Study on the energy-saving measures and the introduction of renewable energy for the winter season road management instructions in Aomori Pref. in Japan

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ABSTRACT

In this study, a case study of energy saving diagnostics (energy saving measures) for winter road management facilities and renewable energy sources was carried out in several locations throughout the prefecture, with interesting results. Also, a concept to introduce energy saving measures and renewable energy sources has been created based on this information, as a guideline for other existing facilities in Aomori prefecture, and for future improvement of road management facilities.

Keywords: energy saving , renewable energy, road management facilities

1. INTRODUCTION

Aomori prefecture is located at the northern tip of Japan's main island, Honshu, and receives the heaviest snowfall in Japan. In particular, drifting snow caused by strong seasonal winds is observed. For winter roads in such weather conditions, facilities such as light emitting delineators and non-water sprinkle melting snow facilities are essential for safe road traffic.

Moreover, Japan experienced two oil shocks which occurred on the global scale in the 1970's. Since then, Japan has made progress in the technological development of energy saving, and currently carries out leading energy saving measures in the world.

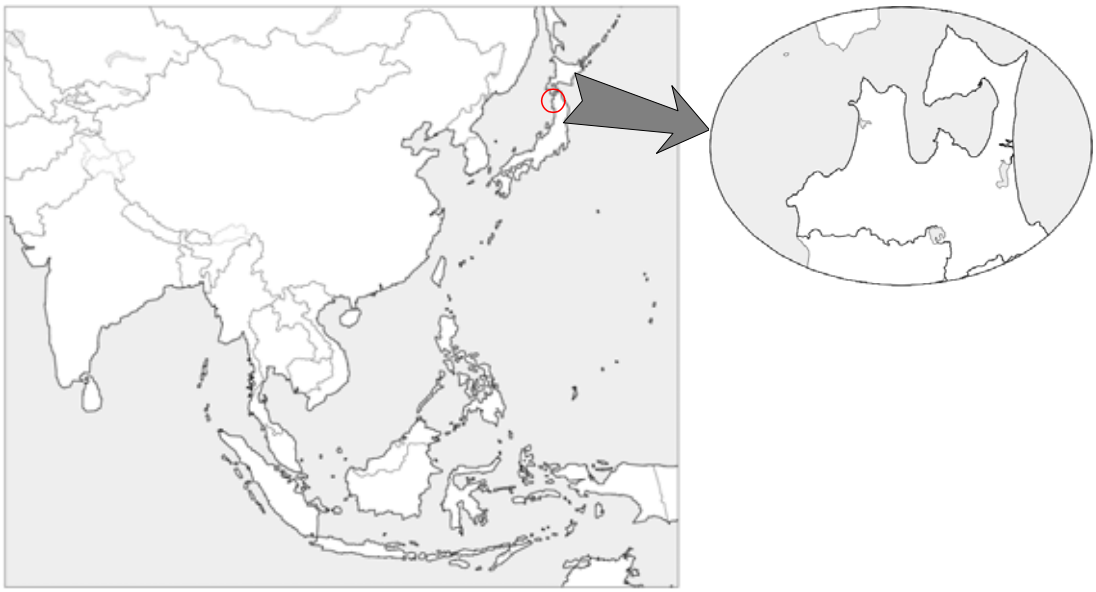
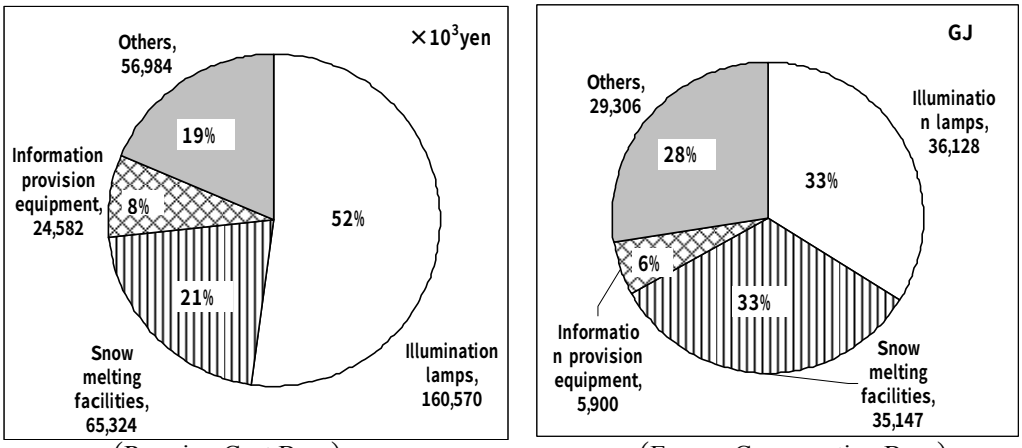


Fig 1. Location of Aomori Prefecture

2. ACTUAL CONDITIONS OF ENERGY CONSUMPTION BY ROAD MANAGEMENT FACILITIES

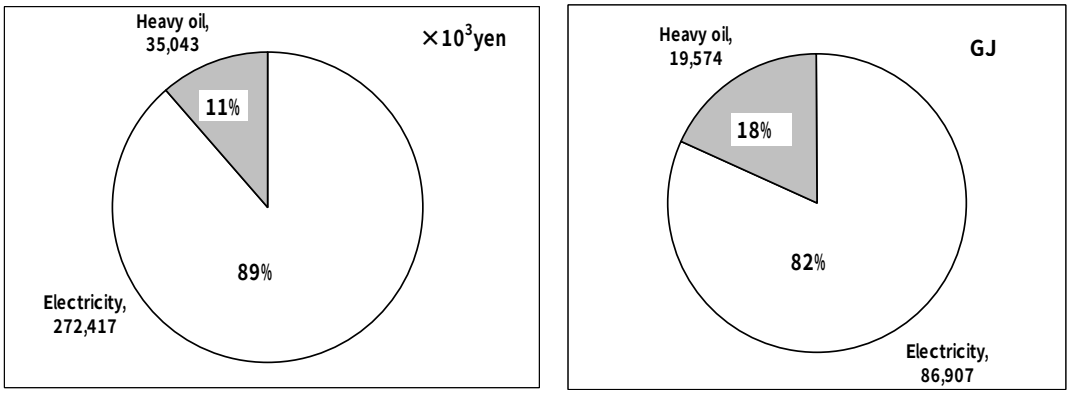
A breakdown of the amount of annual energy consumption by road management facilities in Aomori Prefecture is shown in Figures 2 and 3. Calculation of Year Totals is 307,460,000 yen for the running costs base, 106,481 GJ for the consumption base, and 13,669 t of CO_2 emissions. Road illumination occupies more than half of the total running costs. Moreover, in energy volume base, road illumination and snow melting facilities

have almost the same volume, and these totals occupy approximately 70% of overall total. This demonstrates the need for cost savings and changes toward using eco-friendly energy in illumination and snow melting. When viewing energy consumption according to energy source, electricity occupies 80-90% of overall total.



(Running Cost Base) (Energy Consumption Base)

Fig. 2. Annual Energy Consumption by road management facilities by application (2006)



(Running Cost Base) (Energy Consumption Base)

Fig 3. Annual Energy Consumption by road management facilities according to energy source (2006)

3. ENERGY SAVING DIAGNOSTICS OF ROAD MANAGEMENT FACILITIES

Energy saving diagnostics were carried out in 8 locations of representative road management facilities within Aomori prefecture. The results are shown in Chart 1. According to the results, the following proposals are suggested.

1). Check operational efficiency, such as power factor, air ratio, coefficient of performance (COP) during facility operations. Carry out an improvement scheme in cases where operation efficiency is lower than the design value.
2). Carry out an improvement scheme in cases where facility operations are considered to be consuming excessive energy.
3). Convert to energy saving by changing the lighting rate at the entrance and middle of tunnels.
4). Improve illumination intensity by cleaning the light reflectors on tunnel walls.
5). Regarding the illumination lamps, replace the currently used mercury lamps with highly efficient and low-energy-cost sodium lamps.
6). Regarding electricity, measures should be taken in order to reach a power factor of 100%.
7). Installation of measuring equipment to manage energy is needed.
8). A less expensive electrical power contract should be chosen according to the maximum quantity and time of usage of the electrical power.
9). Farther spaced lighting by illumination lamps, etc., the intermittent operation of snow melting devices, control of facilities where alternative operations are possible according to the weather conditions.
10). Carry out improvement proposals in consideration of the check record during the working season and at the end of the season.

Table 1. Results of energy saving diagnostics of road management facilities

No.	Targeted facilities	Items to be improved	Kind of energy	Amount of energy saved (kWh/yr) (kl/yr)	Price reduced (thous yen/ yr)
1.	Aomori-Namioka Line Sky-bridge	Perform corrective control depending on the traffic. During heavy traffic throughout the day, leave on 2 out of 5 blocks. At night since the traffic is lighter, leave it as is.	Electricity	27,215	334.7
2.	Aomori-Namioka Line Kareizawa	Improvement of boiler air rate (In consideration that the cause of present low boiler efficiency may be the low efficiency of combustion.) Improve the current rate of 1.6 to 1.3.	Heavy oil	2.12	152.4
		Include corrective control depending on the traffic. During heavy traffic throughout the day, reduce hot–water circulation to 75% of current operations of the snow melting device.	Heavy oil Electricity	9.00 4,565	647.7 56.1
3.	Hirosakidake-Ajigasawa Line Ichibancho	Include corrective control depending on the traffic. During heavy traffic throughout the day, leave on 50% of all heaters. At night, since traffic is lighter, leave it as is.	Electricity	22,982	344.7
4.	Hachinohe-Niida Tunnel	Improve COP of a heat pump. 3.15 ⇒3.5	Electricity	3,528	70.9
		Effectively use friction heat of tires. Reduce daytime heat pipe heating range to 50%.	Electricity	15,911	319.8
5	Route 339 Goshogawara-city Ubayachi	mprove COP of the heat pump. 3.15 ⇒3.5	Electricity	7,560	93.0
		Effectively use friction heat of tires. Reduce daytime heat pipe heating range to 25%.	Electricity	8,424	103.6
6	Osame Arito Railway Station Line Arito	Include corrective control depending on the traffic. During heavy traffic throughout the day, leave on 4 out of 6 blocks. At night, since traffic is lighter, leave on 6 heaters as is.	Electricity	4,597	56.5
7	Route 338 Mutsu Kuriyama Tunnel	Improve COP of the heat pump. 3.15 ⇒3.5	Electricity	10,080	124.0
		Effectively use friction heat of tires. Reduce daytime heat pipe heating range to 50%.	Electricity	43,748	538.1
8.	Route 101 Oirase	Improvement of boiler air rate Improve the current rate of 1.6 to 1.3.	Heavy oil	0.75	54.5
		Include corrective control depending on the traffic. During heavy traffic throughout the day, reduce hot–water circulation to 50% of current operations of the snow melting device.	Heavy oil Electricity	14.00 3,170	1,011.7 39.0
Total			Reduced electrical power (Wh/yr) 151,780	Reduced heavy oil (kl/yr) 25.9	Price reduced (thous yen/ yr) 3,946.7

4. CASE STUDIES ON THE INTRODUCTION OF RENEWABLE ENERGY SOURCES IN ROAD FACILITIES

Case studies on the introduction of renewable energy sources were performed in 5 common areas in Aomori prefecture. Two studies are as follows.

4.1 Switch from hot-water kerosene boilers at the snow-melting facilities to wood pellet boilers

When the life cycle costs of hot-water boilers for snow-melting using fossil fuels such as heavy oil, kerosene, etc., were compared with those of wood pellet boilers, wood pellet boilers were found to be more advantageous in the long run, as shown in Figure 4. The following conditions were noted.

- Kerosene boilers (400,000 kcal)- cost: 2m yen, durable yrs: 7 yrs, heavy oil 72 yen/L
- Wood pellet boilers (400,000 kcal)- cost: 11m yen, durable yrs: 20 yrs, wood pellet 30 yen/kg
- Operations of 120 days / yr (December to the following March) and 50% a load rate
- Excluding maintenance and building expenditures

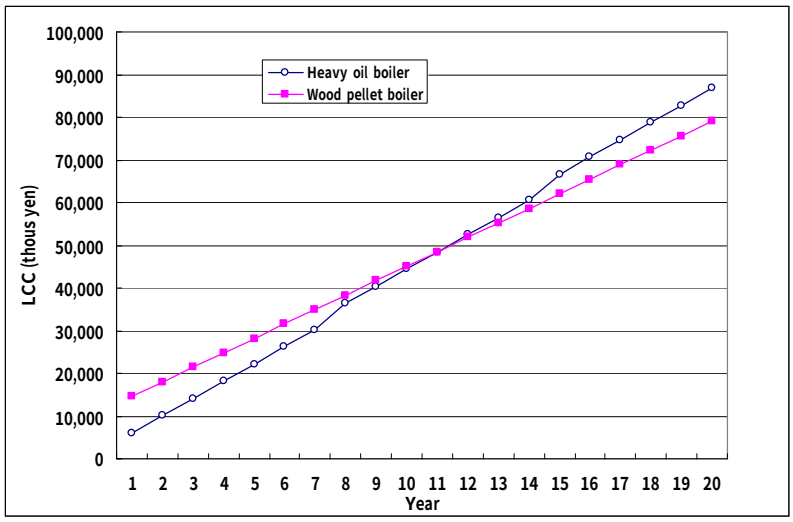


Fig.4. Comparison of life cycle costs for hot water boilers for snow melting facilities

Wood pellets are solid fuel made by pulverizing, compressing, and shaping scrap waste wood or leftover lumber materials such as sawdust and wood shavings. The pellets are formed by heat fusing and fixing lignin, a wood constituent, without adding an adhesive agent and generating poisonous combustion gas. Green-house gases are not released as it is carbon-neutral.

Photo 1. Wood pellets

Photo 2. Wood pellet boiler

4.2 Installation of light emitting delineators (light emitting safety post) equipped with a photovoltaic generator

Light emitting delineators are lifelines for drivers when drifting snow hinders clear vision (called 'white out'). A comparison of life cycle costs by different power line systems is shown in Figure 5. Until a year or two ago, the cost of photovoltaic generator components were expensive, so it was more advantageous to utilize a commercial power source. However, in recent years, there has been a major reduction in cost and photovoltaic generating systems have become less expensive. The following conditions were noted.

- Purchase price of one light emitting delineator- photovoltaic generator: 100,000 yen, commercial power source: 50,000 yen
- Construction cost of one light emitting delineator- photovoltaic generator: 50,000 yen, commercial power source: 90,000 yen
- Yearly maintenance cost of photovoltaic generating systems- battery replacement (once in every 5 yrs): 30,000 yen, maintenance check: 30,000 yen
- Commercial power source systems- Yearly electrical power consumption: 28,000 yen, maintenance check: 22,500 yen

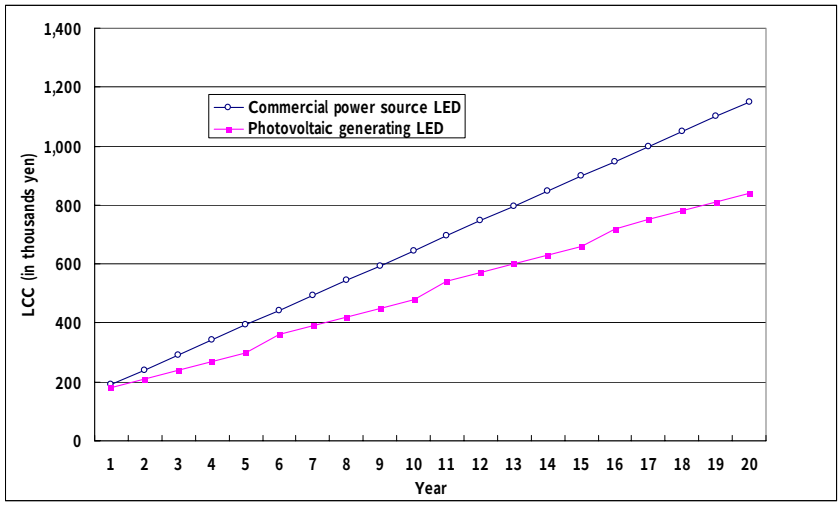


Fig. 5. Comparison of life cycle costs by different power line systems

Photo 3. Light emitting delineator equipped with a photovoltaic generator

5. CONCEPT TO INTRODUCE ENERGY SAVING MEASURES AND RENEWABLE ENERGY TO ROAD MANAGEMENT FACILITIES IN AOMORI

5.1 Basic policy

<Policy 1>

Introduction of eco energy sets Life Cycle Costs (LCC) to be the investment standard.

In the introduction of eco energy, long-period life cycle costs (LCC) that takes into consideration the number of facility durable years, etc. are set as the standard for investment.

Generally, while investment recovery of energy saving can be achieved over a relatively short period, investment recovery of renewable energy requires a longer period of time, and commercial power source tends to be the least expensive. However, by utilizing government subsidy and in considering the difference in durable years, etc., renewable energy is most advantageous.

<Policy 2>

Thorough introduction of energy saving in the existing road management facilities

Some energy saving measures can be achieved by daily management that requires little cost and can result in thorough energy savings for existing road management facilities. In particular electricity charges and electrical power contracts, etc., can be organized and analyzed as valuable basic data.

Energy saving diagnostics are to be implemented based on the results of the regular maintenance inspection and measurements. Improvements, repairs, replacements, etc., shall be carried out in the event the diagnostic results show that LCC is advantageous. Energy savings can be promptly implemented, and unlike renewable energy, regional characteristics do not need to be considered, and thus are easily put into effect.

<Policy 3>

In the event of renovating or new construction of road management facilities, consider introducing new energy sources.

In the event of renovating or making large scale improvement, and new construction of road management facilities, always carry out a comparative investigation of a conventional energy system and a system using new energy sources according to the LCC (including government subsidies and durable years).
Measures to combat global warming should also be considered by comparing the long term LCC, and if the LCC is the same, propose the preferentially introduction of facilities with new energy sources.
When considering the introduction of new energy sources, in addition to LCC, the regional characteristics (abundance/available supply), stable procurement and differences in long-term running costs compared to conventional energy (commercial electricity, kerosene, heavy oil) should be taken into consideration.

5.2 Priority Projects

In the introduction of energy saving as the standard, the introduction of illumination/safety post devices using eco energy is considered to be a priority project. Regarding snow melting facilities, replacing or newly installing wood boilers or heat pumps, and endeavoring to shift from road facilities operating on electricity to facilities operating on new energy sources over the long run, are priority projects.

◆Priority Project 1: short term goal (~5 years)
Energy saving measures by daily management

◆Priority Project 2: short term goal (~5 years)
Energy saving measures along with facility investment such as replacing road illumination lamps to more highly efficient lamps

◆Priority Project 3: short term goal (~5 years)
Replacing to or newly installing facilities equipped with photovoltaic generators

◆Priority Project 4: medium term goal (6~10 years)
For non-water sprinkler, snow melting facilities, replace kerosene (heavy oil) / hot-water boilers with, or newly install, wood boilers

◆Priority Project 5: long term goal (11~20 years)
For non-water sprinkler, snow melting facilities, replace hot air source heat pumps with, or newly install, geothermal heat pumps

◆Priority project 6: long term goal (11~20 years)
For electrical power required by road management facilities, change to in-house generation (BDF diesel generator, wind electricity, etc.) or power supply from public electric industry

Priority projects will be progressively carried out from Project 1 to Project 5. For Priority Project 1, continuous, daily effort is important. Priority Project 1 is directly connected to cost savings. Also, it is implemented without incurring expenses such as facility investment, so life cycle costs do not need to be taken into consideration. As for priority projects 2-6, life cycle costs should be taken into consideration.

Figure 6 shows the procedure flow of considerations for Priority Projects 1, 2 (energy saving), and Figure 7 shows the procedure flow of considerations for Priority Projects 3-6, (renewable energy). An explanation of the flow charts is as follows.

1. Review contract conditions for electrical power, such as electricity fees, usage amount, etc.
2. Check with the electrical power company regarding power factor, maximum demand of electricity (peak demand) and contract types and organize the data with that from 1.
3. If changing the contract type would result in energy savings, request that the electric company review the contract.
4. If the maximum demand of electricity is excessively large, carry out measures to control maximum electrical power by the introduction of a demand controller.
5. If the power factor is 95% or less, carry out measures to improve the power factor (introduce a phase advance capacitor).
6. Collect data on the regular inspection of road management facilities (especially for snow melting facilities). If the regular inspection has not been performed or the data is not incomplete, assign (consign) an inspection.
7. Confirm and calculate air ratio and coefficient of performance (COP). In the event these values do not meet standards, improve the air ratio or take measures to improve the COP (repair heat pumps, etc.)
8. Check the actual conditions of the illumination facilities and snow melting facilities. When introducing energy savings, it is first important to understand the amount of energy consumption by the targeted facility. A current investigation of the condition of the structures and types (system for melting snow, kind of illumination lamps, etc.) is also necessary. A service standard of the targeted lines (road management standard) and road structure should also be understood.

9. Implement farther spaced lighting, clean the reflection plates, alternate operations of snow melting facilities and interval operation as much as possible.
10. Switch illumination facilities to highly efficient lamps.
11. Implement measures to improve the accuracy of the preheating time of snow melting facilities.

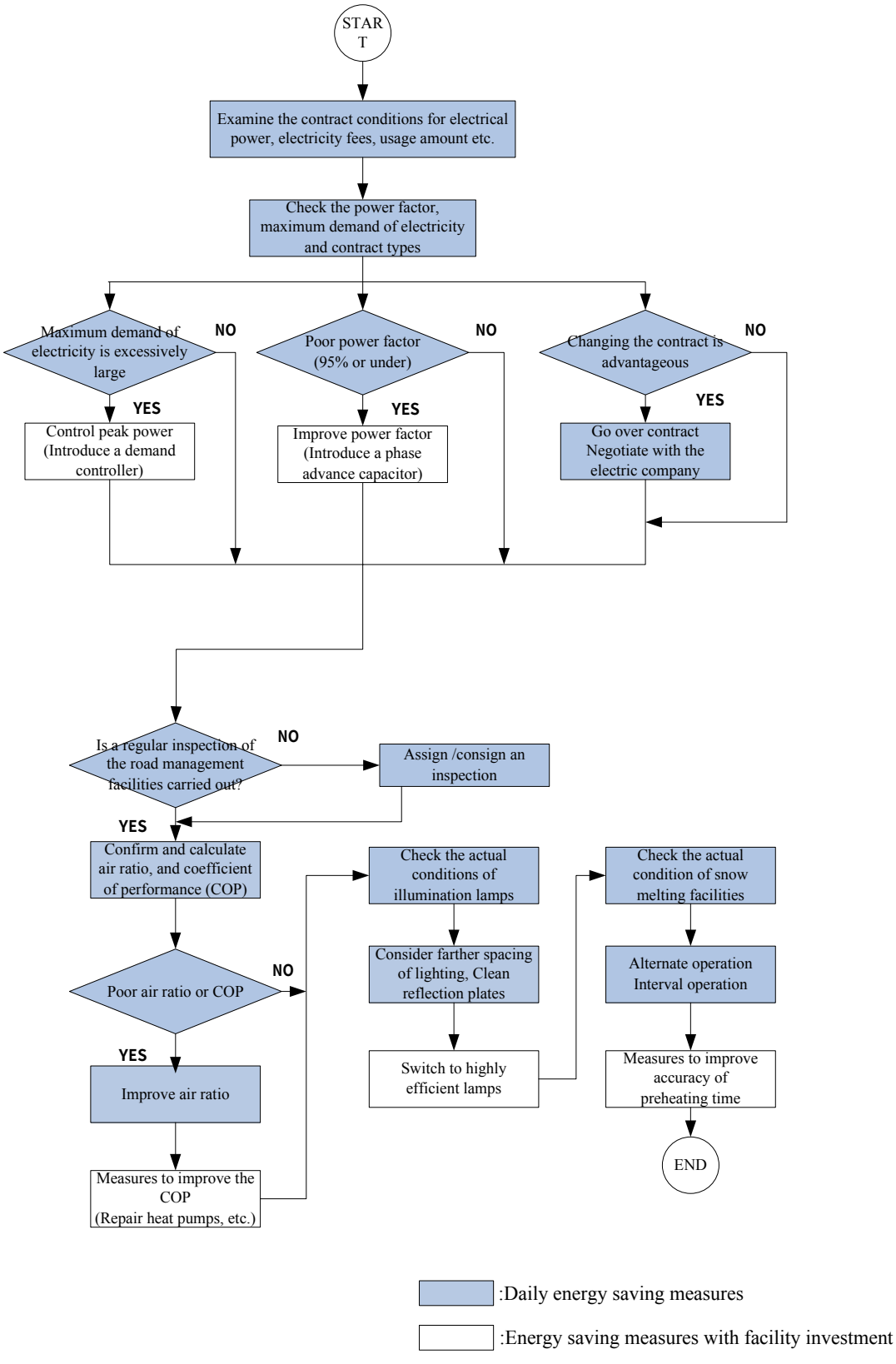


Fig. 6. Procedure Flow of Priority Projects 1, 2 (energy saving) Considerations

12. Perform a regional analysis. Is the location place of the targeted facility is appropriate for new energy introduction?
13. Determine if priority projects can be implemented.
    Priority Project 3: Is there a need to introduce light emitting delineators equipped with photovoltaic generators?
    Priority Project 4, 5: Should new energy sources be introduced at the snow melting facilities?
    Priority project 6: Should a power supply be implemented for other road facilities
14. Understand the abundance of new energy sources.
15. Implement a basic survey. Survey possible usage amount of new energy sources, life cycle cost (LCC), stable supply, etc., amount of energy required by road management facilities (existing, new construction), understand the service standard, etc., relevant information (energy policy implementation by the prefecture, local government, etc.). If there is an investment result (LCC is advantageous), decide for introduction.
16. Carry out an outline plan.
17. Carry out an implementation plan.
18. Carry out installation construction, trial operation, adjustment, inspection.
19. Begin service.

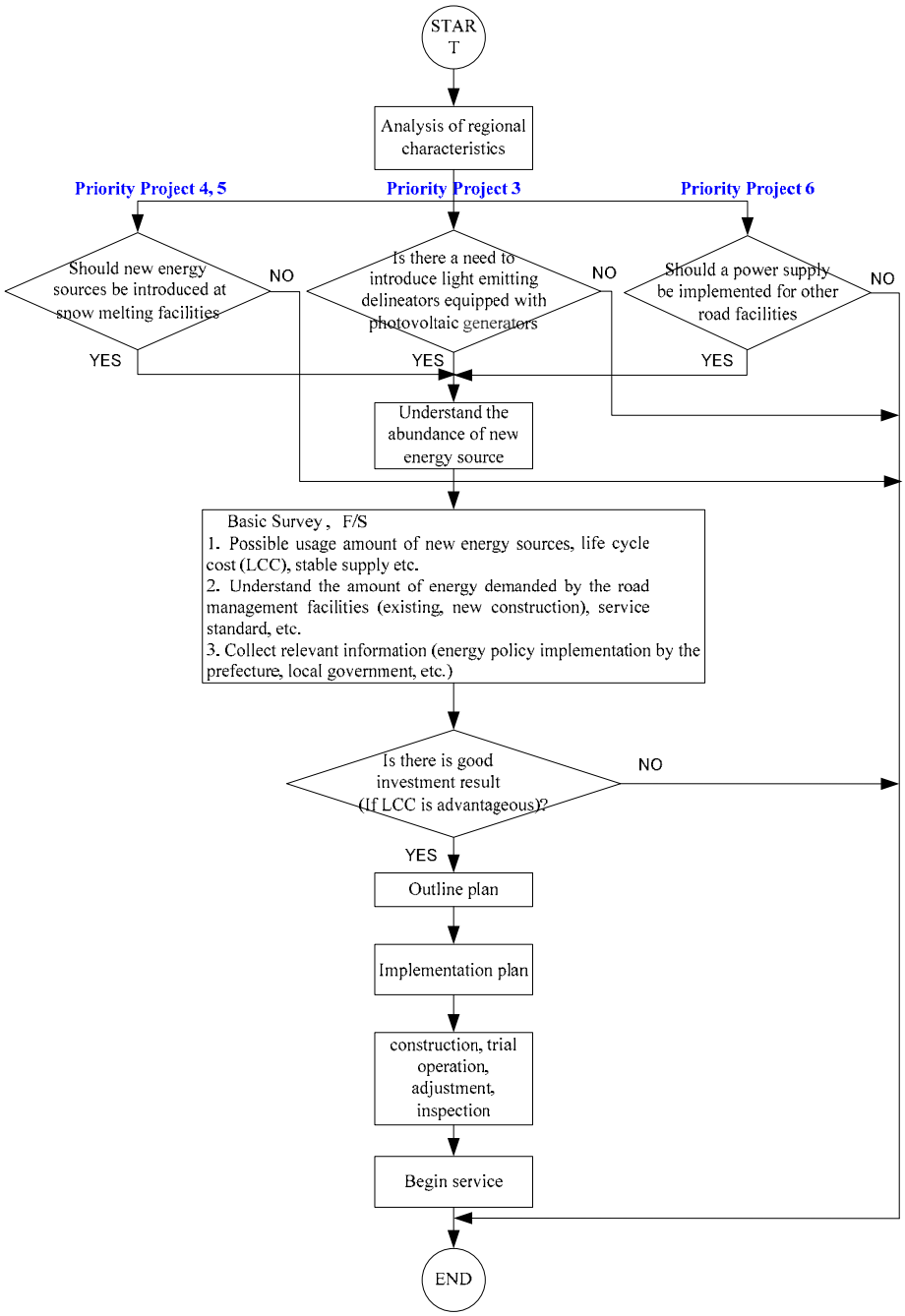


Fig. 7. Procedure Flow of Priority Projects 2-6 (renewable energy) Considerations

5.3 Road map

Introduction target values for energy saving and renewable energy are to be set as achievable values when the above-mentioned priority projects are implemented as planned, especially the values shown in Tables 2 and 3. In other words, to reduce future energy consumption by road management facilities by 33% (35,115GJ), reduce CO_2 by 25.7%（3,515 tons）and electricity / fuel expenses by 19.4% (60,516,000 yen)

Table 2 Target reduction values for fossil fuels at road management facilities

Item	Short term -5 yrs	Mid term 6-10 yrs	Long term 11-20 yrs	Basis for setting the target value
Priority Project 1	3,200 GJ (3%)	—	—	From the results of energy saving inspection etc., a 3-10% reduction is determined as possible. A 3% reduction is by implementing only energy saving on. (Based on actual achievement in 2006)
Priority Project 2	3,000,000kWh (30%)	—	—	Assuming that other prefectural governments would also have the same scale, based on actual achievements by the Sampachi Regional Prefectural Government Development Bureau. (Based on actual achievement in 2005, 2006)
Priority Project 3	— (0%)	—	—	The target value is not set because the number of actual delineators equipped with commercial power source, etc., is small.
Priority Project 4	—	19,574GJ (100%)	—	Considering that the durable years of heavy oil (kerosene) hot-water boilers is approximately 7 years, in the case where 3 heavy oil (kerosene) hot-water boilers in the prefecture are replaced by wood boilers. (Based on actual achievement in 2005)
Priority Project 5	—	—	428,000kWh (70%)	Considering that the durable years of air-source heat pumps is approximately 15-20 years, in the case where 10 air-source heat pumps in prefecture are replaced with geothermal (groundwater) heat pumps. (Based on actual achievement in 2005)
Priority Project 6	—	—	— (0%)	The reduction target value has not been set because future conditions are hard to determine by the current situation.
Cumulative Sum Upper line: Total Calories Lower line: Reduction Rate of Total Energy in Road Management	14,000 GJ 13.1%	33,574GJ 31.5%	35,115GJ 33.0%	—

※Electricity: 1kWh=3.6MJ

The following table shows reduction costs and reduction of CO_2 as estimated by current energy prices.

Table 3. Target reduction value of running costs and CO_2 reduction for road management facilities
[Upper line: reduction cost, lower line: CO_2 reduction]

Item	Short term ~ 5 years	Mid term 6~10 years	Long term 11~20 years
Priority project 1	9,224 thou yen 410 tons	—	—
Priority project 2	48,000 thou yen 1,530 tons	—	—
Priority project 3	— thou yen 0 ton	—	—
Priority project 4	—	296 thou yen 1,357 tons	—
Priority project 5	—	—	2,996 thou yen 218 tons
Priority project 6	—	—	— thou yen 0 ton
Cumulative sum (Reduction rate to total energy for road management)	57,224 thou yen (18.6%) 1,940 tons (14.2%)	57,520 thou yen (18.7%) 3,297 tons (24.1%)	60,516 thou yen (19.7%) 3,515 tons (25.7%)

※CO_2 Emissions basic unit- electricity: 0.510 kg-CO_2/kWh (Official value by Tohoku Electric Co. in 2007), A heavy oil: 2.71kg-CO_2/L. Unit price and calories- heavy oil: 70 yen/L, 39.1MJ/L, wood pellets: 30 yen/kg, 16.9MJ/kg, electrical power for melting snow: 7 yen/kWh, electrical power for Illumination lamps: 16 yen/kWh..

Road Maps shown in Tables 4, 5.

Table 4. Road map (Project base)

	Short term					Mid term					Long term									
Annual	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fiscal year	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Priority Project 1	Energy saving measures by daily management										Continue each year									
Priority Project 2	Change to highly efficient lamps					Energy saving measures in conjunction with other facility														
Priority Project 3	Change to, new construction of facilities equipped with photovoltaic generators																			
Priority Project 4	Change kerosene (heavy oil) hot-water boilers to, new installation of wood boilers																			
Priority Project 5	Change air-source heat pumps to, new installation of geothermal heat pumps																			
Priority Project 6	Obtain necessary electricity for road management facilities from in-house generation from new energy sources (BDF diesel generators, wind/water power)																			

Table 5. Road map (Achievement base)

Achievement rate versus reduction target (%)	10	20	30	40	50	60	70	80	90
Energy reduction amount	Short term target: 40%						Midterm target: 96%		
Electricity / fuel reduction cost	Short term target: 95%						Midterm target: 95%		
CO2 reduction amount	Short term target: 55%						Midterm target: 94%		

7. CONCLUSION

Aomori prefecture receives the heaviest snowfall in Japan, and a practical concept has been created for the reduction of life cycle costs and greenhouse gases. This has been made based on the results obtained from actual energy saving diagnostics and case studies of renewable energy. In this promotion concept, 6 priority projects have been set and are intended to be promoted progressively. In the future, a 33.0% (35,115 GJ) reduction in energy usage is targeted, 25.7% (3,515 ton) reduction in CO_2 and 19.7% (60,516 thous yen) reduction in electricity / fuel expenses.

ACKNOWLEGEMENT

Authors like to express our appreciation to road managers in Aomori Pref. for help with energy saving diagnostics and data collection.