**iiESI Asian Workshop, 12:15-12:45, November 17th, 2014**

# Current Situation and Integration Potential in Transport Area in Japan

Hitoshi HAYASHIYA
Takashi SUZUKI
Hitoshi NAKAJIMA

(East Japan Railway Company)

# Contents

1 Introduction

2 Electric Energy Utilization in Railway Transportation

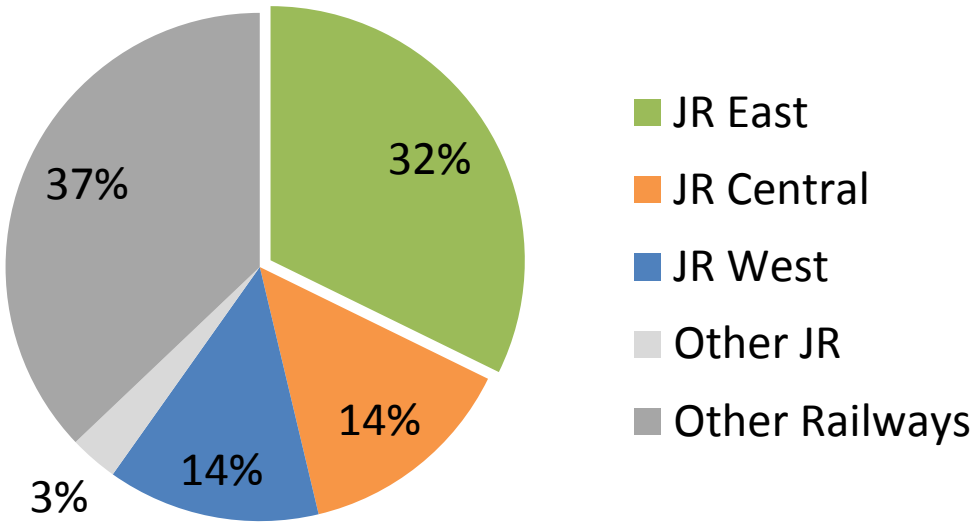
3 Utilization of Regenerative Energy

4 Examples of Other Projects

5 Conclusions

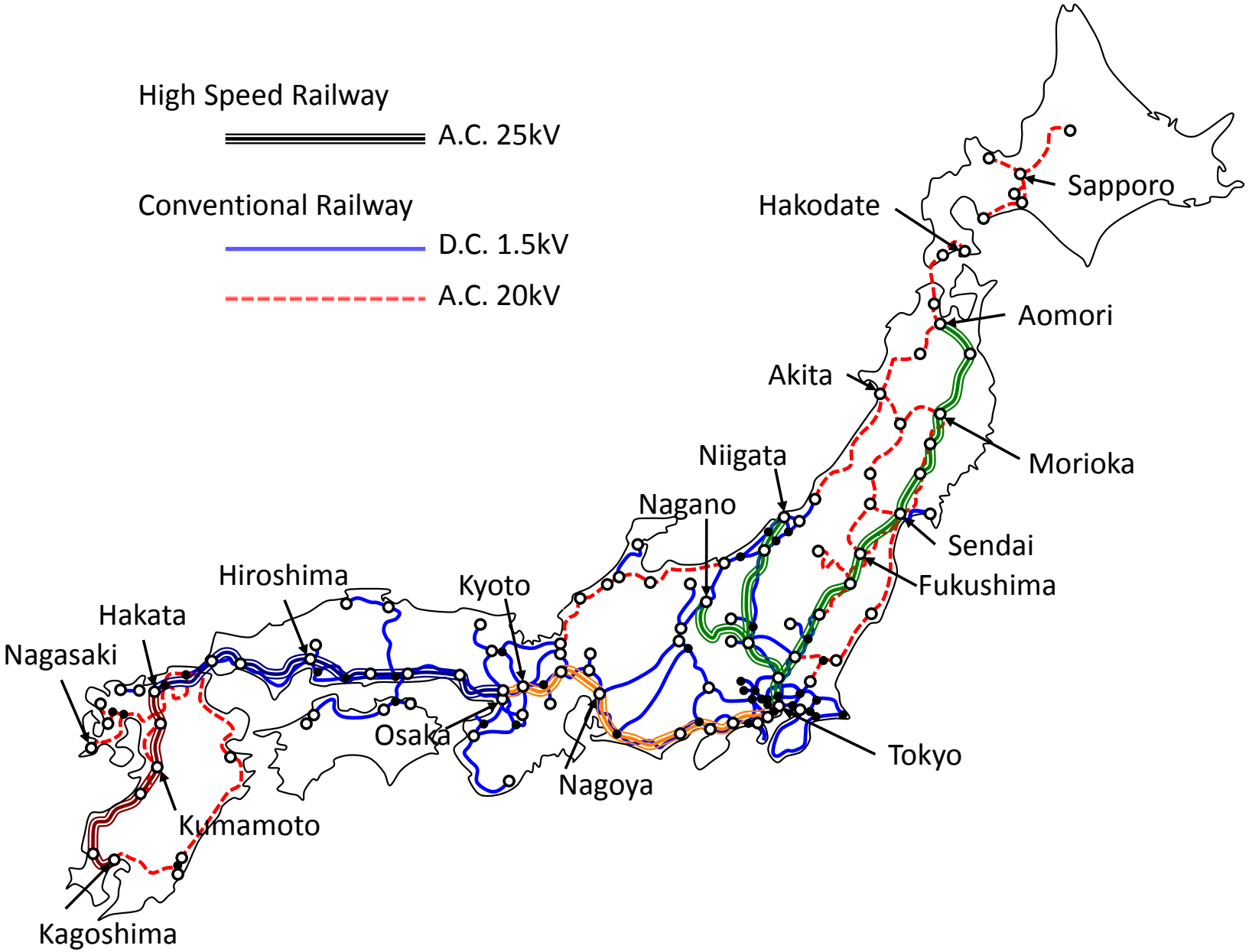
# Introduction

Japan National Railway was privatized and divided into 6 railway company in 1987.

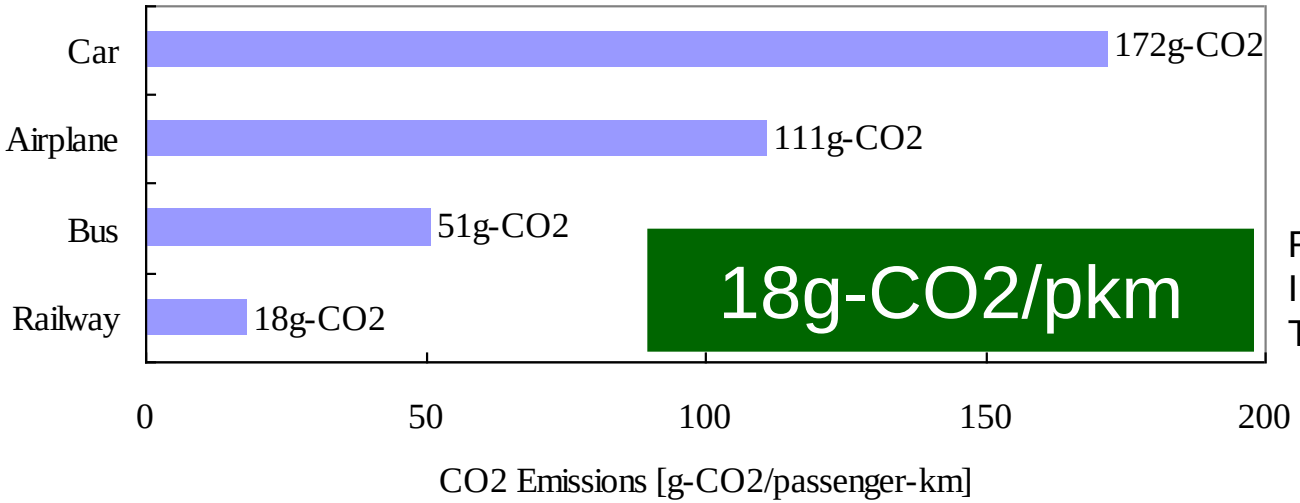




**Railway Transport Volume (passenger km) (2007 FY)**

# Voltage categories of TPS in Japan



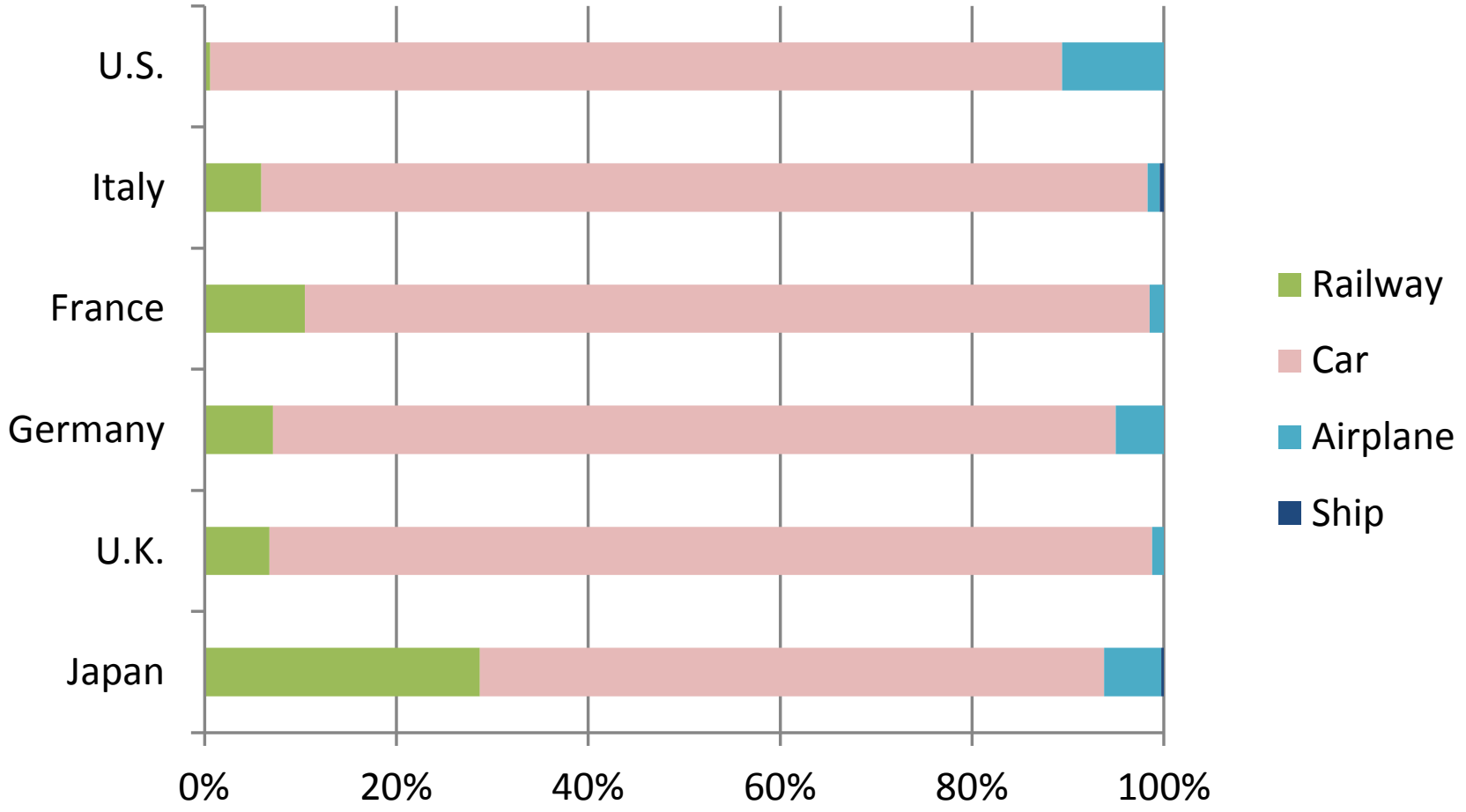
# Eco-friendliness of Railway




Reported by Ministry of Land, Infrastructure, Transport and Tourism in 2007

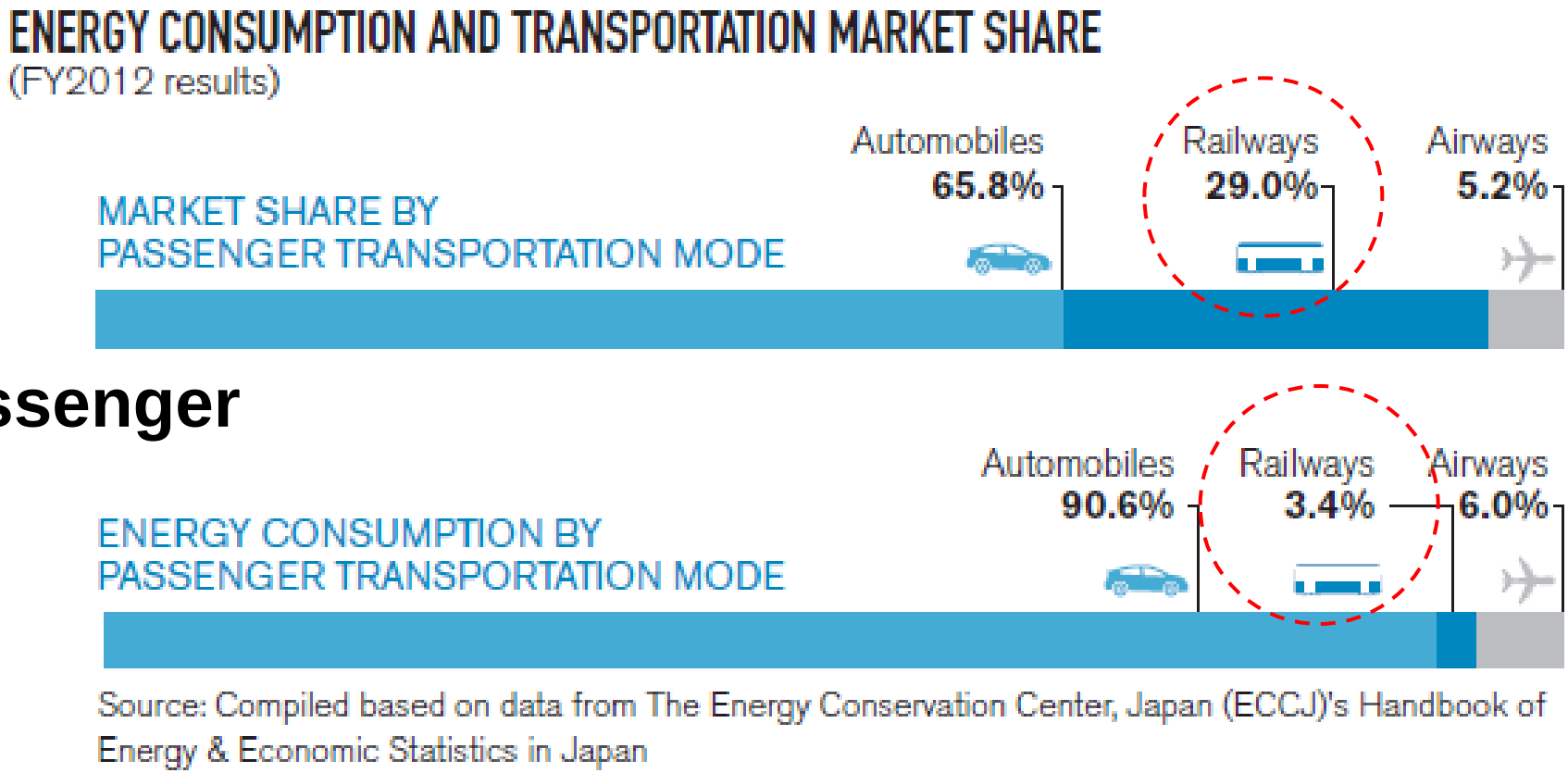
**CO2 emission from each transportation mode**

# Share in Transportation




**Ratio of Each Transportation Mode (passenger km)**

# Total Energy Consumption is not Small




**Passenger**

Source: Compiled based on data from The Energy Conservation Center, Japan (ECCJ)'s Handbook of Energy & Economic Statistics in Japan

**Energy**

# Contents

1 Introduction

2 Electric Energy Utilization in Railway Transportation

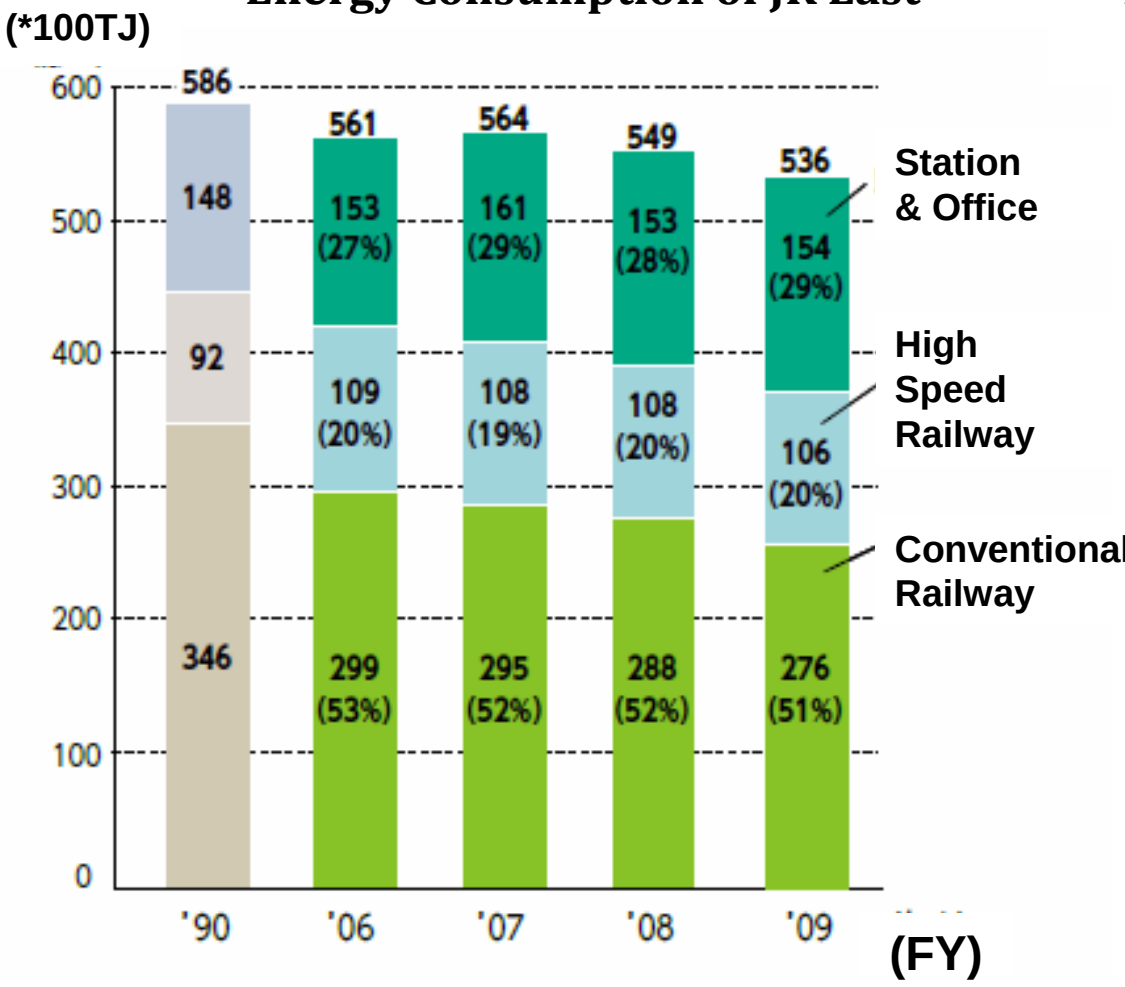
3 Utilization of Regenerative Energy

4 Other Projects in Railway Transportation

5 Conclusions

# Total Energy Consumption is not Small

## Energy Consumption of JR East



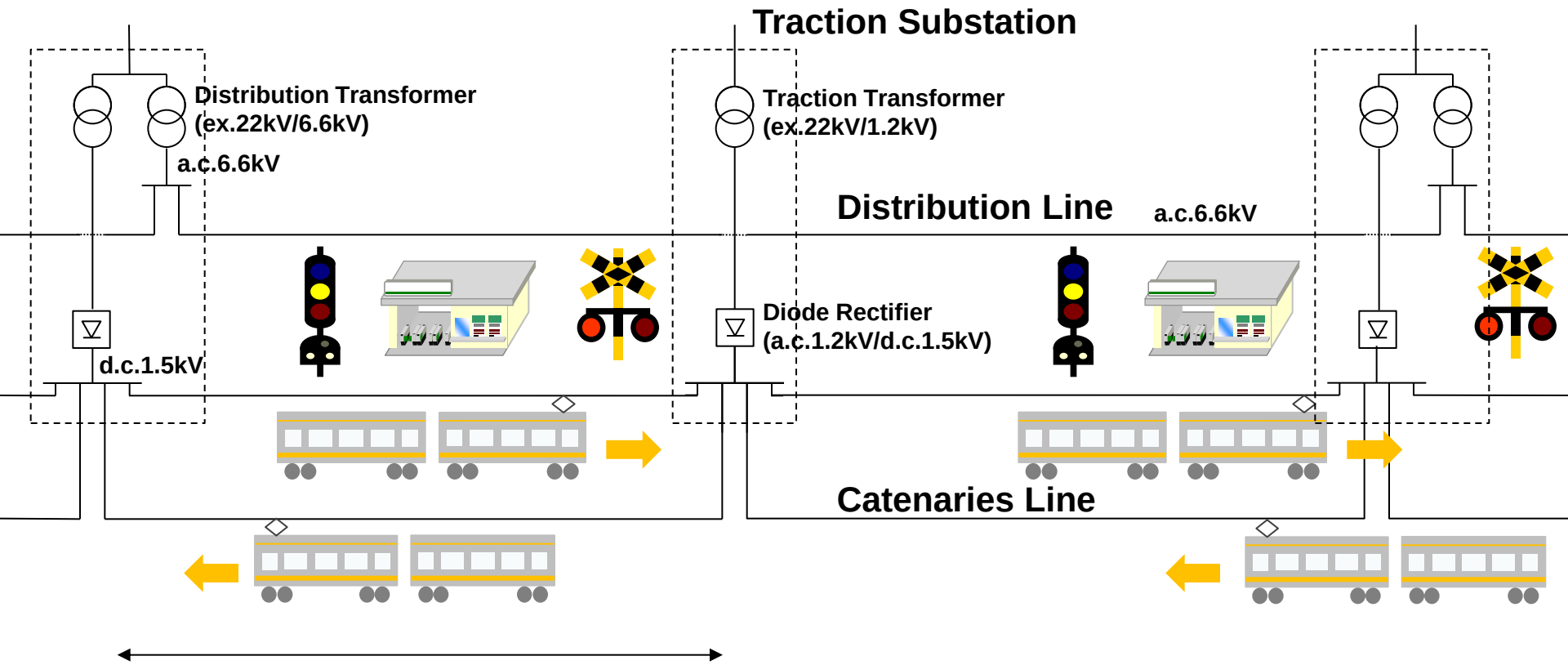

## Total Electric Energy Consumption for Railway Transportation

(JR East)
about 5TWh/year

(Railway Total)
18.073TWh/year
(2009 FY)

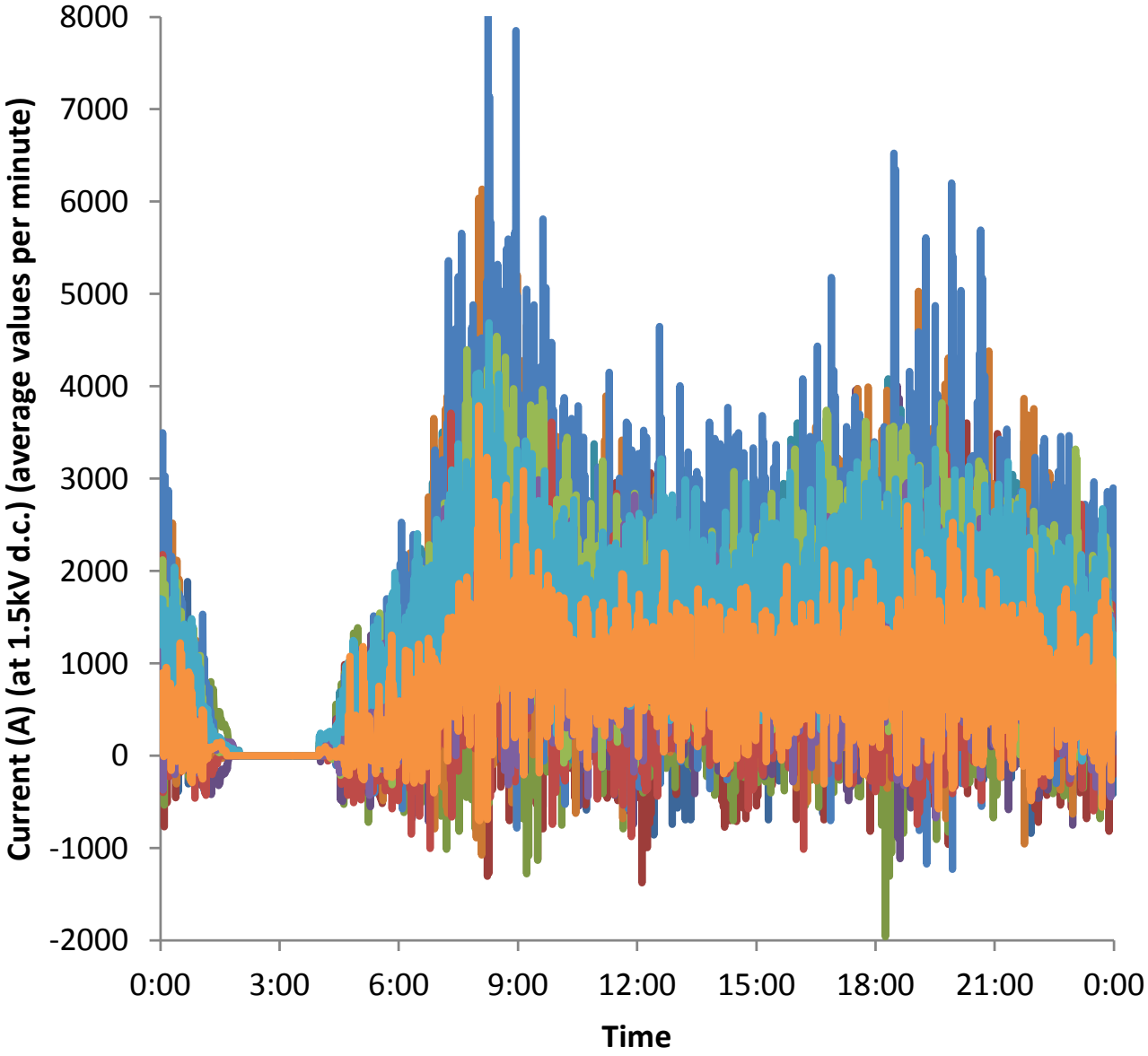
= 1.6%
of total electric energy in Japan

# d.c. Traction Power Supply System




- 1.5kV d.c. for trains and 6.6kV a.c. for station and signaling.
- Interval Length of traction substations is about 3-5km around city area and about 10km in country side.

# d.c. Traction Load Curves



# Contents

1 Introduction

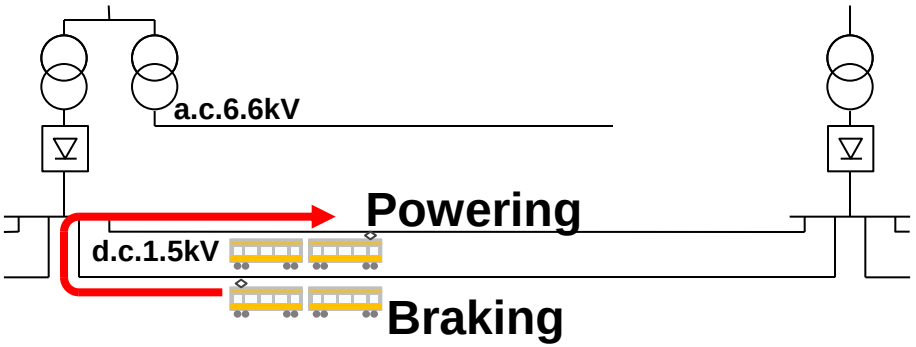
2 Electric Energy Utilization in Railway Transportation

3 Utilization of Regenerative Energy

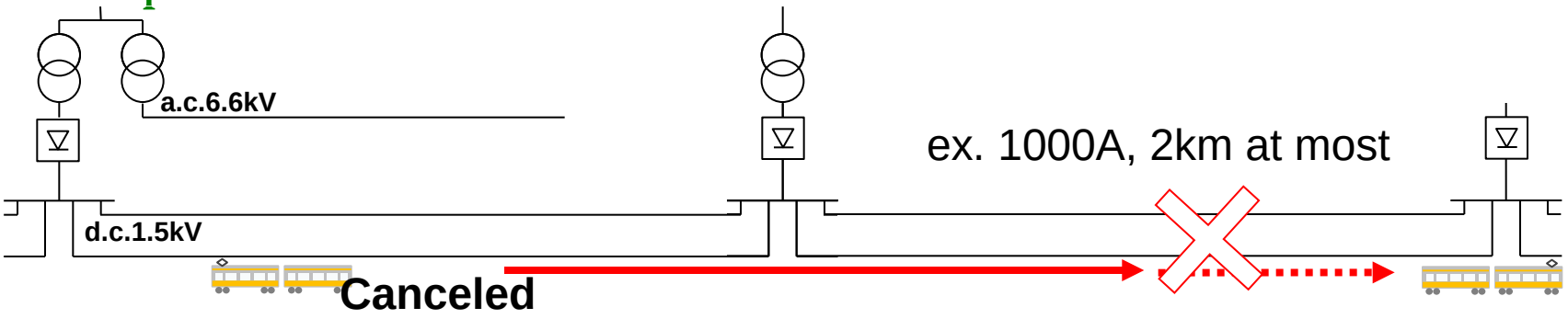
4 Examples of Other Projects

5 Conclusions

# What is regenerative power?




- Regenerative power is utilized by the other powering train simultaneously.
- Inverse power flow from d.c. to a.c. is impossible by diode rectifier.
- Residual regenerative power is canceled and kinetic power is dispersed as heat .



# What is regenerative power?

**Assumption:**
**10 cars (25-30t/car)**
**150 passengers/car**
**90km/h**

**Kinetic energy**
**25m/s, 376t**
**= 117MJ = 33kWh**

**Assumption:**
**Utilization ratio 40%**
**Regeneration time 30s**

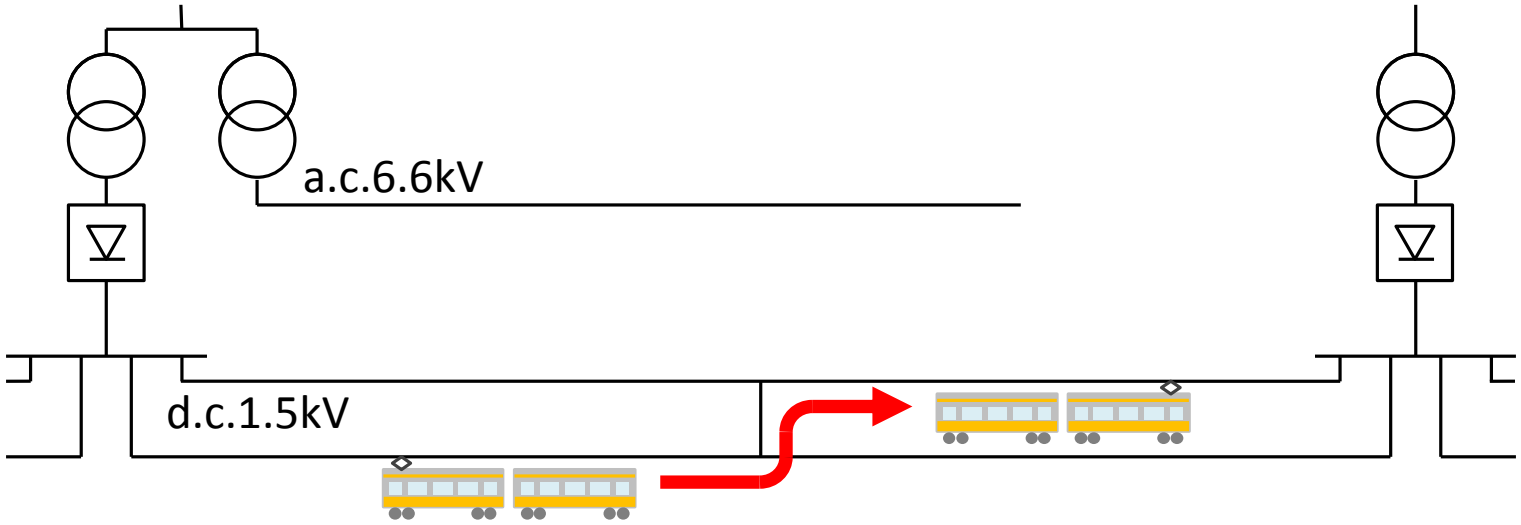
**Electric energy and power**
**13kWh, 1568kW**

# Solutions for residual regenerative energy

- Tie feeding between upward and downward feeders
- Regenerative inverter
- Self-commutation (PWM) inverter
- Energy Storage system (ESS)

# Tie-feeding

- Upward feeder and downward feeder are connected in the middle of traction substations.




- Opportunities to utilize regenerative power increase.
- JR West reported about 3.4% energy saving in suburban line.

# Regenerative inverter

- Regenerative power is converted from d.c. 1.5kV to a.c. 6.6kV and utilized at station or signaling system.


- Realized since 1970's

# PWM inverter

- Function of regenerative inverter is combined to conventional diode rectifier.


- Realized in 2005 at TSUKUBA Express Line.
- They have started selling electricity from regenerative energy since December in 2013.

# Energy storage system

- Flywheel system in 1988.
- First Lithium-ion battery in 2006 by JR West for compensation for voltage drop.


- Storage medium: Lithium-ion battery, Ni-MH battery, Electric double layer capacitor

# Requirement for battery

General requirement for energy storage system for regenerative energy utilization

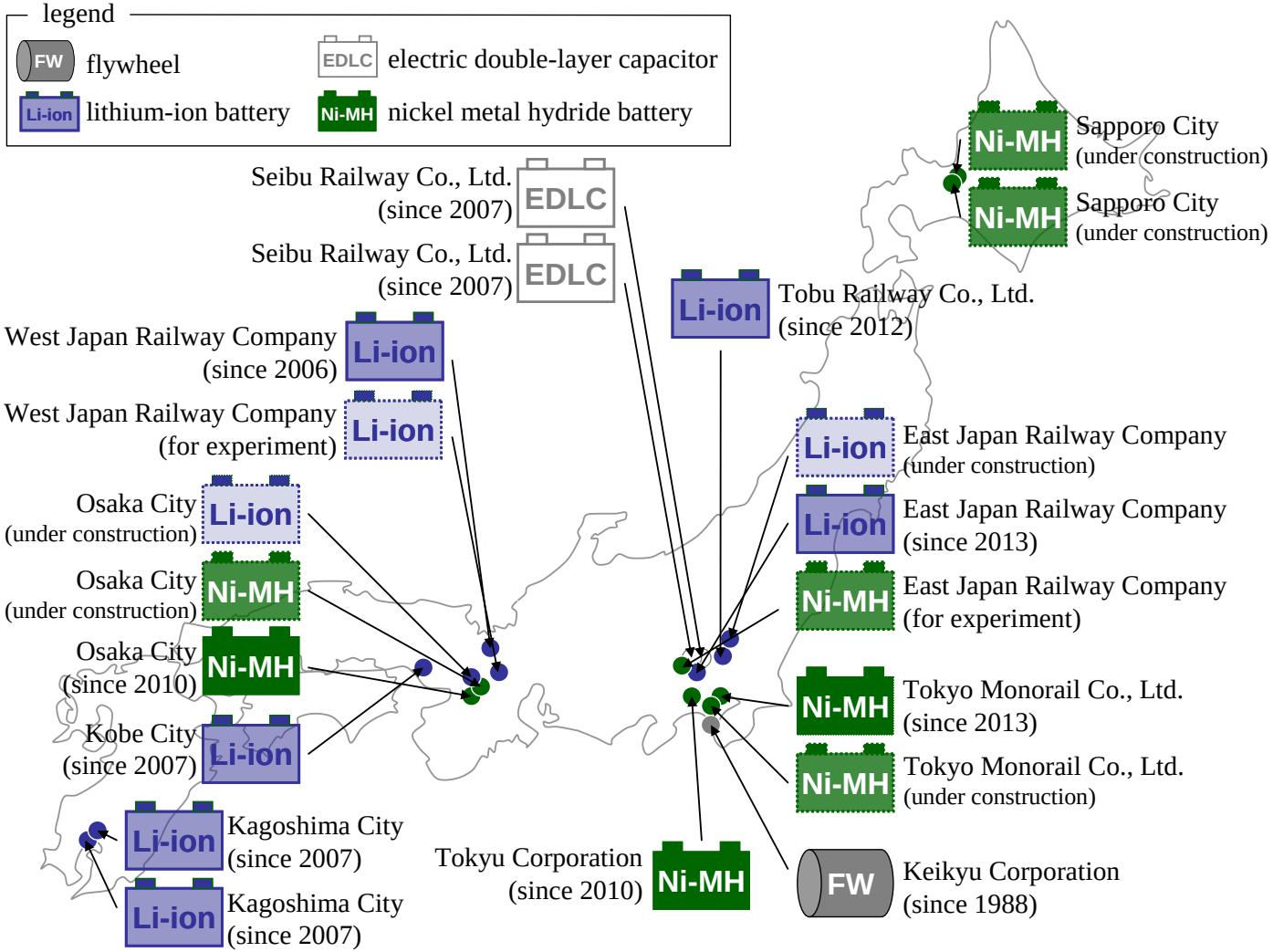
| | |
|---|---|
| **Electric power:** | **500kW – 2MW** |
| **Storage capacity:** | **10kWh – 400kWh** |
| **Voltage:** | **d.c. 1.5kV (or 750V)** |

Price of battery decreases drastically and application of ESS to traction PSS is promoted during last a few years.

# Energy Storage System for Traction in Japan



- More than 10 energy storage systems have already installed in d.c. 1.5kV or d.c. 750V traction PSS (power supply system)



# Purpose of ESS in d.c. traction PSS

- **Compensation for voltage drop**: MW order electric power transmission causes large voltage drop.
  - JR West, Tobu Railway etc.
- **Avoiding regenerative brake cancelation**: Large voltage drop causes regenerative brake cancelation.
  - Seibu Railway, Kobe City, Kagoshima City etc.
- **Utilization of regenerative energy**: Canceled power was conventionally lost as heat generation at brake friction pad.
  - JR East
- **Emergency power supply**: D.c. traction power can be supplied even when black out of utility company happens.
  - Tokyo Monorail

# East Japan Railway Company



Practical installation of Li-ion battery at Haijima SS in 2013 and Okegawa SS in 2014.

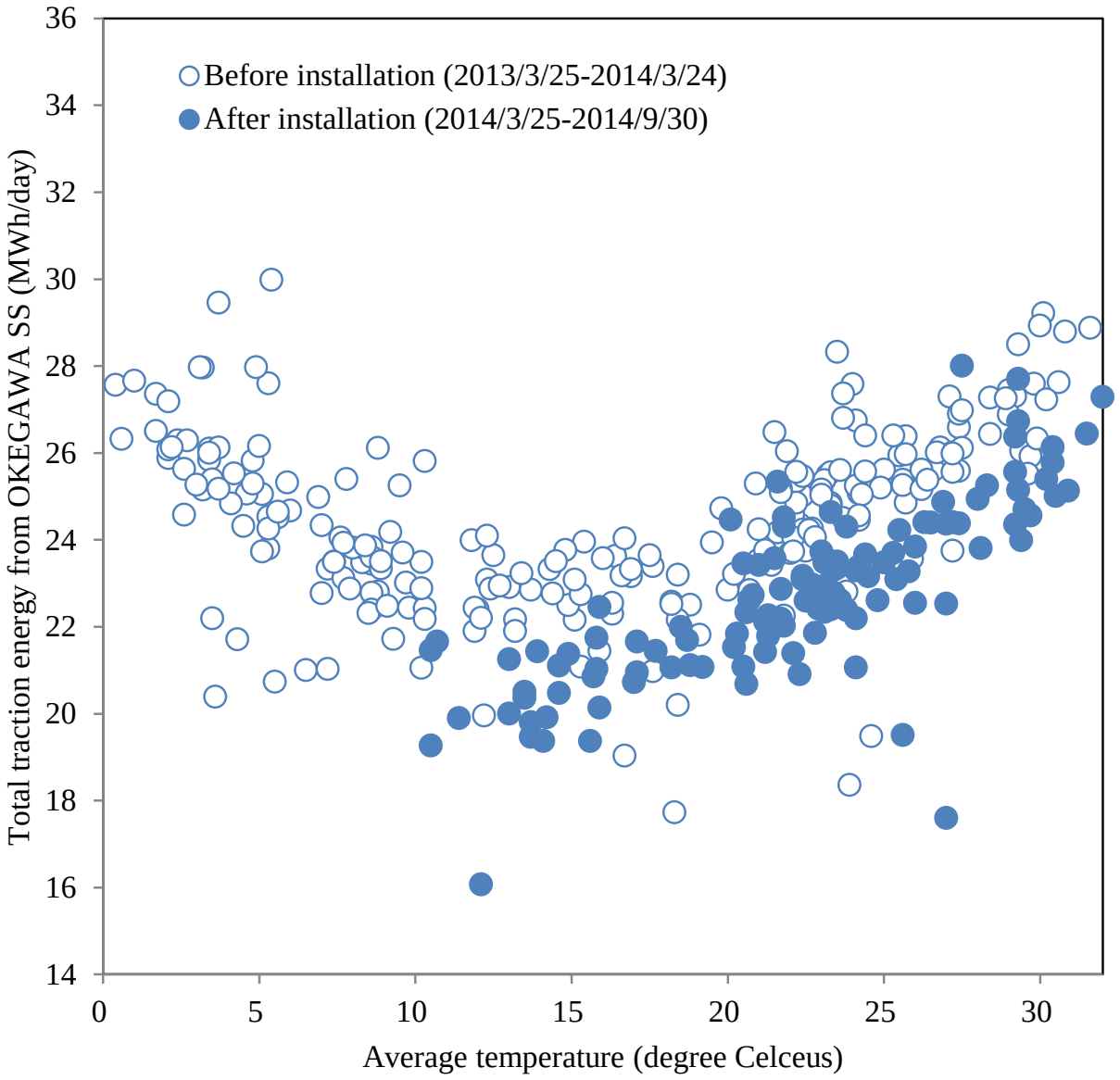
**Energy saving effect of ESS**

Haijima SS
400MWh/year

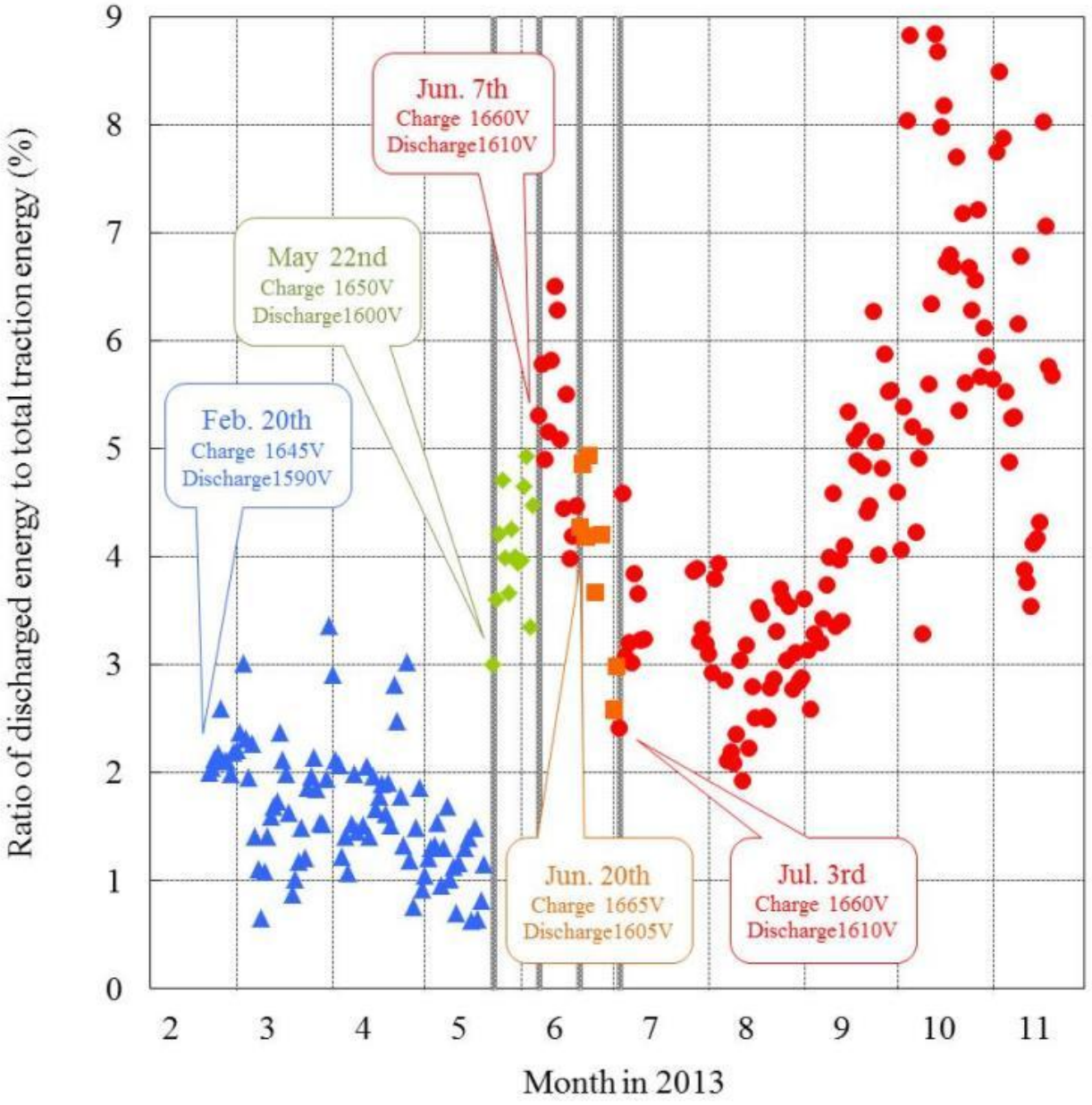
Okegawa SS
700MWh/year

# Effect of Energy Storage System at OKEGAWA





# Effect of Energy Storage System at HAIJIMA




**Reduction ratio to total traction energy of HAIJIMA SS**

# Contents

1 Introduction

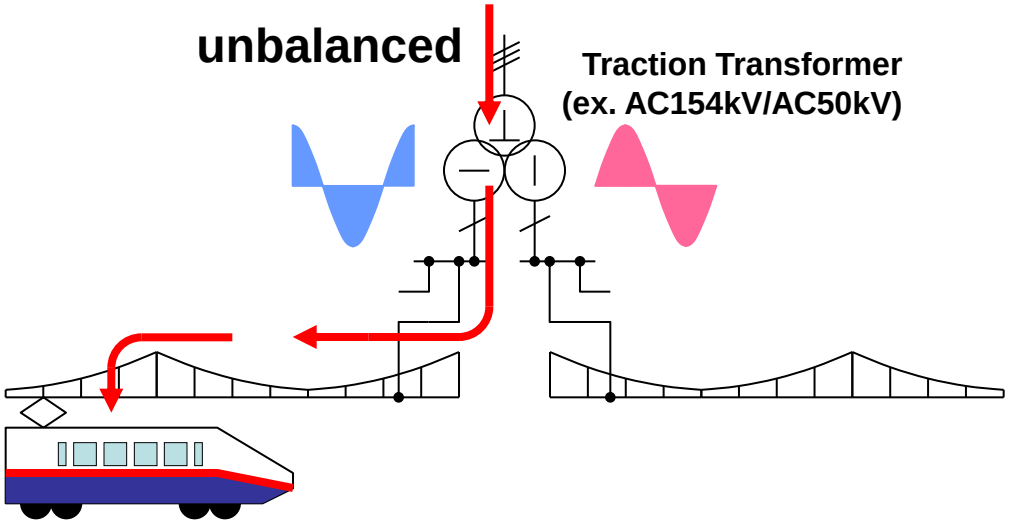
2 Electric Energy Utilization in Railway Transportation

3 Utilization of Regenerative Energy

4 Examples of Other Projects

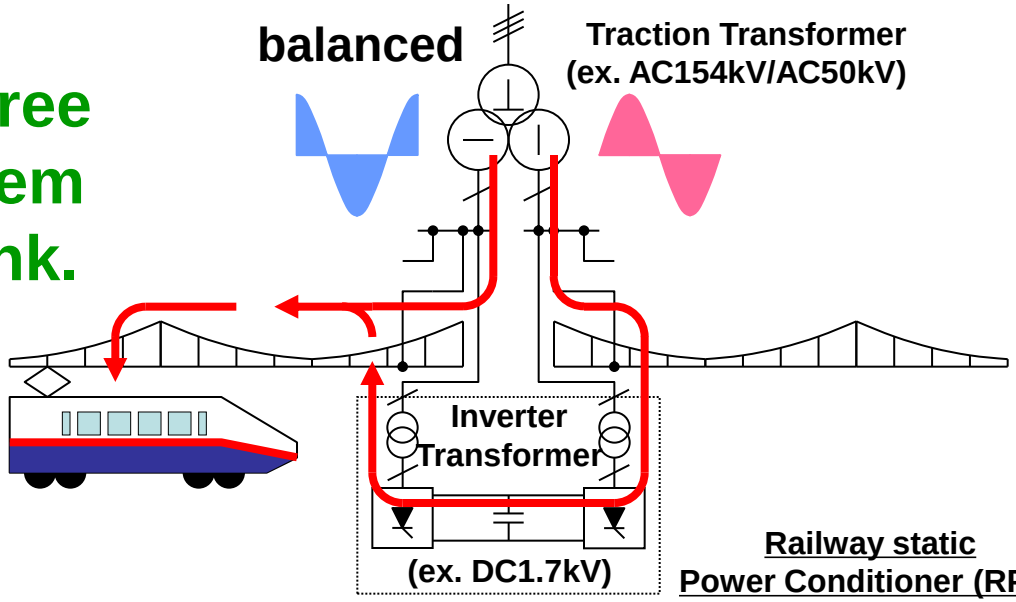
5 Conclusions

# Railway Static Power Conditioner (RPC)




**Railway is single phase load and causes three phase unbalance in grid.**

**By introducing RPC, three phase unbalance problem is solved by ac/dc/ac link.**

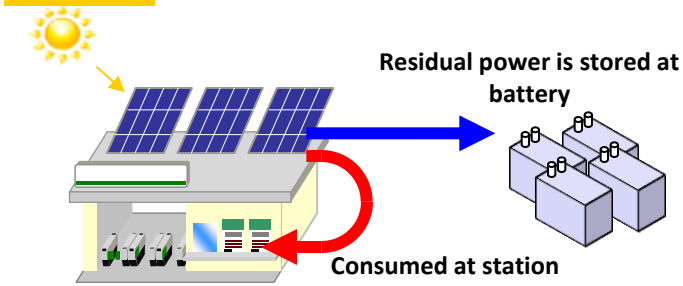



Railway static
Power Conditioner (RPC)

# HIRAIZUMI "Zero Emission Station"

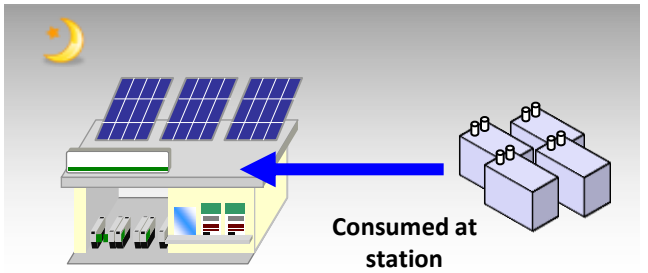
**All electric power are supplied from PV system on the sunny day from 78kW, 500m² PV panel and 240kWh Lithium-ion battery.**

**Day**



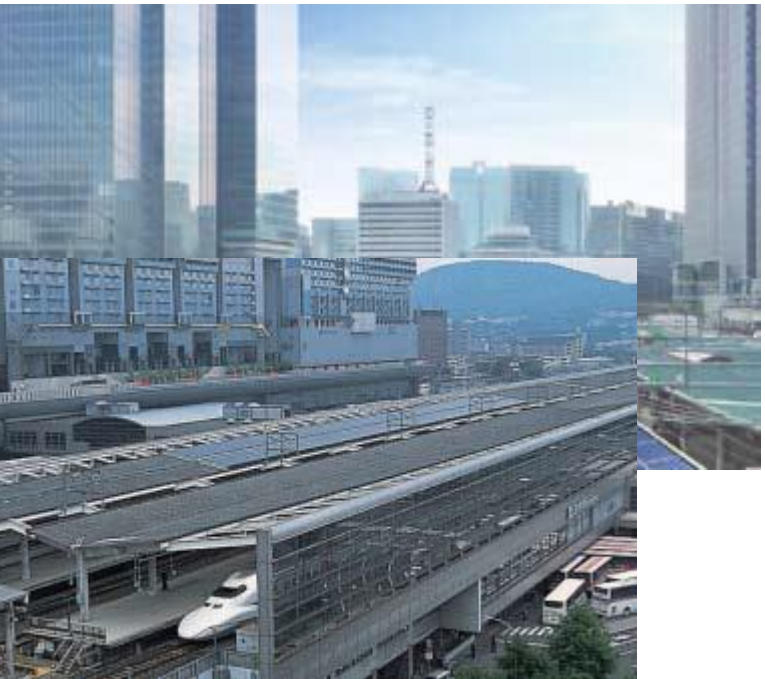

**During the daytime, residual power is stored at Li-ion battery.**

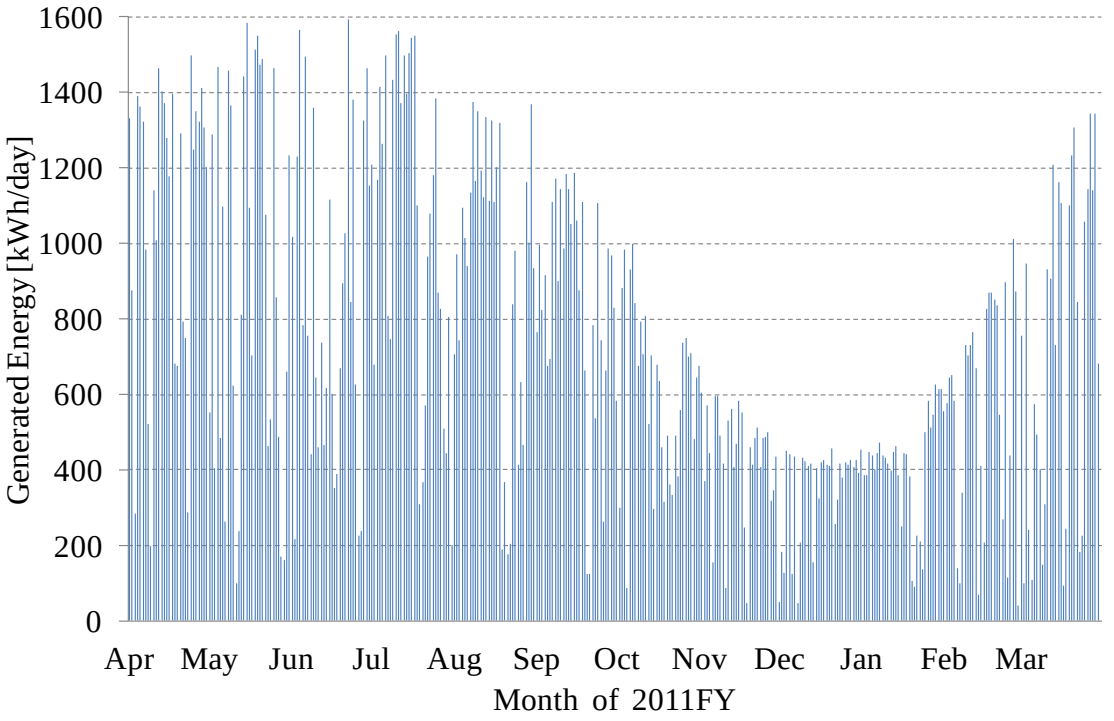
**Night**




**During the night, station power is supplied from stored battery.**

# Rooftop PV System at TOKYO Station



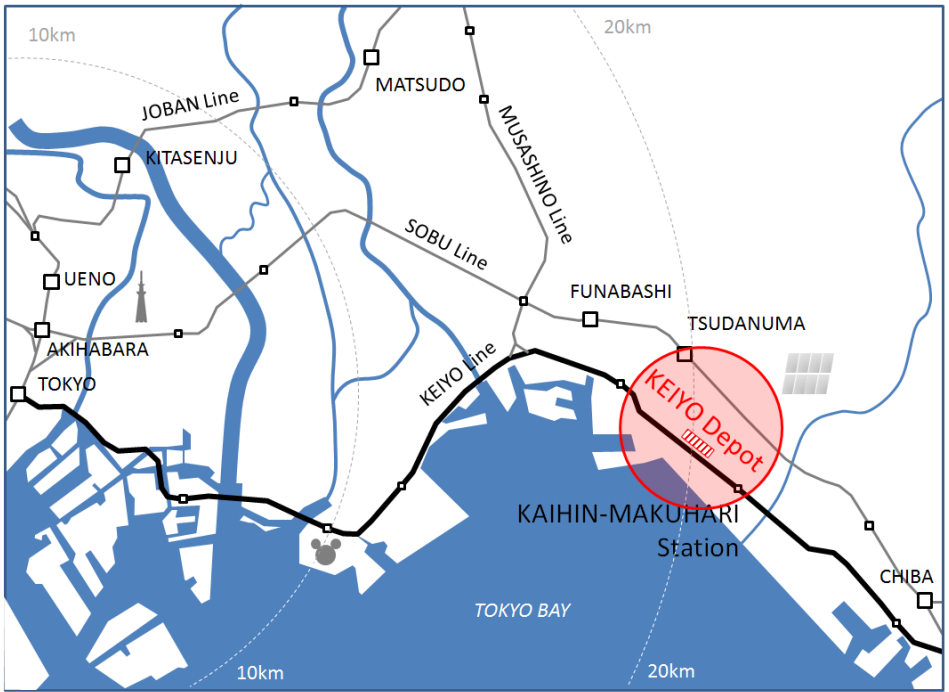


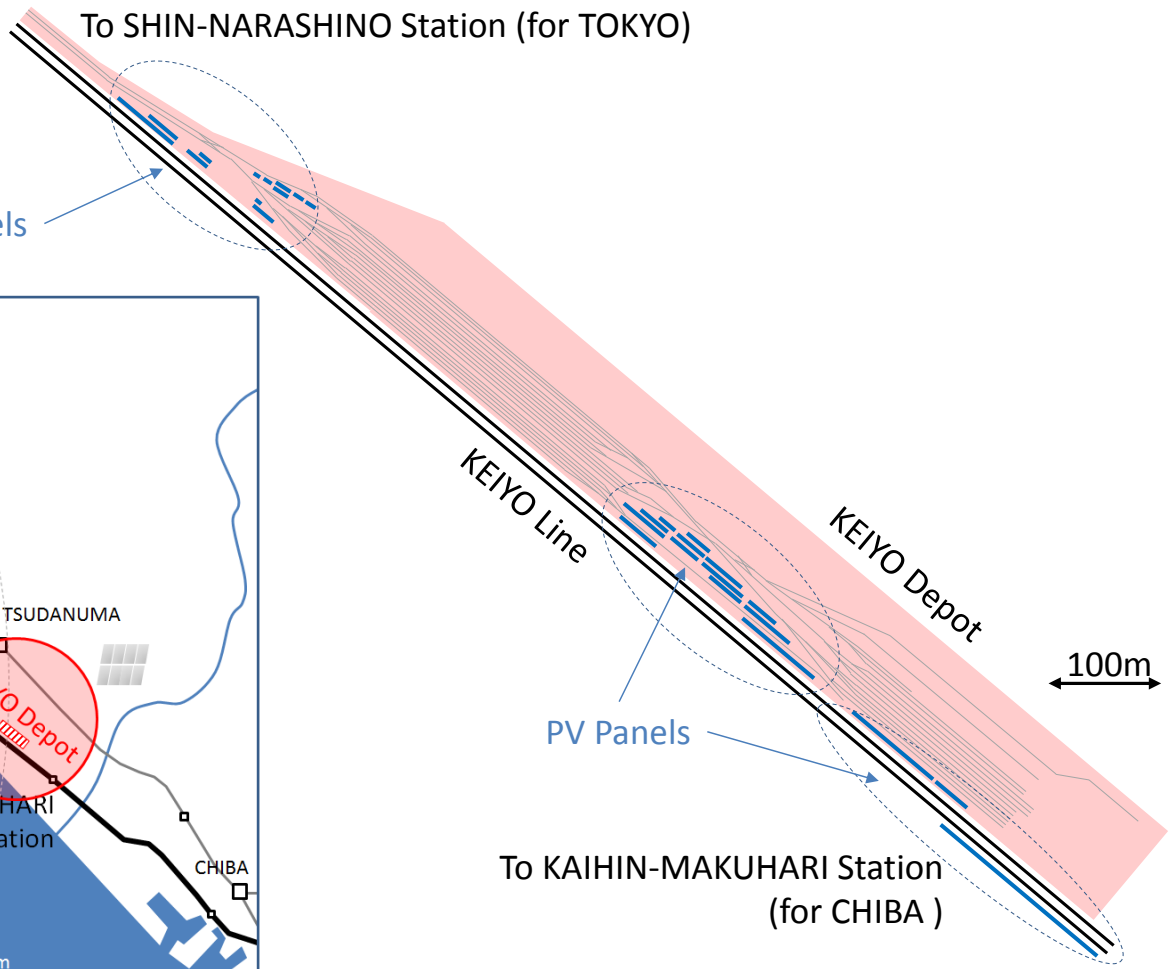

**453kW, 3846m², 300MWh/year**

# KEIYO Depot "Mega-Solar Plant"



**1050kW, 6600m², 1000MWh/year**



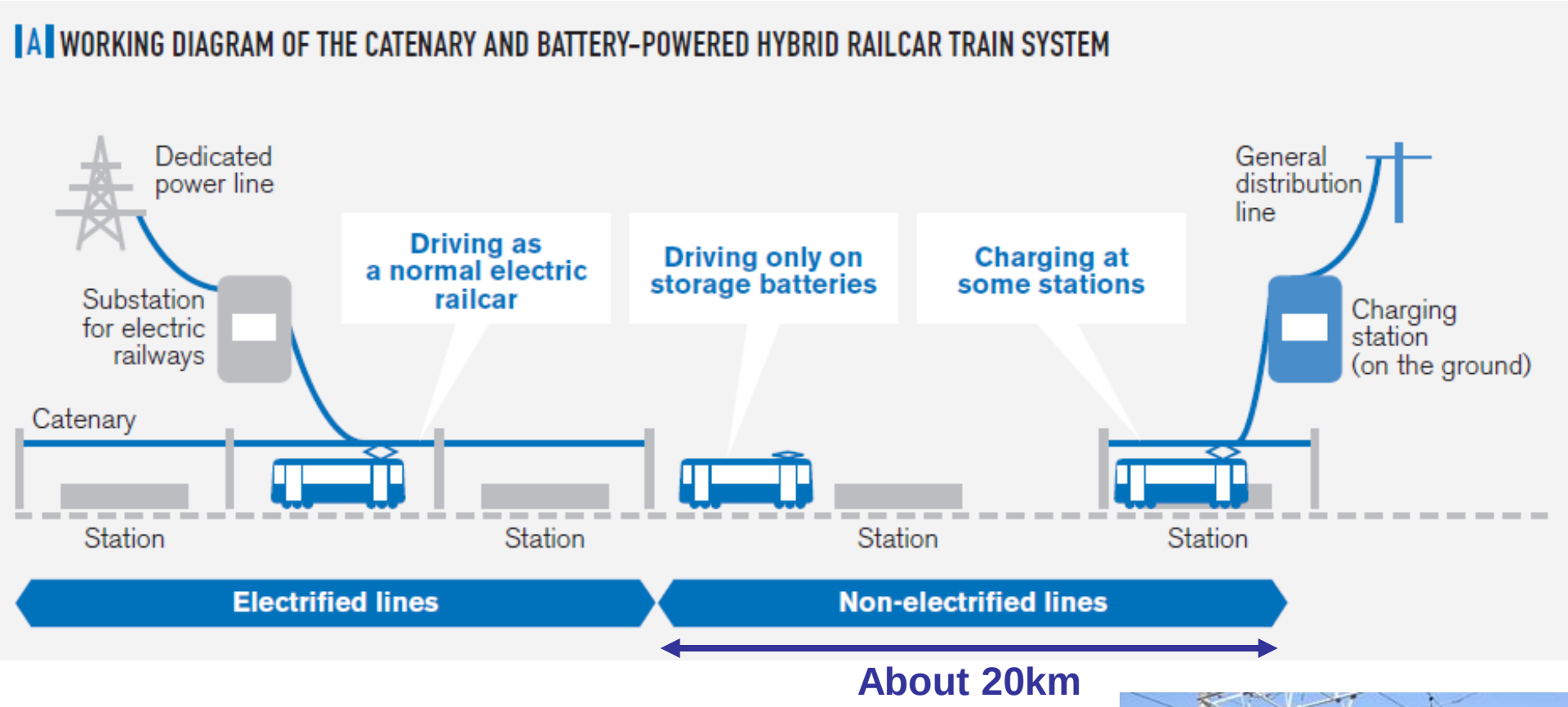



# Comparison between ESS and PV

| | Energy Storage System for Regenerative Power | | Photovoltaic System around Railway Premises | |
|---|---|---|---|---|
| | HAIJIMA SS | OKEGAWA SS | TOKYO Station | KEIYO Depot |
| Started Operation | 2013 | 2014 | 2011 | 2014 |
| Capacity | 78kWh, 2000kW | 137kWh 2000kW | 430kW | 1050kW |
| Effect | 400 MWh/year | 700 MWh/year | 300 MWh/year | 1000 MWh/year |
| Area | 100m$^2$ | 100m$^2$ | 3800m$^2$ | 6600m$^2$ |
| $CO_2$ Reduction / Cost (normalized) | 1.0 | 1.7 | 0.1 | 0.7 |

# Catenary and battery-powered hybrid railcars






- **Started operation on March 2014 at KARASUYAMA Line.**
- **190kWh on-board Li-ion battery.**

# Contents

1 Introduction

2 Electric Energy Utilization in Railway Transportation

3 Utilization of Regenerative Energy

4 Examples of Other Projects

5 Conclusions

# Conclusions

**Integration potential in railway transportation area ?**

- Electric railway is unstable and unbalanced load.
- Changing regenerative energy is utilized within d.c. traction power supply system now.

**Possibility**

- On ground energy storage system can realize peak cut of changing traction load and may contribute to stabilization of power grid in the future.
- Reduction of system cost, not battery cost, will be a key in the future for more introduction.

# New HSR from NAGANO to KANAZAWA