in developing countries affects many individuals, groups and organizations, stakeholder analysis provides valuable insight into the standardization process. We focus on the institutional and industrial level and develop a strategic view of the institutional and industrial landscape in five Asian countries.

## 2. Theory

Over the past few decades, research on standardization has been conducted from a variety of disciplinary backgrounds, including industrial economics [7,8], evolutionary economics [9], strategic technology management [10], marketing [11], social network theory [12], and governance [13]. Research on standardization has mainly focused on developed countries and not so much on developing countries [6].

Standards can be the outcome of a committee-based or a market-based standardization process [14]. In other words, standards can be established through official standardization institutes or through market forces. *De jure* standards are defined by committees and approved by authoritative national or international bodies before market adoption. When standards are established by market forces, they are called *de facto* standards [15]. Considerably few scholars have focused on committee-based standardization (exceptions include e.g. [13,16,17]. The processes within committees are characterized by a high degree of complexity, which is caused by the intertwined political interests of the parties involved [16]. Although such processes are often accompanied by complications that may be detrimental for the outcome of the decision making process, they often result in common standards as actors gradually want to reach consensus [13].

Ample research has been conducted on factors for the establishment of *de facto* standards [18–22]. Various factors for standard dominance have been mentioned, which are mostly related to the ways in which installed base can be increased. This is important as network economists [7,8] have pointed out that under the influence of network effects, installed base is a key precursor for standard success. Network effects refers to the notion that technology increases in value the more it is adopted by consumers. One way for firms to increase installed base is the possession of key resources. Such resources include financial resources [23], reputation and credibility [24], and production capacity [25]. For instance, in the battle for a multi-channel audio sound technology, the fact that Dolby laboratories had actively built up a high reputation among movie studios was one of the reasons why Dolby's standard AC-3 eventually won the battle from MPEG-2 [26]. Essential resources may be applied to pursue strategic maneuvering [20] and set a dominant standard in the market. For example, by entering com-

paratively early in a market, firms can pre-empt rivals and quickly acquire an initial lead [18,19]. Also, marketing strategies may be applied to convince consumers to choose for products in which standards are implemented [27], and penetration pricing strategies may be used to quickly increase installed base [8]. These strategies are often observed in many standards battles including the battle for video gaming console formats [28], and high definition DVD [29]. Apart from resources and strategies, firms may outcompete their rivals by offering a solution that is a technologically better or more advanced alternative. However, a technically more advanced standard may still be out-competed by another rival technology. This happened in the battle between USB vs Firewire where the former standard was initially technically inferior to the latter but still won the battle [26]. Another aspect that falls under the heading of technological characteristics is the extent to which the standard enables backwards compatibility. This can be a key element of standard success as was the case in the battle between WiFi and HomeRF [30]. Recent research points to the importance of flexibility for standard success [31].

The literature on market-based standardization provides us with several frameworks to gain insight in factors for standard dominance such as those mentioned in the previous paragraph [18,20,22]. These frameworks also mention the importance of specific stakeholders such as the regulator, the judiciary, standards committees, and standards consortia. However, the literature hardly devotes any attention to the specific level of involvement such stakeholders have within the standardization process or to how these stakeholders influence the standardization processes and each other. De Vries et al. [32] propose an approach to identify all stakeholders involved in the process and to determine their level of involvement. This approach is based on the Stakeholder Salience Model of Mitchell et al. [33]. The model is not based on characteristics of the stakeholders themselves but on determinants of stakeholder salience – “the degree to which managers give priority to stakeholder claims” [34, p. 870]. The authors distinguish three variables in the stakeholder-firm relationship that determine stakeholder salience: power, legitimacy, and urgency.

Power refers to the degree to which a stakeholder or group of shareholders can influence the standardization process [32] by having access to money, expertise, and knowledge. Legitimacy refers to the degree to which stakeholders and the firm consider each other's actions to be desirable, proper, or appropriate. It refers to whether a firm is actually permitted to participate in the formal standards setting process, but also to whether it is accepted by the other parties involved. Urgency refers to the degree to which the stakeholder's claim is urgent. In other words, it clarifies to what extent stakeholders demand immediate attention. These attributes determine the degree of salience of a stakeholder. The more attributes a stakeholder possesses, the higher the degree of salience, and thus, the more important a stakeholder is. Table 1 gives an overview of stakeholder types.

*Definitive stakeholders* have the power to influence the standardization process. The standard is important for them and their involve-

**Table 1**

Classification of stakeholders according to their importance with respect to power, legitimacy, and urgency [32].

Type	Description	Power	Legitimacy	Urgency	Importance
A	Definitive stakeholders	X	X	X	Very important
B	Dominant stakeholder	X	X		Important
C	Dangerous stakeholder	X		X	Important
D	Dependent stakeholder		X	X	Important
E	Dormant stakeholder	X			Less important
F	Discretionary stakeholder		X		Less important
G	Demanding stakeholder			X	Less important
H	Non-stakeholders				Not important

ment is undeniable. These stakeholders are the driving force behind the standardization process and they are highly committed to standardization activities [32]. Although most *Dominant stakeholders* have no immediate interest in participating in the standardization process, they can have considerable influence on the standardization process because they have legitimate claims in the process as well as the power to act on these claims. An example of a dominant stakeholder is a governmental organization [32]. *Dangerous stakeholders* include stakeholders who take unlawful and violent action to achieve their goals [33]. Although such stakeholders have no formal place in the standardization process, their strategies should be taken into account during the process [32]. *Dependent stakeholders* often lack the resources needed to participate in the standardization process and are dependent on the resources of others. These stakeholders are relevant for the support of a standard and their participation is needed. *Dormant stakeholders* possess power but lack legitimacy and urgency and are therefore not able to use this power. Usually there is no participation or interaction between dormant stakeholders and participants in the standardization process. Since the legitimate role of *Discretionary stakeholders* in the standardization process is acknowledged by other participants or potential buyers of the standard [32], it might be useful to involve discretionary stakeholders. *Demanding stakeholders* are irritating, but not dangerous. As long as demanding stakeholders do not acquire power or legitimacy, their claim remains latent and largely unconsidered [33].

We adopt a comparative institutional perspective on standardization. Comparative institutional analyses focus on how national institutions, mechanisms, norms, and systems such as the labour market system, the financial system or the tendency towards non-market forms of economic coordination affect innovative activities. We examine whether specific institutional arrangements facilitate or constrain specific types of competence development [35, p. 871–873]. An institutional perspective in understanding the development and acceptance of new energy technologies such as LED is crucial. The market failures associated with pollution and energy inefficiency and the market failure related to the innovation and diffusion of new technologies provide a strong reason why policies and regulations play an important role in the development of new technologies and the infrastructure of standardization [36]. Countries vary significantly in terms of institutional regimes and their consequences for the market, technology development, and standardization [37]. Moreover, business systems and institutional regimes in East Asia are considerably different from developed economies in the USA and Western Europe, as argued by Witt and Redding [38] and Whitley [39]. Therefore, in our subsequent analysis we will compare the institutional regimes of five East Asian countries in order to explain their diverging influence on the standardization of LED.

### 3. Methodology

We applied the case study methodology [40] to answer our research questions. We believe that this is an appropriate method since standardization is a complex process, involving numerous institutions, organizations and associations, and the process can differ across countries.

We analyze the standardization process of five developing countries: China, Thailand, the Philippines, Vietnam, and Indonesia. China is the front-runner in LED standard setting in East Asia, involving several different kinds of stakeholders. In Thailand and the Philippines, a number of LED standardization efforts are ongoing, mostly driven by government. Vietnam and Indonesia are lagging far behind in LED standardization.

We first examine the institutional and industry actors that influence the standardization process of LED lighting by applying the stakeholder identification method proposed by De Vries et al. [32]. This approach takes a broad perspective by including all parties that may affect and may be affected by the standardization process. The two-step

stakeholder analysis results in a balanced stakeholder representation. The first step of the analysis proposed by De Vries et al. [32] aims to identify the potential stakeholders in a standardization process using a list of nine categories, based on the diverse ways in which a standard can be important to stakeholders. Not all categories are equally relevant for all standardization processes. In other words, they serve as search heuristic in order to avoid overlooking some stakeholder groups. The nine categories are product chain (e.g. suppliers, transporters, and trade companies), end users and related organizations (e.g. large companies, small- and medium sized enterprises, public organizations and individual employees), designers (e.g. designers of the product the standards relates to, such as specialized companies), physical systems (e.g. hardware and software producers to ensure compatibility with other technical systems), inspection agencies (e.g. dedicated organizations, certification bodies, testing laboratories or government enforcement agencies), regulators (i.e. governmental bodies), research and consultancy (e.g. universities, research institutes, and consultants), education (e.g. educational programs for students and professionals), and representative organizations (e.g. professional organizations and consumer organizations).

The second step of the analysis proposed by De Vries et al. [32] aims to determine the level of involvement of the stakeholders in the standardization process by identifying the extent to which stakeholders possess one or more of the three key attributes: power, legitimacy, and urgency. As such we can determine the type of stakeholder.

We used both primary and secondary data to list and categorize these stakeholders. Secondary data was gathered from academic publications, books, reports, and websites. This was complemented with in-depth interviews with relevant stakeholders in the countries involved, as interviews are a highly efficient way to collect rich, empirical data [41]. In total, we conducted 12 interviews between 2011 and 2016 (six in China, two in the Philippines, one in Thailand, one in Vietnam, one in Indonesia, and one interview with an objective outsider that has an international perspective).

During the interviews, we asked stakeholders various questions so we could categorize them according to the three attributes (stakeholder power, legitimacy, urgency). A table in which we include the question, the purpose of the question (in terms of assessing stakeholder power, legitimacy or urgency) and why we included it in the questionnaire is available upon request. To assess the score of each stakeholder on the attributes power, legitimacy and urgency, we analyzed the secondary data and compared these findings with those from the interviews, thereby triangulating the evidence. Quotations from non-English-speaking interviewees were translated into English by the authors.

Second, we discuss the institutional context in these five countries, mainly focusing on the policy and regulatory institutions involved in energy efficiency and lighting. We analyze and compare the institutional regimes in China, the Philippines, Thailand, Vietnam, and Indonesia to explain how diverging institutional contexts may explain development differences in LED standardization. Our analysis is based on an institutional understanding of these five countries, on indicators from the Worldwide Governance Indicators (WGI) project of the World Bank (1996–2014) as produced by Kaufman and Kraay [42], and on the research program on Asian business systems by Witt and Redding [38].

## 4. Results

### 4.1. China

Since 2002, LED production and use in China has increased sharply. A table listing the relevant stakeholders is available upon request. Although some firms are involved in LED standardization, many seem to be unaware of the existence of these standards and as a result tend to manufacture inferior quality products. This is the case for both small and big companies.

Our interviews suggest that a LED standards battle is currently being fought in China, comparable to the VHS vs. Betamax battle, but even bigger. Trying to achieve one generic standard is challenging, certainly on a chip level. The Chinese government is driving the process by putting standardization on the political agenda and subsidizing manufacturers, but industry and test centers are playing the main role in terms of content. The government is pressurizing all stakeholders to accept a standard that is acceptable to these two main players. Our interviews suggest that manufacturers are pushing the Chinese government to develop standards for LED. International organizations are mainly used by China as an informational resource.

Standardization development in China has undergone a shift from depending solely on international standards to independently developing its own standard, and from government-mandated standardization to a more collaborative form, involving other stakeholders such as industrial organizations. As our interviews and Suzuki [43] suggest, standardization and technology development in China has focused on protecting and promoting domestic technology, companies, and industries. The government has provided flexible policies and financial support to promote the development of its own standards, aiming to avoid dependence on western technology. Nevertheless, even though the government strongly supports its own standards, it does allow the development of international standards in China, and the country is an active player in international standardization organizations.

#### 4.2. The Philippines

The Philippines is currently focusing on clean energy solutions and energy efficiency to reduce the impact of energy use on climate change and to achieve the energy requirements of its economic and social development programs. The policy and regulatory framework for energy efficiency in the Philippines consists of various policy and regulatory instruments which are responsible for the creation of regulatory authorities, the provision of incentives, and the development of technical, safety and product standards. Within the energy sector, the government plays a key role both in terms of participation and regulation. However, institutional barriers to the effective implementation of policies and programs still exist. Energy agencies do not seem to cooperate with other departments and institutions, standards are not verified or enforced, and laws are weakly implemented. Regulators and manufacturers do not have enough capacity to harmonize energy efficiency standards, and government agencies lack adequate institutional capability as they do not have enough manpower. Moreover, current regulation does not provide incentives to utilities to implement demand-side management projects. A table listing the relevant stakeholders is available upon request.

Our interviews suggest that the government is the main driver of the standardization process of LED in the Philippines. The Department of Energy (DOE) promotes the development of standards for appliances and lighting products and the Bureau of Product Standards and its TC (Technical Committee) is the government agency mandated to promulgate standards. The Philippines Lighting Industry Association (PLIA) plays an important role in terms of the performance aspects of the standard. There are few LED manufacturers in the Philippines.

#### 4.3. Thailand

As a result of the economic growth since the mid-1980s, energy consumption in Thailand has increased rapidly. In order to secure energy supply and sustain Thailand's economic development, the Thai Government took several steps to improve energy efficiency and energy conservation. The main government energy agency is the Ministry of Energy (MOEN), which consists of six offices and departments involved in energy-related activities. Since 1992, various laws and decrees to promote energy efficiency and renewable energy programs have been issued. However, although these programs have been implemented,

many were not cost-effective or successful. Institutional barriers to the effective implementation, monitoring, and evaluation exist. While Thailand has adequate regulations related to energy efficiency, it fails to effectively enforce them, and although all energy related activities are consolidated under one ministry, policy coordination among agencies is lacking. Furthermore, effective incentive programs to encourage energy saving are not in place. A table listing the relevant stakeholders is available upon request. According to one interviewee, Thailand uses western standards and adapts them to suit its own requirements. International organizations (especially the International Electrotechnical Commission, IEC) are the main drivers of LED standardization in Thailand.

#### 4.4. Vietnam

In 2005, the Ministry of Industry and Trade (MOIT) approved the Vietnam Energy Efficiency and Conservation Program 2006–2015, aimed at increasing energy efficiency and reducing energy consumption. The Ministry of Science and Technology (MOST) also has several responsibilities in terms of energy conservation, such as issuing national standards for the energy efficiency of end-use devices and appliances, including lighting products. However, although energy efficiency laws and decrees exist, implementation is still a major issue due to lack of capacity, technical knowledge, and resources. Stable and sufficient human and financial resources are needed to implement energy efficiency laws and policies in the long-term. In addition, capacity building, and labeling and testing regimes are lacking. A table listing the relevant stakeholders is available upon request.

The national standard body (STAMEQ) and the government are the main drivers of the standardization process of LED in Vietnam. By law, Vietnam has to develop some energy standards. The work is ongoing but has not been finalized. Vietnam is far behind in LED standardization compared to China, the Philippines, and Thailand.

#### 4.5. Indonesia

The Indonesian government has given relatively little attention to energy efficiency. As a result of subsidized energy prices, investing in energy efficiency has been unattractive. Recently, the Indonesian government have moved away from subsidies, which has led to higher prices for electricity and fuels. Hence, more efficient energy has become more attractive for consumers.

Although investing in energy efficiency has been unattractive, Indonesia has launched several demand side management programs with some success. However, the government has not promoted the standardization process of LED. Although Indonesia has established testing laboratories, these have not sought international accreditation yet. Indonesia's major institutional challenge is to generate sufficient support to overcome inertia in the field of energy efficiency. Other institutional challenges related to standard-setting in Indonesia include transparency during the preparation of technical regulations and coordination among ministries. In addition, limited availability of accredited product certification bodies and inspection bodies are a major obstacle. A table listing the relevant stakeholders is available upon request.

#### 4.6. Comparative institutional analysis

All five countries in our study have various institutions in place to manage the energy sector and formulate policies related to energy efficiency and climate change, such as the China Ministry of Science and Technology, the Department of Energy in the Philippines, the Ministry of Energy in Thailand, the Ministry of Industry and Trade in Vietnam and the Ministry of Energy and Mineral Resources in Indonesia. In China, Thailand and Indonesia, national standards organizations are actively pursuing LED standardization following the

mandates issued by the Government. We now examine the institutional context in each of the countries in more detail.

China is a one-party communist state. It has a population of over 1.3 billion, and had strong economic growth of around 6.9% GDP in 2015. It is a de facto federalist state with provincial autonomy [44,45]. It is important to realize that China's scientific and technological development suffered a severe blow during the Cultural Revolution (1967–1976) [46]. Nevertheless, the country has changed from a centrally-planned socialist economy to a market-oriented economy since reforms started in 1978 [44].

China has relatively weak institutions as a result of the co-existence of socialist institutions and newly created, market-based institutions [47]. The legacy of state socialism is still ingrained and pervasive in current institutions, resulting in unexpected policy changes, unclear implications of policies, and a general lack of trust in the rule of law [48]. Decision making in China is therefore also ambiguous and includes both top-down and bottom-up processes. The provinces have considerable economic and political autonomy, also in standardization processes [6]. While China scores particularly low on governance indicators such as voice and accountability, and protection of intellectual property rights, government effectiveness is improving and above the average of our five case countries [42].

The Philippines is a unitary presidential constitutional republic. It has a population of 100 million, and had \$292 billion GDP and 5.8% growth in 2015. Aside from the period of Japanese occupation, the United States retained sovereignty over the islands until after World War II, when the Philippines was recognized as an independent nation. Since then, the Philippines has often had a tumultuous experience with democracy, which included a non-violent revolution overthrowing the dictatorship. The return of democracy and government reforms beginning in 1986 were hampered by national debt, government corruption, coup attempts, disasters, communist insurgencies, and military conflicts. Despite constraints, the Philippine economy has transitioned from one based on agriculture to an economy with more emphasis on services and manufacturing. The Philippines is characterized by a government with medium involvement in the market and business. There is a strong tradition of business groups with many family firms. The state is predatory, with widespread corruption and with top-down decision making. The country scores low on indicators such as accountability, government effectiveness, intellectual property rights protection, and regulatory quality [42].

Thailand is a constitutional monarchy under the rule of a military junta. It has a population of 68 million, and had \$400 billion GDP and 2.8% GDP growth in 2015. After the World War II, Thailand emerged as an ally of the United States. Thailand then went through decades of political instability, as one military regime replaced another, but eventually progressed towards a stable democracy in the 1980s. It experienced rapid economic growth between 1985 and 1996, becoming a newly industrialized country and a major exporter. In 1997, the first constitution was drafted by the popularly elected Constitutional Drafting Assembly. The first election under the 1997 Constitution in 2001 was called the most open, corruption-free election in Thai history. Nevertheless, the subsequent period was again characterized by instability, military junta, protests, eventually leading to a military coup and the suspension of the constitution in May 2014. Thailand has a developmental but predatory state with strong top-down decision making. The decades of political and military upheaval makes it a relatively unstable institutional environment. A constitutional referendum in August 2016 could lead to significant change and reform. While Thailand scores relatively well on indicators such as government effectiveness and regulatory quality due to the autocratic military regime, it scores low in terms of voice and accountability [42].

Vietnam is a unitary Marxist–Leninist one-party state. It has a population of 91 million and had \$200 billion GDP and 6.7% GDP growth in 2015. The Vietnam War ended with a North Vietnamese victory in 1975. Vietnam was then unified under a communist

government but remained impoverished and politically isolated. In 1986, the government initiated a series of economic and political reforms which began Vietnam's path towards integration into the world economy. The country has changed from one of the poorest in the world to a middle-income country within a quarter of a century, and has changed from a reliance on predominantly agriculture to a focus on manufacturing, information technology and high-tech industries. Since 1990, Vietnam's per capita GDP growth has been among the fastest in the world, averaging 5.5% a year.

Vietnam has a strong central state with significant market involvement and a dominant communist party. There is a long tradition of family firms but the importance and involvement of the communist party and their officials is significant. The state is considered to be predatory. The country scores low on indicators such as voice and accountability, government effectiveness, intellectual property rights protection, and regulatory quality [42].

Indonesia is a unitary presidential constitutional republic. It has a population of 250 million population, and had \$860 billion GDP and 4.8% GDP growth in 2015. It is the largest economy in Southeast Asia with a diverse archipelago nation of more than 300 ethnic groups. It has charted strong economic growth since overcoming the Asian financial crisis of the late 1990s, although political and economic instability, social unrest, corruption, and terrorism have slowed progress.

Indonesia is characterized as an *arm's length state* with limited to medium government involvement in business and market. The market has a strong tradition of business groups with a considerable amount of family firms. Nevertheless, the state is often considered to be predatory with top-down decision making. The country scores low on indicators such as accountability, government effectiveness, and regulatory quality [42].

Table 2 shows a comparison of the institutional context, main drivers of standardization, and different types of stakeholders in each of the five countries.

## 5. Discussion

China has spent significant resources on standards development and is the only country which has already developed standards for LED. The other four countries currently have no standards for LED. Various interviewees predict that China will be leading the developing countries in LED standardization. In the Philippines, the Department of Energy is playing an important role in promoting the development of standards for lighting. Thailand uses IEC standards, adapts them to suit its own requirements and makes them into national standards. Vietnam and Indonesia are struggling in the dark and are lagging far behind.

The question arises whether the institutional and standardization context is related to these developments? Following an institutional logic, the institutional context in China is more stable compared to the other countries (see Table 2). This means that firms can be more involved in the standardization process. Indeed, our analysis indicates that Chinese firms are strongly involved in the standardization process. Regulatory agencies promote standardization and national standardization organizations are active in pursuing this (top-down). At the same, manufacturing firms are actively pursuing standardization in strong competition in the local market (bottom-up). Many multinationals have established R&D centers in China. For instance, Philips, a leading firm in LED technology, has set up its global R&D headquarters for LED in Shanghai. Firms like Philips are strongly involved in global LED standardization initiatives and extremely motivated to be part of the Chinese market for LED. China's institutional context, stable and with top-down and local bottom-up processes from both government and industry, is more beneficial for the development of LED standardization than the other countries. In this respect, China's institutional context best resembles the international

**Table 2**  
Cross case analysis comparison.

	<b>Institutional context</b>	<b>Main driver of standardization</b>	Standardization progress	Definitive stakeholders	Dominant stakeholder	Dangerous stakeholder	Dependent stakeholders	Dormant stakeholder	Discretionary stakeholder	Demanding stakeholder	Non-stakeholders
China	One-party communist state, stable, top-down and bottom-up processes, developmental state with strong industry policy targets.	3 Governmental agencies 3 Standardization organizations 1 Industry consortium	Far ahead	7			1		3		
Philippines	A unitary presidential constitutional republic, unstable democracy, top-down processes.	1 Governmental agency 1 Standardization organization	Lagging behind	2			1		3		
Thailand	A unitary Marxist–Leninist one-party state, unstable democracy, top-down processes, relatively effective government.	2 Governmental agencies 1 Standardization organization	Lagging behind	3	1		1				
Vietnam	A unitary Marxist–Leninist one-party state, top-down processes, relatively stable, developmental state with strong industry policy targets.	1 Standardization organization	Lagging behind	1	2				2		
Indonesia	A unitary presidential constitutional republic, relatively stable democracy, top-down processes.	1 Governmental agency 1 Standardization organization	Lagging behind	2			2		3		

LED standardization context in which government agencies, standardization organizations, and firms are equally involved in the standardization process. Although it is often assumed that China has a strong central state that may push standardization top-down, China more resembles a de facto federalist state [45] where standardization is highly complex and decentralized with a variety of stakeholders involved in the process in collaboration with the business community [6]. In the other four countries, governmental agencies and/or standardization organizations are involved in the standardization process but industry is not. Indeed, the institutional context in each of these countries is more unstable, and in unstable situations top-down processes are necessary to keep a certain degree of stability by a strong centralized government. Moreover, these countries have been facing more recent political instability that has severely affected the institutional context and business community. They are too unstable to have bottom-up processes whereby firms are involved in the standardization process. So we provide a first indication that the institutional context in terms of stability positively relates to the diversity of stakeholders involved in LED standardization, and in turn is positively related to LED standardization.

The countries involved all have to deal with challenges related to the standardization of LED. In particular, we see challenges in terms of market requirements and capabilities, and in terms of institutional challenges. In terms of market requirements, it is of major importance that small Chinese manufacturers gain more knowledge about LED, buy equipment so they can test LED, and train their employees so they can reach the international level of quality control. Another challenge is that China has different regional requirements, especially for outdoor lighting, given the country's size and temperature differences among regions. Moreover, patent issues, and new industries moving into the lighting market are slowing down the standardization process of LED. In the Philippines, the major challenges are related to time and technical competence. In Thailand, Vietnam, and Indonesia, the lack of testing facilities is the main challenge. So far, only China has the capacity to test LEDs and verify standards. Even if a country adopts the IEC standard for LED, products that meet these standards might be too expensive for the local market.

In terms of governmental initiatives and projects to promote energy efficient lighting, China and the Philippines take the lead. These countries both have programs to phase out incandescent lamps. The other three countries have launched successful programs as well. An example is the Energy Efficiency Public Lighting project in Vietnam. Both Thailand and Indonesia have had successful demand side projects, mainly focused on CFLs. Although most countries have an adequate policy and regulatory framework for energy efficiency, there are major institutional barriers, which include unclear government policies and procedures, lack of infrastructure, lack of information and awareness, and lack of consumer acceptance. Moreover, the Philippines, Indonesia and Thailand lack policy coordination among government agencies, which makes the standardization process even more complex. As a result, energy saving standards and regulations are often not effective.

In particular, intellectual property rights are a key barrier for the diffusion of LED. Suzuki explains: “it is a highly protected technology. As there are various processes involved in manufacturing LED chips, each process is patented and requires a huge investment. At present the cost of investing in both chip manufacturing and resolving the IPR issues is substantially high compared to importing the chips.” [43, p. 237]. Beyond a capacity building program, easier access to IPRs has been high on the political agenda in clean energy technology development since the 1990s [49].

## 6. Conclusion and policy recommendations

By conducting a stakeholder analysis of the actors involved in the standardization of LED technologies, we show that contrary to our



expectations, developing countries in the Asian region are actively involved in standardization. Furthermore, the findings show that various stakeholders are involved in LED standardization across developing countries in Asia and that these have different degrees of salience. Widely diverging institutional environments pose different conditions for LED standardization across the case countries. We propose that the institutional environment influences the standardization regime, which in turn affects the standardization process. Our study provides a first indication that the institutional context in terms of stability positively relates to the diversity of stakeholders involved in LED standardization, and in turn is positively related to LED standardization.

Within the Asian region, major differences between the countries in terms of local conditions and institutional environment make it difficult to develop one overall standard that can be applied to all the countries involved. Therefore, it can be useful to categorize each country by looking at its standardization regime. Krasner [50] defines a regime as “principles, norms, rules, and decision making procedures around which actor expectations converge in a given issue-area.” This broad definition includes human interaction ranging from formal organizations to informal groups. The landscape of the standardization regime is shaped by political, professional and business interests, which are represented by stakeholders involved in the standardization process. Research shows that institutions of emerging economies significantly differ from those in developed economies [51]. Moreover, emerging economies are not homogeneous, and show a rich variety of institutional contexts [52]. The findings presented in Section 4 illustrate this point clearly.

According to Hoskisson et al. [53], institutional theory is one of the most insightful theories for analyzing emerging economies. Institutional theory “emphasizes the influences of the systems surrounding organizations that shape social and organizational behavior” [53]. The authors further argue that institutional forces influence organizations’ processes and decision making. Moreover, research shows that institutions such as the government, the private sector, and international organizations influence the standard setting process [54]. Other studies highlight the importance of industry and trade associations within the standardization process [55].

This research contributes to the literature in several ways. First, we identify the most important stakeholders involved in LED standardization in Asia and show that their importance differs per country. Second, we discuss that this can be captured by the concept of standardization regime. Third, we provide a first indication that the institutional context in terms of stability positively relates to the diversity of stakeholders involved in LED standardization, and in turn is positively related to LED standardization. Finally, we provide a first empirical validation of the stakeholder identification method as proposed by De Vries et al. [32].

This research leads to several important policy recommendations. First, policy makers must be aware of the strongly diverging institutional conditions across emerging economies in Asia. Standardization in such contexts is unlikely to be successful across countries if the standardization process does not actively involve the variety of stakeholders, both local and international. Second, policy makers could view China as an example for other emerging economies in terms of policy directions. However, China’s unique institutional setting, with both wide local diversity and a socialist legacy, may make it harder to benchmark China’s experience than would seem at first sight. Nevertheless, China showcases that the involvement of a variety of stakeholders from government, standardization organizations and the business community is crucial for successful standardization. Third, most emerging countries fail to develop an LED standard and this is both a challenge and an opportunity for policy makers. In particular, local policy makers could benchmark each other’s processes and stakeholder infrastructure, while international policy makers could play a more active role in coordinating stakeholders across emerging

countries. Fourth, policy makers should consider that efficient protection of intellectual property rights and infrastructure for LED testing and manufacturing are important challenges.

This research is subject to some limitations. One limitation is the number of in-depth interviews. It was difficult to get a response from relevant stakeholders, especially in Indonesia. In addition, data gathered from interviews might be biased, caused by image-conscious informants [41]. In order to limit this bias, we interviewed knowledgeable stakeholders who view the standardization process of LED from different perspectives.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.rser.2017.01.101.

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