Energy Efficiency Road Mapping in Three Future Scenarios for Lao PDR

***Hajime Sasaki*[1], *Kensuke Yamaguchi*[2], *Go Yoshizawa*[3], *Ichiro Sakata*[1], *Hideaki Shiroyama*[1]**
[1]Policy Alternatives Research Institute, The University of Tokyo, Tokyo, Japan
e-mail: sasaki@pp.u-tokyo.ac.jp

[2]Graduate School of Public Policy, The University of Tokyo, Tokyo, Japan
[3]Department of Biomedical Ethics and Public Policy, Graduate School of Medicine, Osaka University, Osaka, Japan

Cite as: Sasaki, H., Yamaguchi, K., Yoshizawa, G., Sakata, I., Energy Efficiency Road Mapping in Three Future Scenarios for Lao PDR, J. sustain. dev. energy water environ. syst., 1(2), pp 172-186, 2013, DOI: http://dx.doi.org/10.13044/j.sdewes.2013.01.0013

ABSTRACT

Climate change, pollution, and energy insecurity are among the greatest problems of our time. These problems are no longer issues in particular countries but international issues. Several framework conventions on these issues are now in place throughout the world, and developing countries are no exception. Energy efficiency is one of the important issues for developing countries. Lao PDR is one such country. This paper proposes a technology roadmap and policy recommendations for Lao PDR with consideration given to a wide range of economic and social impacts of prospective technologies. For the implementation of technology assessment in the formulation of an energy efficiency roadmap, we first elaborate the social and economic conditions of Lao PDR through preliminary research and field research, and then design three scenarios for a future Lao PDR. These three scenarios are as follows: 1. The "Poverty Reduction" scenario is for electrification rate improvement; 2. The "Industrial Creation" scenario is for stable domestic energy supply; and 3. The "GMS Integration" scenario is for the acquisition of foreign exchange by energy export.

KEYWORDS

Developing countries; Energy Efficiency; Supply-side electricity; Technology Road map; Technology Assessment; East ASIAN, Policy suggestions;

INTRODUCTION

Climate change, pollution, and energy insecurity are amongst the paramount issues of our era. These issues are no longer those of specific countries but have become international issues. A number of framework conventions on these issues have now been put in place throughout the world. Rapid growth of energy demand in developing countries is a dramatic global dynamic, driven by economic growth, increased industrialization, and rising standards of living. One of the important aspects for such countries is to consider energy efficiency before they achieve developed status.

In 1993, the World Bank estimated that developing countries could increase their energy efficiency by 30–60 % and save money at the same time, even at today's subsidized energy prices [1]. In recent years, the focus in Asia has been on energy efficiency. It was estimated that the economic energy efficiency potential in Southeast Asia to the year 2020 will be in the range of 20 % in the industry sector, and 20–60 % in the residential sector [2].

As a first case study of the above project, we selected Lao PDR for the following reasons: (i) the country could be the battery of the ASEAN region, exporting power to its vicinity (indeed, its slogan of "Battery of ASEAN" is to be achieved by 2020); (ii) it has huge hydropower potential due to its mountainous geographical location; and (iii) its domestic power demand is only expected to increase forthwith. In particular, its aluminium industry is expected to consume a huge amount of electricity.

In spite of development challenges, Lao PDR is on an increasingly sustainable growth path. The reforms underway have reduced poverty and stimulated growth. Real GDP grew at an average rate of 7.1 % a year from 2000 to 2010. In 2010, Lao PDR achieved a GNI per capita of US$ 1,040 and, as such, progressed from being a lower-income economy to a lower-middle-income economy. At this pace, Lao PDR is on track to achieve its long-term vision: to graduate from least developed country status by 2020.

ENERGY SITUATION IN LAO PDR

The primary energy supply in the country is shown on Figure 1 [3]. Wood fuel is mostly used in the country, which accounts for no less than 56 % of the total primary energy. Then, the proportion of fuel, electricity, and charcoal is between 10 and 20 % followed by coal (3 %). While the domestic power market is not as big as that of firewood, the export power market and its potential is huge in neighbouring countries such as Thailand, Vietnam, and China. Therefore, in this report, the focus is on electricity.

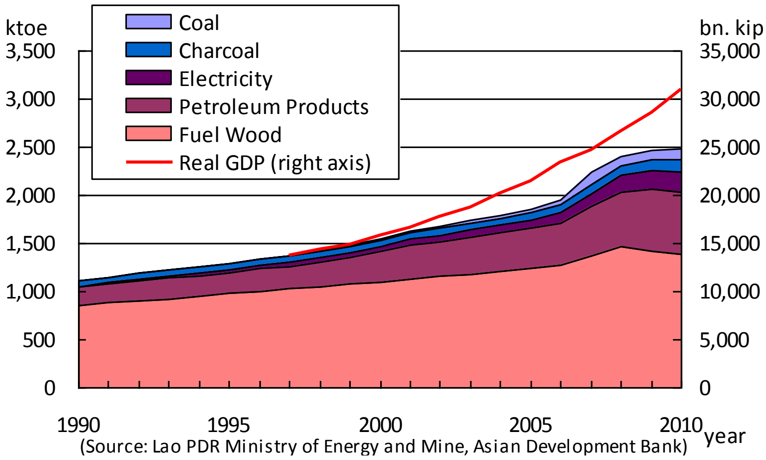


Figure 1. Total Final Energy Consumption by Energy Source

Thus, electric power demand is rapidly increasing according to the fast economic growth. As Figure 2 shows [4], in 2000-2010, electricity consumption in the country marks 11 % as a yearly average.

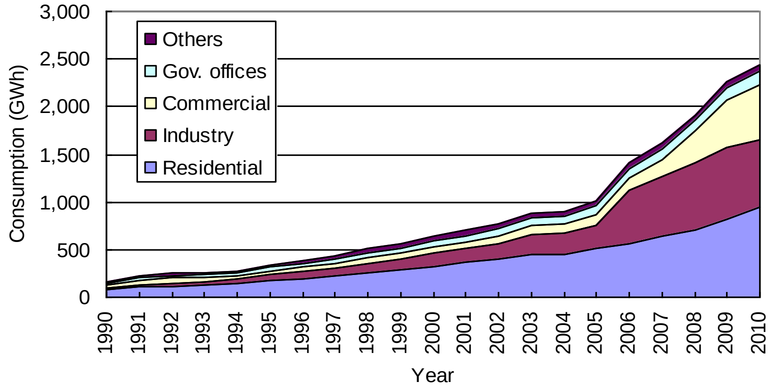
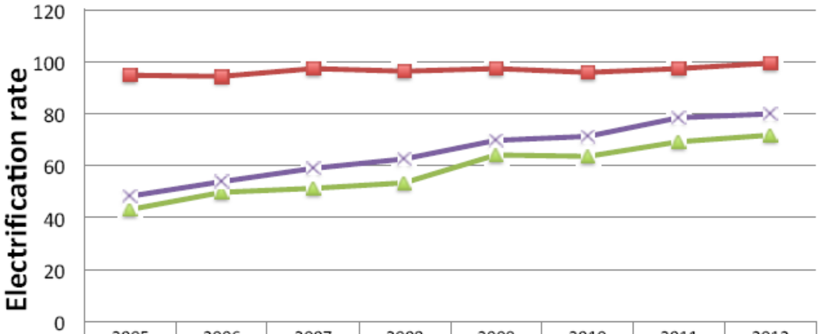


Figure 2. Total Consumption of Electric Power

The government has set a target household electrification rate of 90 % to be achieved by 2020. They are trying to promote rural electrification mainly by grid extension. Figure 3 [4] indicates the transition of the electrification rate in Lao. In fact, in recent years, the electrification rate is rising rapidly. In fact, a household electrification rate of 80 % was achieved in 2012.



	2005	2006	2007	2008	2009	2010	2011	2012
County	95	94.3	97.1	96.5	97.2	95.8	97.2	99.3
Rural Community	43.1	50	51.3	53.5	64.1	63.8	69.1	71.7
Household	48.3	54.1	59	62.6	69.6	71.3	78.3	80.1

Figure 3. Transition of the Electrification Rate

In this country, energy demand is remarkable in the residential, transportation, and industry sectors. According to the analysis by the Institute of Energy Economics of Japan (IEEJ) however, the transportation sector is estimated to grow five-fold compared to current consumption. Also, the consumption of the industrial sector is estimated to be increasing significantly. The same IEEJ's analysis estimated the impact of the alternative energy policy scenario (APS) on the amount of energy consumption. It was found that the APS, or energy efficiency policy in this developing country, has limited potential to reduce energy consumption. Instead, energy supply should be the focus at this development stage so as to reduce the unproductive use of energy. Then, in this paper, we focus on the supply side of its electric power system.

METHODOLOGY

Stakeholder's Meeting

Several studies have provided a great deal of insight into technology road mapping [5-9]. In accordance with the methodologies in these studies, obtaining a shared vision through a stakeholders' meeting should be the first step. To determine Laos' energy vision, we conducted a series of stakeholders' meetings mainly with the power regulators and utilities in the country. We also collected data through interviews with villagers, international donors, and their neighbour countries.

We held three main stakeholders' meetings to communicate the Lao energy vision. First, we discussed the vision with the local regulator and utility in Vientiane in March 2011. Second, targeting Japanese stakeholders, we conducted a workshop with the Institute of Energy Economics of Japan (IEEJ) and the Institute of Developing Economies (IDE) in Tokyo, June 2011. Third, in Vientiane, August 2011, we conducted a workshop among power utilities in Thailand and Vietnam as well as Lao PDR to communicate the Lao vision with the neighbouring countries. Also, other international key stakeholders such as the Asian Development Bank (ADB) and the Japan International Cooperation Agency (JICA) participated in the final meeting.

In addition, to enhance the meetings, we launched the following series of meetings entitled "Energy Policy Roundtable 2012." The series is held approximately every two months, and we have so far communicated the energy vision to NEDO (New Energy and Industrial Technology Development Organization), the National University of Singapore, and IEA. This process will be even further enhanced with other domestic and international stakeholders in the coming meetings in this series.

Technology Assessment/ Technology Roadmap

Technology assessment (TA): Technology assessment (TA) refers to activities comprehensively analysing the social impacts of the development of science and technology from an independent and unbiased perspective and informs the public, politicians, and administrators of these impacts to facilitate wider discussions and support their decision making. There are various ways that TA can contribute to government policy and society: (1) examining what is known and what is unknown in terms of science and technology and its social implications; (2) clarifying social and policy issues accompanying the development of science and technology; (3) visualizing a variety of cognitions and values concerning science, technology, and society; (4) facilitating mutual understanding, collaboration, and knowledge exchange between stakeholders; (5) supporting innovation and new institutional design; and (6) deepening communications with a wide range of the public.

Technology roadmap: The TRM (technology roadmap) approach was formally developed and executed by Motorola in the late 1970s to support integrated product technology planning. TRM has been used by a variety of firms, industries, and countries for strategic and technology planning [10, 11]. Former Motorola chairman Robert Galvin defined a roadmap as an "extended look at the future of a selected field of inquiry composed from the collective knowledge and imagination of the brightest drivers of the change" [12].

TRM helps to provide a framework for future innovations in a number of key technology areas and ensure that investment in technology and research is linked to business drivers and market trends [13]. Also, TRM provides a framework to link business and product plans directly to technology by establishing linkages between technological and commercial functions [14-18].

Specifically in the energy sector, the goals and objectives of its TRM differ at the national, industry/sector, and organization levels [15]. In this report, we focus on the sum total of the levels to determine better implications of the energy policy in Lao PDR. While we focus on multiple levels, our scope is limited to the supply side of electricity power policy. This is because our rationale for focusing on Laos is drawn from its power sector. Moreover, developing countries, like Lao PDR, do not have sufficient potential for energy efficiency on the demand side.

Consensus Building

After the technology assessment/roadmapping phase, we position our output in the final process of consensus building in accordance with its process consultation. This process is particularly important for determining effective policy implications. While there are several processes in "consensus building" [19], two of them are highlighted here.

First, we conducted the Energy Efficiency Conference in Vientiane, Lao PDR, where a diverse group of stakeholders gathered. There, we presented our scenarios as interim findings with the aim of building consensus among stakeholders in our interim report.

Second, after evaluating the scenarios in the interim report, we conducted a second consensus building in Vientiane, Lao PDR. In this phase, we held a consensus-building meeting regarding our final findings and recommendations with the Ministry of Energy and Mines in Lao PDR.

Through the process, political decision makers and specialists in Laos' energy situation are involved in every meeting for this policy suggestion. They are from the Ministry of Energy and Mines, Electricite du Laos (EDL), and the National University of Laos. First of all, we had a kick-off meeting to share the situation and to create consensus with them regarding problems of Laos' energy. Then, based on this shared awareness, the stakeholders' meeting ran over for the sake of consensus building. As a result, we and these stakeholders could attain options for Lao PDR as three key scenarios.

RESULTS

Stakeholder's Meeting

<u>Scenario X: "Poverty Reduction"</u>*:* This scenario prioritizes poverty reduction. The basic tenet is to graduate from least developed country status by 2020. For this purpose, the government's target is to achieve electrification at a rate of 90 % by 2020 following the former target of 70 % by 2010. The energy plan aims at a distributed system in order to improve the electrification rate in remote and rural areas through the distribution of micro-/off-grids.

One of the underlying motivations for this scenario is ensuring energy diversity. The development distributes diverse renewable energy resources that lower the overdependency on hydropower and improve the robustness and security of the energy system. Also, in terms of non-electrical energy saving, the consumption of firewood, charcoal, and other non-commercial energies is expected to decrease.

The incentive for energy efficiency in Scenario X is the sharing of mini-/micro-grid systems with more households in a community. Among the technological mechanisms available are pico-hydro, micro-hydro, PV/SHS (solar home system), and hybrid systems. Pico-hydro is a hydropower generation system of less than 5 kW that is distributed and promoted by some NGOs. An estimated 60,000 low-head pico-hydropower units provide electricity for about 90,000 households. However, this can be a disincentive for electrification rate improvement because of its low reliability.

Social and policy mechanisms might include cross-subsidies, price gap reduction, and peak-shift promotion. As an institutional approach to commercial loss reduction, there are high penalties for misuse, and rewards for reporting by meter readers and the general public [20]. Promotion of regional industry development utilizing surplus electricity in the daytime (e.g., "One District, One Product" project) may also be effective.

<u>Scenario Y: "Industrial Creation"</u>*:* This scenario prioritizes stable domestic energy supply. The basic tenet is to achieve economic development by creating its own industry instead of depending on power export. In particular, the value chain in aluminium-relevant industries is critical to achieving its economic development. According to current Power Development Plan, local peak demand is estimated to double in 2014 from 765 MW to 1,600 MW and will rise to around 3,000 MW in 2020. To satisfy such demand, the following technological mechanisms may be required:

(1) Grid extension: Whereas a 115 kV transmission system is created between different areas within the country, 22 kV and 35 kV distribution systems in the border provinces are interconnected with neighbouring countries.

(2) Load-dispatching centres (LDC): National/regional control centres maintain a reliable and stable system and efficiently manage power trading between Electricite du Laos (EDL) and power producers.

(3) Mine development and coal-fired plants: In the long run, coal will be a key alternative energy source to supplement hydropower and meet the demand for mine development in the southern area.

In this scenario, the incentive for energy efficiency is increasing cost efficiency in energy supply. Among the technological mechanisms utilized are the introduction of thicker and multiple transmission lines, actions to prevent leakage of electricity in limited-design low-voltage transmission, and more networks to switch distribution lines in a system.

The phase which will be focused on this scenario's vision is one of the appropriate terms during which the country will install new, efficient technologies such as high-efficiency coal fired power plants, integrated coal gasification combined cycle, and so on. Therefore, remarkable efficiency is expected by these technologies from this period. On the other hand, as social and policy mechanisms, promising labour-based approaches to commercial loss reduction include regular patrols by inspection teams, sealing all existing meters [20], promotion policies for IPP's domestic energy supply, and a nationwide educational campaign for energy conservation.

Scenario Z: "GMS Integration": This scenario prioritizes the acquisition of foreign currencies by power export. Table 1 shows power trade and net imports in GMS in 2010 [21]. As the table shows, Lao PDR exports around 7000 GWh, which is more than China's energy exports.

Table 1. Greater Mekong Subregion Power Trade and Net Imports, 2010 (GWh)

	Imports	*Exports*	*Total Trade*	*Net Imports*
Cambodia	1,546	–	1,546	1,546
Lao PDR	1,265	6,944	8,210	-5,679
Myanmar	–	1,720	1,720	-1,720
Thailand	6,938	1,427	8,366	5,511
Vietnam	5,599	1,318	6,917	4,281
China	1,720	5,659	7,379	-3,939
Total	17,069	17,069	34,139	–

According to government estimates, it will be selling 7,000 MW of hydroelectric power to Thailand by 2015 and 5,000 MW to Vietnam by 2020. This is in line with large-scale hydropower plant development, which will amount to 6,796 MW in 2010–20. Energy import and export are necessary to balance the energy demand-supply within Lao PDR. Also from the viewpoint of geopolitical relations, Lao PDR is a central location for the transportation and interconnection of high-voltage transmission lines (500 kV, 230 kV) in the Greater Mekong Subregion (GMS).

The incentive for energy efficiency in Scenario Z is the extension of GMS-wide high-voltage transmission lines. Technologically, the installation of more transformers, efficient long-range transmission (e.g., high-voltage DC transmission), and high-voltage

(500 kV, 230 kV, 115 kV) transmission systems are prospective mechanisms. Social and policy actions can refer to cross-border economic regions, water system management (not only as an energy resource but also as a measure preventing water disaster, and use of water resources for other purposes), and memorandums of understanding between Lao PDR and neighbouring countries.

Stakeholder's Meeting

Category of relevant technologies: Based on the preliminary study, we classified the relevant technologies into three categories: generation, transmission and distribution, and operation and management. First, regarding generation technology, we focused on two technologies: high-efficiency coal-fired power plants and renewable energy (wind power, solar power, and hydropower).

Second, regarding transmission that involves the transfer of electrical energy, we focused on three technologies: existing transmission and distribution, high-efficiency transmission, and micro-grids. Third, regarding management, we focused on two technologies: energy management and hybrid systems. Each of these major categories has related sub-category technologies as shown in Table 2.

Table 2. Technologies for Assessment

	Large Category	*Small Category*
Generating	High efficiency coal fire power plant	
		Integrated coal Gasification Combined Cycle
		Supercritical Pressure Coal-Fired boiler
	Renewable energy (without Hydro)	
		Silicon photovoltaic
		Thin film Silicon photovoltaic
		CIS/CIGS photovoltaic
		Dye Sensitized photovoltaic
		Onshore wind power
	Hydropower	
		Hydro power
Transmission and Distribution	Existing transmission and distribution	
	High efficiency transmission	
		Large capacity transmission
		Energy efficiency trans
		Superconducting High-Voltage Power Lines
		High Voltage Direct Current
	Microgrid	
		Microgrid
		Digitalgrid
Management	Energy management	
		Regional Energy management
		Optimize Energy Use
	Hybrid system	
		Hybrid system

In Table 2, some technologies should be noted here due to the country's unique character. For example, one may consider that the installation of High Voltage Direct Current (HVDC) in the least developed countries would be impossible. The introduction of transmission technologies such as large-capacity transmission has been conducted in recent years in developed countries, particularly interconnection between multiple countries. HVDC and superconducting transmission are a part of this. Considering the recent super-grid initiative in East Asia, these technologies should be considered. In addition, digital grids have yet to be implemented even in developed countries. However, we consider the possibility of leapfrogging in certain conditions.

Also, we include the solar/hydro hybrid system in the table. Normally, this technology is not utilized in developed countries. Considering the local weather, however, this hybrid system should be on the list as there are distinctive dry and rainy seasons in this region. Moreover, taking into account the high rate of power loss and energy theft, we must highlight the need for improving the existing transmission and distribution. In addition to the hard-technology solution to these problems, soft measures in operation and management are also available. We will include these aspects in our scope of technology assessment.

The technologies in each category are assessed in terms of their affinity with each scenario. As each scenario has its own distinctive goal, technology solutions are required accordingly. In the following, for each of the three scenarios, the technology is presented as shown in Table 3.

Table 3. Expected Package of the Power and Non-Power Sector

	Power Sector	*Non Power Sector*
Generation	･Decentralized Generation System (Include. Pico/Micro Hydro)	･Water Management
	･Data Collection of Hydro Potential	･Social / Environmental Impact Assessment
	･Development of Thermal Generation	･Investment Management for Strategic Development
	･Strengthen the Finance of EDL-Gen	･Trans-boundary River Management
	･Institutional Development of IPPs	･Flexible Financial Mechanism through Bond Market
Transmission	･International/Domestic Construction of Transmission line	･Road Construction
	･Reduction of Power Loss	･Border Security
	･Administrative Capacity Building of the EDL's local office	･Strategic Land Planning
Distribution	･Rural Electrification	･Relocation Policy
	･Prevention of Power Theft	･Rural Development
	･Capacity Development of Demand Estimation	･Industrial Creation out of mining
Others	･Data Maintenance	･Donor Coordination
	･Price Mechanism between Urban and Rural	･Expert Training in higher education institutions

Scenario X: "Poverty Reduction"

Renewable energy (without hydropower): In general, photovoltaic energy (solar power energy) is in a transitional period of research and development (R&D) of the technology phase. In fact, current photovoltaic energy is an expensive technology and will be obsolete before it even has time to be introduced. Therefore, the large-scale or full-scale introduction of such technology with the aim of industrial creation is impractical for Laos. On the other hand, onshore wind power is unlikely to generate a significant cost reduction in the future.

In the context of poverty alleviation in Laos, improving the electrification rate in rural areas is essential. In such areas, early adoption of new large power generation facilities and existing facilities of the grid is difficult. Neither is it feasible to be dependent on hydroelectric power because, even in rural areas, it is difficult to provide a stable supply between day and night or among seasons. Therefore, the use of solar power and wind power is considered to be one of the methods to achieve rural electrification. As auxiliary power, a renewable option should be considered to enhance rural electrification. This technology corresponds to "Recommendation 1" of the Ten Key Recommendations in concluding remarks.

Hydropower: Hydropower is also one of the renewable energy resources. In the Lao context, however, it should be separated from other renewable energy sources due to its dependency on them as an energy resource. Even if the demand for renewable energy and coal-fired power generation as a source of power increases in a future Laos, hydroelectric power will remain an important source of energy in the future.

Hydroelectric power generation technology is sufficiently mature and the possibility of high efficiency and low cost being achieved through this technology is unlikely in the future. Thus, Laos is at the stage of absorbing the technology and knowledge of hydroelectric power systems in the "Poverty Reduction" scenario. Although there are some benefits from water regulations, it should be noted in this context that excessive development of dam construction with the focus on power generation will cause flooding, water control issues, and other adverse environmental/social impacts.

Thus, in this country, it is essential to employ knowledge of location planning to achieve an appropriate water storage and outflow schedule. The knowledge required in this scenario is know-how acquisition and investigation of the entire power generation potential of hydropower in Laos and evaluation of the environmental impact caused by new construction and so forth. This technology corresponds to "Recommendation 6" and "Recommendation 7" of the Ten Key Recommendations.

Micro-grid: In order to achieve a 90 % electrification rate in 2020, simply connecting to the existing power transmission and distribution network is difficult to achieve with rural mountainous areas in Laos accounting for 90 % of the country. Developing a facility of the grid in a distributed manner in each region will have a good influence on improving the electrification rate and enhancing transmission networks in the future.

As described above, in the scenario focusing on poverty reduction in Laos, micro-grid technology is essential. In addition, adjusting electricity prices between rural and urban areas is necessary in accordance with each income standard, which is also critical from a power management perspective between the local or micro-grid and existing main grid in urban areas. Rural development is lowering the governmental cost of the adjustment policy. This technology corresponds to "Recommendation 1" "Recommendation 2" "Recommendation 4" and "Recommendation 8" of the Ten Key Recommendations.

Scenario Y: "Industrial Creation"

High-efficiency coal-fired power: As stated in the chapter on the "Industrial Creation" scenario, local demand is estimated to double in 2014 from 765 MW to 1,600 MW and will even rise to around 3,000 MW in 2020. One of the reasons for the increasing demand is that the aluminium industry such as SLACO will consume a huge amount of electricity. With the existing hydroelectric power generation, it is difficult to ensure the stable power supply required by the aluminium industry. And, from the viewpoint of transmission, long-distance power transmission to the south from the existing hydroelectric power supply will incur a significant loss. At the same time, we can also expect Laos to be at the stage of exporting a significant amount of electricity.

It is required for a country like Laos, which has no possibility of nuclear power, to install high-efficiency coal-fired power plants as a complementary power supply. High-efficiency coal-fired power, such as the supercritical-pressure coal-fired boiler and the integrated coal gasification combined cycle, has shown remarkable improvement in terms of low CO_2 emissions and other environmental impacts, compared with the existing coal-fired power generation. This technology corresponds to "Recommendation 3" and "Recommendation 7" of the Ten Key Recommendations.

Transmission and distribution (existing): In the industrial creation phase, throughout the development of power transmission and the distribution network, prevention of electricity theft and reduction of transmission loss are required. In the condition of a complex blend of fixed-wire networks, it is difficult for the regulatory authorities to govern the networks so that some power users can easily intercept them. This situation is typically observed in other developing countries.

At the stage of industrial development in Laos, there is a need to replace the power transmission and distribution at an appropriate timing from the viewpoint of power management. In addition, the technological introduction of appropriate materials for the transmission and distribution grid is desirable in order to contribute to highly efficient power transmission and distribution. This technology corresponds to "Recommendation 4" of the Ten Key Recommendations.

Energy management: In the industrial creation phase in Laos, it is critical to enhance power generation, transmission, and distribution technology. It is software technology that is essential to manage them properly. Also, in order to achieve a hybrid power system, it becomes necessary to introduce energy management such as demand estimation. Moreover, some energy management systems are important because Laos must perform proper monitoring of theft of electricity or power usage in each region.

Together with the accumulation of data, knowledge of the development of power-related statistics is essential. Demand forecasting will be possible by the acquisition of sufficient statistical data. Such knowledge contributes to the appropriate pricing of power, as well as the planning of new power generation and the planning of power export. This technology corresponds to “Recommendation 4” and “Recommendation 5” of the Ten Key Recommendations.

Hybrid system: In the industrial creation phase in Laos, stable and multiple power supply through a “hybrid system” that is not limited to small pockets of rural areas but also includes urban areas is required. Therefore, high-efficiency coal-fired power generation can also compensate for the expected demand for significant hydropower due to the considerable size of the aluminium industry. The technology manages the multiple sources of power generation, and it is part of the energy management system. This technology corresponds to “Recommendation 5” of the Ten Key Recommendations.

Scenario Z: “GMS Integration” Scenario

High-efficiency transmission technologies: The high-voltage, direct-current (HVDC) system is one of the representative technologies of high-efficiency transmission. The HVDC electric power transmission system uses direct current for the bulk transmission of electrical power, in contrast with the more common alternating-current systems. For long-distance transmission, HVDC systems may be less expensive and incur fewer electrical losses. One of the advantages of HVDC is the lower line costs—beyond a certain distance (break-even distance: 600–800 km for overhead cables), the DC line pays for the investment cost for the DC stations [22].

In southern prefectures such as Champasak or Atap, significant increase in regional power demand is expected because of the aluminium industry. On the other hand, large existing dams such as the Nam Ngum hydroelectric facilities are mainly located in the centre of the north in Laos, so that long-distance power transmission is and will be further required. The existing transmission incurs significant power loss. In considering long-distance power transmission whose distance is longer than the break-even distance of HVDC, introducing HVDC is a practical option for Laos.

Moreover, to achieve Laos’ aim of becoming the “Battery of ASEAN,” long-distance power transmission loss should be avoided where possible because not only Laos but also the neighbouring ASEAN countries are developing long-distance high-voltage transmission as part of the ASEAN Super Grid plan. This technology corresponds to “Recommendation 4” of the Ten Key Recommendations.

Technology Roadmap

Figure 4 shows the technology roadmap in Laos as listed above. In the figure, each technology is listed along with the scenario on which it is focused. And these technologies (major category) have some sub-category technologies. The roadmaps are designed from a purely technological viewpoint.

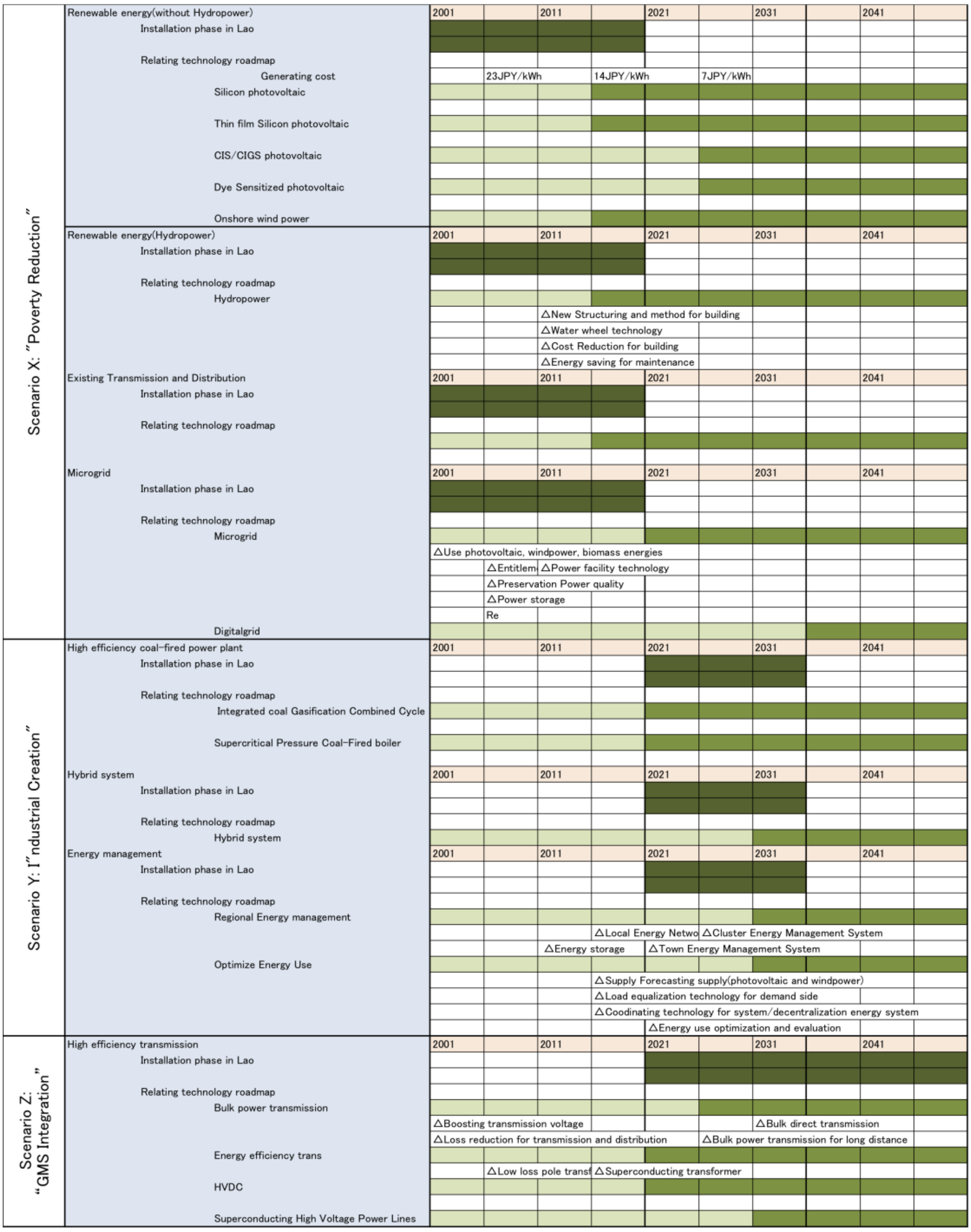


Figure 4. Technology Roadmap in Laos

- The dark green cells mean a reasonable period for introducing these technologies based on consensus in general.
- The green cells mean a period that is the development phase of these technologies.
- The light green cells mean a period that is the preparation phase of these technologies.

CONCLUDING REMARKS

In conclusion, we have presented a technology roadmap in line with the target set by the Lao government. Undoubtedly, poverty reduction through rural electrification, industry creation through stable power supply, and acquisition of foreign currency through exporting electricity are all important and critical for Laos' development. The point is, however, prioritization among policies. Considering the country's budget allocation, it cannot target all the goals as it has implied. Rather, allocation should be prioritized in accordance with each vision, which are poverty reduction, industry creation, and regional integration.

Principally, it is noted that the three visions are all critical in the real world. While there is a number of trade-offs in between, the appropriate balance among visions must be ascertained in reality. In this way, we would contend that the country should not put its first priority on Scenario Z, at least in an exclusive fashion, at this moment in time. Firstly, ASEAN integration has not yet attracted foreign capital under its own control. Secondly, if Scenario Z was pursued now, this would detract from the other visions in Scenarios X and Y. Thirdly, on the other hand, the other two visions could be co-evolutionary without foreign investors. Thus, at this moment, Scenarios X and Y should take precedence over Scenario Z.

One may argue that poverty reduction can never be achieved through rural electrification alone. Others might wonder whether stable power supply is necessary and whether utilizing bauxite would be sufficient for industrial development. In addition, there would be an adverse impact of power development on local society, with which the country has to contend. To deal with these concerns, we have to properly package the power sector policy with the policies of other sectors to achieve these visions. Thus, in addition to Recommendations 1–8 determined from our analysis, we emphasize the importance of Recommendations 9–10 as follows. Also, the recommendations with relevant issues are categorized in Table 3.

Ten Key Recommendations:

1. Installation of small-scale distributed energy systems swiftly according to need
2. Linking rural electrification to rural development
3. Complementing existing energy systems with thermal power
4. Strengthening power governance in transmission and distribution systems
5. Improving the capacity of estimating demand in the power market
6. Integrating water management into the hydropower development plan
7. Internalizing environmental/social external costs into the major hydro plans
8. Determining electricity pricing policy according to urban-rural relationships
9. Developing diverse methods of funding for EDL generation
10. Strategically managing foreign investments in a comprehensive plan

Currently, Japan has strengthened its ties with Lao PDR. The Ministry of Foreign Affairs resumed yen credit and it is aggressive in the field of energy infrastructure and mining. Indeed, in 2012, both governments agreed on the Southern Region Power System Development Project. In addition, the Ministry of Finance launched the ABMI (Asian Bond Markets Initiative) to enhance the bond market in the region. This initiative may achieve a more flexible financing mechanism in the future. By strategically managing these movements with international donors, it is recommended that Lao PDR combine the power and non-power sector to tackle its energy issues as shown in Table 3.

REFERENCES

1. World Bank, Energy Efficiency and Conservation in the Developing World: A World Bank Policy Paper World Bank, Washington, D.C., 1993.
2. UNDP, World Energy Assessment, *UNDP Publication*, ISBN: 92-1-126126-0, Sep. 2000.
3. Lao PDR Ministry of Energy and Mine, Asian Development Bank.
4. Department of Electricity, Ministry of Energy and Mines, "ELECTRICITY STATISTICS YEARBOOK OF LAO PDR", 2010.
5. Garcia, M.L. and Bray, O. H., Fundamentals of Technology Roadmapping, *Sandia Nat. Labs., Albuquerque, NM, SAND97-0665*, Mar. 1998.
6. Canmet Energy Technology Centre, Canada's Carbon Dioxide Capture and Storage Technology Roadmap, 2006. <http://www.co2trm.gc.ca> [Accessed: 15-Jan-2013]
7. Chikkatur,A.P. and Ambuj, D.S., Cleaner power in India: towards a clean coal technology roadmap, *Discussion paper*, *Belfer Center for Science and International Affairs, Cambridge, Mass.*, Dec. 2007.
8. Daim T.U. and Oliver T., Implementing technology roadmap process in the energy services sector: a case study of a government agency, *Technological Forecasting and Social Change*, Vol. 75, pp.687–720, 2008. (http://dx.doi.org/10.1016/j.techfore.2007.04.006)
9. Lee, S. K., Mogi, G. and Kim, J. W., Energy Technology Roadmap for the Next 10 Years: The Case of Korea, Energy Policy, Vol. 37, pp.588–596, 2009. (http://dx.doi.org/10.1016/j.enpol.2008.09.090)
10. Holmes, C., and Ferrill, M., The application of Operation and Technology Roadmapping to aid Singaporean SMEs identify and select emerging technologies, *Technological Forecasting and Social Change*, Vol. 72, No.3, pp.349–357, 2005. (http://dx.doi.org/10.1016/j.techfore.2004.08.010)
11. Phaal R., and Muller G., An architectural framework for roadmapping: towards visual strategy, *Technological Forecasting and Social Change*. Vol. 76, No. 1, pp 39–49, 2009. (http://dx.doi.org/10.1016/j.techfore.2008.03.018)
12. Galvin, R., "Science Roadmaps", *Science*, Vol. 280, pp.803, 1998. (http://dx.doi.org/10.1126/science.280.5365.803a)
13. Amer M. and Daim T. U., Application of technology roadmaps for renewable energy sector, *Technological Forecasting and Social Change*, Vol. 77, No. 8, pp.1355-1370, Oct. 2010. (http://dx.doi.org/10.1016/j.techfore.2010.05.002)
14. Phaal R., Technology roadmapping - a planning framework for evolution and revolution, *Technological Forecasting and Social Change*, Vol. 71, No. 1–2, pp.5–26, 2004. (http://dx.doi.org/10.1016/S0040-1625(03)00072-6)
15. Kostoff R.N., and Schaller R.R., Science and technology roadmaps, *IEEE Transactions on Engineering Management*, Vol. 48, No. 2, pp.132–143, 2001. (http://dx.doi.org/10.1109/17.922473)

16. Bray, O. H. and Gracia, M. L., Technology Roadmapping: the Integration of Strategic and Technology Planning for Competitiveness, *Proceedings of PICMET '97: Portland International Conference on Management and Technology*, 1997., pp.25–28.
17. Nauda, A. and Hall, D. L., Strategic Technology Planning—Developing Roadmaps for Competitive Advantage, *Proceedings of PICMET '97: Portland International Conference on Management and Technology*, 1991, pp.745–748.
18. Probert, D. R., Farrukh, C. J. P. and Phaal, R., Technology Roadmapping-Developing a Practical Approach for Linking Resources to Strategic Goals, *Journal of Engineering Manufacture*, Vol. 217, No. 9, pp.1183–1195, 2003. (http://dx.doi.org/10.1243/095440503322420115)
19. Straus, David A., Designing A Consensus Building Process Using a Graphic Road Map, *In The Consensus Building Handbook: A Comprehensive Guide to Reaching Agreement,* Edited by Susskind, Lawrence, Jennifer Thomas-Larmer and Sarah McKearnan, eds. Thousand Oaks, CA: Sage Publications, 1999. (http://dx.doi.org/10.4135/9781452231389.n4)
20. TEPCO, Lao People's Democratic Republic Rural Electrification Phase I Project of the Rural Electrification (APL) Program, Power Distribution System Loss Reduction, PhaseII, Final Master Plan, pp.7, Dec. 18, 2008.
21. Asian Development Bank, Greater Mekong Subregion power trade and interconnection: 2 decades of cooperation, *Asian Development Bank*, 2012.
22. ABB, HVDC Efficient Power Transmission, *Pamphlet. Power Systems AB Publ, Ludvika, Sweden*, 1998.

Paper submitted: 28.02.2013
Paper revised: 19.05.2013
Paper accepted: 20.05.2013