Promotion of Energy Conservation Activities in Factories (Electricity)

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In Thailand
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1. Promotion of Energy Conservation Activity

2. Viewpoint of Power-saving

3. Methods of power-saving of major electric facilities

4. Power-saving Examples of existing facilities in Japan
1. Promotion of Energy Conservation Activity

1.1 Significance of Energy Conservation Activity

Energy Conservation Activity has contributed to Cost Down of each factory moreover, Improvement of Cost and “SEC” (“SEC” is Specific Energy Consumption and defined as energy conservation divided by production)

&

Energy Conservation Activity has contributed to Reduction of the global warming

- Estimation in oil: 0.252 [kL / MWh]
- Estimation in CO₂: 0.555 [t-CO₂ / MWh]
1.2 Control of Energy Conservation

- Establish organization control
  - Management has to keep consciousness of employees.
  - All staffs have to be involved in the project.

- Set the goal

- Grasp the circumstances
  - Establishment of Criteria: Energy management, operation, inspection, maintenance, and budget

- Perform
  - Preparation of reference data and document
  - Setup of measuring and recording devices

- Make an improvement plan
  - Implementation of energy conservation by
    1. Small group activity
    2. Day-to-day business of staff
    3. General development

- Assess the results

- Implement revised plans

Repeat PDCA cycle of energy management
1.3 3 steps for Promotion of Energy Conservation

1st step: Reinforce energy management and increase efficiency of operations

- To avoid wastefulness
- To optimize use of existing equipment
- To avoid unscheduled stop of operations

2nd step: Modify and/or add equipment

- Modification and/or addition of equipment (It will be ineffective if main facilities are renewed or replaced)
- Introduction of energy-saving devices

3rd step: Introduce new processes and high efficiency equipment

- It is necessary to develop and introduce new processes.
1.4 Work Flow of Energy Conservation Activity in Factory

< Incentive of activities by management in the factory >
- To set a goal
- To select objectives
- To set a deadline

< Establish an organizational system for activities >
- To organize a team for activities
- To organize a team for measurement

< 1st STEP : Prepare for activities >
- To collect related information
- To make action plan for the activities
- To analyze existing processes
- To analyze energy consumption

< 2nd STEP : Extract and winnow ideas for energy conservation >
- To collect energy conservation ideas by
  1. check list
  2. brainstorming
  3. recruiting
- To winnow energy conservation ideas

< 3rd STEP : Select measures for energy conservation >
- To make budget for energy conservation measures, modification of equipment
- To estimate effects on energy conservation measures
- To transfer ideas to other equipment
- To assess energy conservation measures (effect on energy conservation and investment)
- To select plans for energy conservation
1.5 Energy Audit

**Brief Audit**

- To fill out questionnaire about situations of energy conservation in a factory

- Hearing from staffs in a factory

- Inspection of a factory

- Identification of basic problems in a factory
- Proposal for overcoming (probability, latency and directions)

**Detailed Audit**

- Cooperation with specialists in energy conservation

- Investigation in detail: understanding of present situation, making guideline, and assessment of results

- Identification of quantitative issues on energy usage
- Proposal of definite guidelines (effect of investment for equipment and control)
1. Promotion of Energy Conservation Activity

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2. Viewpoint of Power-saving

2.1 Breakdown of Energy Consumption by its Usage

<table>
<thead>
<tr>
<th>Working hour</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>A</td>
</tr>
<tr>
<td>9</td>
<td>A</td>
</tr>
<tr>
<td>10</td>
<td>B</td>
</tr>
<tr>
<td>11</td>
<td>B</td>
</tr>
<tr>
<td>12</td>
<td>A</td>
</tr>
<tr>
<td>13</td>
<td>A</td>
</tr>
<tr>
<td>14</td>
<td>C</td>
</tr>
<tr>
<td>15</td>
<td>C</td>
</tr>
<tr>
<td>16</td>
<td>D</td>
</tr>
<tr>
<td>17</td>
<td>D</td>
</tr>
<tr>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

- Variable part
  - A: to be proportional to production
  - B: to keep product plants
  - C: to start up or shut down lines
  - D: to keep utility plants
3 Viewpoints of Energy Conservation Activity

- Now:
  - Transfer fixed into variable part

- Production:
  - Production-up SEC-down

- Saving energy:
  - Decrease P.C.
  - Increase V.P.

- Constant:
  - Variable part
  - Fixed part
2.2 Viewpoint of Energy Conservation Activity

- Is a machine paused during a resting period in intermittent operation?
  - To pause a coupling of product lines
  - To make an automatic ON or OFF

- Is a capacity of equipment too large against requirement?
  - To introduce an inverter for pressure regulation in place of valve and damper
  - To scale down a capacity

- Is a fluctuation of workloads properly regulated?
  - Automatic control of workloads
  - Variable flow control

- Are inspection and maintenance definitely carried out?
  - Guideline on leakage prevention of air and water
  - Prevention of pressure loss with cleaning filters etc
  - Inspection with regular dismantlement of devices

Awareness in operators and maintenance staff on energy conservation is of primary importance.
2.3 Point of Selection of equipment for Energy Conservation

- Equipment (electric motor, transformer, cable) is subject to be audited only when they are established or renewed.

It is difficult to renew electric motor, transformer, and cables except for lighting facility for energy conservation, because these equipment contribute too little to operating efficiency and are too expensive to increase efficiency.

- Main target is motor-powered equipment for energy conservation.

Energy conservation may be expected by avoiding wastefulness and improving efficiency of motor-powered equipment (pump, fan, blower, air-compressor, chiller, etc) because these equipment represent a large portion of energy consumption.
Example of energy flow and electric power consumption

Electric power receiving/distributing equipment (transformers, cables, etc.)

< 95-97%

Electric motors, inverters, etc.

< 70-95%

Pumps, fans, etc.

Valves, dampers, etc.

Piping, ducts, etc.

Excessive supply (flow rate, pressure)

(Depending upon the way to use)

Contents inside parentheses □ are examples of efficiency (depending upon facilities)

Contents inside parentheses ( ) are examples of electric power that can be used at the end of each equipment unit when it has received the power of 100 at the power receiving point.

Power receiving point (100)

Substitute transformer

Power receiving transformer

Electric motor

Load

(95-97)

(66-82)

Load

(39-70)

(7-70)

(Decreasing further due to piping pressure loss or others)

(If excessive supply occurs, it decreases further)

Load

Nozzle

Nozzle

Nozzle

Excessive supply (flow rate, pressure)

(Depending upon the way to use)
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**3. Methods of power-saving of major electric facilities**

**3.1 Pumps, Fans, and Blowers**

<table>
<thead>
<tr>
<th>Viewpoint of power-saving</th>
<th>Examples regarding methods of power-saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Reduction of flow rate</td>
<td>Anti-leak measure of air and water, prevention of excessive use, etc</td>
</tr>
<tr>
<td>b) Reduction of pressure</td>
<td>Reduction of operating pressure, Reduction of pressure loss (filter, etc)</td>
</tr>
</tbody>
</table>
| c) Reduction of excessive specification (reduction to reasonable level) | - To replace to small capacity or machine of less pressure loss  
- To change impeller, to cut down impeller diameter, and to decrease stages of rotor impeller  
- To change a rotating speed (pole change or pulley, inverter) |
| d) Addition of variable flow control and multi-unit control | - Addition of multi-unit control system  
- Selection of big and/or small machines  
- Addition of variable flow control (pole change, pulley, fluid coupling, vane control, inverter) |
| e) Replace to high efficiency machine | - To replace to high efficiency machine |
| f) Pause at a resting time in intermittent load | - To replace to motor of high frequency start type  
- Addition of soft starter with inverter  
- Addition of fluid coupling |
Example of Power-saving by Speed Control (1)

- Resistance curve at flow (Qb) with valve control
- Pipeline resistance curve
- Q-H curve at rated speed (N0)
- Q-H curve at a speed (Nn)

Qb/Qa = Nn/N0, Hb/Ha = (Nn/N0)^2, axis power: Lb/La = (Nn/N0)^3
Example of Power-saving by Speed Control (2)

System 1:

When the pressure of the feeding side is the same as that of the load side and pumps compensate piping pressure loss:

(1) If there is no valve restriction, pressure is $P_{1r}$ and flow rate is $Q_{1r}$ at a rotation speed of 100%.

(2) If an additional valve restriction bears a flow rate of $Q_a$, the pump discharge pressure becomes $P_a$. Therefore, valve restriction performed until pressure becomes $P_1$ leads to a flow rate of $Q_a$.

(3) If a further rotation speed change leads to a pressure of $P_1$ and a flow rate of $Q_a$, valve restriction will result in greater energy saving.

(4) The figures below show the property of the necessary motive power at that time.

System 2:

When the pressure of the load side is higher by $P_{20}$ than that of the feeding side, pumps compensate this differential pressure and piping pressure loss.

(1) The principle of reducing the necessary motive power is the same as in item (1) of System 1.

(2) Higher pressure of the load side results in smaller energy saving effect by controlling the rotation speed.
**Pump efficiency and Selection of pump capacity**

Figure (a) shows the curves of specific flow rate to pump efficiency for pump A (efficiency: 85%) and pump B (efficiency: 80%).

(1) With respect to the ratio of efficiency at each flow rate, pump A improves by 5% more than pump B.

Figure (b) shows the curves of specific flow rate to pump efficiency for pumps with a capacity of 100, 80, and 50.

(1) Employ pumps with appropriate capacity

With respect to pump efficiency at a flow rate of 70%, pumps with a capacity of 80 improve by approx. 10% more than pumps with a capacity of 100.

(2) Quantity control of pumps

With respect to pump efficiency at a flow rate of 40%, pumps with a capacity of 50 improve by approx. 35% more than pumps with a capacity of 100. Controlling the quantity of pumps by installing several small capacity pumps in place of large capacity pumps results in energy savings.
### 3.2 Air Compressor

<table>
<thead>
<tr>
<th>Viewpoint of power-saving</th>
<th>Examples regarding methods of power-saving</th>
</tr>
</thead>
</table>
| a) Reduction of necessary air flow rate | - Measures against air leak  
- ON/OFF control and intermittent operation  
- Making nozzles smaller and changing to energy-saving nozzles  
- Employing constant pressure discharge blowers, etc |
| b) Reduction of pressure loss | - Employing filters with small pressure loss  
- Making tube diameters larger  
- Decreasing discharge air pressure, etc |
| C) Correction of specification on pressure requiring excessive to a more appropriate value | - Making air compressors smaller incapacity and lower in pressure  
- Adjusting the opening of inlet side vanes |
| d) Selection of the number of running air compressors or introduction of variable discharge flow-rate control according to the fluctuating load | - Adjusting the number of parallel running air compressor, etc  
- Selecting small-capacity air compressor and controlling their actual operation  
- Adjusting the discharge air flow and pressure to appropriate values by controlling the capacity of air compressor  
- Integrating air compressors  
- Correcting the capacity of receiver tanks to a appropriate value |
| e) Enhancement of the function high efficiency air compressor | - Changing to high efficiency air compressor  
- Lowering the temperature inlet side air |
| f) Reduction of operating time of air compressor | - Shutting down air compressor when operation is unnecessary  
- Providing air compressor with automatic start/stop functions |
(Examples)
Comparison of electricity consumption of the compressor at variable capacity system

![Graph showing comparison of electricity consumption]
## 3.3 Lighting apparatus

<table>
<thead>
<tr>
<th>Viewpoint of Power-saving</th>
<th>Examples regarding methods of power-saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice of high efficiency light sources</td>
<td>Choice of high efficiency lamp such as sodium lamp, Choice of Hf fluorescent lamp utilizing inverter, Choice of low loss type stabilizer</td>
</tr>
<tr>
<td>Reduction of illumination</td>
<td>Adequacy of lighting standards in workshop, Reduction of whole illumination and use of part illumination, Dimming of lighting through proper lighting control</td>
</tr>
<tr>
<td>Reduction of illumination object</td>
<td>Review and reduction of place needing illumination</td>
</tr>
<tr>
<td>Choice of high efficiency lamps</td>
<td>Choice of high efficiency lamp, floodlight beams</td>
</tr>
<tr>
<td>Improvement of illumination rate</td>
<td>Consideration such as reflection efficiency to lighted location</td>
</tr>
<tr>
<td>Improvement of maintenance rate</td>
<td>Periodical cleaning of lamp, Appropriate exchange of lamps</td>
</tr>
<tr>
<td>Reduction of lighting time</td>
<td>Close lights out, Extinguishing of lighting through proper lighting control</td>
</tr>
</tbody>
</table>
## Energy Consumption of Lighting Apparatus

The energy consumption of lighting apparatus can be calculated using the following formula:

\[
N = \frac{E \times A}{U \times M}
\]

where:
- \(N\): Number of lighting apparatus installed
- \(E\): Average luminance on working place [LX]
- \(A\): Luminous flux per lighting apparatus [lm]
- \(U\): Utilization factor
- \(M\): Maintenance factor

### Power Consumption

- **Power consumption [kWh]**
- **Power consumption per apparatus [kW]**
- **Lighting time [h]**
- **Number of apparatus \(N\) [set]**

### Energy Consumption Standards in Workshop in Japan

- **JIS Z9110**

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*Note: Additional details or context may be necessary for a complete understanding.*
Replace with more efficient light

40w 2 tubes with C &C stabilizer

36w 2 tubes with C &C stabilizer

32w 2 tubes with Inv. stabilizer

Light flux

Original

Fix a reflection plate

Replace Hf tube

Reflection plate
3.5 Electric Power Distribution System

Viewpoint of power-saving

Selection of high efficiency transformer

Examples regarding methods of power-saving

Addition of condenser for improvement of power factor

Selection of high power factor apparatus

Improvement of power factor

apparatus with pause at a resting time

Integration and halt of light-load transformers

Pause of fans for transformers when transformers are loaded lightly and/or not heated

Consider when facilities will be replaced or equipment will be newly installed
1. Promotion of Energy Conservation Activity

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3. Methods of power-saving of major electric facilities

4. Power-saving Examples of existing facilities in Japan
4. Power-saving Examples of existing facilities in Japan

4.1 Example-1: Power-Saving regarding Pump

<table>
<thead>
<tr>
<th>Title</th>
<th>Power-saving by rotation speed control of Descaling Pumps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Jetting work by descaling nozzles is intermittent and short period is required for the rolling materials surface scale removal. On this account, the rotation speed of the pump at the time of no jetting could be lowered for power-saving.</td>
</tr>
</tbody>
</table>

**Plan Summary**

**a) Figure of facilities summary**

- **Main Pipe for Water**
  - Descaling Pump
  - Motor
  - VVVF device
  - Control Device for Rolling Mill

- **Angled**: Descaling Nozzle for the top surface, side, and back side

**b) Facilities remodeling items**

1. Introduction of a VVVF Device
   - 2400kVA
2. Exchange of a Pump Rotor
   - For mechanical strength improvement
3. Addition of a Accumulator Interception Valve
   - For low pressure measure
4. Exchange of Bypass Orifices
   - For low pressure measure
5. Remodeling of a Control Device
   - Addition of an automatic picking up pump speed and slowing down sequence
Object Facilities
Ironworks Rolling Mill

Power-saving Logic
Summary

a) Speed pattern of the pump

- [Remarks]: ----- : Before measures  ---- : After measures
  ① Power-saving range  ② Power increase range

b) Power-saving logic

① Power-saving by lowering the speed of pump at the time of no jetting.
- Speed of the pump: 100% (Top speed) → 40% (Low speed)
- Power-saving: \( P_1[kW] - kW1 \rightarrow kW0 \)

  Furthermore, power-saving by a fine adjustment of the pump turns at the time of jetting work.
  - Nozzles non-jet time/jet time: \( T_1 \) (Low Speed) / \( T_2 \) (Top Speed) [h/Y]

② The incremental power consumption due to efficiency of VVVF device.
- Power increase: \( P_2[kW] - kW1 \rightarrow kW2 \)

☆ The power-saving volume: \( \Delta kWh = P_1 \times T_1 - P_2 \times T_2 \) [kWh/Y]
4.2 Example-2 : Power-Saving regarding Brower

Title: Power-saving by rotation speed control of Heating Furnace Combustion Blowers

Purpose: We introduced a set of VVVF device for load adjustment of heating furnace combustion blowers from suction dampers and planned power-saving. In addition, only one set of VVVF device was introduced for two blowers and manages it.

Plan Summary

a) Figure of facilities summary

b) Facilities remodeling items

1. Introduction of a VVVF device
   350kW/VA
2. Exchange of Gear Couplings
   For mechanical strength improvement
3. Remodeling of a Control Device
   Addition of automatic change-over of the VVVF setting function
a) Flow Quantity—Pressure Curve (Q—H curve) of blowers
A conception diagram when a variable speed runs for one of them at the time of two blower driving,

\[ H_0 \]

required Q—H \( (Q_0, H_0) \)
commercial frequency driving
VVVF driving at rotation speed \( N_1 \)

\[ Q_0 = Q_1 + Q_2 \]
\[ N_1 = N_1^* \times \left( \frac{Q_1}{Q_1^*} \right) \]  \( \star \) Flow Quantity \( Q_1^* \) at rotation speed \( N_1^* \)

b) Power-saving logic

<table>
<thead>
<tr>
<th>Driving Cases</th>
<th>Proportion ([h/Y])</th>
<th>Quantity of Power-saving ([kW])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two Blower driving</td>
<td>( T_1 )</td>
<td>( P_1 )</td>
</tr>
<tr>
<td>One Blower driving</td>
<td>( T_2 )</td>
<td>( P_2 )</td>
</tr>
<tr>
<td>Maintenance Furnace Temperature</td>
<td>( T_3 )</td>
<td>( P_3 )</td>
</tr>
</tbody>
</table>

\( \star \) The quantity of power-saving : \( \Delta \text{kWh} = P_1 \times T_1 + P_2 \times T_2 + P_3 \times T_3 \) [kWh/Y]
4.3 Example-3: Power-Saving regarding Aircompressor

<table>
<thead>
<tr>
<th>Subject name</th>
<th>Electric power saving by changing the pressure specification of air compressors and modifying them</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Compressed air facilities have been operated according to the designed specifications of a discharge pressure of 0.78 MPa (8kg/cm²) since they were started, and in recent years, are operated at a lower discharge pressure of 6.4 MPa (6.5 kg/cm²) after the pressure necessary for terminal equipment was reviewed. Therefore, because the efficiency of air compressors was caused to become lower, their modification has been performed according to the actual load, thereby leading to the achievement of electric power saving thanks to higher efficiency.</td>
</tr>
</tbody>
</table>

**Overview of plan**

**a) Comparison of the specifications of each facility**

<table>
<thead>
<tr>
<th></th>
<th>Initial specification</th>
<th>Before measures</th>
<th>After measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge air pressure [MPa]</td>
<td>0.78</td>
<td>0.64</td>
<td>0.64</td>
</tr>
<tr>
<td>Capacity Q₀ [Nm³/h]</td>
<td>33,000</td>
<td>33,000</td>
<td>33,000</td>
</tr>
<tr>
<td>Axial motive power [kW]</td>
<td>P₀</td>
<td>P₁</td>
<td>P₂</td>
</tr>
<tr>
<td>Isothermal efficiency [%]</td>
<td>η₀</td>
<td>η₁</td>
<td>η₂</td>
</tr>
<tr>
<td>Electric power energy intensity [kW/Nm³]</td>
<td>P₀/Q₀</td>
<td>P₁/Q₀</td>
<td>P₂/Q₀</td>
</tr>
<tr>
<td>Number of air compressors</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

Differences between the properties: \( P₁ > P₀ > P₂ \)  \( (η₁ < η₀ < η₂) \)

**b) Facility modifications**

①: A set of modifications of the existing air compressors (by manufacturers)
- Modifying and replacing diffusers with vanes, impellers, and scrolls

**ECCJ**
### a) Property of axial motive power

<table>
<thead>
<tr>
<th>Axial motive power</th>
<th>Flow rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Sigma P_1'$</td>
<td>$Q_{12}$</td>
</tr>
<tr>
<td>$\Sigma P_2'$</td>
<td>$[\text{Nm}^3/\text{h}]$</td>
</tr>
</tbody>
</table>

### b) Electric power saving logic

1. Electric power saving by the higher efficiency of air compressors
   - Before measures: $P_1'(at\ Q_0)$ → After measures: $P_2'(at\ Q_0)$

Amount of electric power saving: $\Delta kW\text{h} = (P_1'/Q_0 - P_2'/Q_0) \times Q_{12} \times T$  

(Explanatory note)

$T$: Hours of operation ($24\ [\text{h/D}] \times 365\ [\text{D/Y}] = 8760\ [\text{h/Y}]$)
4.4 Example-4 : Power-Saving regarding Lighting Equipment

<table>
<thead>
<tr>
<th>Subject name</th>
<th>Electric power saving by changing factory ceiling lighting from the existing lamps to sodium ones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>For a long time, all ceiling-mounted lighting in factories consisted of mercury vapor lamps, and electric power saving was attained by changing them to sodium lights.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overview of plan</th>
<th>a) Target lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mercury vapor lamps 1000W</td>
</tr>
<tr>
<td></td>
<td>N1</td>
</tr>
</tbody>
</table>

★ The lighting not targeted this time is:
(a) Lamps always blacked out by thinning out illumination or otherwise
(b) Lamps lit only during inspections
(c) Lamps that have problems from the standpoint of their color rendering properties during work, even among sodium lamps with high color rendering properties (product inspection site, etc.)
(d) Mercury vapor lamps left on in mixed-illumination ceilings equipped with both mercury vapor lamps and sodium lamps
(e) Outdoor lamps (lighting-up hours: hours for indoor lamp × approx. 1/2): thereafter, a better plan will be established after consideration of the energy saving effect.

<table>
<thead>
<tr>
<th>b) Facility modifications</th>
</tr>
</thead>
</table>
| (1) Changing from mercury vapor lamps to sodium lamps and ballast chokes from HRF1000 to NHR660

★ : Price difference between the lamps (one example): Sodium-lamps/mercury-vapor-lamps = approx. 2.6

(2) A set of the exchanged lamps and ballast chokes
### Comparison of properties between the lamps

<table>
<thead>
<tr>
<th>Kinds of lamp</th>
<th>Before measures</th>
<th>After measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury vapor lamp</td>
<td>HRF1000</td>
<td>NHR660</td>
</tr>
<tr>
<td>Sodium lamp</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lamp model</th>
<th>1000</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal electric power [W]</td>
<td>59500</td>
<td>69000</td>
</tr>
<tr>
<td>Light flux [lm]</td>
<td>12000</td>
<td>12000</td>
</tr>
<tr>
<td>Average life [h]</td>
<td>1030</td>
<td>700</td>
</tr>
<tr>
<td>Electric power rate</td>
<td>100</td>
<td>68</td>
</tr>
</tbody>
</table>

### Energy saving logic

1. Electric power saving by changing from mercury vapor lamps to sodium ones:
   - Input electric power of lamps [kW]: Change from L1 (mercury vapor lamps) to L2 (sodium lamps)
   - Electric power saving amount: $P [kW] = (L1 - L2) \cdot \Sigma N$

\[ \Delta k\text{Wh} = (L1 - L2) \cdot \Sigma N \cdot T \text{ [kWh/Y]} \]

(Explanatory note)

$\Sigma N$: Number of lamps replaced [tubes]

$T$: Operational hours of lamps (example: 16-24 [h/D]) x 365 [D/Y] = 5840 - 8760 [h/Y]