Winter Seminar
on Human Security Development and Energy Science

History of Keage Hydroelectric Power Plant — TANABE Sakuro & Lake Biwa Canal —

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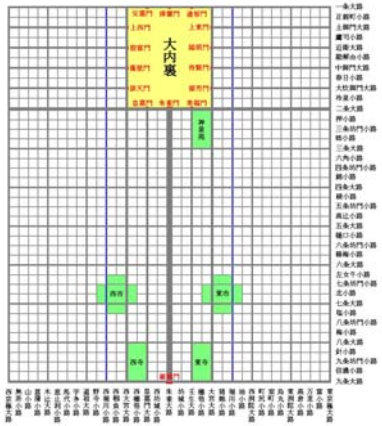
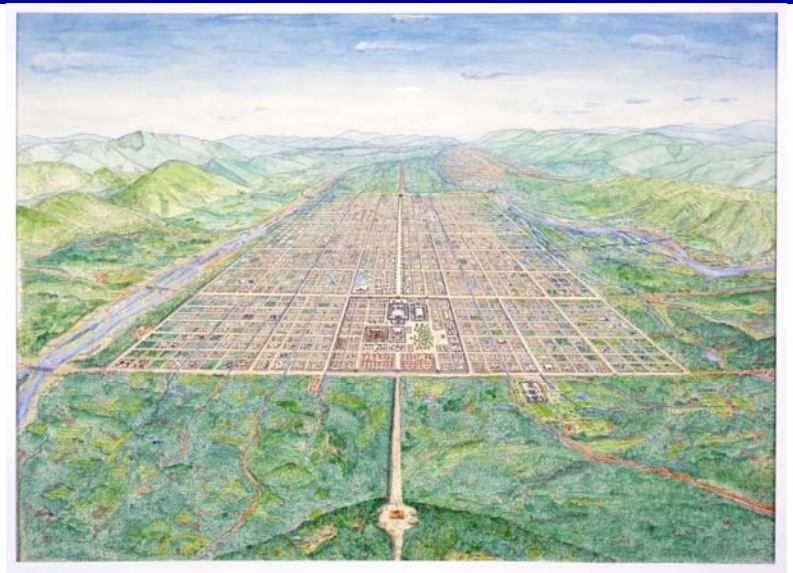
1. Kyoto — Ancient Capital and Transfer to Tokyo

平安京 Heian-kyo (Heian era: 794-1192)

The city was modelled after the Tang Dynasty Chinese capital of Chang'an長安 (modern-day Xi'an 西安).



Heian-kyo (View from the North)



Courtesy of KAJIKAWA Toshio, Kyoto City Archeological Res. Inst.

京都 Kyoto: Japanese Capital for 794-1868

in 794:

from Heijo-kyo（平城京）to Heian-kyo（平安京）
from the Nara（奈良）era to the Heian（平安）era
Heian Shrine: in 1895 (+1100)
Kyoto Station: in 1997 (+1200)

http://find-travel.jp/article/679

“京”: big or high hill
→ many people → capital

“都”: capital

in 1868: Transfer of the Capital
from Kyoto（京都）to Tokyo（東京=江戸）
from the Edo（江戸）era to the Meiji（明治）era
population decrease: 350,000 → 200,000

2. Lake Biwa Canal

NDL: Kyoto Incline and Lake Biwa Canal (1)
What is the Incline?

←picture in (1)

picture in (2)→

See the picture of the Incline published in “Kyoto Meishocho” (1907). It was taken at Keage (Higashiyama-ku, Kyoto), located at the east end of the Kyoto Basin.
(omit)
The “Incline” is also called as the “inclined railway,” comprising the rail, machine and related facilities installed to convey cargo on a sloping surface of canals, mountainside and others. The Kyoto Incline was also a railroad to tow boats using a hydraulic power generation system. As one looks at the center of the photo, the rail and a carrier on the rail can be seen. The carrier becomes a bedplate to carry boats.
http://ndl.go.jp/scenery/kansai/e/column/kyoto_incline_and_lake_biwa_canal.html

NDL: Kyoto Incline and Lake Biwa Canal (2)
The Incline and Lake Biwa Canal

Why was a railroad required to carry boats? The Incline was made as a part of the canal construction (1885-1890) to pull water from Lake Biwa into Kyoto. The overall length of the Incline is 587 meters.

Before the Canal construction, people and horses were only means of transportation between Kyoto and Otsu, so it was difficult to transport massive loads. Therefore, people were looking forward to the construction of the Lake Biwa Canal that would open a waterway to transport goods by boat, which was intended to contribute the development of Kyoto, after the capital was relocated to Tokyo.

The Canal project was not just a enormous project to connect the distance of 20 kilometers from Lake Biwa to downtown Kyoto through many mountains, but it was also a comprehensive development project to improve waterway transportation in addition to acquire water for the city, irrigation, power generation and other uses.

The Canal starts from Otsu where Lake Biwa is located, goes through many tunnels including ones dug under Nagarayama, running along the foot of mountains, and arriving in Keage. From Keage, boats go down a steep of 35 meters using the Incline, to enter Kyoto's city-center through the Kamo River. Boats can not go down a steep slope alone, so the construction of a railway (Incline) was required to carry the boats on the steep.

http://ndl.go.jp/scenery/kansai/e/column/kyoto_incline_and_lake_biwa_canal.html

NDL: Kyoto Incline and Lake Biwa Canal (3)
Kunimichi Kitagaki, Governor of Kyoto Prefecture, and a Civil Engineer Sakuro Tanabe

Although the idea of constructing the Canal was around since the Edo period, it was Kunimichi Kitagaki (1836-1916), the third Governor of Kyoto Prefecture, who promoted the construction in spite of the amazing cost of 1,250,000 yen (it was an extraordinary price for that time).

The Governor Kitagaki found a civil engineer Sakuro Tanabe (1861-1944) and appointed him as the project's chief engineer. He was appointed a Kyoto government official in 1883, at the young age of 21. He was such a young genius that the prototype of the concept for the Canal had already been done as his graduation thesis at Kobu Daigakko (The Imperial College of Engineering) “Biwako Sosui Koji no Keikaku (A Plan for Lake Biwa Canal Construction).”

In 1888 when hydraulic power was successfully generated at Aspen in the United States for the first time in the world, Tanabe immediately visited the site. Tanabe contributed a great deal towards the decision to construct a hydroelectric plant during the Lake Biwa Canal construction. As a result, the Japan's first hydroelectric plant started its operation here in Keage.

http://ndl.go.jp/scenery/kansai/e/column/kyoto_incline_and_lake_biwa_canal.html

Governors of Kyoto Prefecture

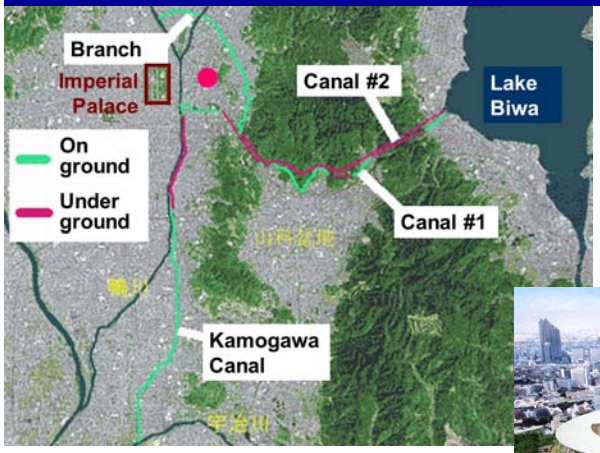
1st: 1868-1875
長谷 信篤 NAGATANI Nobuatsu (1818-1902)
2nd: 1875-1881
槙村 正直 MAKIMURA Masanao（1834-1896)
3rd: 1881-1892
北垣 国道 KITAGAKI Kunimichi (1836-1916)

田辺 朔郎 TANABE Sakuro (1861～1944)

1877
Entered the Imperial College of Engineering, Kobu Daigakko (Predecessor of U. of Tokyo)
1882
Bachelor thesis: *A Plan for Lake Biwa Canal Construction*
1883
Graduation from the Imperial College of Engineering
1885
Began the construction of *Lake Biwa Canal*
1890
Completed the construction of *Lake Biwa Canal*
1900
Professor, College of Science and Engineering Kyoto Imperial University (Predecessor of Kyoto U.)
1916
President, College of Engineering, Kyoto Imperial University

http://wattandedison.com/biwako_tanabe.pdf (in Japanese)

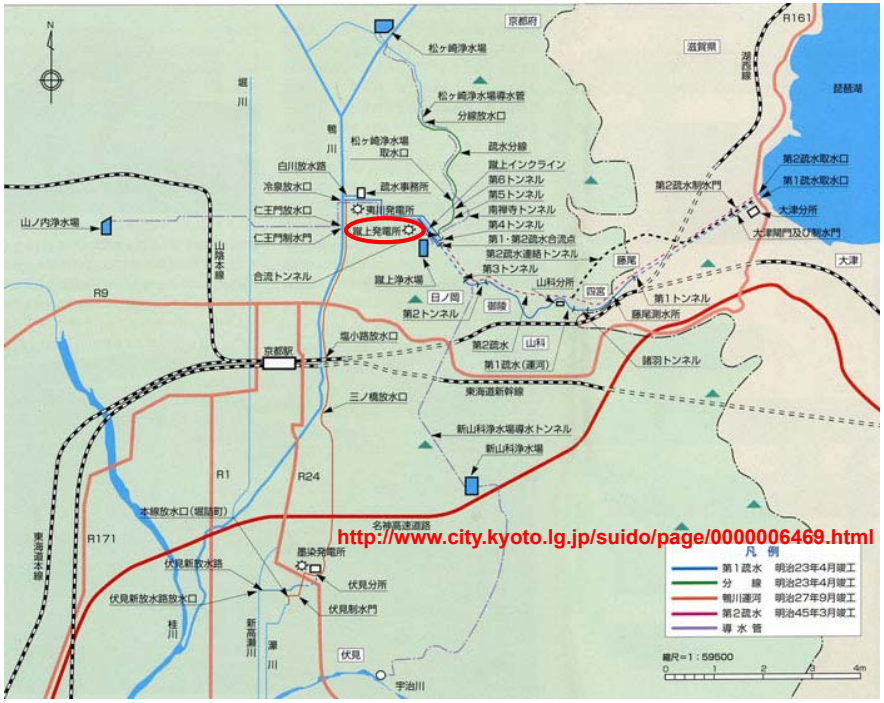
Huge Project



http://agua.jpn.org/biwacanal/route.html

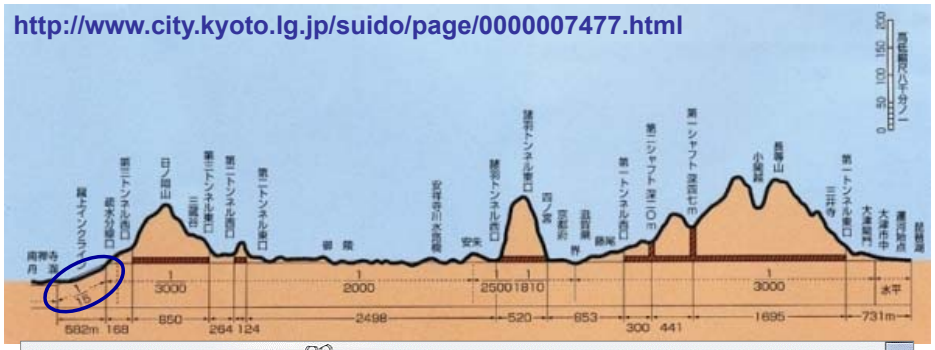
Project with ¥ 1,250,000 at that time
(now equivalent to more than ¥ 1000 billion)

¥ 150 billion



http://www.city.kyoto.lg.jp/suido/page/0000006469.html

http://www.city.kyoto.lg.jp/suido/page/0000007477.html



http://www.city.kyoto.lg.jp/suido/page/0000007764.html

Hydroelectric Power Generation

A waterway bridge of
南禅寺 Nanzen-ji

Pelton water wheel

American Stanley
AC generator

蹴上 Keage Hydroelectro
power generation station
4500 kW, 1897
(Electricity was first supplied in 1891)

http://www.kepco.co.jp/energy_supply/energy/newenergy/water/plant/ (in Japanese)

The First Train in Japan (Heian Shrine & Meiji-Mura)

Kyoto is the place where the first train in Japan was opened to traffic in January 1895. This train runs on electric energy coming from hydroelectricity in the Lake Biwa canal. The purpose of this train was sending off customers of The Fourth National Industrial Exhibition held in that year. This Kyoto electric railway was merged by Kyoto city in 1918, and the name was changed as Kyoto city Line. But the last line of Kyoto city line stopped in 1978.

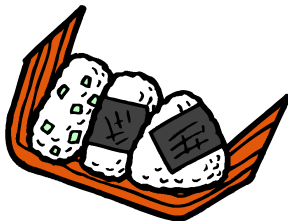
http://www.kyoto-okazaki.jp/spot/spsetrn
http://www.meijimura.com/enjoy/sight/building/3-24.html (in Japanese)

Meiji (1968-1912) was a period in which Japan opened her doors to the outside world and laid the foundation for Modern Japan by absorbing and assimilating Western culture and technology.

3. Light & Electricity

Green-Tea Break: 1st Law of Thermodynamics

Onigiri: 160kcal
How high is the potential energy for a person who is 50kg in weight?



$$[\mathrm{J}] = [\mathrm{N}\cdot\mathrm{m}] = \left[\frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}\cdot\mathrm{m}\right] = \left[\frac{\mathrm{kg}\cdot\mathrm{m}^2}{\mathrm{s}^2}\right]$$

$$mgh = 160[\mathrm{kcal}] = 160\times 4.2[\mathrm{kJ}] = 670[\mathrm{kJ}]$$

$$h = \frac{670\times 10^3[\mathrm{J}]}{50[\mathrm{kg}]\times 9.8[\mathrm{m/s^2}]} = 1370[\mathrm{m}]$$

- We can climb Mt. Fuji with 3 onigiri.
- If we fall from the height of 1370m, we clash on the ground with velocity of

$$v = \sqrt{2gh} = \sqrt{2\times 9.8[\mathrm{m/s^2}]\times 1370[\mathrm{m}]} = 164[\mathrm{m/s}] = 590[\mathrm{km/h}]$$

Light & Human Being

An old legend recorded in the fifth century BC by Herodotus, although probably apocryphal, captures the self-indulgence of the Old Kingdom. In the tale Pharaoh Menkaure-Khufu's grandson and the builder of the third Giza pyramid-receives an oracle that predicts he will live only six years longer. The pharaoh, says Herodotus, "had innumerable lamps made, by the light of which he set himself every evening to drink and be merry, and never ceased day or night from the pursuit of pleasure.... His object in this was by turning night into day to extend the six remaining years of his life to twelve, and so to convict the oracle of falsehood. "
http://cyberperv.narod.ru/pages/edu.htm

李白(Li Po, Li Bo, Li Bai; 701-762)
夫天地者，萬物之逆旅。光陰者，百代之過客。
而浮生若夢，為歡幾何？ 古人秉燭夜游，良有以也。
"春夜宴桃李園序: Prologue on a Spring Evening Spent with Cousins in a Peach Blossom Garden"
http://www.kyohaku.go.jp/eng/dictio/data/kaiga/tourin.htm

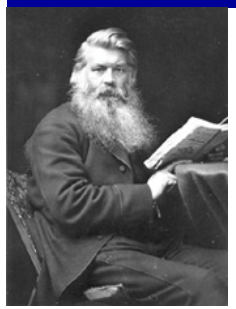
Lighting in Japan

Gas light,
Yokohama (1872)
Tokyo (1874)

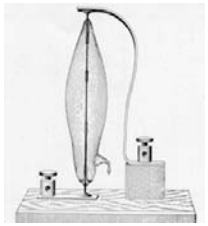
Ark light
Tokyo (1882)
(Electricity was supplied by a small generator.)

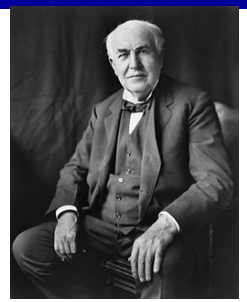
https://www.kandenkyo.jp/pdf/yukari_vol02.pdf (in Japanese)
https://www.ieij.or.jp/IP/akarinotayori/H17special/ginza.html (in Japanese)

Incandescent Electric Light by Swan & Edison (1880)



Joseph Wilson Swan (1828-1914, England)

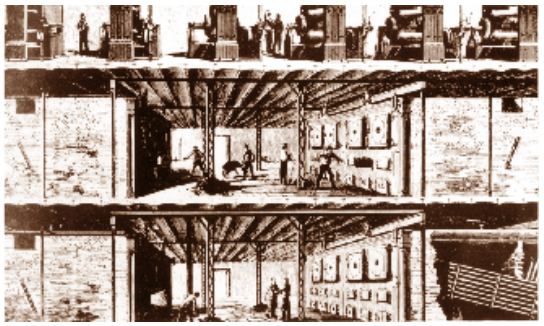




Thomas Alva Edison (1847-1931, America)

Thomas Alva Edison, the Bamboos of Yawata and the light for Humankind
It was in 1880 that the genius of Edison and excellent properties of the bamboo on the Otokoyama gods' Mountain in Yawata joined to make the electric light as a common property of humankind.
http://www.geocities.jp/general_sasaki/yawata-edison-eng.html
http://www.city.yawata.kyoto.jp/0000000459.html (in Japanese)

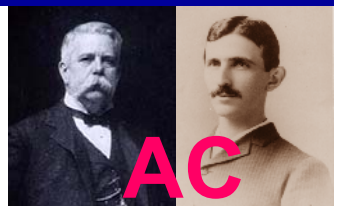
The First Centralized Power Plants & Lighting in NY Pearl Street (1882)



War of Current (General Electric vs Westinghouse)

Thomas Edison (1847-1931)
[Henry Ford (1863~1947)]

George Westinghouse (1846 - 1914
Nikola Tesla (1856-1943)



With the opening of the Pearl Street station in New York in September 1892, Thomas Edison ushered in the electric age. Ironically, however, the success of Edison's original lighting system in some ways proved its undoing—or rather, its forced modification. Though Edison himself emphasized scale and distribution in his system, the demand for electricity soon led to the desire to build ever-larger power plants and transmit that power over greater distances. Additionally, with the rapid distribution of industrial electric motors came a strong demand for voltages other than the 110 volts used for lighting. The Edison system, which used direct current (DC), was ill suited to meet these new demands. The problem of transmission was even more difficult, since the long distance transmission of bulk quantities of DC at 110 volts was very expensive. In 1886, George Westinghouse, a wealthy and respected inventor, but a newcomer in the electric power industry, founded Westinghouse Electric in order to compete with Edison. Westinghouse's system relied on the discoveries and patents of Nikola Tesla, a Serbian (from Croatia) immigrant who passionately believed in the superiority of alternating current (AC) power.
(omit) the use of AC equipment at the huge new Niagara Falls power facility in 1895 marked the rise of AC current. (IEEE)

Energy for Moving between Kyoto/Osaka & Tokyo

Means	Time	[MJ]
Walking (Meal: 2500kcal/day)	15days	160
Shinkansen (N700: full)*	2hour30min	200
Automobile (15km/L: 4persons)	6hour	290
Aircraft (Boeing777-200: full)	45min	580

* Power generation efficiency is assumed to be 50%

Thermal Engineering Laboratory: for all & from all

Thermal Engineering Laboratory

for all & from all

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