Welcome to the best practice workshop

TRACKSIDE ENERGY STORAGE

Proposed by the UIC Energy efficiency and CO₂ Emissions Sector

Organised by the Sector’s Chairpersons:

Bart Van der Spiegel, Infrabel,
Gerald Olde Monnikhof, ProRail.
Philippe Stefanos, UIC
TRACKSIDE ENERGY STORAGE

- Please change your ID as [Company-Name Surname]
- The meeting will be recorded.
- Please remain on mute while the speaker is active.
- Please keep your camera off while the speaker is active.
## Workshop timeline

### 10 h  First part: Overview, research and innovation

- **European Battery Alliance (EBA)**
  - Johan Soderbom

- **Dutch railways: ProRail and NS**
  - Herman Sibbel
  - Martijn Wolf

- **Railway Technical Research Institute (Japan Railways)**
  - Takeshi Konishi

### 11 h  Second part: Application

- **SNCF**
  - Tony Letrouvé
  - Hervé Caron

- **East Japan Railway Company (JR East)**
  - Koji Kasai
EUROPEAN BATTERY VALUE CHAIN

Market outlook and application examples

Johan Söderbom
Thematic Leader Smart Grid and Energy Storage

UIC Trackside energy storage
Topics

- Why talk about batteries?
- Market development
- European Battery Alliance
- Applications
Topics

• Why talk about batteries?
• Market development
• European Battery Alliance
• Applications
Why energy storage?

Extremely tough measures in order to achieve the target

- Dispatchable RES
- Low carbon generation
- Energy Storage
Why focus on Li-Ion Batteries?

- Covering a large power and energy span
- Mature technology
- Automotive industry is pushing the limits regarding cost and performance
Lithium-ion battery pack prices and cumulative deployment

Source: BloombergNEF. 2020 Lithium-Ion Battery Price Survey
Li-Ion will be competitive in several applications

- Lithium Ion is becoming more and more competitive in different applications
- No other battery technology seems to be able to catch up
Batteries has the fastest falling cost in the Power System

Bloomberg NEF:

“Already cheaper to install new-build battery storage than peaking plants”
The time for Lithium-Ion is here

Nobel Prize in Chemistry

John B. Goodenough (USA, left), M. Stanley Whittingham (UK, centre), and Akira Yoshino (JPN, right) share the Nobel Prize for the development of lithium-ion batteries.
Topics

• Why talk about batteries?
• Market development
• European Battery Alliance
• Applications
Annual lithium-ion battery demand by application

Lithium-ion battery demand outlook
GWh/year

Most probably an understimation!
Growth of electric vehicles

Global EV share of new passenger vehicle sales by region

Annual passenger EV sales by region
Growth of electric vehicles

Key Milestones to IEA's Pathway to Net Zero

BY 2025:
- No new unabated coal plants approved for developments
- No new oil and gas fields approved for development; no new oil and gas extensions

BY 2030:
- Universal energy access
- All new buildings are zero-carbon ready
- 60% of global car sales are electric
- Most new clean technologies in heavy industry demonstrated at scale

BY 2035:
- Most appliances and cooling systems sold worldwide are zero-carbon ready
- 50% of heavy truck sales are electric
- No new ICE car sales
- All industrial electric motor sales are best in class

BY 2040:
- 50% of existing building stock retrofitted to zero-carbon ready levels
- 50% of fuels used in aviation are low-emissions
- Around 96% of existing capacity in heavy industries reaches end of investment cycle
- Net zero emissions electricity globally

BY 2045:
- 50% of heating demand met by heat pumps
- More than 85% of buildings are zero-carbon ready
- More than 50% of heavy industrial production is low-emissions
- Almost 70% of electricity generation globally from solar PV and wind

Sales of battery electric, plug-in hybrid and fuel cell electric vehicles soar globally

Source: IEA. All rights reserved.
Stationary storage
Utility dominates, US fastest growing market

Global energy storage build by country

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RoW</td>
<td>1.7</td>
<td>3.4</td>
<td>3.4</td>
<td>5.3</td>
<td>9.7</td>
<td>11.5</td>
<td>13.8</td>
</tr>
<tr>
<td>Latin America</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>India</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE Asia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Korea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: BloombergNEF. Note: SE Asia = Southeast Asia, RoW = Rest of the World.

Global energy storage build by segment

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility</td>
<td>1.7</td>
<td>3.4</td>
<td>3.4</td>
<td>5.3</td>
<td>9.7</td>
<td>11.5</td>
<td>13.8</td>
</tr>
<tr>
<td>Residential</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utility-scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: BloombergNEF.
Lithium-ion dominating the market

Technology mix of commissioned utility-scale storage projects based on power output

Source: BloombergNEF. Note: Excludes pumped hydro and compressed air energy storage projects. If multiple applications are selected, the capacity is divided equally amongst them.
### Application mix of commissioned energy storage projects based on power output

<table>
<thead>
<tr>
<th>Year</th>
<th>Other</th>
<th>Residential</th>
<th>Commercial</th>
<th>Distribution</th>
<th>Transmission</th>
<th>Energy shifting</th>
<th>Peaking capacity</th>
<th>Ancillary services</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>38%</td>
<td>17%</td>
<td>10%</td>
<td>23%</td>
<td>9%</td>
<td>5%</td>
<td>2%</td>
<td>10%</td>
</tr>
<tr>
<td>2013</td>
<td>31%</td>
<td>28%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>5%</td>
<td>2%</td>
<td>15%</td>
</tr>
<tr>
<td>2014</td>
<td>32%</td>
<td>29%</td>
<td>15%</td>
<td>15%</td>
<td>15%</td>
<td>5%</td>
<td>2%</td>
<td>15%</td>
</tr>
<tr>
<td>2015</td>
<td>24%</td>
<td>22%</td>
<td>5%</td>
<td>32%</td>
<td>4%</td>
<td>6%</td>
<td>7%</td>
<td>32%</td>
</tr>
<tr>
<td>2016</td>
<td>24%</td>
<td>22%</td>
<td>5%</td>
<td>32%</td>
<td>4%</td>
<td>6%</td>
<td>7%</td>
<td>32%</td>
</tr>
<tr>
<td>2017</td>
<td>19%</td>
<td>21%</td>
<td>6%</td>
<td>30%</td>
<td>14%</td>
<td>30%</td>
<td>11%</td>
<td>30%</td>
</tr>
<tr>
<td>2018</td>
<td>14%</td>
<td>22%</td>
<td>6%</td>
<td>30%</td>
<td>14%</td>
<td>30%</td>
<td>11%</td>
<td>30%</td>
</tr>
<tr>
<td>2019</td>
<td>8%</td>
<td>21%</td>
<td>4%</td>
<td>29%</td>
<td>8%</td>
<td>29%</td>
<td>4%</td>
<td>29%</td>
</tr>
<tr>
<td>2020</td>
<td>4%</td>
<td>21%</td>
<td>4%</td>
<td>29%</td>
<td>8%</td>
<td>29%</td>
<td>4%</td>
<td>29%</td>
</tr>
</tbody>
</table>

Source: BloombergNEF. Note: Excludes pumped hydro and compressed air energy storage projects. If multiple applications are selected, the capacity is divided equally amongst them. This chart includes behind-the-meter + utility-scale capacity.
Topics

• Why talk about batteries?
• Market development
• European Battery Alliance
• Applications
Situation 2017

Global battery value chain

Global car manufacturing

Sources: Roskill, Peteves et al., World Resource Forum 2017, European Commission

(1) Including interim or estimated figures.
(2) Including light trucks.
(3) North American Free Trade Agreement covering Canada, the United States and Mexico.
(4) Southern Common Market covering Argentina, Brazil, Paraguay and Uruguay.

Source: VDA. http://www.vda.de
Ecosystem approach in Europe

**Boom in battery production in Europe** catalysed by concerted policy and investment effort

- **Securing Access to Raw Materials**
  - Communication on critical raw materials
  - Raw Materials Alliance with a focus on upstream supply chain elements

- **Accelerate R&D Innovation**
  - Various programs such as Horizon 2020, Batteries Europe, Horizon Europe, Battery 2030+ promoting technology leadership

- **Sustainability Focus**
  - Battery Regulation Proposal (Dec 2020) as part of a Circular Economy Action Plan

- **Supporting Cell Manufacturing**
  - Important Projects of Common European Interest to the tune of €3.2bn (Dec 2019) and €2.9 BN (Jan 2021) launched and funded

- **Securing Skilled Workforce**
  - Dedicated projects such as ALBATTs, DRIVES, and COSME
  - Automotive Skills Alliance launched (Nov 2020)
  - EBA ACADEMY

- **Policy Consistency**
  - Aligning broader frameworks like EU’s trade policy, clean energy strategy, mobility packages, and Green Deal

*Sources: European Commission, Oliver Wyman*
The industrial development programme of the European Battery Alliance

**EUROPEAN BATTERY ALLIANCE**

EBA250

This cooperative ecosystem gathers the European Commission, interested EU countries, investment institutions and key industrial, innovation and academia stakeholders

EIT InnoEnergy has been trusted by the European Commission to drive forward and promote EBA250 activities, acting as network manager and project facilitator

700+ members

Creating a competitive and sustainable battery industry in Europe by 2025, to capitalise on opportunities and capture a new market worth €250bi/year

- 100+ Raw Materials
- 110+ Active Materials
- 120+ Cell manufacturing
- 120+ Battery parts and Systems
- 200+ Application and Integration
- 100+ Recycling/2nd life

- 60+ Research and associations active in large parts of the value chain
- 10+ European Commission Services
- 50+ Financial Institutions
The European Battery Alliance – overview

**EU and Member States providing the supportive framework**
- EU = Strategic Action Plan on Batteries
- EU = Sustainable Batteries Regulation
- Other legislative & funding initiatives at EU and national level

**The industrial workstream of the Battery Alliance led by EIT Innoenergy**
- Open and inclusive platform for the entire battery ecosystem
- Policy insight
- Accelerating battery projects

**R&I Networks and initiatives**
- Batteries &I strategies and short to medium-term technology roadmaps
- Coordination of battery initiatives
- Drive forward SET-Plan action on batteries

**Battery Partnership (BEPA)**
- Battery specific programmes under Horizon Europe

**Other partnerships**
- Battery downstream work programmes under Horizon Europe

**Other R&I activities**
- Two Battery IPCEIs

**Interregional partnership on advanced battery materials (ERDF/Smart specialisation)**

**National and bilateral R&I activities**

Capture a new market worth 250B€/year in 2025

A competitive and sustainable European battery value chain!
Ongoing and Planned Battery Cell Factories in Europe

I would take out this since it is repeated in next slide.
Bottlenecks in the value chain

EU Example: Investment and planning is currently working backwards

Note: Above shows announced plans as of June 2020, not a forecast of capacity in each year.

Source: Benchmark Mineral Intelligence
Examples of projects along the European value chain

**Mines, active materials, recycling**

- **SKALAND GRAPHITE**
  - Graphite Anode Production
  - Start 2021, Ramp Up 2023

- **REVOLT (NORTHVOLT)**
  - Recycling Pilot Plant
  - Start 2020

- **BASF**
  - Cathode Material Plant
  - Start 2022

- **REVOLT (NORTHVOLT)**
  - Full-Scale Recycling Plant
  - Start 2022

- **ELXEM**
  - Battery Graphite Pilot Plant
  - Start 2020

- **VOLKSWAGEN & SALZGITTER**
  - Recycling Pilot Plant
  - Start 2020 (Capacity 1200t/a)

- **VULCAN ENERGY**
  - Lithium from Brine
  - Start 2021

- **SAVANNAH RESOURCES**
  - Lithium Mine
  - Start 2021

- **INFINITY**
  - Lithium Mine
  - Start 2021 (Capacity 15000t/a)

- **KELIBER**
  - Lithium Mine
  - 2021 (Capacity 1.5 Gt/a)

- **FORTUM & BASF & NORMIKE**
  - Recycling Centre
  - Announced

- **UMICORE, NYSA**
  - Cathode Material Plant
  - Start 2021

- **BASF & SCHWARZHEIDE**
  - Cathode Material Plant
  - Start 2020

- **PROMOBUS**
  - Recycling Plant
  - Start 2021

- **CINOVEC**
  - Lithium Mine
  - (Capacity 2.25 Gt/a)

- **EURO MANGANESE**
  - Manganese from Tailings, Start 2020 (Capacity 1.2 Mt)

- **RIO TINTO & JADAR**
  - Lithium Mine
  - Start 2022

- **SNAM & HONDA**
  - Recycling Project
  - Announced

**Giga Factories**

- **FREEV**
  - Start 2022, Up to 32 GWh

- **NORTHVOLT ET**
  - Start 2021, Up to 40 GWh

- **NORTHVOLT Labs**
  - Start 2020, Up to 0.3 GWh

- **MORROW**
  - Start 2021, Up to 33 GWh

- **ENVISION AESC**
  - Start 2021, Up to 32 GWh

- **BRITISHVOLT**
  - Start 2021, Up to 32 GWh

- **ACC (France)**
  - Start 2021, Up to 24 GWh

- **ACC (Germany)**
  - Start 2021, Up to 16 GWh

- **BMW**
  - Pilot Plant
  - Start 2021

- **VERKOR**
  - Start 2021, Up to 50 GWh

- **LITHOPS**
  - Start 2021
  - 200 MWh

- **INORAT**
  - Start 2021, Up to 10 GWh

- **CATL**
  - Start 2022, Up to 70 GWh

- **TESLA**
  - Start 2021, Up to 40 GWh

- **CELLENCORE**
  - Announced, Up to 1 GWh

- **LG CHEM**
  - Start 2018, Up to 67 GWh

- **NORTHVOLT ZWEI**
  - Start 2021, Up to 20 GWh

- **VARTA**
  - Pilot Plant
  - Start 2021

- **FARASIS**
  - Start 2021, Up to 15 GWh

- **MES**
  - Start 2020, Up to 15 GWh

- **Samsung**
  - Start 2018, Up to 30 GWh

- **SK Innovation**
  - Start 2021, Up to 18 GWh

2020 ~ 26 GWh Capacity

2030 > 500 GWh Capacity
Topics

- Why talk about batteries?
- Market development
- European Battery Alliance
- Applications
Electric roads

- Electricity from either overhead lines or from the road
- Several tests in the world not the least in Europe
- Can reduce the need for large batteries
- Requires substantial investments over many years
Battery powered heavy vehicles, does it make sense?

• Several OEMs on their way

• Driving regulation (Europe)
  • Maximum driving time 4.5 hours
  • Mandatory rest of 45 minutes
  • Ideal for charging intervals

• Driving
  • @ average 80 km/h: 500 kWh battery required (Tesla spec.)
  • Add 25% for safety: ~ 620 kWh
  • Tesla mod 3 battery ~5 kg/kWh

• Approx 3 100 kg of battery added to a total vehicle weight of 40 tonnes
Battery powered heavy vehicles, How to charge?

- High power charging
  - New standards under development
- High demand on the local grid
- Buffer battery ("Trackside")
- Already an existing solution
Trackside energy storage for trains
(An amateurs view)

• Ultracaps as an option
• Collecting braking energy at station
• Delivering acceleration energy at station
• Fast charging of battery electric trains from buffer battery at station
• PV + batteries along the track
Questions

Discussion

Johan Soderbom
Thematic Leader Smart Grid and Energy Storage

Thank you for your attention.
DUTCH RAILWAYS
The presentation is based on research on the use of energy storage for different purposes. 
NS and ProRail are the founders/sponsors of the research.
TRACKSIDE ENERGY STORAGE

The Dutch situation

Herman Sibbel (Movares), Martijn Wolf (Ricardo Rail)

Trackside energy storage, the Dutch situation
Content

• Background of the project
• Applications for trackside energy storage
• Matching possibilities with sustainability goals
• Review energy storage systems
• Conclusions and next steps
Background of Trackside energy storage project

- Team

ProRail

RICARDO

Movares

adviseurs & ingenieurs
Background of Trackside energy storage project

Sustainability goals NS (railway operator) and ProRail (rail infrastructure manager)

ProRail
- Energy neutral in 2030 by making use of self-generated sustainable electricity
- Increase energy efficiency with 30% in 2050 compared to 2010

How can trackside energy storage supports these goals?
Background of Trackside energy storage project

Project Goals

Investigate how trackside energy storage can improve the sustainable energy and reliability goals and objectives of NS and ProRail by assessment of the technical and financial feasibility.
Applications for trackside energy storage

Nine applications for the use of energy storage have been identified:

1. “Bringing home” function if a major power failure occurs
2. Contribution to national frequency containment reserve (primary reserve)
3. Contribution to peak shaving at network connections for traction
4. Optimising of overhead line voltage
5. Hourly Matching (match between time of generation and time of use)
6. Storage of self-generated sustainable electricity
7. Replacement of fossil fuel emergency power generators
8. Contribution to energy/mobility hub
9. Storage of regenerative braking energy
Matching applications with the sustainability goals

- Combining of applications is financially the best option
- But very complex to decide how to combine (many parameters)
- First: the number of applications to analyse are reduced by matching with the sustainability goals:
  - Hourly matching
  - Storage of self-generated energy
  - Storage of regenerative energy

- Combined with applications with highest financial returns
  - Primary reserve
  - “Bringing home” function
  - Energy/mobility Hub
Review energy storage systems

- Which technical solutions are feasible?
- Examples:
  - Chemical batteries, e.g. Pb battery, NiCd battery, lithium-titanate-oxide battery
  - Chemical flow batteries, e.g. Vanadium Redox flow Battery
  - Electromagnetic, e.g. (super) capacitor, Superconducting magnetic energy storage
  - Thermal energy storage
  - Mechanical energy storage, e.g. flywheel, compresses air energy storage (CAES), water reservoirs
Review energy storage systems

Two solutions identified

- Vanadium Redox flow Battery (VRB) and lithium-titanate-oxide battery (LTO):
  - Combination of maximum capacity/power, Charge/Discharge cycles, relatively low costs, acceptable size

[Source: https://vrbenergy.com]

[Source: www.leclanche.com]

[Source: https://www.global.toshiba/ww/products-solutions.html]
Review of energy storage systems

Preliminary financial results:
• Investment costs are relatively high and income not significant. Examples:
  • Lower energy costs
  • Lower substation network connection costs
  • Lower CO2 emissions
  • Reduced operational costs
  • Income via primary reserve
  • Reduced costs for emergency power generators.

→ Payback period varies between 5 years (regenerative braking energy) to decades (improvement of hourly matching)

However:
• Combination of applications decreases the payback period
• The payback period depends strongly on the valuation of items such as hourly matching, CO2 reduction, sustainable transport etc. (important matters for society). This can increase significantly the coming years due to recent and new climate agreements.
Conclusions and next steps

Conclusions
• Technical it seems feasible to make use of trackside energy storage in the railways
• Combining energy storage applications is essential for a positive business case
• Sustainability should be valued more highly and considered in the business case

Next steps
• Setup a business case with combination of possibilities
• Determine juridical impact: e.g. is an infrastructure manager allowed to deliver electricity? Who owns recuperated energy? etc.
• Determine risks: financial, EMC, fire safety, space occupancy etc.
• Setup of a pilot
For questions you can contact:

Martijn.Wolf@ricardo.com
+31-645698648

Herman.Sibbel@movares.nl
+31-615063561
Questions

Discussion

Herman Sibbel
Martijn Wolf

Thank you for your attention.
OUTLINE OF TRACKSIDE ENERGY STORAGE SYSTEM IN JAPAN

Takeshi Konishi
Railway Technical Research Institute
Outline of this presentation

Trackside Energy Storage System (TESS)
- Introduction status in Japan
- Constitution
- Control methods
- Recent topics
Traditional Trackside Energy Storage System

1912, Shin-etsu Line Maruyama Substation

Substation

Battery room (1322Ah)

Restored battery room as historic monument

(in Japanese)

(in Japanese)

Purpose: Peak Shaving, Supplementary power supply

Before 1928, such batteries (Lead-acid) had been installed also in Tokyo metropolitan area (ex. Keihin-Tohoku line)
All the batteries have been abolished by 1941 in Japan.
TESSs in Japan have been revived since 1988.
TESS application status in Japan

Before 2011, 8 systems

More than 40 TESSs have been applied (2019)
Recent increase of TESSs in Japan

The Great East Japan Earthquake in 2011 has influenced tremendous shock of energy policy for Japanese railway. TESSs have been installed for the purpose of two reasons.

- Energy Saving
- Emergency traction power supply (especially subway and monorail)
## Specifications of various type of TESSs

<table>
<thead>
<tr>
<th>Energy Storage Unit</th>
<th>Rated Power (kW)</th>
<th>Rated Energy (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flywheel</td>
<td>3000</td>
<td>25</td>
</tr>
<tr>
<td>Supercapacitor</td>
<td>2000 – 2600</td>
<td>7 - 17</td>
</tr>
<tr>
<td>Lithium-ion Battery</td>
<td>250 - 3000</td>
<td>18 - 600</td>
</tr>
<tr>
<td>Nickel-metal hydride Battery</td>
<td>According to the internal resistance</td>
<td>100 - 1000</td>
</tr>
</tbody>
</table>

**Flywheel, Capacitor: Capable of deep-cycle charge/discharge**

**Secondary Batteries: Deep-cycle charge/discharge is generally not recommended to avoid fast degradation of lifetime (dependent on chemical design of each battery)**
SOC range control of secondary batteries (Li-ion)

SOC range control of secondary batteries is very important to use TESSs for long years.

Usable SOC range for Energy Saving in normal use is very limited.

- Not used (to avoid degradation of lifetime of Li-ion battery in general)
- Normal charge/discharge for operation of energy saving
- Reserved range for discharge in case of blackout
Suitable application area of TESSs for Energy Saving

Images of timetable

NOT so effective (metropolitan area)

Suitable (suburban area)

NOT so effective (countryside area)

Regenerative energy can be easily transferred to and reused by other powering trains via contact line system.

Pretty well amount of regenerative energy is expected but transfer it via contact line system is slightly difficult due to distance.

Too little amount of regenerative energy is expected.
Fundamental Constitution of TESSs in Japan

TESS with electronic power converters

Feeding line (Catenary)

Disconnector

Circuit breaker

Reactors for filter

Capacitors for filter

Bi-directional dc-dc converter

Energy storage unit (ESU)

Rail

TESS without power converter

Feeding line (Catenary)

Circuit breaker

Reactors

Energy storage unit (ESU)

Circuit breaker

Rail
This circuit configuration allows the outer shape of TESS to be reduced.
Fundamental control of TESS

Charge/discharge current

Maximun charge current

Discharge voltage

Discharge area

Charge area

Maximun discharge current

Charge voltage

DC feeding bus voltage

Discharge

Standby

Charge
Example of charge/discharge strategy (A)

If DC feeding bus voltage is between charge and discharge starting voltage, the SOC of the TESS is controlled within this target range.

Charge starting voltage is raised up to suppress the charge in the range of high SOC.

Target SOC on standby mode.

DC feeding bus voltage (V)

Charge starting voltage

Discharge starting voltage

SOC (%)
Example of charge/discharge strategy (B)

- **Charge/discharge current**
- **Charge area**
- **Discharge area**
- Rush hour time (6:00-9:00, 17:00-21:00)
- Early morning time (5:00-6:00)
- Late evening time (21:00-25:00)
- Normal time (10:00-17:00)

DC feeding bus Voltage
Problem of introducing TESSs

(A) Direct charge from rectifiers

If the charge voltage setting(s) of the TESS is inappropriate, unnecessary charge occurs.

- Regenerative energy is reused between two trains **Good!**
- Unnecessary / undesired charge/discharge by the TESS **Bad!**

(B) Unnecessary charge

**Energy Saving**

**Increasing energy!**
New control without the information of feeding voltage

Control Method based on Train Energy

\[
\text{Train energy} = \text{kinetic energy} + \text{potential energy}
\]

Calculating the sum of the weight for the train energy

Increasing discharge, decreasing charge

Calculation the sum of weight
Problem of high frequency switching noise

Obtaining the characteristics among feeding circuit, rail, and earth is important to grasp the level of switching noise.
Conclusions and New topics for Carbon Neutral

More than 40 TESSs for energy saving or emergency compensation in Japan.

Each rated energy is less than 1 MWh. \( \rightarrow \) Too small impact for carbon neutral!

In 2019, in Kintetsu Railway Co. Ltd., TESS (7.1MWh) has been installed for the virtual power plant (VPP)

It will be indispensable to install large capacity of TESSs to charge/discharge renewable energy.

The coordination between power supply companies and railway companies will be also important to operate large capacity of TESSs effectively.
Thank you for your attention!

Merci

ありがとうございます
Questions
Discussion

Takeshi Konishi
Lead Design Engineer & OCL expert

Thank you for your attention.
Railways and UIC members are invited to join the UIC project:

“H2TR - Operating hydrogen powered trains”

In partnership with the IEC

If interested, please reach out to stefanos@uic.org

Resuming at 11h12
Break

Resuming at 11h12

New UIC Sustainability projects:

- NOise and Vibration Technical Advice (NOVITA)
- Routes out of Homelessness: Addressing Homelessness on the Railway (ROOH)
- Zero Waste Railway workshops - circular economy best practice workshops
- International guidance for managing risk of human trafficking and modern slavery in rail

Previous workshops:
### New UIC Rail system projects:

- Harmonized methodology for drone / UAV use for plain track inspections (D4R-PT, DPT)
- Heavy Rain. REsilient RAilways facing Climate Change. Operation Management and Impact on Infrastructure (RERA-Rain)
- Robotic based Inspection Sensor Monitoring (ROB-Inspection)
- Digital Automatic Coupling (DAC)
- Future Railway Operations and Traffic Control Center
- LL shoes behaviour in a locked brake situation
- Operational Use Cases of 5G for Rail
- New methods for safety demonstrations
- IRS 50553 – Functional requirements for HVAC systems
- Publication funding of rolling stock IRSs standards for the year 2022
- Non-craneable semi-trailers suitable for rail-road CT
- Updating of general provisions for passenger vehicles
Now resuming

Second part: Application

<table>
<thead>
<tr>
<th>Company</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNCF</td>
<td>Tony Letrouvé, Hervé Caron</td>
</tr>
<tr>
<td>East Japan Railway Company (JR East)</td>
<td>Koji Kasai</td>
</tr>
</tbody>
</table>
SNCF

Energy storage system at SNCF réseau
SNCF

Energy storage system at SNCF Réseau

Specification of ESSs for an IM and first experiments in the French railway network.

Hervé CARON
SNCF Réseau
Group leader in energy innovation and sustainable development

Tony LETROUVE
SNCF Innovation and Research.
Energy project manager
ENERGY STORAGE SYSTEM AT SNCF RÉSEAU

Learning and experiments
OUTLINE

1. ESS why and when?

2. Specification of ESS for railway infrastructure

3. Simulation results and tests in industrial laboratories

4. Conclusions & outlooks
ESS – WHERE AND WHY?
SMART INFRASTRUCTURE PROJECT

Definition of different solutions that can be coupled to switch to an active and multidirectional DC network

* Power Electronic

MVDC – superconducting feeder

Trackside energy storage system
TRACKSIDE ENERGY STORAGE SYSTEM
A response to the challenges and needs of SNCF Réseau

Operation
- Reinforce the catenary voltage (ensure the transport plan)
- Add more flexibility
- Resilience

Sustainable development
- Improve the receptivity of the infrastructure to reduce emissions of fine particles due to mechanical braking

Energy
- Reduce the financial impact of electrical losses on the network (consumption and variation)
- Develop braking energy recovery
- Add more services like demand-response (railway smart grid project)
# TRACKSIDE ENERGY STORAGE SYSTEM

For what uses? What are the criteria?

<table>
<thead>
<tr>
<th></th>
<th>Paralleling station</th>
<th>Classic DC substation</th>
<th>Trackside ESS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>implementation schedule? (increase traffic, temporary reinforcement)</strong></td>
<td>2 to 3 years</td>
<td>3 to 5 years</td>
<td>Time divided by 2 compared to a classic SS</td>
</tr>
<tr>
<td><strong>Cost / availability of land?</strong></td>
<td>5 to 20 m² (land price)</td>
<td>300 to 500 m² (land price)</td>
<td>Installed in the railway trackside</td>
</tr>
<tr>
<td><strong>Distance from the upstream supply network?</strong></td>
<td>0€</td>
<td>150 to 170 k€/km (excluding reinforcement of the electric network’s substation)</td>
<td>0€</td>
</tr>
<tr>
<td><strong>Power?</strong></td>
<td>0 MW</td>
<td>2 to 10 MW</td>
<td>2 to 3 MW</td>
</tr>
<tr>
<td><strong>Modularity, mobility</strong></td>
<td>No</td>
<td>No</td>
<td>Yes Without traffic interruption</td>
</tr>
</tbody>
</table>
Peaks shaving in consumption, optimizing the energy bill
Emergency power supply for railway signalling and the station,
Voltage and frequency support for the upstream electric network
 Establishment of a demand response service to reduce the return on investment of batteries
SPECIFICATION OF ESS FOR RAILWAY INFRASTRUCTURE
ESS incident survey

Preliminary risk analysis

- Battery technology: thermal runaway
- Power electronic failure
- Climatic environment
Life Cost Assessment with a sensitivity study

**SPECIFICATION OF ESS FOR INFRASTRUCTURE**

Auxiliaries' consumptions and a high efficiency

For the Manufacturing phase:
- Impose high recycling rates
- Rationalize the use of impacting materials

For the use phase:
- Closely monitor all energy consumption and losses
- Converter efficiency
- Battery efficiency
- Consumption of the cooling system and its optimization
SPECIFICATION OF ESS FOR INFRASTRUCTURE

Conclusion

- Safe connection with the electric environment
- Recyclable and safe component (incl. battery cells) chemistry
- High efficiency
- A lower price than the conventional substation

Lithium Iron Phosphate Technology

MFT with SiC component
SIMULATION RESULTS AND TESTS IN INDUSTRIAL LABORATORIES
VALIDATION IN A SIMULATION ENVIRONMENT
Model under PLECS of a sector with traffic grid

- Developed DC / DC converter with galvanic isolation
- ESS has been sized using internal tools

Substation 1 1500 V

Substation 2 1500 V

Catenary

Rail

- D = 15 km
- D/2 = 7.5 km

PS

ESS

15km

7,5km

T=10min

T=11min

Time (min)

Trains position (km)

14
13
12
11
10
9
8
7
6
5
4
3
2
1
0

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

15km

7,5km
Hypothesis:

If the storage device is not present, $V_{\text{train}}$ drops below 1300V (the trains are restrained in power).

### VALIDATION IN A SIMULATION ENVIRONMENT

Simulations results: Measurement from trains with and without ESS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catenary section (S)</td>
<td>630 mm$^2$</td>
</tr>
<tr>
<td>Distance between substations (D)</td>
<td>15 km</td>
</tr>
<tr>
<td>Trains power</td>
<td>4.5 MW/train</td>
</tr>
<tr>
<td>Energy storage system size</td>
<td>16 elementary blocks in parallel</td>
</tr>
</tbody>
</table>
### VALIDATION IN A SIMULATION ENVIRONMENT

Simulations results: Conclusion

| Energy (MWh) | $E_{\text{substation } 1}$ | $E_{\text{substation } 2}$ | $E_{\text{trains } I \text{ (IMPAIR)}}$ | $E_{\text{trains } P \text{ (PAIR)}}$ | $E_{\text{batt}}$  
(in source convention: negative in charge and positive in discharge) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Without ESS</strong> (2h)</td>
<td>7,769</td>
<td>7,769</td>
<td>6,563</td>
<td>5,998</td>
<td>0</td>
</tr>
<tr>
<td>(E_{\text{substation } 1 + 2} = 15,538)</td>
<td>(E_{\text{trains } I \text{ et } P} = 12,561)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **With ESS** (2h) | 6,472                       | 6,472                       | 6,749                            | 6,186                            | 1,910                
\(\text{depth of discharge } 81.2\%\) |
| \(E_{\text{substation } 1 \text{ et } 2} = 12,944\) | \(E_{\text{trains } I \text{ et } P} = 12,936\) |                              |                                  |                                  |                      |
| **With ESS** (2h Without train trains, total de 4h) | 1,021                       | 1,021                       | 0                                | 0                                | -1,984               
\(\text{battery fully charged in } 116 \text{ min}\) |
| \(E_{\text{substation } 1 \text{ et } 2} = 2,042\) | \(E_{\text{trains } I \text{ et } P} = 0\) |                              |                                  |                                  |                      |

- With these simulation assumptions, it takes 2 hours to reach the maximum depth of discharge that we had set (81.2% here). It will take a little less than 2 hours more without any trains to fully recharge the batteries.
- The efficiency of the installation is improved, it goes here from 80.84% without a storage device to 86.31% with this battery storage device.
TEST IN INDUSTRIAL LABORATORIES
From laboratory hardware to the on-site experiment

MFT test at full scale at EURAIL TEST

Full system test in emulated environment at SCLE

Test at Lezignan-Corbière railway power station…

…industrialized by SCLE
CONCLUSIONS & OUTLOOKS
Economic studies
An economically viable solution in SNCF studies: flashback on the studies

Short-term solution more interesting than a traditional solution!
Economic studies
An economically viable solution in SNCF studies: flashback on the studies

- Classic DC power station
- Battery substation pessimistic scenario
- Battery substation medium scenario
- Battery substation optimistic scenario
Economic studies
An economically viable solution in SNCF studies: flashback on the studies

The solution shows all its relevance in its modular and movable aspect!
NEXT STEP
RACCOR-D*: Get ready for the future of the 1,5kV DC network

- Increase energy efficiency and robustness of the rail system
- Coping with the increase in traffic and more powerful trains
- Decarbonize the network and rationalize the use of primary resources

* Project proposed to CORIFER French call of interest
NEXT STEP
RACCOR-D*: Get ready for the future of the 1,5kV DC network

* Project proposed to CORIFER French call of interest
Stay in touch with UIC:

www.uic.org

#UICrail

Thank you for your attention.

Contact:
Hervé CARON – SNCF Réseau
Herve.Caron@reseau.sncf.fr
Tony LETROUVE – SNCF
Tony.Letrouve@sncf.fr
Questions
Discussion

Hervé CARON
Tony LETROUVE

Thank you for your attention.
Workshop timeline

11h  Second part: Application

- East Japan Railway Company (JR East)  Koji Kasai

Mr Koji Kasai

Deputy General Manager,
Management Planning Department,
Corporate Planning Headquarters
EAST JAPAN RAILWAY COMPANY

JR East's strategy for Energy and Environment
JR EAST'S STRATEGY FOR ENERGY AND ENVIRONMENT

Zero-Carbon Challenge 2050

Koji KASAI
Deputy General Manager, Corporate Management Planning Department, East Japan Railway/JR East

7th Oct, 2021
Agenda

1 Summary of JR East – 3 Features

2 Our Energy and Environment Strategies and Initiatives
1 Summary of JR East – 3 Features

2 Our Energy and Environment Strategies and Initiatives
We own, operate and maintain all the railway infrastructure as a fully integrated railway.

Network: 7,401.7 km
Trains: approx. 12,300 /day

Figures are as of 2020.
Feature 2 - Horizontal Structure

WE OPERATE ALL CATEGORIES OF RAILWAY

- Network: 7,401.7km*
- No. of Passengers: 17.8 Million /day*
- No. of Trains: 12,300 /day* (the largest in the world!)
- Annual Operating Revenue: $15.8 Billion**
  ($26.8 Billion*)
- (no subsidies from the government)
- Net Annual Income: △$5.2 Billion**
  ($1.8 Billion*)
- No. of Employees: 51,560*

*Numbers are as of FY ended March 31, 2020 (Calculated by 1$ = 110JPY)
**Numbers are as of FY ended March 31, 2021 (Calculated by 1$ = 112JPY)
We own and operate a non-transport business utilizing assets from railway operations.

*FY2020 REVENUE $26.8 B

68% RAIL OPERATIONS
Revenue from Rail Operations $18 Billion

32% LIFESTYLE BUSINESS

65% Tokyo Metropolitan Area Network
32% High-speed
3% Other rail network

*Numbers are as of FY ended March 31, 2020
Calculated by 1$ = 110JPY
1 Summary of JR East – 3 Features

2 Our Energy and Environment Strategies and Initiatives
Practicing ESG Management for Carbon-free Society

Realizing sustainable growth of JR East Group

SUSTAINABLE DEVELOPMENT GOALS

- Realization of low-carbon society (decarbonization)
- Energy consumption by railway business
  - FY2031 50% reduction (from FY2014)
  - FY2051 Net-Zero (from FY2014)

- Making cities more comfortable
  - Making regional areas more affluent
  - Developing businesses for the world

Environment
- Prevention of global warming
- Diversification of energy

Social
- Service quality reform
- Responding to social issues (childcare support, responding to a variety of customers, fostering of global-minded railway-related personnel)
- Supporting cultural activities

Governance
- Ultimate safety levels
- Risk management
- Compliance

Flexible services
Diverse customers
Stable return
Shareholders and investors

Regional society
Trust

Contribution to development

JR East Group

SUSTAINABLE DEVELOPMENT GOALS: 17 Sustainable Development Goals the world agreed upon for 2030
Overview of Zero-Carbon Challenge 2050

Zero-carbon challenges in 2050.

A verification test of fuel cell railcars called "HYBARI" is planned around March 2022.

Utilization of hydrogen

- Kawasaki Thermal Power Station: Introduce CO2-free hydrogen power generation
- Renewable energy power sources: Aim to achieve total power output of at least 1 million kW

Fuel battery bus

- Started service: Tokyo - Around Takeshiba From Oct 2020
Zero-Carbon Challenge 2050 – JR EAST

Net Zero CO2 Emissions by FY2051.3

- FY2021: 1.94 mn t CO2
- FY2031: Reduction 50%
- FY2051: Net Zero

<table>
<thead>
<tr>
<th>Energy type (Breakdown of CO2 emissions)</th>
<th>~FY2031.3</th>
<th>~FY2041.3</th>
<th>~FY2051.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchased Electricity (52%)</td>
<td>Advance the introduction of energy-saving facilities</td>
<td>Tohoku area CO2 free by FY2031.3</td>
<td>Purchase area CO2 free by FY2051.3</td>
</tr>
<tr>
<td>Self-generated electricity (40%)</td>
<td>Reduce carbon in step with renewal of power plants and other facilities</td>
<td></td>
<td>Our power plants CO2 free</td>
</tr>
<tr>
<td>Fuel (8%)</td>
<td>Introduction of energy-saving facilities</td>
<td>Deploy catenary and battery-powered hybrid railcars</td>
<td>Develop fuel cell railcars, conduct verification tests, etc.</td>
</tr>
</tbody>
</table>

Tohoku area CO2 free by FY2031.3

Our power plants CO2 free
Energy Creation – Introducing Renewable Energy

Targets
0.7 GW in FY2031
1 GW in FY2051.

The JR East Group’s current renewable energy development plan

- **Akita Prefecture**
  - In operation
    - Mihojima Wind Farm* 5MW
    - Mitane Wind Farm* 7.5MW
    - JR Akita Misohama Wind Power 2MW
    - Development feasibility study underway
      - Yuri Honjo Offshore Wind Power Project* Approx. 700MW
      - Noshibo, Mitane and Oga in Akita Prefecture Offshore Wind Power Project* Development feasibility study underway
  - Undergoing assessment or development
    - Nishime-Nishinosawa Wind Power Project* Approx. 7.5MW
    - Yuri-Duchi Wind Power Project* Approx. 42MW

- **Yamagata Prefecture**
  - Undergoing assessment or development
    - Kuriko-Yama Wind Power Project* Approx. 34MW

- **Kanagawa Prefecture**
  - In operation
    - J Bio Food Recycle’s Yokohama plant

- **Chiba Prefecture**
  - In operation
    - Otaki Solar Power Plant* Approx. 15MW

The star (*) indicates JR East Energy Development Co., Ltd. development and investment projects.
- Wind power generation
- Solar power generation
- Geothermal power generation
- Wood biomass power generation
- Biogas power generation

- **Aomori Prefecture**
  - In operation
    - Hachinohe biomass power plant Approx. 12MW
    - Undergoing assessment or development
    - Nasheji-Shiboukai Wind Power Project* Approx. 7.5MW

- **Iwate Prefecture**
  - Development feasibility study underway
    - Omata-kunakama southern Geothermal Assessment

- **Miyagi Prefecture**
  - In operation
    - Osaki Sambongi Solar Power Plant* Approx. 6MW
    - Scheduled to start operations in FY2023
    - Tohoku Bio Food Recycle Sendai Plant Approx. 0.8MW

- **Fukushima Prefecture**
  - In operation
    - Tomioka Revitalization Mega Solar Power Plant SAKURA* Approx. 30MW
    - Undergoing assessment or development
    - Otaki-Yama Wind Power Project* Approx. 150MW
    - Kawauchi Onitama-Yama Wind Power Project* Approx. 45MW
    - Ukamae-Yama Wind Power Project* Approx. 30MW
    - Kagura-San Wind Power Project* Approx. 60MW

- **Ibaraki Prefecture**
  - In operation
    - Tohama Solar Power Plant* Approx. 17MW
    - Undergoing assessment or development
    - Daigai Solar Power Plant* Approx. 40MW
Energy Creation – Operating our Plants

JR East breakdown of electricity consumption FY2021.3

- Power Purchases: 2.36TWh (42%)
- Self-Generation: 3.33TWh (58%)

60%: Self-generation electricity
40%: Purchase electricity

Tokyo Area (FY2020)

- Self-Generation: 3TWh (79%)
- Power Purchases: 0.84TWh (21%)

- Hydroelectric: 1.21TWh (36%)
- Thermal: 2.12TWh (63%)

Approx. 80% Self-generation

60%: Hydroelectric
40%: Thermal

Chubu Electric Power Company, Incorporated Area

Tokyo Electric Power Company Holdings, Inc. Area

Tohoku Electric Power Co., Inc. Area

Hydroelectric Power Plant

Thermal Power Plant

Energy Creation – Operating our Plants
Energy Creation – Hydro Power Station

- Location: Shinano-gawa River Water System (Niigata Pref.)
- Total Output: 449,000kW
- Power Generation: 1.23 billion kWh annually
Energy Creation – Thermal Power Station

We renewed with combined cycle power generation, and switched LNG from kerosene, which reduced CO2 emissions. We achieved higher efficiency of the power generation facilities, and we will consider the use of hydrogen as fuel and CCUS* technology in the renewal.

*Carbon Capture Utilization and Storage.

◆ Location : Kanagawa Pref.
◆ Total Output : 809,000kW
◆ Power Generation : 2.07bil kWh/y
We are promoting the installing energy storage facilities for utilizing regenerative energy.

- **Regenerative Energy Storage (Battery Post)**
  - Storing regenerative energy generated when trains brake in an energy storage device

- **Regenerative Inverter**
  - Stored regenerative energy is converted from DC to AC, and used for train operation

- **RPC (Railway Static Power Conditioner)**
  - Also, stored regenerative energy is used for other sections
Energy Storage

We are developing a Superconducting Flywheel, which can minimize energy decrease due to friction loss as well as eliminating the need for periodic large-scale maintenance.
Energy Saving – Rolling Stocks

Introduction of energy-saving vehicles which possess:
- Regenerative Brake
- VVVF Invertor; Variable Voltage, Variable Frequency

E235 Series Commuting train
E7 Series Shinkansen
Energy Saving – Rolling Stocks

We have reduced energy consumption for train operations.

Energy Consumption

Energy Saving – Rolling Stocks (non-electrified section)

We have proactively introduced **Hybrid Railcar** (Diesel-Powered, Electric-Motor-Driven), and **ACCUM**, an electrically driven railcar whose energy is derived from rechargeable batteries.

- **Oga Line** (ACCUM)
- **Karasuyama Line** (ACCUM)
- **Komi Line** (Hybrid)
- **Gono Line etc.** (Hybrid)
- **Senseki-Tohoku Line** (Hybrid)

Note: Electrically Driven railcar
Energy Saving – *ecoste*

*ecoste* Environment Earth Conscious Station of East Japan Railway Company

We are introducing a variety of elements at stations under the 4 headings.

- **Energy Conservation**
  Promoting more advanced energy conservation

- **Energy Creation**
  Actively implementing renewable energy

- **Eco-Awareness**
  Preparing facilities evoking users’ eco-awareness

- **Environmental Harmonization**
  Creating vitality by harmonizing people with their environment
Energy Saving – *ecoste*

We have introduced 12 *ecoste* stations and will continue to develop.
Energy Saving – *Oga station*

We introduced 9 small wind turbines and batteries, supplying the electricity to facilities at the station. Excess power is used for ACCUM, battery driven train.

Oga Station is a CO2-free station operated with electricity from JR Akita Shimohama Wind Power Station.
Energy Saving – Musashi-Mizonokuchi Station

The hydrogen-based autonomous energy supply system (H2One) is in operation to use hydrogen from renewable as a model station. Electricity is used for LED lighting on the platforms. Under emergency, it is used for lightings outside of the station and restrooms.
Diversification of Energy - Hydrogen Energy

We will continue to work to diversify our energy sources, and we will accelerate efforts to realize a hydrogen society based on our station and railway line resources.

- Hydrogen Station Opening
- Adapting Fuel Cell Buses and replacing business-use automobiles
- Hybrid railcar (fuel cell) test trains (HYBARI)
Diversification of Energy – Hybrid/Fuel Cell Test Trains

We will commence trial runs of hydrogen-powered fuel cell test trains on the Tsurumi Line and other lines starting in FY2021.

Roadmap for achieving hybrid/Fuel Cell Trains

<table>
<thead>
<tr>
<th>~FY2031.3</th>
<th>~FY2041.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop fuel cell railcars</td>
<td>Consider line segments for deployment</td>
</tr>
<tr>
<td>Conduct verification tests</td>
<td>Implement for passengers</td>
</tr>
</tbody>
</table>
TCFD Recommendation-Related Initiatives

In January 2020, JR East announced its support for the Task Force on Climate-related Financial Information (TCFD) recommendations. We analyzed the financial impact until 2050 based on the flooding scenario, and the estimated financial impact as follows;

<table>
<thead>
<tr>
<th>Presence or absence of inundation measures</th>
<th>Scenario</th>
<th>Increase in financial impact (Billion of yen) (decrease in fares and increase in disaster recovery expenses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No inundation measures (hardware / software)</td>
<td>RCP2.6(2℃)</td>
<td>+51.4</td>
</tr>
<tr>
<td></td>
<td>RCP8.6(4℃)</td>
<td>+60.0</td>
</tr>
<tr>
<td>Inundation measures in place (hardware / software)</td>
<td>RCP2.6(2℃)</td>
<td>+19.8</td>
</tr>
<tr>
<td></td>
<td>RCP8.6(4℃)</td>
<td>+24.2</td>
</tr>
</tbody>
</table>

In order to alleviate the risks and financial impact, JR East has developed countermeasures for natural disasters according to the importance of facilities from both perspectives of hardware (facilities) and software (human responses).

For example, decision support system for vehicle evacuations.

For details can be found on our website JR-EAST:Integrated Report.
Thank you for your attention.
Questions
Discussion

Koji KASAI
Deputy General Manager,
Corporate Management Planning
Department,
East Japan Railway/JR East

Thank you for your attention.
Questions

Discussion

General

Thank you for your attention.
Stay in touch with UIC:

www.uic.org

#UICrail

Medias to be made available on the event page
https://uic.org/events/trackside-energy-storage

Thank you for your attention.