INTERNATIONAL DESIGN CONFERENCE - DESIGN 2014
Dubrovnik - Croatia, May 19 - 22, 2014.

A REAL-WORLD EXPERIENCE OF PRODUCT-SERVICE SYSTEM DEVELOPMENT FOR INTELLIGENT LED SYSTEM

J. S. Baek

Keywords: LED, ESCO, PSS, stakeholder, need, sustainability

1. Introduction

In the recent years, light-emitting diode (LED) market has grown rapidly as the aggravating energy scarcity is accompanied by the technology advancement and price declines. The global LED market has expanded from 1.36 billion dollars in 2005 to 20.5 billion in 2012, and it is estimated to reach 57 billion in 2018. In Korea, the LED market has exploded from 50 million dollars in 2005 to 1 billion in 2012, and possibly 5.6 billion in 2018 [KOPTI 2008]. The penetration rate of LED in the global lighting market is also expected grow rapidly from 9% in 2012 to 28% in 2015, and 75% in 2020 [Ji 2012]. The LED industry is at the growth phase with intensifying competition and deceleration of product innovation, anticipating the differentiation of business models through service innovation [Tukker and Tischner 2006], [Young 2008].
Despite longevity and high energy efficiency of LEDs, still high prices make them as yet to be competitive. Some LED products try to overcome the drawback by achieving even higher energy efficiency through integration with other technologies. For instance, the intelligent LED system to be introduced here achieves 31% higher energy efficiency than conventional LEDs by incorporating dimming technologies, sensors, and ICTs. However, the system costs 70 dollars per unit while a fluorescent light of the equivalent luminance costs only 3 dollars.
Another weakness of LEDs is the environmental impact after use. While they are energy efficient and mercury-free, they contain lead, copper, nickel and silver to the level that has an environmental impact. In addition, they contain rare earth metals such as gold that could increase pressure on natural resources [Seung-Rim et al. 2011]. Hence the used LED need to be properly recycled, but effective incentive mechanisms to recover old lamps is absent in most countries. Lessons can be learnt from the failure of recycling fluorescent lamps in Korea. The fluorescent lamps are subject to extended producer responsibility (EPR). However, less than 30% of the used products are collected and disposed safely. More than 130 million tubes end up in landfills illegally every year, raising serious environmental and health issues. The reasons are twofold: users have to pay approximately \$0.1 ~ 0.2 for the safe disposal; and in many cases they are ignorant of their duty [Cho 2013]. On the contrary, LEDs are at present neither in scope for EPR or any other measures that enforce proper disposal. Because used LEDs have little economic value - at least not enough to motivate voluntary recovery, it is difficult to achieve a close loop economy without regulatory or other equivalent measures. In short, high prices and increasing environmental potential of LEDs make them a relevant subject for PSS. Energy saving companies (ESCO) addresses some of these issues.
ESCO business model is a B2B PSS solution for facilitating the penetration of energy efficiency measures by providing users with incentives to adopt them based on the market principle. ESCO is defined as "a business that develops, installs, and arranges financing for projects designed to improve

the energy efficiency and maintenance costs for facilities" over a certain period of time (National Association of Energy Service Companies) [NAESCO 2013]. These services are bundled into the project's cost and are repaid in installment from the savings achieved through the project, thereby providing financial incentives to energy users to adopt high-cost energy-efficiency projects. In addition, it reduces the risk of investment by guaranteeing the energy saving performance through measure and verification (M&V). In short, ESCO provides packaged solutions on financing, operating and maintaining the facilities.

Since the introduction of ESCO in 90s, Korean ESCO industry has grown to a 170 million-dollar worth market (the Ministry of Knowledge and Economy) [MKE 2011], accounting for roughly 1.2 % of the global ESCO market. There are over 220 registered ESCO as of 2012 (Korea Energy Management Corporation) [KEMCO 2013]. Their main items include high efficiency lighting, waste heat recovery, heating and cooling systems, process improvement, and combined heat and power [Hansen et al. 2009]. Among them, the lighting sector accounts for roughly 8% of the ESCO market and only 1 % of the total sales of LED [KEMCO 2013]. The reasons behind little contribution of ESCO to sales of LED are elaborated in the section 2.2. It is only mentioned here that there is a significant gap between the expected values of ESCO from societal and environmental perspectives and the perceived values of offering and using it from stakeholders' perspectives, thereby leading to a stagnant market for more than a decade. Government has intervened periodically with command-and-control measures to reinvigorate the market, which ironically distorted the fundamental driving force of ESCO, market principles and impeded the growth of the industry.

Product-service system (PSS) can be a useful strategy to break the gridlock by providing methodologies to approach complex problems in the ecosystem through analysis of stakeholder needs and generating solutions that effectively address them. This paper introduces a case to develop sustainable PSS for LED luminaries in the real world. The project scope includes understanding the market and stakeholders' needs, identifying secondary schools as a potential target customer, and generating product-service integrated solutions with improved environmental sustainability and economic viability.

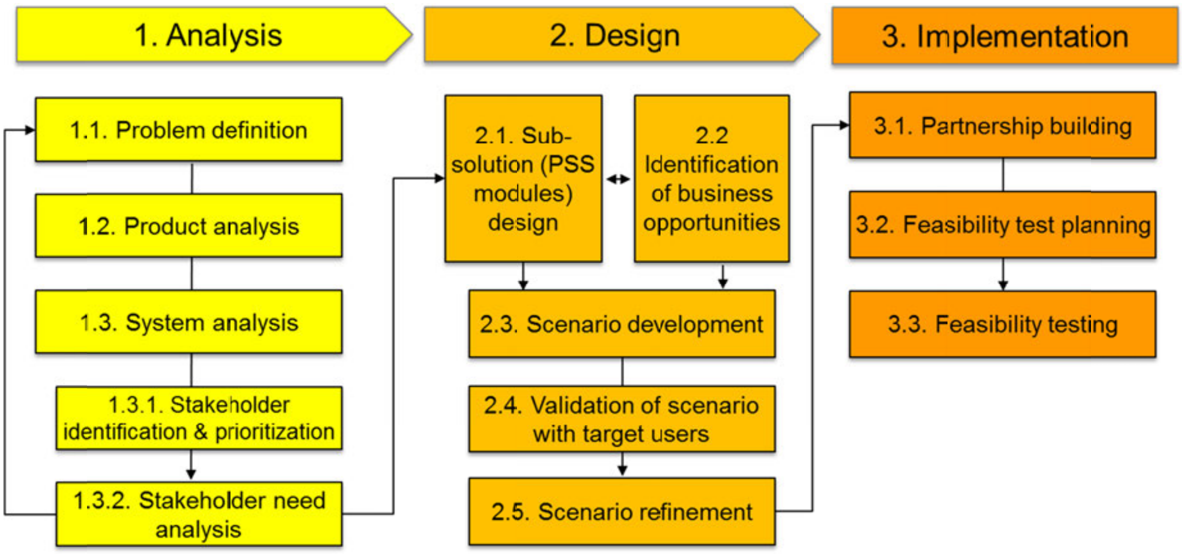

Figure 1. PSS development procedure

2. Methodology

The process of designing PSS for the intelligent LED system was developed based on the PSS development process by Wimmer et al. [2007], and the PSS toolset by Kang [2008]. These approaches are relatively simple and efficient - and therefore quite usable - compared with other methodologies such as MEPSS [Halen et al. 2006] without sacrificing the rigor. Wimmer et al.'s model streamlines the PSS development procedure into three phases - 1) strategic system analysis, 2) PSS design, and 3)

PSS implementation - and can be easily replicated and updated at need. Kang's PSS toolkit lays out fifteen basic instruments that stem from existing PSS methodologies or new ones. The process was modified to serve the purpose of the project (Figure 1): 1.4 and 1.5 were added to meet the goal of finding new business opportunities; 2.3 were added for validation of the new business model. In this paper, strategic system analysis and PSS design stages are elaborated.

2.1 Product analysis

During the phase of strategic system analysis, product and system analyses were conducted. The product to be analyzed was an intelligent light management system developed by an electric appliance manufacturer in Korea. Product analysis addressed functional specifications, technology benchmarks, energy efficiency, environmental impact, product design, and price. In system analysis, ESCO business model in general and for LED were examined. It included market investigation, value chain analysis, stakeholder identification and prioritization, stakeholder need analysis, business opportunities and target user identification.

2.1.1 Product specification

The product to be introduced is an intelligent light management system for indoor application with 28W LED lamps. It aims at optimizing the light use through sensors, dimming technology, and energy monitoring system. The system is composed of a LED lamp, motion sensor, dimming converter, software can control individual lamps via Bluetooth or transmission control protocol/Internet protocol (TCP/IP), and an energy monitoring system that collects the data of energy use. The motion sensor detects the presence and movement of users and signals the data to the dimming converter through Zigbee module to provide the optimal luminance, thereby providing the optimal lighting environment while consuming minimal energy. The energy monitoring system empowered by a remote access to individual lights enables diagnosis of energy usage and allows centralized control of the lights (Figure 2). The product is particularly effective in environments that require heavy use of lighting and are exposed to frequent changes in the presence of users and ambient luminance.

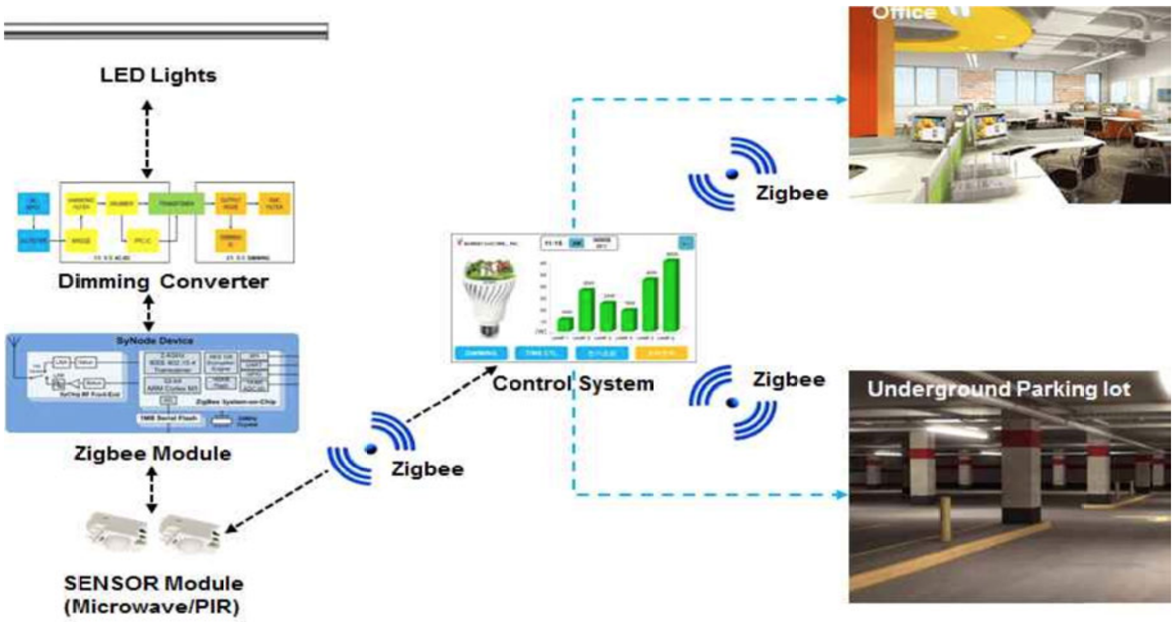

Figure 2. A schematic view of the intelligent light management system [Lee and Jang 2012]

The environmental aspects of the product during the use and after the use were analyzed. During the use phase, the system saves energy up to 60 %. The LED lamp in this project is a 14W tube type and has the efficiency of 100 lm/W. Together with the sensor and the dimming technology, the system can save energy up to 31 % compared with conventional LED (T8 32 W/22) and 60 % compared with a

fluorescent tube T8 32 W. This is equivalent of reducing 1 tCO2 compared with conventional LED and 1.9 tCO2 compared with the fluorescent tube [KILT 2013].
The analysis of the product components revealed that the product was not designed for reuse or recycle. Out of more than 90 components, none of them is considered for reuse for the following reasons: First, the manufacturer finds it economically not feasible to reuse components. Second, the environmental benefits are not compensated by the risk of increasing defects caused by the reused components. Some electrical components including printed circuit board (PCB) have longer lifespans than the product itself but are not reused because the quality of the reused parts cannot be guaranteed. Third, the rapid change of technologies and design as opposed to the long lifespan of the product makes it difficult for the manufacturer to forecast which parts can be reused. Mechanical parts such as screws, bracket or body are theoretically reusable but it is unlikely that the product design after 10 years will be the same as the current one. Due to such limitations, the focus of product design was set to recycle rather than reuse.
The major challenge to commercialization of the system is the high price. It costs nearly 70 dollars, considerably more expensive than fluorescent lights or even LEDs. If the installation cost is taken into account, the total cost rises even further. This has led the manufacturer to consider PSS - more specifically ESCO - as a business strategy. In the next section, the analysis of the Korean ESCO market is elaborated.

2.2 System analysis

ESCO market in Korea is suffering from chronic problems that inhibit the growth of the market. In a report to describe the situation of the ESCO market a decade ago, Lee et al. [2003] emphasized the role of government as a market creator that removes barriers and mobilizes necessary capital, and identified the future challenges as 1) creating continuous demands by expanding the market from the public sector to the private sector; 2) building capacity for local ESCOs; and 3) promoting private financing and guaranteed savings. The government has indeed been active in promoting ESCO and thus played a leading role in expanding the market through financial and institutional supports. It has invested total 1.7 billion dollars in ESCO business since 1993 and the number of registered ESCOs has grown from 5 to 227 during this period.
Surprisingly, however, the future challenges identified by the authors still exist, suggesting that the market is still dependent on the government support and that its capacity - both in quality and quantity - is inhibited for more than a decade. Several studies report problems that limit the growth and performance the industry such as: heavy dependence on the low-interest government loans; a lack of suitable financial intermediation in the private sector; overburden of credit risks to ESCO; and a lack of rigor and technological capacity [Hansen et al. 2009], [MKE 2010], [Koh 2010].
In the 145-million-dollar worth market, 70 % is financed by the government loans and 30% by the private loans from banks [MKE 2010]. To mitigate the problem without a risk of shrinking the market, more private funds with more attractive conditions and larger scales are needed (Hansen et al, 2009). Private loans are available from banks and non-monetary institutions but their relatively high interest rates and stringent loan conditions make them underutilized by ESCOs that are used to low-interest public loans.
A lack of rigorous measure and verification (M&V) among local ESCOs is another barrier. For decades, Korean ESCOs have avoided rigorous and systematic M&V - verification of energy saving through quantitative measurement - to reduce transaction costs [Lee at al. 2003]. While such a tendency kept their services lean and affordable, it also contributed to establishing a culture where ESCOs did not guarantee energy saving performance or, in some cases, failed to achieve the goal as promised. The result was increased uncertainty of return on investment of the business and damaged the credentials of ESCO in general. Majority of customers nowadays are dissatisfied with the performance of local ESCOs regarding energy and cost saving [Koh 2010].

2.3 Stakeholder analysis

ESCO has a delicate value network consisting of multiple stakeholders. Figure 3 illustrates the involvement of the stakeholders along the ESCO process [Goldman et al. 2010], [Kim et al. 2011]. In the planning & project management phase of ESCO, central and local governments, energy managers, and technical support service providers, and accreditation consultants are involved to plan and conceive projects. During the consulting and auditing, ESCO design and engineering firms, energy managers and accreditation consultants collaborate to audit the energy use status and set the goal and scope of project accordingly. Necessary energy facilities and knowledge are delivered and constructed during the installation and construction phase by ESCO, building and construction firms, design and engineering firms, and technical service providers. Finally, the performance of energy efficiency measure is measured and verified by accreditation consultants and reported to the energy managers during the M&V phase. The financier is involved throughout the process.

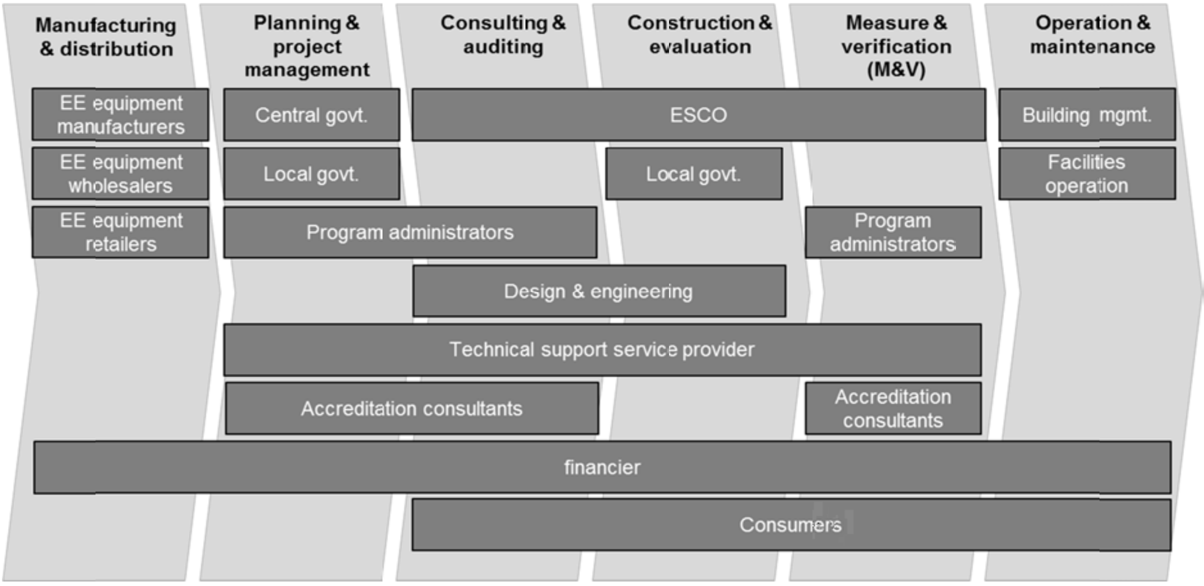

Figure 3. Value chain of ESCO ([Goldman et al. 2010], [Kim et al. 2011])

The stakeholders were prioritized according to their influence over and interest to the system [Eden and Ackermann 1998], [Wimmer et al. 2006]. Large ESCOs, Korea Energy Management Corporation (KEMCO), a government agency that administers ESCO programs, and customers were chosen as key stakeholders as they exert high influence and have high interest on the system. Mid-priority stakeholders group consisted of central and local government, small and medium ESCOs, accreditation consultants, manufacturers, financiers and users. Large and small and medium ESCOs were distinguished because of their different role and influence on the industry. Customers (building owners) and users (e.g. tenants, employees, etc.) were also distinguished as they typically play different roles and have different interests in ESCO. Low-priority stakeholders included Korea Association of ESCO (KAESCO), brokers, subcontractors, mass media, and pressure groups. Amongst them, high and mid-priority stakeholders were investigated further in terms of their needs to the current system and their potential roles in the new solutions as they are likely to have high influence on market success of the proposed solutions.

2.4 Stakeholder need identification

Poor performance of ESCOs in LED industry can be explained twofold: on one hand, the aforementioned barriers to the growth of ESCO industry impede the overall performance of ESCOs and their contribution to the LED industry. On the other hand, barriers may also lie in LED, i.e., immature technologies, customers' perception of products, structure of the industry, and regulations and policies. To gain more in-depth information about LED ESCO, literature reviews and empirical studies were conducted.

Literature studies included news articles, magazines, government or independent reports, laws and academic publications. The collected data include: a survey of 146 ESCOs, a survey 446 users in local governments, 6 interviews with ESCOs, 2 interviews with government, and 3 interviews with ESCO experts. While the secondary data provides comprehensive information of the targeted industry from a macro perspective, it tends to be limited in terms of diversity and quality. The viewpoints of the government and large ESCOs dominated while those of local ESCOs' were rarely covered. Furthermore, information on specific needs of stakeholders was hardly observed. We thus conducted a series of interviews with key stakeholders in order to answer the following question: *"Whatspecific and contextual needs do ESCO stakeholders have in engaging in and implementing projects?"* Answering to the question would lead to identifying design problems and business opportunities.

The interviews were conducted from December 2012 to March 2013. The interviewees were selected among the high and mid-priority stakeholders, and 61 % of the requests for interviews were accepted. Total 12 organizations were interviewed: 2 large ESCOs, 2 Small and medium ESCOs, Korea Energy Management Corporation, a bank, 3 local governments, 2 manufacturers, and Korean Association of ESCO (KAESCO). KAESCO was interviewed, despite its low ranking in the priority, since it represents ESCOs as an interest group. Each interview was conducted vis-à-vis based on a semi-structured questionnaire with open questions. They lasted from thirty to ninety minutes, and were recorded and transcribed for analysis.

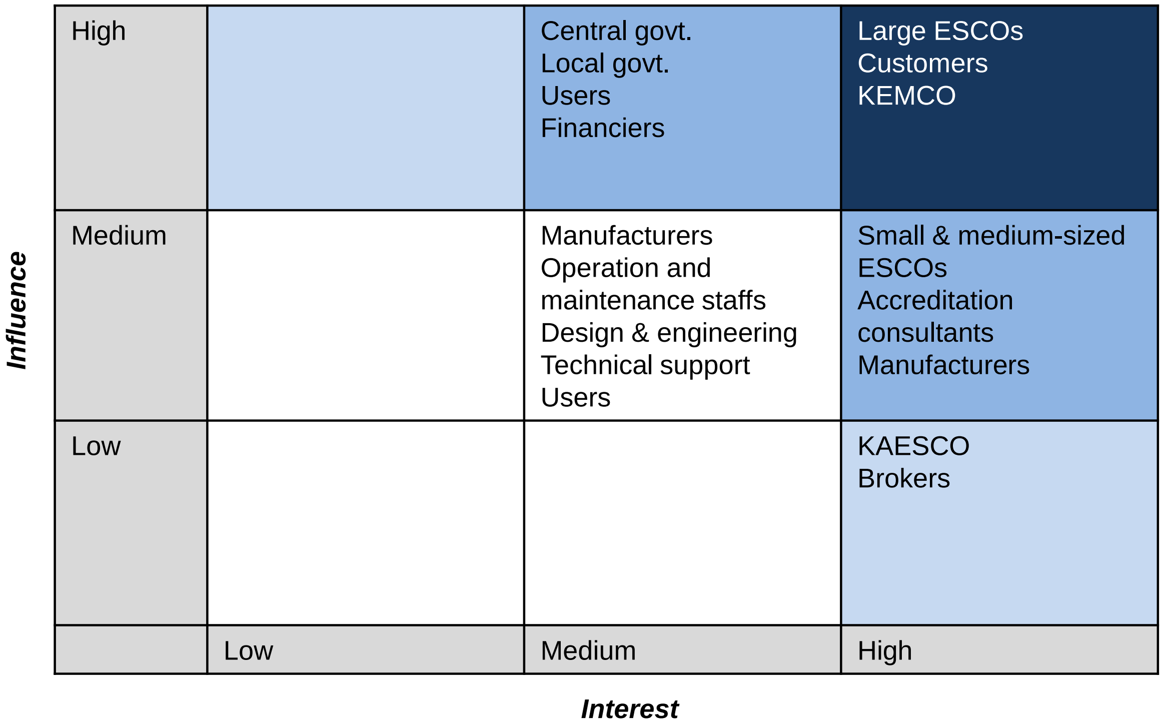

Figure 4. Prioritization of stakeholders

Interview questionnaires were divided into 4 sections: 1) profile of the stakeholder including its role in the ESCO system, 2) business model (for ESCO, bank, and manufacturer only) or policies and regulations (for government agency and local government only), 3) specific needs fulfilled/unfulfilled through participating in the system, and 4) an overall diagnosis of the current system encompassing social, economic, technical, and environmental aspects. Information to be gathered for each type of stakeholder are listed in Table 1.

Table 1. Interview summary

	1) Profile of a stakeholder	2) Biz model / policies & regulations	3) Needs	4) Overall diagnosis of the system
ESCO	Products and/or services offered,	Business model	Specific needs fulfilled/unfulfilled through participating	Perceived strengths & weaknesses of the industry, suggestions

	performance in the market, target customers, competitors and/or partners		in the system	to policy makers
Government agency (KEMCO)	Role of the organization, performance in the market, target customers, competitors and/or partners	Related policies	Specific needs fulfilled/unfulfilled through participating in the system	Diagnosis of the current policies
Financier	Products and/or services offered, performance in the market, target customers, competitors and/or partners	Business model, Finance and insurance policies, interest rates	Specific needs fulfilled/unfulfilled through participating in the system	Perceived strengths & weaknesses of the industry, Suggestions to policy makers
Local government	(As a facilitator) Role of the organization, Industry/market trends in the region	Related policies	Specific needs fulfilled/unfulfilled through participating in the system	Perceived strengths & weaknesses of ESCO
	(As a customer) Products and/or services purchased	Related policies, Financing method	Specific needs fulfilled/unfulfilled through participating in the system	Perceived strengths & weaknesses of ESCO, Evaluation of service quality
Interest group (KAESCO)	Role of the organization, Products and/or services offered	-	Specific needs fulfilled/unfulfilled through participating in the system	Diagnosis of the current policies, suggestions to the vitalization of ESCO market
Manufacturer	Products and/or services offered, target customers, competitors and/or partners	Business model	Specific needs fulfilled/unfulfilled through participating in the system	-

2.5 Stakeholder need analysis

In data analysis, any patterns or insights related to stakeholders' needs were sought for using content analysis. Content analysis is a qualitative and quantitative tool for identifying patterns or themes through a detailed and systematic examination of raw data [Leedy and Ormrod 2010]. From the survey report, interview articles, and transcripts of the interviews, 74 problems and needs of stakeholders were extracted, and analyzed in terms of: 1) its origin and destination, 2) similarity in characteristics, and 3) point of occurrence along the ESCO process.

Firstly, the origin and destination of a need are obtained from the direction of a need in stakeholder network. By isolating which stakeholder the need is coming from (origin) and going to whom (destination)[1], designers can identify key actors to resolve the need and utilize the finding to develop a solution. A tool called the 'need matrix' was developed for this process. It stems from the 'motivation matrix' proposed by Jégou, Manzini and Meroni [2004] in order to understand the motivations of different actors participating in developing a new PSS. In the need matrix, needs having direction are mapped on a matrix with identical x- and y-axes filled with actors of a system. Then a coordinate (X,Y) in the matrix is assigned to a need of origin X and destination Y, i.e., a need coming from the stakeholder X and going to the stakeholder Y.

Secondly, needs are organized based on their similarity using the affinity diagram and mapped onto the ESCO process. This process allows designers to position at which stage the identified needs are raised and to determine which needs are in the scope of project to be pursued and which are not. The former, the internal needs, are further classified in terms of the stakeholders involved in fulfilling them and fed back into the sub-solution phase. The latter, the external needs, are typically beyond the scope of PSS and requires the introduction of long-term measures such as policies, regulations, education, societal and cultural changes.

The needs of stakeholders boil down to the followings: 1) technological expertise of small and medium-sized ESCOs, 2) mitigation of financial and legal liabilities of ESCOs, 3) simplified and customer-friendly contracting, 4) reinforcement of consulting and maintenance, 5) rigorous and "paid" M&V to reduce the uncertainty of return on investment (ROI), 6) affordable and accessible private funds for SMEs, 7) improved information management system, 8) a safeguard against users' financial instability, 9) enhanced energy savings and reduced CO2 emission, 10) a regulatory measure to ensure responsible disposal of LEDs, 11) attractive and competitive services, and extrapolating from this, and 12) the culture of service-oriented consumption. In addition, the need analysis led to the following insights which need to be addressed in the solution generation phase.

2.5.1 Highly interlinked needs

While few identified needs are self-oriented, i.e., related to a lack of stakeholders' internal resources such as knowledge, technologies, or financial capacities, most are oriented to partners in the system. It implies that stakeholders are highly interlinked in terms of need fulfillment, and that problem solving must involve multiple stakeholders. For example, fulfilling the need of having a safeguard against customers' financial instability may require a consensus among an ESCO, customer, an insurance company, and even KEMCO for a higher liability of an insurance company and a higher price for customer.

2.5.2 Conflicting interests

The most complicated and challenging needs involve conflicting interests of stakeholders, and some remain in the deadlock for years. For example, deregulation is a controversial issue in the ESCO industry. Currently, the size of an ESCO project that can be funded by the public fund is regulated. Large ESCOs want this regulation removed and argue that it discourages their participation and makes the industry unattractive. On the other hand, small and medium ESCOs support it because it prevents the monopoly of large ESCOs. They further insist that the ESCO industry is becoming dominated by large corporations, and more regulations to empower SME's are needed. In another example, the government tries to expand the ESCO market by mobilizing private financing. The financing sector argues that their products are not attractive to clients because the low interest rate of the public loan while the government.

2.5.3 Long-term needs

Some needs involve behavioral, cultural or societal changes, and require long-term measures such as policies, legislations, promotion and education to be addressed. They include: 1) a higher priority to

---

[1] The need matrix tool stems from the 'motivation matrix' developed by Jégou, Manzini and Meroni in 2004 which aimed at understanding the motivations of different actors to participate in developing the E-Meal system. In this tool, motivations having direction are mapped on a matrix with identical rows and columns which are filled with actors of a system.

energy conservation policies, 2) higher electricity prices, 3) expanding public fund, 4) mobilizing private financing sector, 5) deregulation of the market (for large ESCOs), 6) empowerment of small and medium ESCOs, 7) users' behavioral changes for more efficient use of lighting facilities, 8) quality control of ESCOs to improve the industry credentials, and 9) promotion of ESCO to the public.

2.6 Business opportunities

Despite increasing pressure on CO2 emission and growing interests in LED among potential users, a major barrier to widespread use is that LEDs are still too expensive and thus cannot compete with incumbent technologies in terms of economically feasibility. The market in Korea has thus been led by the public sector which tends to have more ambitious CO2 reduction goals and higher priority in energy saving. In this context, public institutions with the critical mass of potential users and heavy use of lights are the primary target of our solution. In addition, the potential users should be susceptible to interventions that induce behavioral changes, which can enhance energy saving. They should also be in need of additional services related to the use of LED such as consulting and maintenance. In short, potential target users are such that they are willing to pay for a product-service mix with additional cost that may involve behavioral changes in return for functional and environmental benefits.

2.7 PSS modules design

Identified stakeholders' needs fed back into generating sub-solutions or solution modules. These solution modules address specific needs of the stakeholders and provide functional blocks of the final solution. Below are the examples of solution modules.

1. *CER-integrated loan system*. Certified Emission Reduction (CER) is generated when CO_2 reduction is achieved from the implementation of ESCO. CER belongs to the owner of facilities, i.e., loaner, and can be used to paying back the loan. This concept was first proposed in the wind power plant industry (Hyun, 2008) where the heavy initial investment is a major obstacle to spreading the plants. If the CER is used to pay back the interest, it generates the effect of lowering the interest rate, which can be particularly useful if the financial source comes from the private sector.
2. *Extended Producer Responsibility (EPR).* In order to improve the environmental potential after use, solutions were conceived to ensure recuperation of used lamps for recycling. ESCO guarantees recycling of old lamps by contract so that The average expected usage period of LED (8.3 years[2]) is longer than the contract period (6 years) so that replacement of LEDs will happen after the contract is over. After the use, consumers can remove the lamps and have them collected by the ESCO without additional charges. Collection fee can be included in the overall cost so that even after the contract period, the ESCO is responsible for recuperating them. In the absence of regulations that enforce LED recycling, as in Korea, recycling tends to be an environmental choice rather than an economic one. If, however, EPR or WEEE (The Waste Electrical and Electronic Equipment Directive) applies to LEDs, which already happened in UK, this idea can also be economically feasible.
3. *Energy saving education.* Although LED is already an energy-efficient product, appropriate measures to change user behaviors can leverage energy saving. Training has hence been an integral part of ESCO service. We extended the notion of training to energy-saving education targeting primary students. In partnership with schools, local governments, civil society, and service designers, ESCO can offer a comprehensive and creative action plan to save energy in school[3]. For example, service design and gamification can be utilized to develop collaborative services organized by students and teachers to save energy and resources in the form of a game.

[2] Conditions for the calculation are that the average lifetime of LED is 30,000 hours and it is used for 12 hours per day.
[3] Existing energy saving education programs offered by local governments and civil organizations such as the Green School Consultancy Program by the Kyunggi Province could be incorporated into the system.

4. *Online matching platform*. In order to lower the transaction costs and increase transparency in the tendering process, an online platform was proposed that connects ESCO, energy facilities providers, and consumers. The platform is equipped with a database of registered ESCO, energy facilities providers and customers in demand of energy saving, and allows its users to search potential partners, and take part in a tendering process through the platform. The platform runs on membership fee and is a self-standing business model rather than a component of ESCO.
5. *Functional result of maintenance.* Due to the longevity and technical immaturity of existing products, LED users have either implicit or explicit needs to be freed the chores of maintenance. During the interviews, we discovered that there exists a discrepancy between what is promoted by manufactures and what is perceived by users in terms of the product quality and lifespan, and it results in consumers - especially large organizations - to be hesitant to invest in LED. One way to address such a need is to provide the functional result in which the provider guarantees the desirable outcomes (e.g. a pleasant working environment) while being completely free as to how to deliver them [Tukker 2004].
6. *Lighting consultancy.* This solution module takes advantage of a competitiveness of LED over other lighting sources in that the illuminance and color temperature can be configured to create a wide range of lighting conditions that affect customers' emotions. Application of this particular feature is commonplace in areas such as hotels, offices, restaurants, gymnasiums and theaters. Through lighting consultancy, teachers and students can also be offered with lighting atmospheres optimized for their need.

2.8 Solution design

2.8.1 Scenarios

Solution scenarios were conceived by combining sub-solutions, i.e., PSS modules. A scenario contains a PSS concept that targets a predefined user segment, addresses business opportunities based on the stakeholder need analysis. In this paper, a scenario titled energy-saving school is introduced.

The energy-saving school aims at facilitating energy saving and improving study atmospheres at schools by introducing a packaged lighting solution. The main target users are primary and secondary schools which use non-LED lighting sources and want to achieve both energy saving and a better working environment. A school finances the project with a condition that ESCO guarantees energy saving and the optimal luminance in the classroom during the contract period. Guaranteeing final results assign more responsibility and reliability for ESCO and greater satisfaction for consumers [Tukker and Tischner 2006]. CER-integrated loan system can reduce the financial burden of school. A local NGO and ESCO organize a workshop with teachers and students to make an energy saving action plan that involve various activities at school. The implementation of the action plan is accounted for in the assessment of performance at the end of every year. At customer's request, a waste management agency collects the used lamps for recycling (Figure 5).

The proposed solution addresses many of the needs identified from both empirical and literature studies. For example, user-financing model not only eliminates the financial burden of ESCO, but also attracts the finance sector, thereby mitigating the dependence on government subsidies. Primary and secondary schools - both public and private - have a relatively sound financial status compared with ESCO and hence are a more reliable customer to financiers. More than 11,000 primary and secondary schools in Korea with a majority of them being potential LED users make an attractive ESCO market to finance. Incorporating energy saving education into PSS can provide competitiveness advantage to ESCOs not only by enhancing energy saving, but also differentiating them from manufacturers. Utilizing CER generated from the project to pay back the loan increases the perceived value of customers and provide an incentive to use ESCO. Finally, provision of the 'pleasant working environment' as a functional result can be an alternative to ESCO as a solution aiming at higher customer satisfaction and profitability.

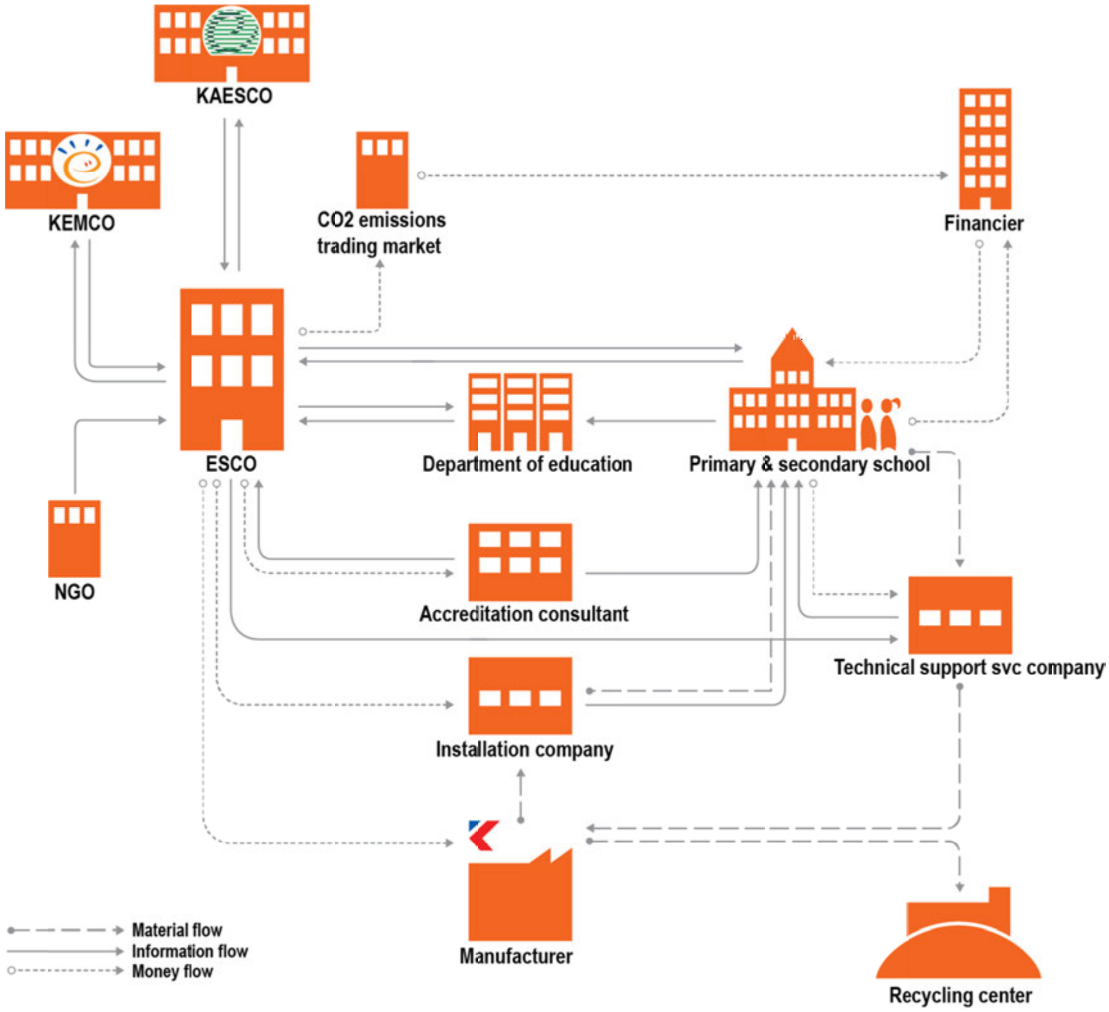

Figure 5. A system map of energy-saving school

2.8.2 Financial analysis

The economic viability of the energy-saving school was tested through a simulation. The conditions for simulation were set as follows: annual inflation rate 5 %, interest rate 5 %, annual change of electricity price 1 %, lighting hours 84 hours per week, and classroom size 118m square meters. The product in comparison is a typical fluorescent tube used in an ordinary classroom. The efficacy, average lifespan, and reserved stock of the product were provided by the manufacturer (Table 2). The classroom size and lighting hours were provided by a local education department. The profit margin and cost of providing services were provided by one of the small and medium-sized ESCO interviewees. The other data were estimated based on the trend over the past 10 years.

Table 2. Model specification

Type	fluorescent tubes	LED
efficacy (lm/W)	75	100
Power (W)	64	32
No. of lamps/class	10	10
Price (won)	5280	50000
Average lifespan (hours)	9000	30000
Reserved stock (%)	60	20

The simulation result shows that a high school that uses the energy saving school service and replaces conventional 32W fluorescent tubes with LEDs of the equivalent illumination would meet the break-even point within five years (Figure 6). From the 4th year, the school starts generating profit until the 8th year when the LEDs are to be replaced. Considering that the average break-even point for LED ESCO projects in Korea is three to five years, the proposed solution has a competitive ROI.

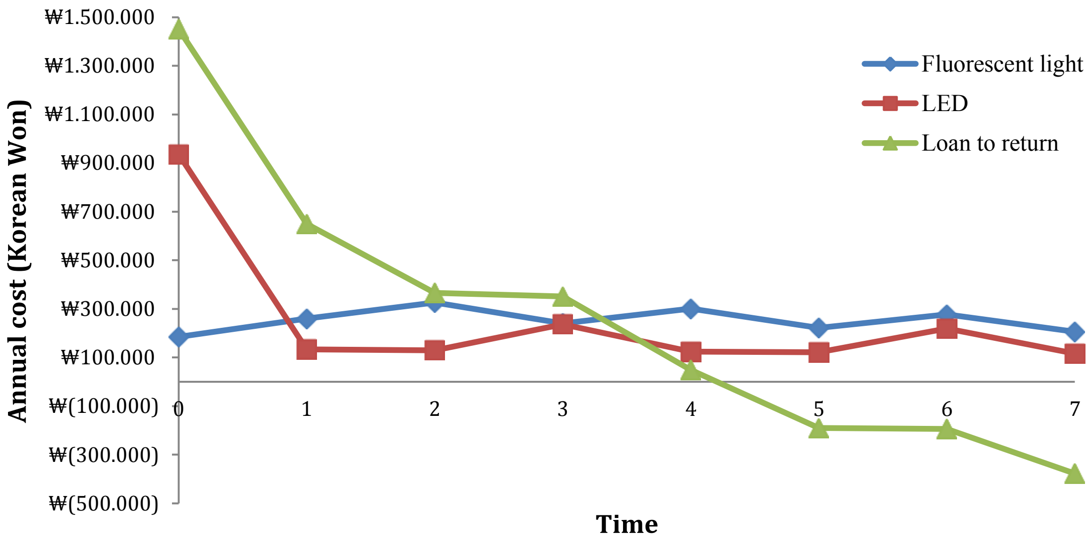

Figure 6. The cost of using fluorescent lamps vs. LED lamps and the amount of loan to return per class room

3. Conclusions

This paper revisits Korean ESCO model as a sustainable PSS for LED lamps and proposes a new business opportunity for an intelligent light management system. Starting from the analyses of the product and the system, it argues that there exists a gap between perceived values of LED ESCO from stakeholders' perspectives and the expected values from societal and environmental perspectives. To match the gap, competitive and sustainable ESCO models can be generated using PSS design methodology. Addressing the needs of various stakeholders in a PSS is critical in developing successful value propositions for the final users and building a network of stakeholders whose partnership as well as economic prosperity is assured. Based on the primary and the secondary data, the needs of stakeholders in the LED ESCO industry were identified. The system is highly complex, composed of multiple stakeholders whose needs are diverse and often conflicting. Stakeholder need analysis leads to identifying business opportunities and generating of functional modules of PSS. At the end, a PSS concept titled energy-saving schools is introduced. Future works include the validation of the concept with target users, pilot testing, and evaluation before the market launch. The paper can provide insights to policy makers, manufacturers and ESCOs who are interested in supporting or developing competitive and sustainable services for LED.

Acknowledgement

The presented work is based on research supported by the Korean Ministry of trade, industry and energy to develop global innovative technologies (number: 10039544).

References

"Comparison chart: Led lights vs. Incandescent light bulbs vs. CFLs", 2013.

Cho, S. E., "Soo-eun deongeori pyehyungkwangdeung hamburo beoryeojinda. (Used fluorescent lights filled with mercury are being dumped)", Retrieved Jan 10, 2014, from <http://www.recyclinglamp.org/>, 2013.

Eden, C., Ackermann, F., "Making strategy: The journey of strategic management", Sage Publications, London, 1998.
Halen, C. v., Vezzoli, C., Wimmer, R., "Methodology for product service system innovation", Van Gorcum, Assen, 2005.
Hansen, S. J., Bertoldi, P., Langlois, P., "ESCOs around the world: Lessons learned in 49 countries", CRC Press, Florida, 2009.
Hwant, M. K., "LED jomuyung sanup vision mit baljeonjeonrkyak (Vision and development strategy for LED luminarire industry)" KOPTI (Korea Photonics Technology Institute), Retrieved Jan 10, 2014, from <http://www.recyclinglamp.org/>, 2008.
Jegou, F., Joore, P., "Food delivery solutions: Cases of solutions oriented partnership", Cranfield University, Cranfield, 2004.
Ji, M. H., "2013 LED Jomyung sanup-jeonmang (2013 Forecast of LED luminaire industry)", Meritz Securities Research Center, Seoul, 2012.
Koh, J. K., "Promotion of ESCOs in gyeonggi-do" Gyeonggi Research Institute, Suwon, 2010.
Lee, J. C., Jang, H. J., "Jineunghyung LED jomyung mit energy jeolyakhyung jae-o-kwanli system gaebal bogoseo (A report on the development of intelligent LED luminaire and energy-saving controller system)" Kumho Electric, Osan, 2012.
Lee, M.-K., Park, H., Noh, J., Painuly, J. P., "Promoting energy efficiency financing and escos in developing countries: Experiences from korean ESCO business", Journal of Cleaner Production 11, no. 2003, 2003, pp. 651-657.
Leedy, P. D., Ormrod, J. E., "Practical research: Planning and design", Pearson, 2010.
MKE, "Energy jeolyak-ui sanuphwarul wihan ESCO sanup hwalseonghwa bangan (Strategies to reinvigorate ESCO industry for the industrialization of energy saving)", Ministry of Knowledge and Economy, 2010.
NAESCO, "What is an ESCO?", vol. 2013, NAESCO, Washington, DC, 2011.
Peters, J. S., Albers, N., Goldman, C. A., Stuart, E., Fuller, M., "Energy efficiency services sector:Workforce education and training needs", Ernest Orlando Lawrence Berkeley National Laboratory, 2010.
Seong-Rim, L., Kang, D., Ogunseitan, O. A., Schoenung, J. M., "Potential environmental impacts of light-emitting diodes (LEDs): Metallic resources, toxicity and hazardous waste classification", Environmental Science & Technology, no. 45, 2011, pp. 320-327.
Tukker, A., Tischner, U., "New business for old europe", (Editors), Greenleaf Publishing, Sheffield, 2006.
Wimmer, Kang, R., Oketani, M. J., Nishimoto, S., Oikawa, N., K., Kawafuchi, T., "Sekisui chemical uru project final report (under non-disclosure agreement), " GrAT, Vienna, 2006.
Wimmer, R., Kang, M. J., Tischner, U., Verkuijl, M., Fresner, J., Moller, M., "Success strategies for product service systems (erfolgsstrategien für produkt - service systeme), final report", Federal Ministry for Transport, Innovation and Technology (BMVIT): Factory of Tomorrow (Fabrik der Zukunft) Program, Vienna, Austria, 2007.
Young, L., "From Products to Services", West Sussexw: Wiley, 2008.

Dr. Joon Sang Baek, Assistant professor
UNIST/School of Design and Human Engineering
1st Engineering Building Room 1001-2, UNIST-gil 50, Ulsan, South Korea 689-798
Telephone: +82 52 217 2720
Telefax: +82 52 217 2708
Email: joonsbaek@gmail.com