Assessing the impacts of shutdown of TEPCO's nuclear reactors on CO_2 emission in the Japan's electricity sector

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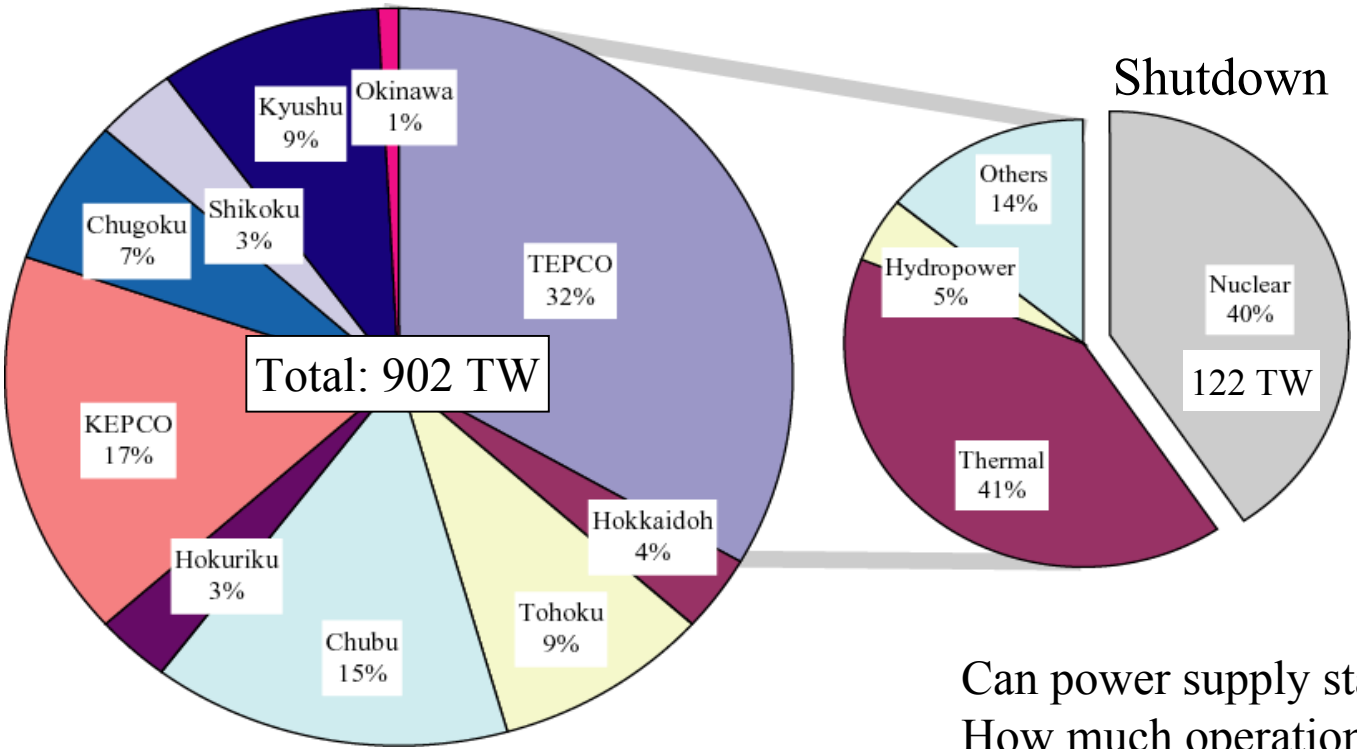
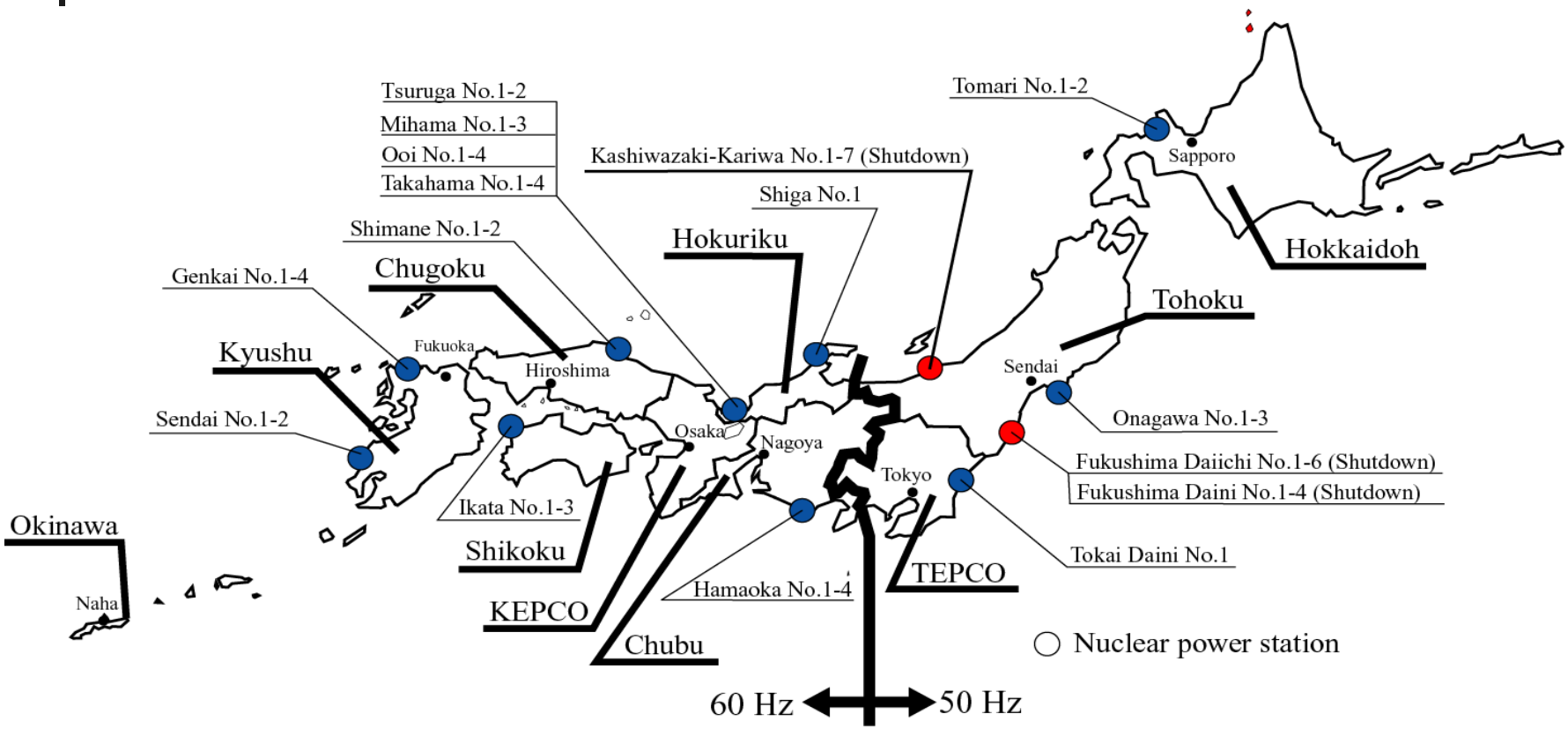
Background

Electricity generation in Japan



Can power supply stability be assured?
How much operation cost rise?
How much CO_2 emission increase?

Nuclear power stations in Japan



Number of nuclar power plants: 52
Total installed capacity of nuclear power plants: 45,617 MW

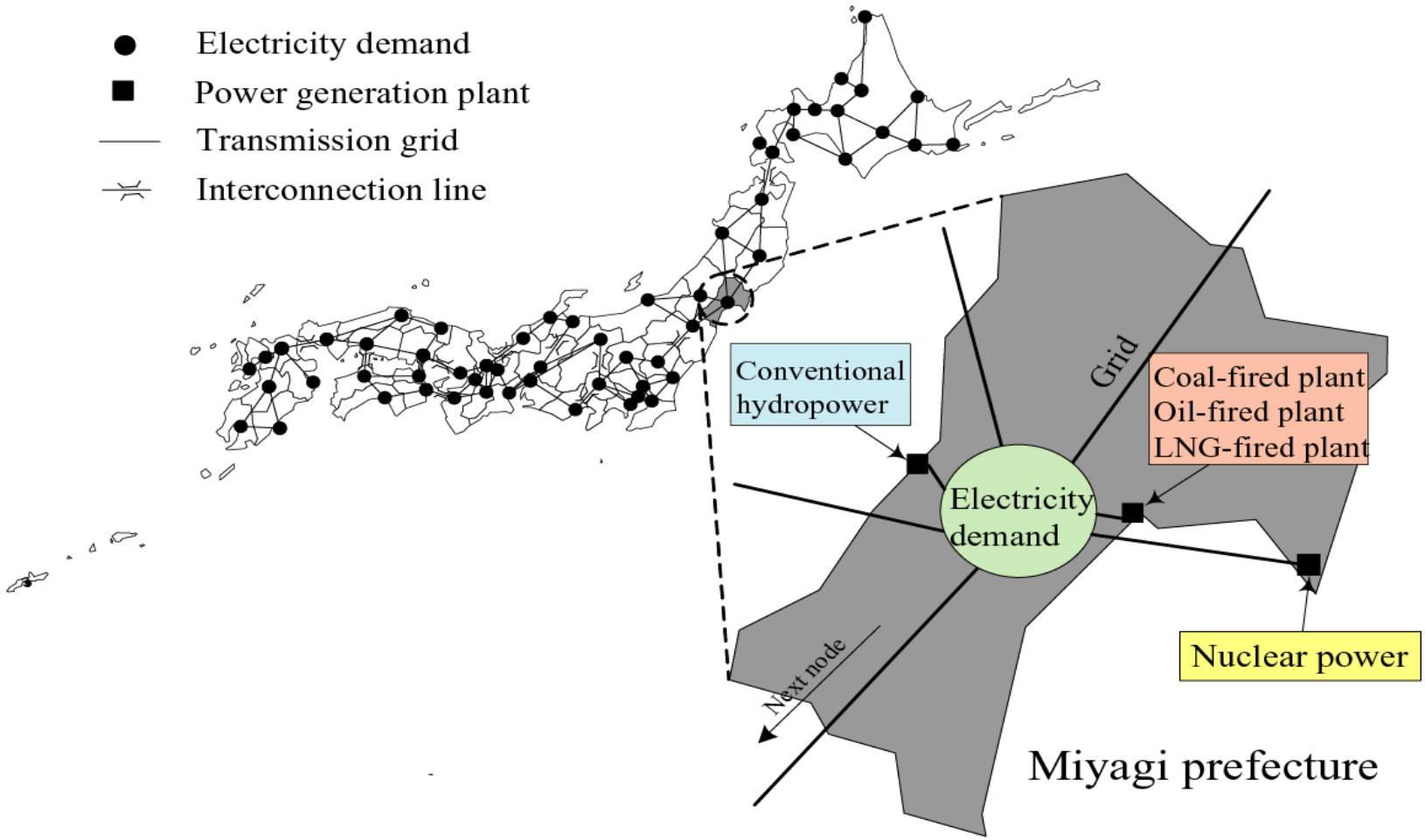
Purpose

- Analyze the impacts of shutdown of nuclear power plants at Tokyo Electric Power Company (TEPCO) on energy systems in Japan.
- Evaluate electricity supply security, operation cost and CO_2 emission.

Methodology of the analysis

- Consider the site of power plants and the distribution of regional electricity consumption.
- Separate Japan into sixty regions.
- Include transmission grids and its capacity limits.

Schematic structure of the Multi Node Model



Objective function

$$\min TC = \sum_{P,T,R} \left(V(P,T,R) \right)$$

TC:	Total Operation and maintenance cost.
P:	Pattern (1-7).
T:	Time (1-24).
R:	Region (1-60).
V:	Operation and maintenance cost

- Operation and maintenance (O&M) costs are considered according to amount of dispatches.

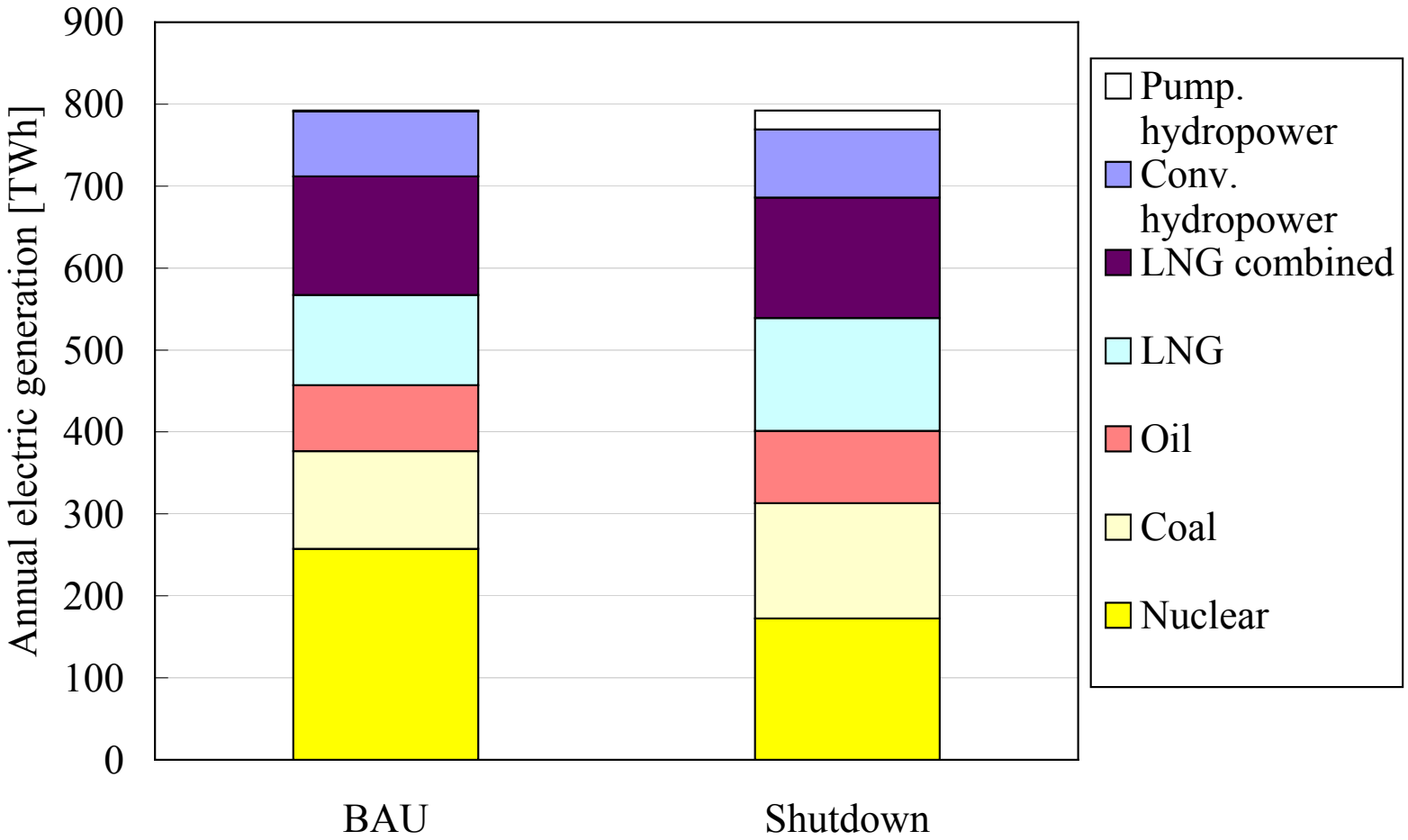
Demand patterns

	Demand pattern	Days in a year
A	Maximum demand days in Summer	3
B	Weekdays in Summer	98
C	Weekdays in Winter	95
D	Weekdays in Spring and Autumn	97
E	Holidays in Summer	21
F	Holidays in Winter	26
G	Holidays in Spring and Autumn	25

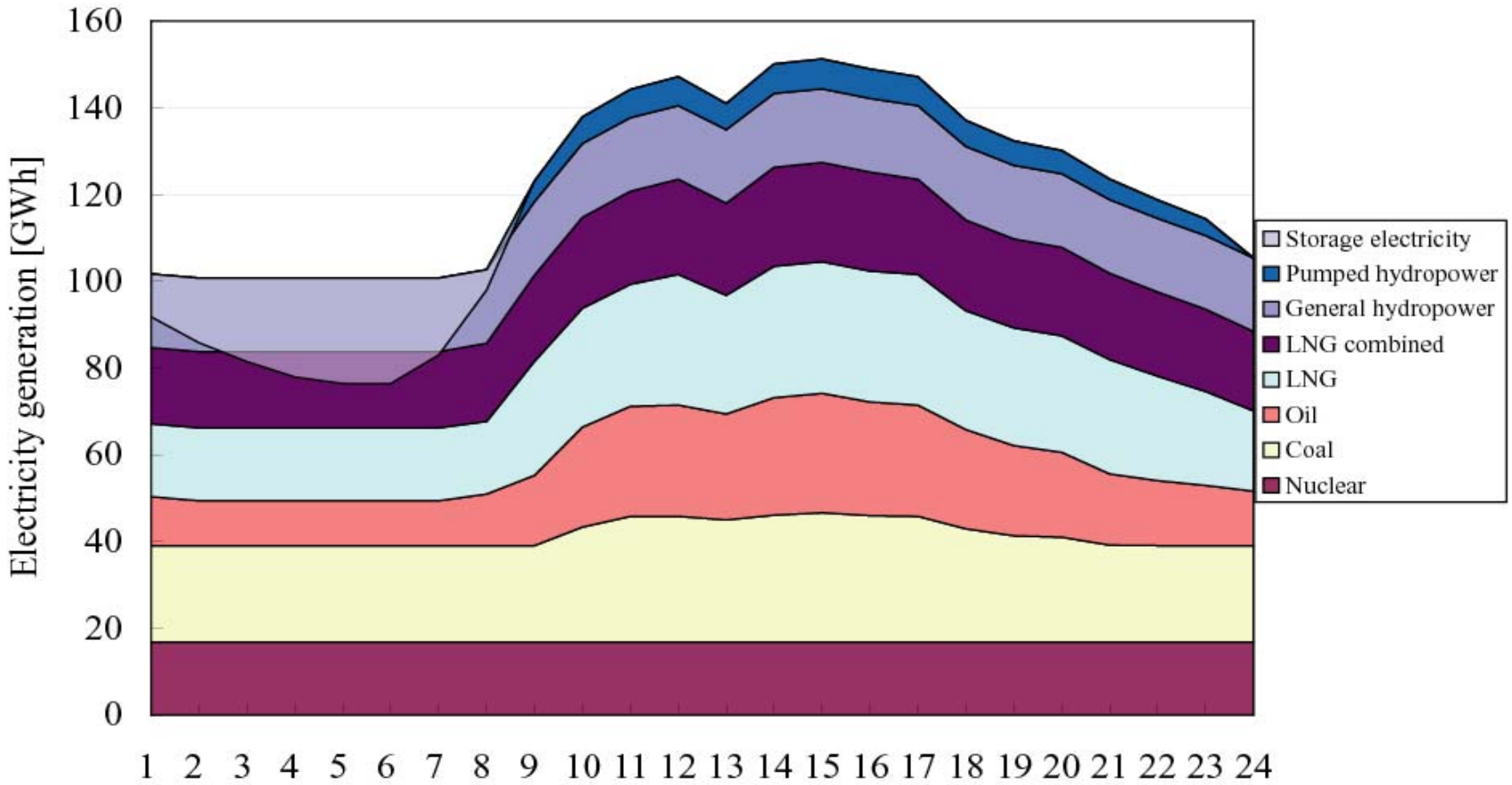
Analyzed scenarios

- Business as Usual scenario (BAU scenario)
  - All 17 nuclear power plants at TEPCO are in operation.
- Shutdown scenario
  - Shutdown of all nuclear power plants at TEPCO.

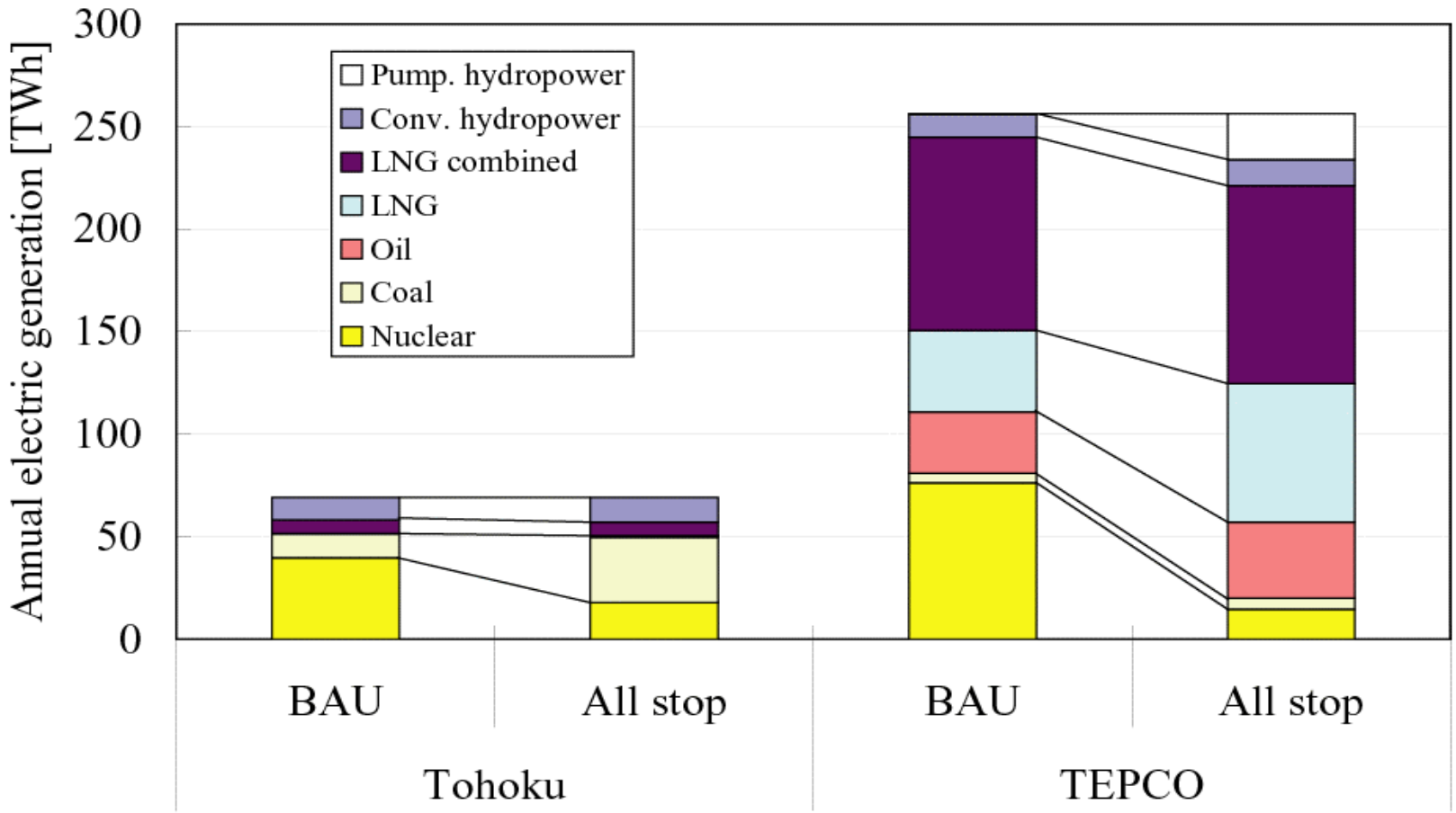
Result: Changes in electric generation in Japan



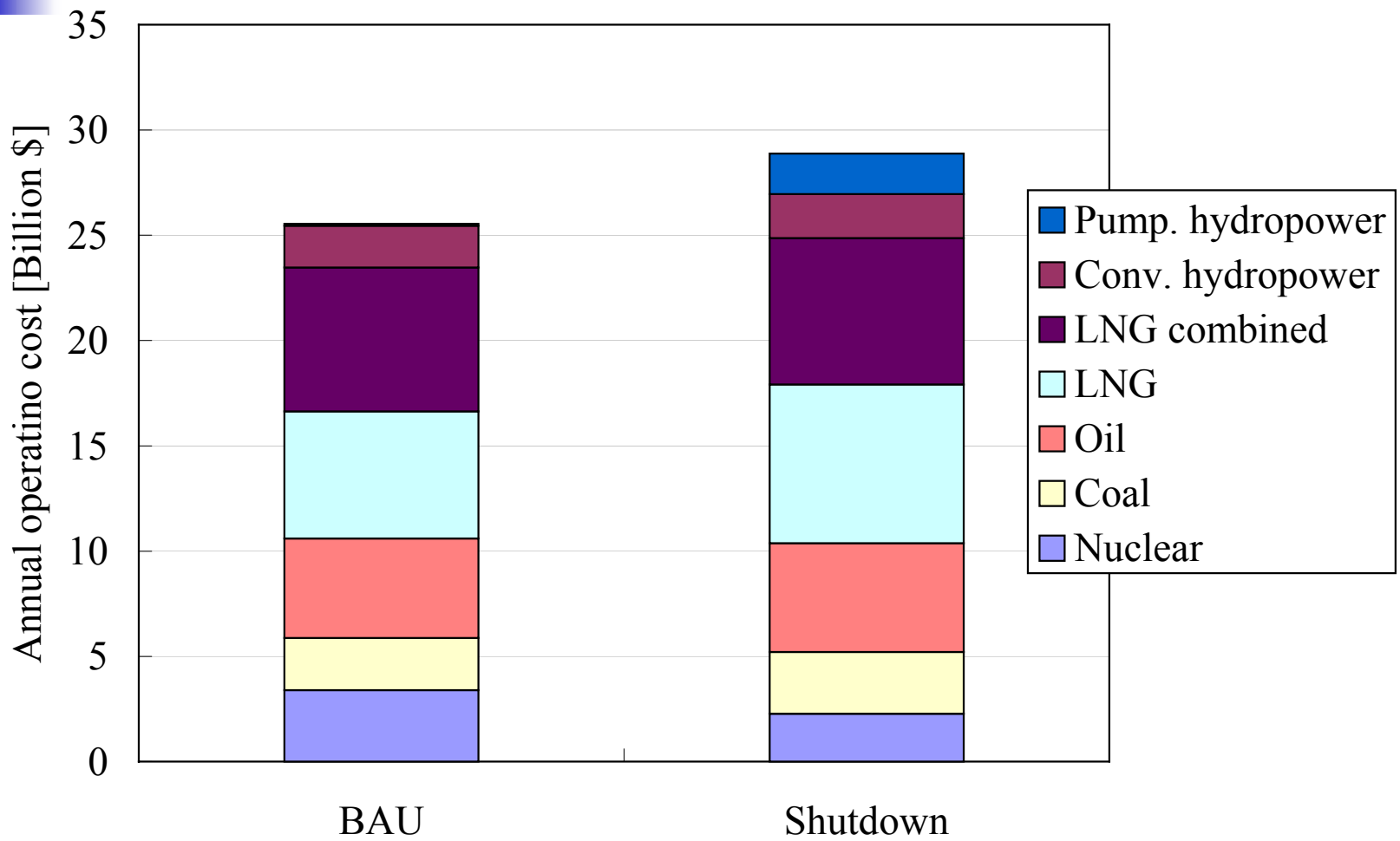
Result: Mixture of power sources at pattern A (Shutdown case)



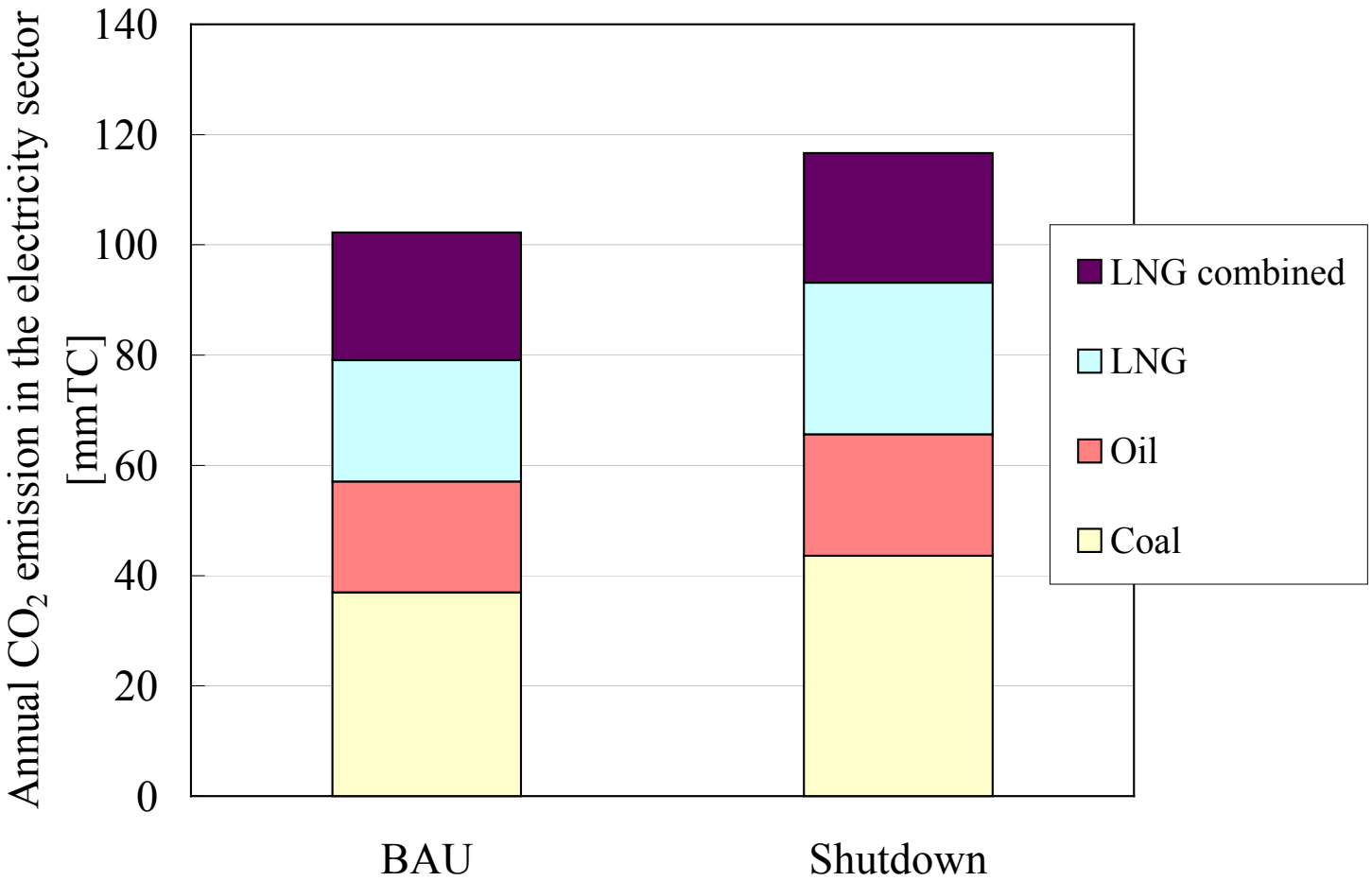
Result: Changes in electric generation in TEPCO and Tohoku



Result: Annual operation cost



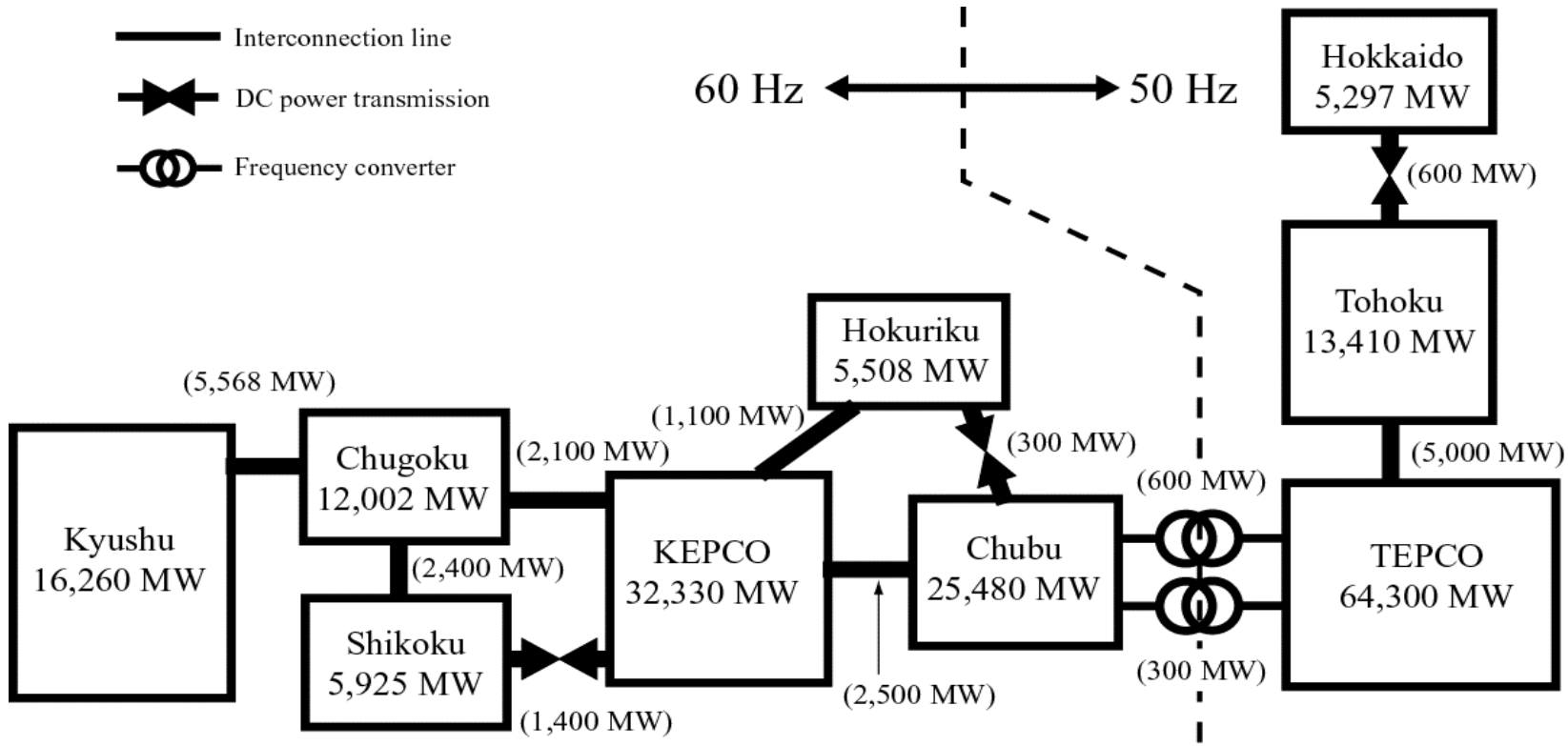
Result: Annual CO_2 emission in the electricity sector



Results

- The shutdown of nuclear power plants at TEPCO has following impacts:
  - Electricity supply stability is assurable.
  - Electricity generation of coal-fired boiler and LNG-fired boiler in both TEPCO and Tohoku (next to TEPCO) increases.
  - Annual operation cost rises 13 %.
  - CO_2 emission in Japan's electricity sector increases from 102 mmTC to 117 mmTC.

Interconnection capacities and peak loads in the year 2001



Capacity constraints of power plants

$$CAPLO(P,T,RP) \leq POW(P,T,RP) \leq CAPUP(P,T,RP)$$

P: Pattern (1-7).
T: Time (1-24).
RP: Region (1-60).
POW: Electricity generation.
CAPUP: Upper limit of generation.
CAPLO: Lower limit of generation.

Supply constraint of electricity

$$\sum_{R}\left(X(P,T,R)-S(P,T,R)\right)=\sum_{R}D(P,T,R)$$

R:	Region (1-60).
X:	Supply of electricity.
S:	Supply to the pumped hydropower plant.
D:	Electricity demand.

Constraints of load-following capability

$$POW(P,T,RP) \le FUP(RP) \times POW(P,T-1,RP)$$

$$POW(P,T,RP) \ge FLO(RP) \times POW(P,T-1,RP)$$

FUP: Upper limit of load-following capability.
FLO: Lower limit of load-following capability.

Constraint of transmission capacity

$$TRANS(P,T,R_1,R_2) \leq TRUP(R_1,R_2)$$

TRANS: Transmission power from region R_1 to R_2.

TRUP: Upper limit of Transmission capacity from region R_1 to R_2.

Nuclear power plants at TEPCO

- Total installed capacity of nuclear power reaches 17,308 MW.
  - The capacity corresponds to 38.8 percent of total installed capacity of nuclear power in Japan.
- All of this nuclear power plants has suspended operations at April 14, 2003.
- TEPCO has restarted 8 reactors, which capacity is 8,680 MW.

Assumptions of the analysis

- Power generation plants include:
  - Nuclear
  - Thermal power (coal-fired boiler, LNG-fired boiler, LNG combined cycle, oil-fired boiler)
  - Hydropower (conventional, pumped).
- Electricity transmission is supposed to lose 1% of its power per 100km.
- The capability margin of electricity supply is set at 8%.

Characteristics of power plants

	Capital cost[1] ($/kW)	Fixed O&M[1] (cents/kW-yr.)	Variable O&M[1] (cents/kWh)	Fuel cost[1] (cents/kWh)	Thermal efficiency[2] (H.H.V.) (%)
Nuclear power	2,950	2.84	0.042	1.26	32.10
Coal-fired	2,167	2.36	0.338	2.08	38.98
Oil-fired	1,667	1.37	0.010	5.83	37.04
LNG-fired	1,583	1.44	0.010	5.48	38.13
LNG combined	1,000	1.53	0.052	4.73	43.27
Hydropowered pumping	5,000	8.33	0.000	0.00	None
Conventional hydropower	2,500	2.50	0.000	0.00	None

[1]Federation of Electric Power Companies. (2003). Handbook of electric power industry, Japan Electric Association, Tokyo.
[2]Thermal and Nuclear Power Engineering Society. (2003). *The Thermal and Nuclear Power*, Thermal and Nuclear Power Engineering Society, Tokyo.

Result: CO_2 emission in TEPCO and Tohoku