

**GX Infrastructure**  
**with Digital x Energy**  
**for Carbon Neutral**  
**by EP 100**

**(\*) EP: Energy Productivity**

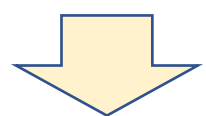
**Hiroshi Esaki, Ph.D.,**  
**Professor, The University of Tokyo**  
**Director, WIDE Project**  
**Vice President, Japan Data Center Council (JDCC)**  
**Director, Green Univ. of Tokyo (GUTP).**

# Overcoming pollution in Kitakyushu City (論語と算盤: economy and ethics)

【資料：小宮山 宏 先生】



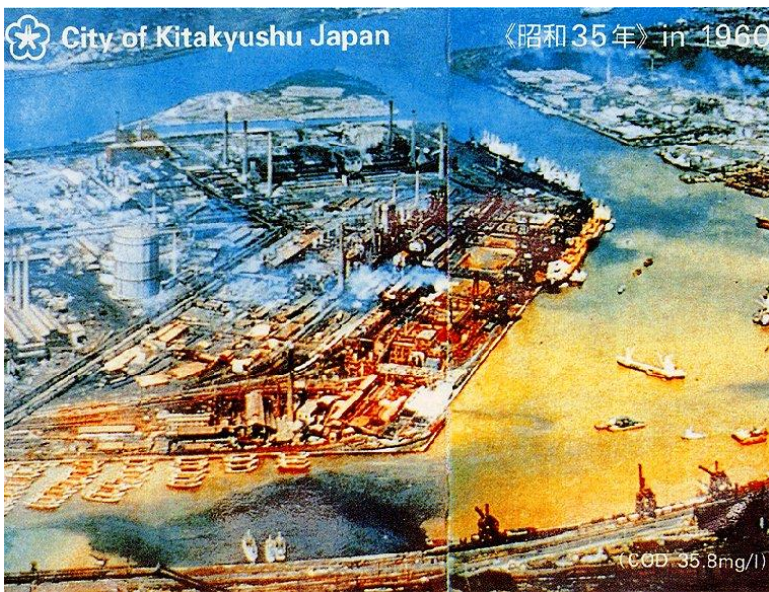
① damage to **life**  
= **Public** interest,  
not private



② ↗ **EP** = **Private** interest  
by reduce ↘ **wastes**  
with **new technologies**



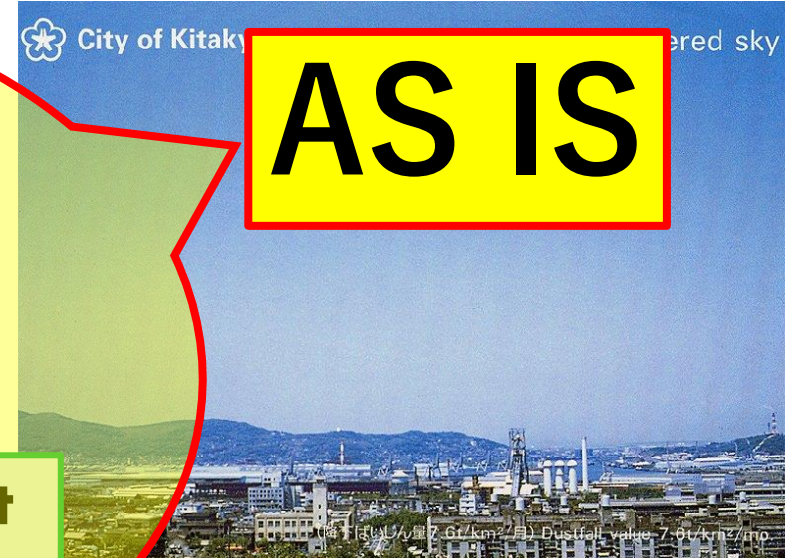
③ To **new** industry  
= **Private** interest  
+ ↗ **tax** revenue  
(= **Public** interest)  
**Good ESG Scope 3**



# Overcoming pollution in Kitakyushu City

(論語と算盤: **economy and ethics**)

【資料：小宮山 宏 先生】



**AS IS**

① **damage to life**  
= **Public** interest,  
not private



② ↗ **EP** = **Private** interest  
by reduce ↗ **wastes**  
with **new technologies**



③ **To new industry**  
= **Private** interest  
+ ↗ **tax revenue**  
(= **Public** interest)  
**Good ESG Scope 3**



**TO BE**

# 【Message 1/2】

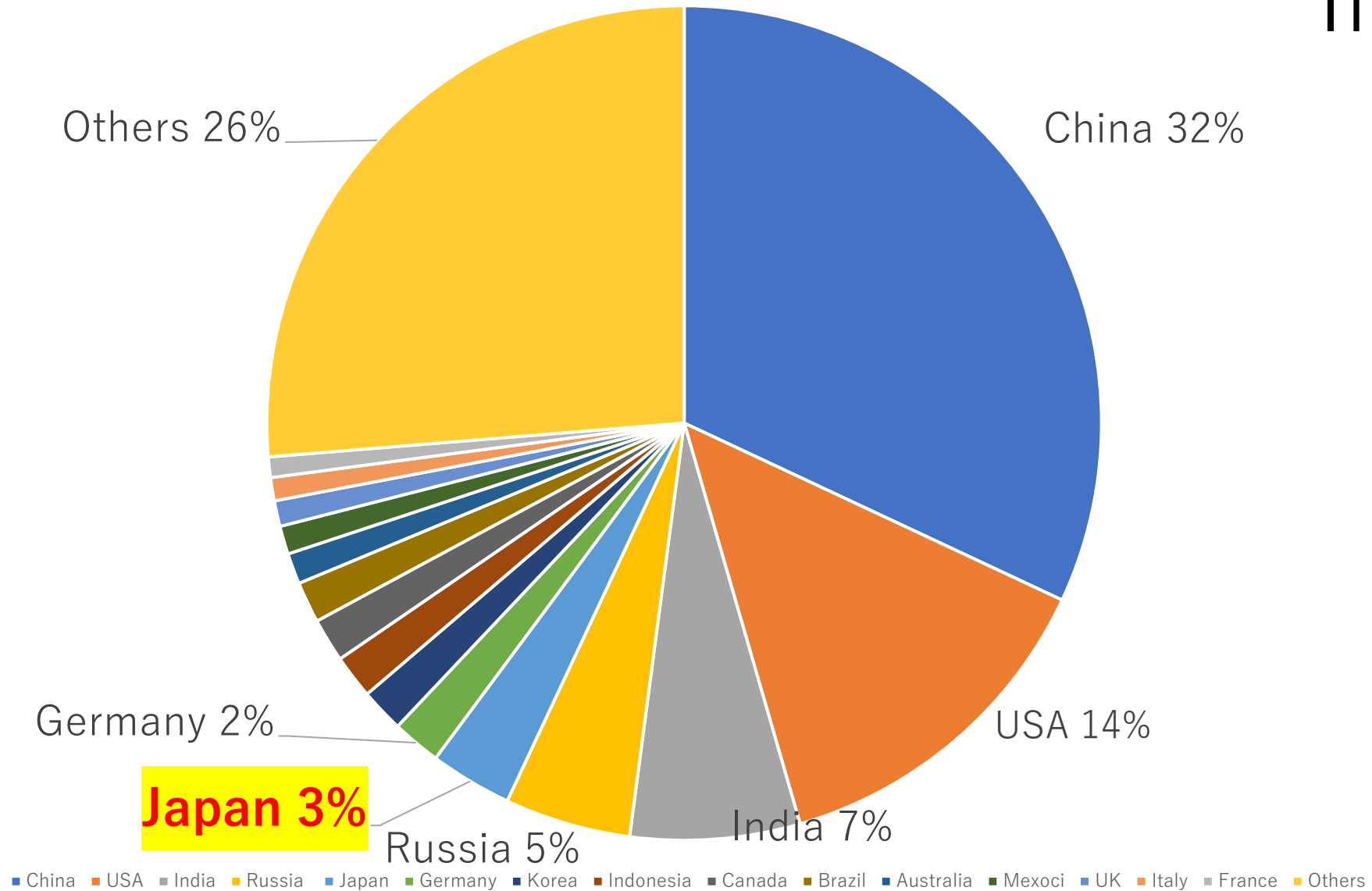
**Carbon Neutral**  
**by**

**EP** **100** (=50%)

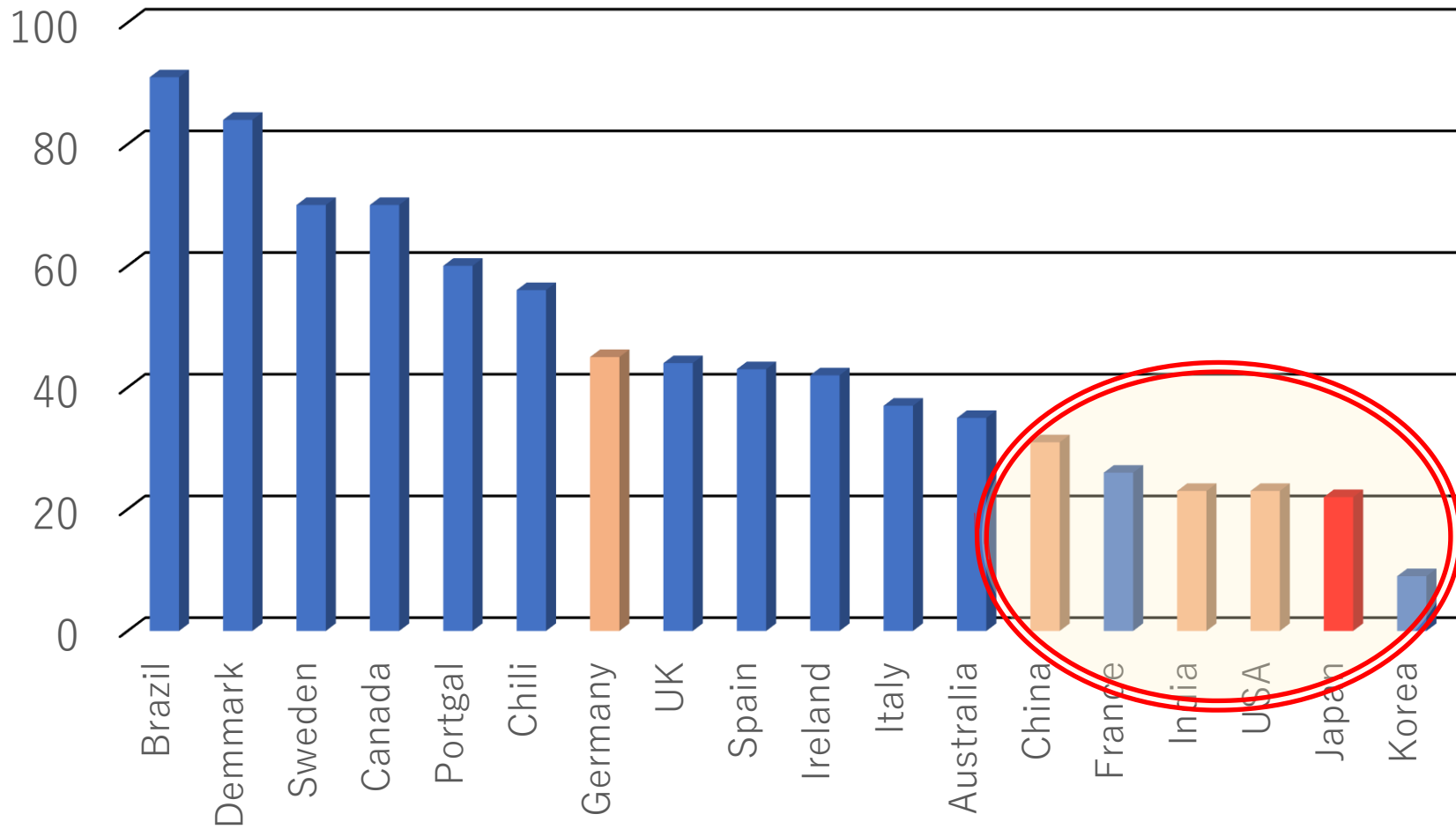
**x**

**RE-50** (not 100%, but **50%**)

# In 2022



# Renewal Energy Ratio in 2022



# Germany, UK, Spain, Ireland

	Now	Target
EP (Energy Productivity)	100	50 (Reduce <b>50%</b> )
RE (Renewal Energy)	40	50 ( <b>Plus only 25%</b> )

# India, USA, Japan

	Now	Target
EP (Energy Productivity)	100	50 ( <b>Reduce 50%</b> )
RE (Renewal Energy)	20	50 ( <b>Plus 150%</b> )



**Techniques for reducing  
energy consumption  
in each business segment**

# Techniques for reducing energy consumption in each business segment

- 1. Reduce the number of {physical} things newly required when we build a system**
- 2. Reduce the amount of required energy during system operation (AS IS)**
- 3. Reduce costs required for system construction and operation (TO BE)**

# Techniques for reducing energy consumption in each business segment

- 1. Reduce the number of {physical} things newly required when we build a system**
  - a. Replacing “things newly needed” with “things manufactured in the past” by applying reusing/recycling/circular economy**
  - b. Reduce “things newly needed” by sharing economy**
- 2. Reduce the amount of required energy during system operation (AS IS)**
- 3. Reduce costs required for system construction and operation (TO BE)**

# **(1) Reusing/recycling/circular economy**

## **Practical examples:**

**i. Reuse of used EV battery and computing capacity**

**ii. Scrap & Build to Skelton & Infill  
in Buildings**

## i. Reuse of used EV battery at Amsterdam stadium

### ■ {Electric} Power distribution base

#### Capacity of EV's used battery packs

✓ **3MWh only with 148 EVs**

✓ **100KW in peak per EV**

✓ **20KW in average per EV**

**1. Normal situation;**

**Power DR (Demand Response)**

**2. Emergency case;**

**Local self power supply**



# Energy x Digital

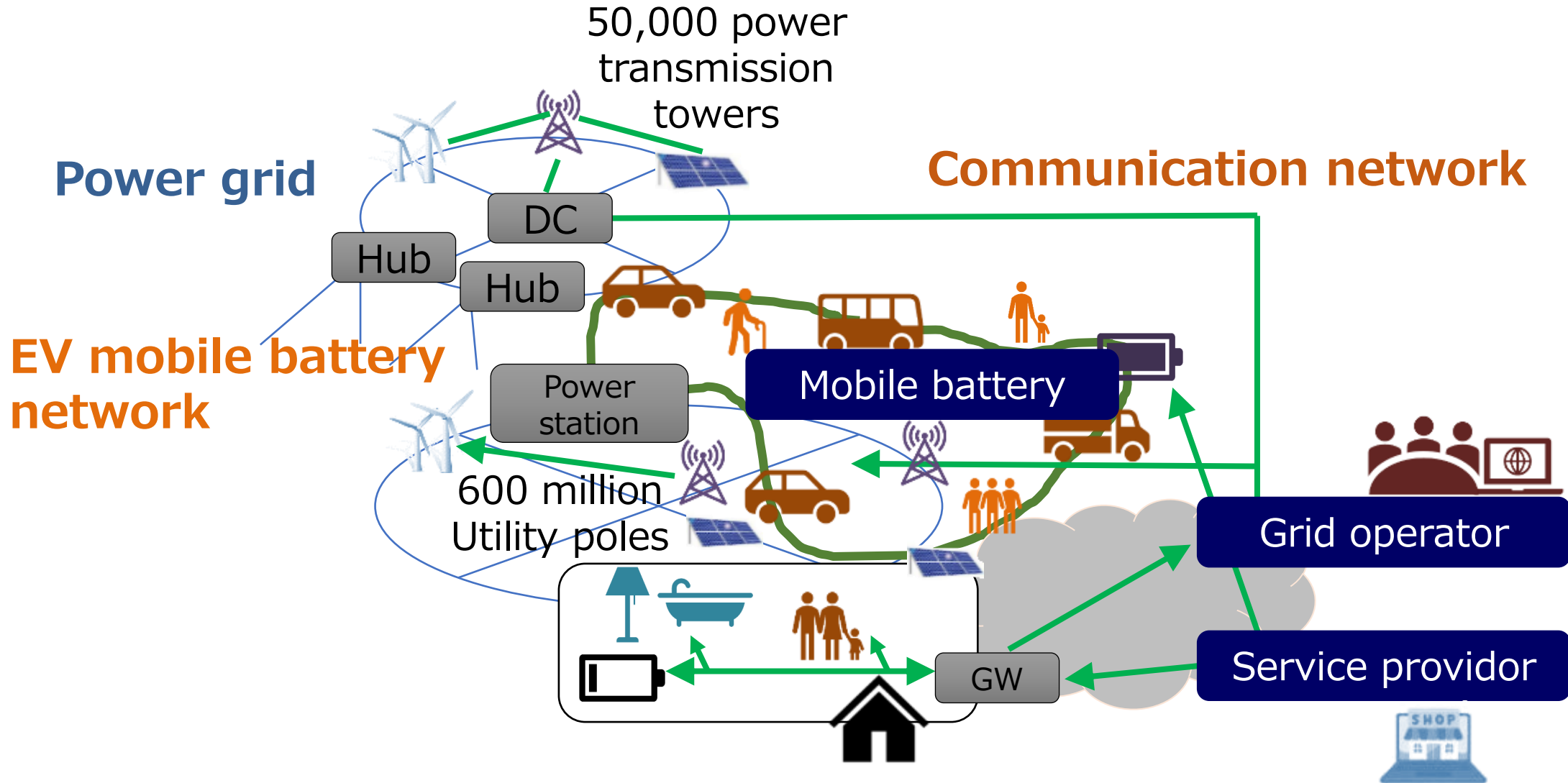
## EV as new component

【Operating rate】

- Private : 4~5%
- Commercial : 24%

1. **B**attery
2. **C**omputation
3. **M**obility

# ① Battery x ② Computation x ③ Mobility



# ① Battery x ② Computation x ③ Mobility

50,000 power

◆ Nissan EV : 30kW(Ave.), {100kW(Peak)}, 100kWh



1.  $10^6$  (1 millions) : 30GW(Ave.), 100 GWh(Peak)

➤ Pumped storage power in TEPCO (=9GWh) **x 10**

➤ 黒部ダム (=335MW) **x 10**

2. 100 EVs : 3MW(Ave.), {30MW(Peak)}

➤ Eng.No.2 Bldg (12F) : 700kW (≐ **35 EVs**)

➤ Hongo Campus(No.2 in Tokyo) : 30MW (≐ **1 k EVs**)



# ① Battery x ② Computation x ③ Mobility

50,000 power

◆ Tesla (by AMD@CES2023) : **10 T**FLOPS ( $10^{13}$ )

<https://car.watch.impress.co.jp/docs/news/1469629.html>

◆ 富岳 (No.3 Super Computer) : **1,000 P**FLOPS ( $10^{18}$ )

➤ **3 T**FLOPS/node

➤ 158,976 nodes ( $1.5 \times 10^5$ )

<https://www.fujitsu.com/jp/about/businesspolicy/tech/fugaku/specifications/>



$100k(=10^5)$  Tesla  $\div$  富岳 (No.3 Super Computer)

## ii. Scrap & Build to Skelton & Infill in Buildings

by Prof. Nicolaas John Habraken of MIT in the 1960s.

- ① No need to dismantle and rebuild the frame, ② waste (including industrial waste) can be reduced, and resources and energy required for ③ rebuilding can be reduced

- ✓ Condominium in China
- ✓ Rapid functioning in East Germany after cold war

### ■ Sharing hardware

- Owner's exclusive (not sharing) asset among multiple generations
- Sharing assets by tenants among same generation

### ■ Digital Twin in Hardware and Software

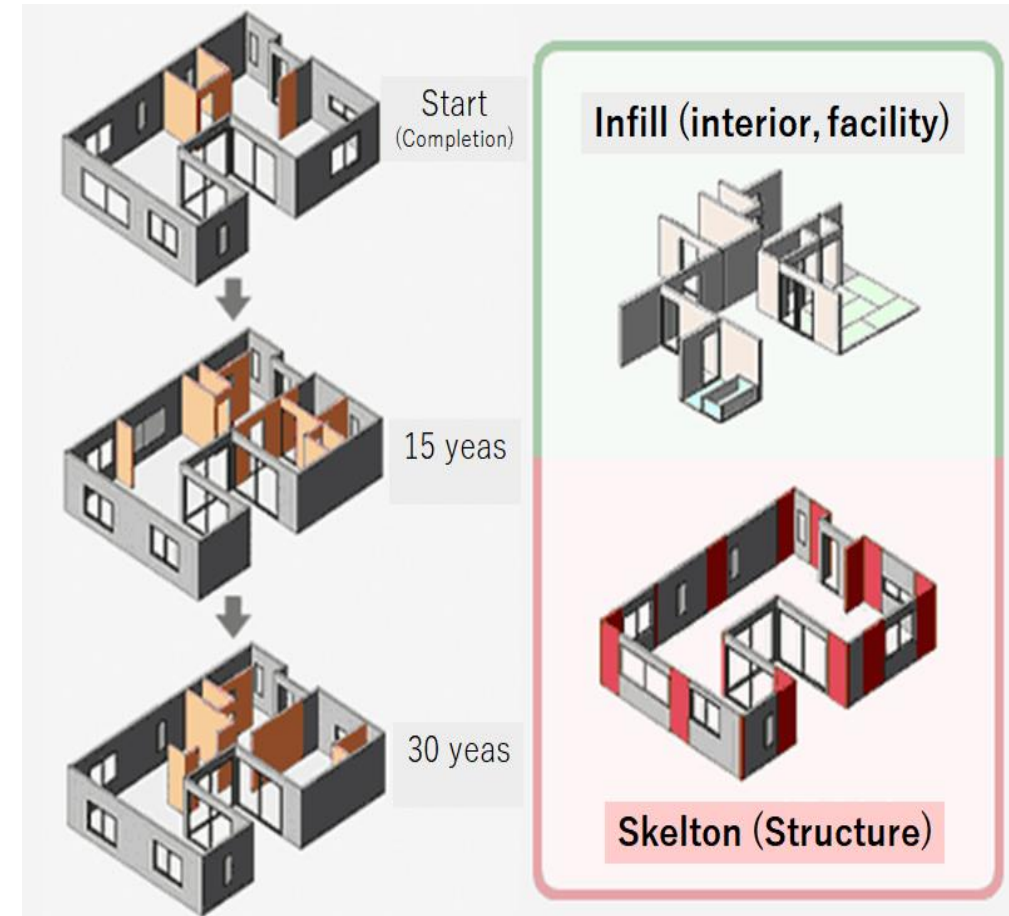


Fig.8 Skelton & Infill (as Hardware)

# Techniques for reducing energy consumption in each business segment

1. Reduce the number of {physical} things newly required when we build a system
2. Reduce the amount of required energy during system **operation (AS IS)**
  - **Cloud** by Default
  - Application and diffusion of **digital twins**
3. Reduce costs required for system construction and operation (TO BE)

# Carbon Neutral by **EP-x00** (Energy Productivity)

	<b>Of IT</b>	<b>By IT</b>
<b>AS IS</b>	<ul style="list-style-type: none"><li>● <b>Virtual Machine</b></li><li>● <b>Huge Memory &amp; Processor</b></li></ul>	<b>Digital Twin</b> (CPS; Cyber Physical System) with <b>LoD</b>
<b>TO BE</b>	<b>Electron</b> → <b>Photon</b> → <b>Quantum</b>	<b>Cyber First</b>

# **“Cloud-by-Default”** for **multiple pay off** (June 2018 by Japanese gov.)

1. **De-Silo-ing**: Silo-structure of ministries and agencies should be interconnected as a shared infrastructure to deliver **innovative use of data**, while collapsing walls among them.
2. Leave infrastructure cybersecurity operation to experts.  
Also **reduces & improve fixed costs for personnel** in charge of on-premises facilities.
3. Reduce & improve **CAPEX and OPEX**, {incl labor costs,}.  
Hardware, software, people: from ownership (BS) to usage (PL)
4. Expand **BCP against natural disasters and cyber attacks**.
5. Achieve **energy savings** for contribution to global warming.

# Tremendous earth quake on March 11, 2011



Smart HQ office of  
Microsoft Japan in Tokyo

**【Moving branch offices went to a HQ】**

- ① Any server moves to Data Center
- ② Full online business operation

**【Right after earth quake...】**

- ① Business continuation only with few % of employees in HQ office
- ② Work at home = Safety for employees

**【After earth quake】**

- ① Referenced recommended office for all Microsoft offices
- ② Supporting handicapped employees

# Tremendous earth quake on March 11, 2011



Smart HQ office of  
Microsoft Japan in Tokyo

## ① Life time cost reduction with comfortable working environment by no noisy, hot and big eating servers !!

1. Initial move-in
2. During occupancy
3. Exit and return to status quo

## ② Cyber security improvement (=BCP)

1. Intellectual property on the computers
2. Information leaking

## ③ Energy saving (=CSR)

1. Digital Twin + Cloud computing
2. Big eating computers go to DC

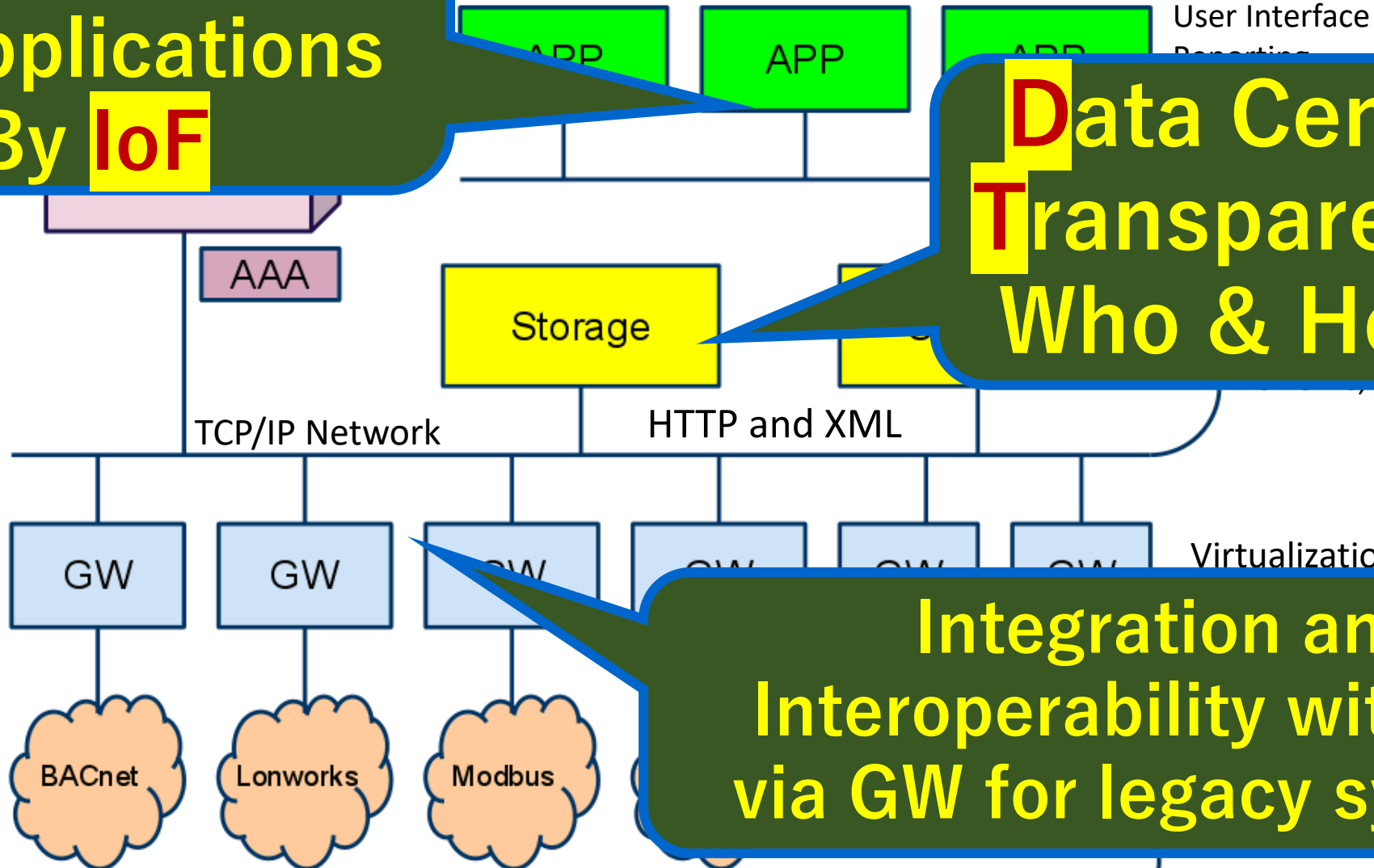
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# System Architecture

Independency  
from hardware  
for applications  
By **IoF**



**D**ata Centric for  
**T**ransparency for  
Who & How use

Integration and  
Interoperability with **LoD**  
via **GW** for legacy systems

# The University of Tokyo in Summer of **2011**

## **Hacking building/campus facilities with IP**

	Peak (2010)	Peak (2011)	Total (2011)	RoI
Major 5 campuses	66 MW	69% ( <b>△31%</b> )	75%-78% ( <b>22%-25%</b> )	less than <b>1 month</b>
Eng. No2 Bldg.	1 MW	56% ( <b>△44%</b> )	69% ( <b>△31%</b> )	<b>2 years</b>

### **[Contributions]**

- 1. Multi-Vender for sustainability by TCP/IP**
- 2. Global standard for interoperability**

The University of Tokyo in Summer of **2011**

**Hacking building/campus facilities with**

**[Fact/Lesson 1]**

**{almost} Only by visualization  
(aka., by **Digital Twin**)**



**25% reduction in total**



**EP-50**

**2. Global standard for **interoperability****

# The University of Tokyo in Summer of **2011** **Hacking building/campus facilities with**

## [Fact/Lesson **2**]

-- Important rule --

Capacity of power network is determined  
by **peak power demand !!**

Reduction of demand at peak time contribute to the  
reduction of

**the cost for capacity of power supply network.**

2. **GLOBAL STANDARD FOR INTEROPERABILITY**

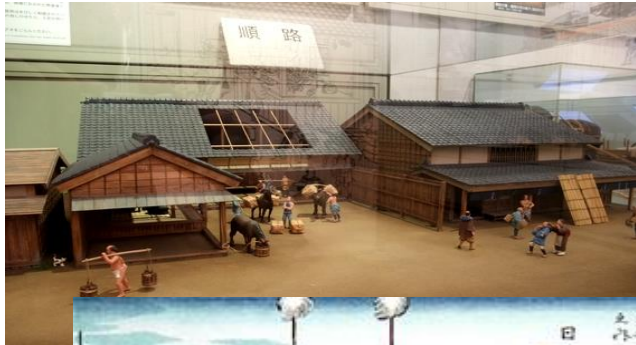
# Techniques for reducing energy consumption in each business segment

1. Reduce the number of {physical} things newly required when we build a system
2. Reduce the amount of required energy during system operation (AS IS)
3. Reduce costs for **construction and operation (TO BE)**
  1. Things can be selected by unbundling things and things  
= **IoF(Internet of Functions)**
  2. Strategic use of communication infrastructure  
"Movement of **physical things**  
>>Movement of **energy** (including power)  
>>Movement of **digital bits** (things and functions that are digitized)".  
(\* ) More than two orders of magnitude smaller

# Innovation in Logistics

2020s = Cyber-First Sharing Economy

19<sup>th</sup> century = exclusive separated system

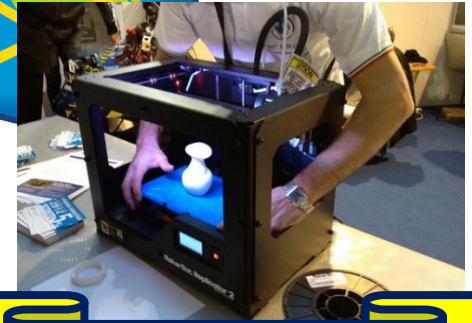


20<sup>th</sup> century

(1) Physical Sharing Economy



Container  
Parrett  
(1956)



General printer  
e.g., 3D printer

Late 20<sup>th</sup> century  
(2) Sharing Economy  
in cyber space

Digital package  
(=IP Packet)

# Innovation in Logistics

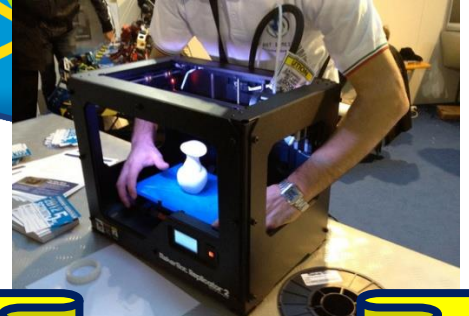
=Cyber-First Sharing Economy

19<sup>th</sup> century =

Object transfer/mobility  
over sharing platform !!

1. **Physical** object

2. **Digital** object



Sharing Economy

Cost of object transfer/mobility?

Physical **>>>** Digital

**Huge** EP(Energy Productivity)  
improvement !!!

Container  
Parrett  
(1956)

# 【Message 2/2】

Transfer cost ... ..  
= Energy Productivity...

**M**aterial >> **E**lectricity >> **D**igital bits  
(**P**ower) (digital **F**unction)

**x0000** : **x00** : **1**



# ~When we Think about the Earth~

① Speed of light is **not fast**...

Inter-Continent: 200-300 msec.

Domestic: 30- 50 msec.

Intra-facility: 2- 3 msec.

② **Mal-distribution** of Renewal Energy

Far North/South  
Cold!!

rural area  
Carbon Negative

# ~When we Think about the Earth~

① Speed of light is **not fast**...

continent: 200-300 m

Don't

It

**3 layered global  
Reconfigurable  
"Computing" Networks**

② **Mal-distribution** of Renewal Energy

Far North/South

rural area

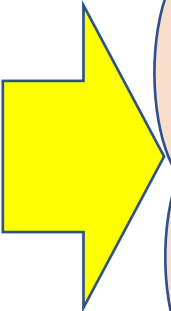
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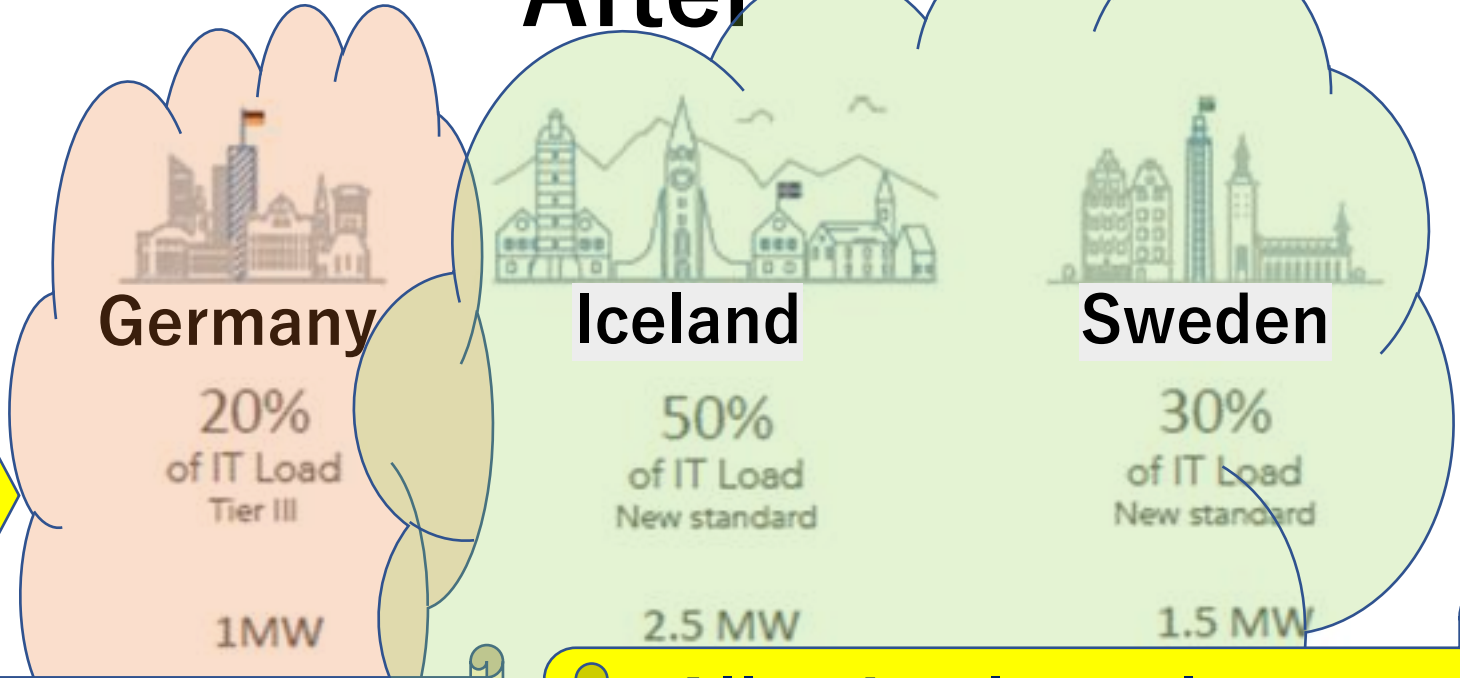
# Business case

# BMW in Germany

## Before



## After



**Small latency  
&  
Critical data  
at {dark-side}DC**

**Allowing large latency  
&  
Non-Critical data  
at cheap and green DC**

## **Transfer** DCs to energy clean sites (Iceland & Sweden)

- ✓ 100% Renewal Energy (Hydro & Geothermal)
- ✓ There are a lot of non-real time processes



### 1. Gentle to Earth

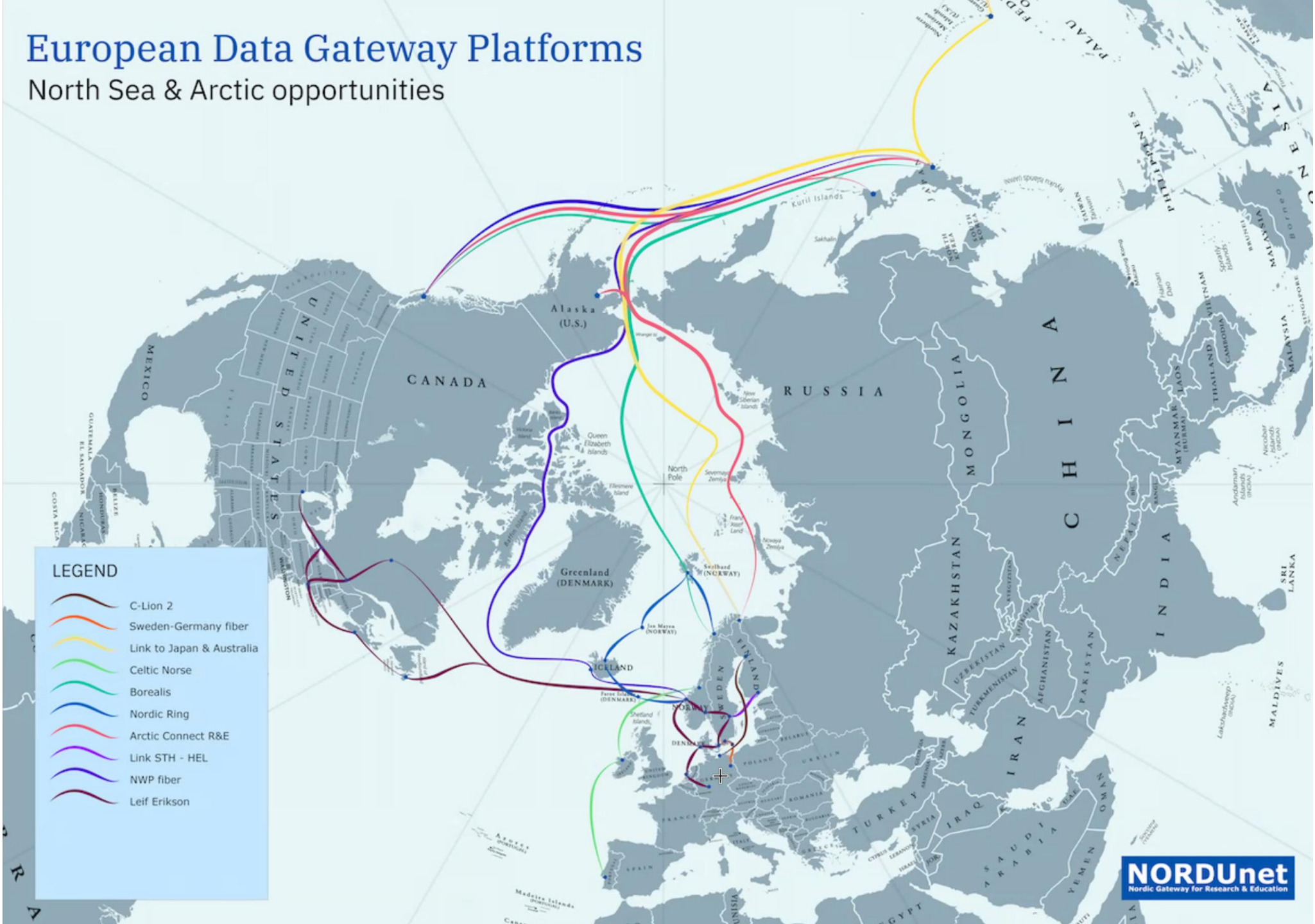
- ✓ by use of renewal energy (RE-100)
- ✓ by use of cool air (EP-100)

### 2. Cost reduction (EP-x000)

- ✓ Replacing power cable (copper) to communication cable (glass)

# European Data Gateway Platforms

North Sea & Arctic opportunities



## HIGH LEVEL OVERVIEW



### CURRENT DESIGN

- The cable transits the Northwest Passage offering a new route in subsea cables
- Significant latency reduction versus routes available today
- 16 fiber pair system
- Landings: dual landings in Japan (Hokkaido and Tokyo region), Europe (Ireland, Norway/Finland) and North America (Prudhoe Bay)
- Branching Units to support remote northern regions

### ESTIMATED LATENCIES

Segment	RTD/ms
Japan (Chikura) – Ireland	152
Japan – Norway/Finland	166
Japan – Alaska (Prudhoe Bay)	70
Alaska – Ireland	82
Alaska – Norway/Finland	96

## PROJECT TIMELINE, PRELIMINARY:

2022 Supply Contract-in-Force (CIF)

2022 - 2023 Marine Route Survey

2022 - 2023

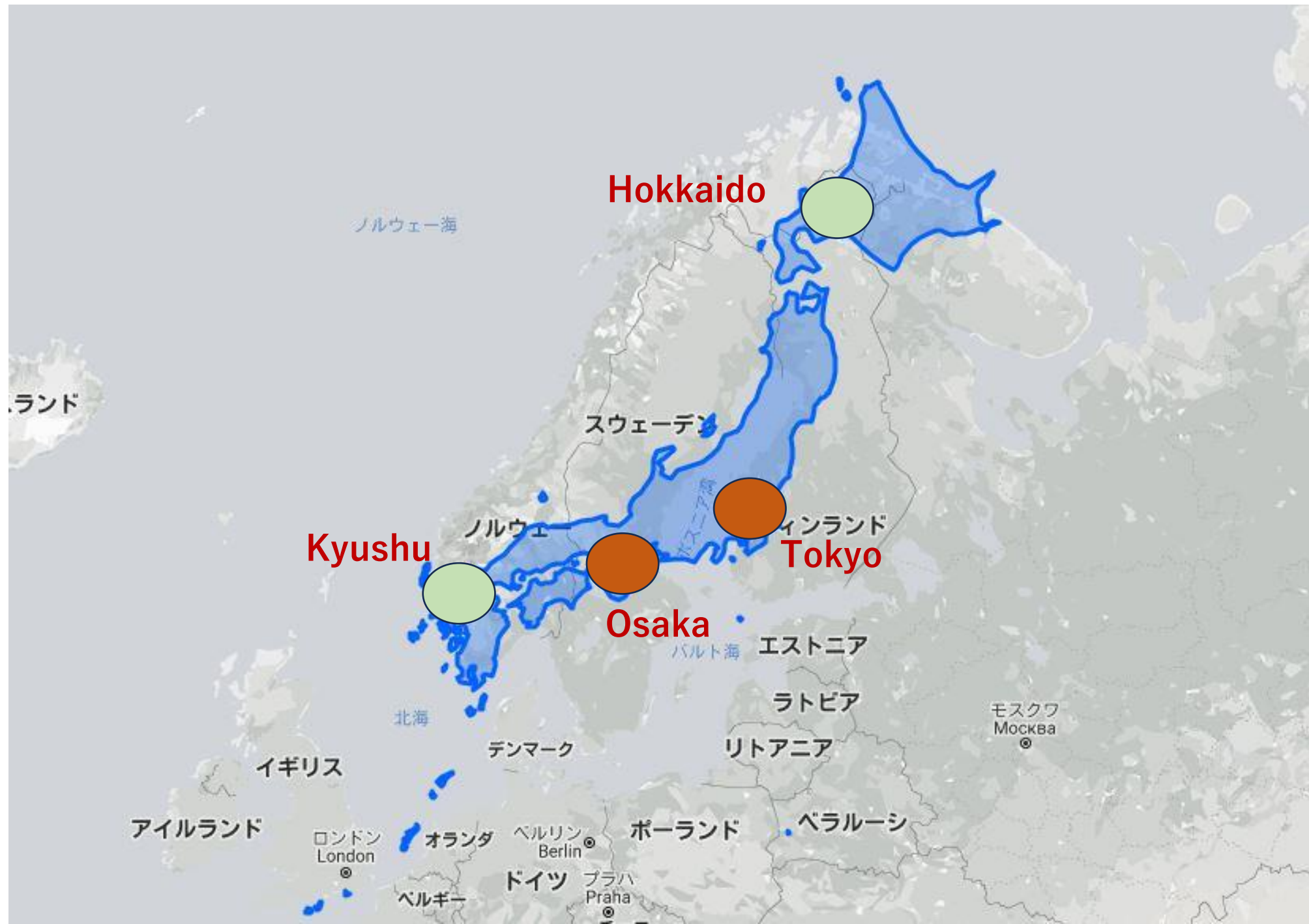
 **Far North Digital, LLC**

2026

 **Cinia**

**ARTERIA**

アルテリア・ネットワークス株式会社



Hokkaido

Kyushu

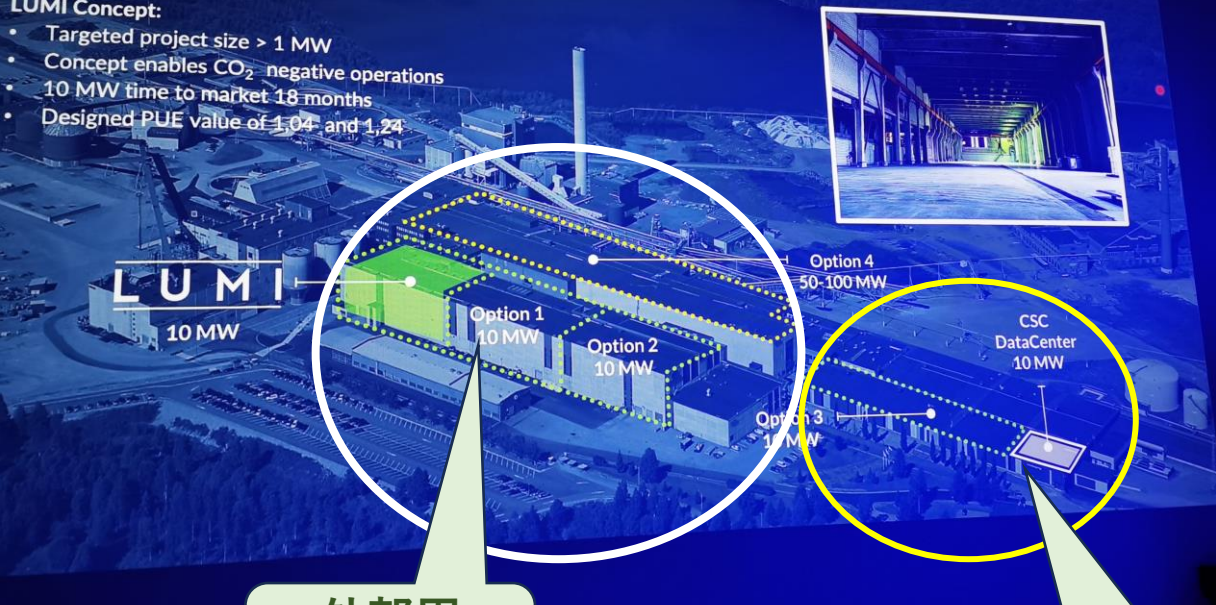
Osaka

Tokyo

# Taylorable LUMI concept



- LUMI Concept:
- Targeted project size > 1 MW
  - Concept enables CO<sub>2</sub> negative operations
  - 10 MW time to market 18 months
  - Designed PUE value of 1.04 and 1.24

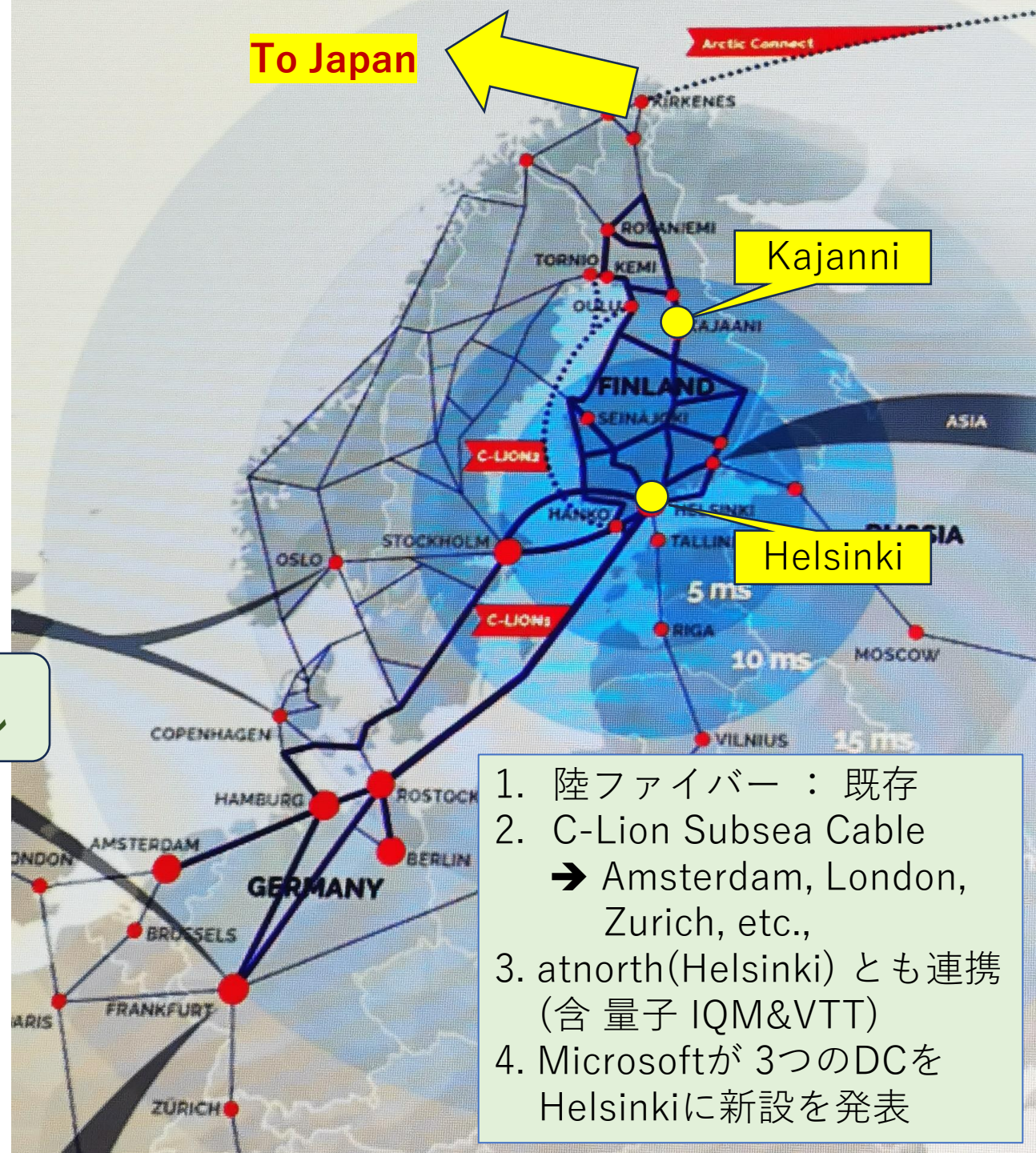
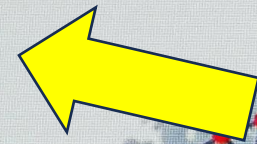


外部用  
スパコン

政府  
スパコン

1. 100% 水冷
2. 非常用自家発電機は無し (データバックアップは有り)
3. 場所・電力の拡張性 有り

To Japan



Kajanni

Helsinki

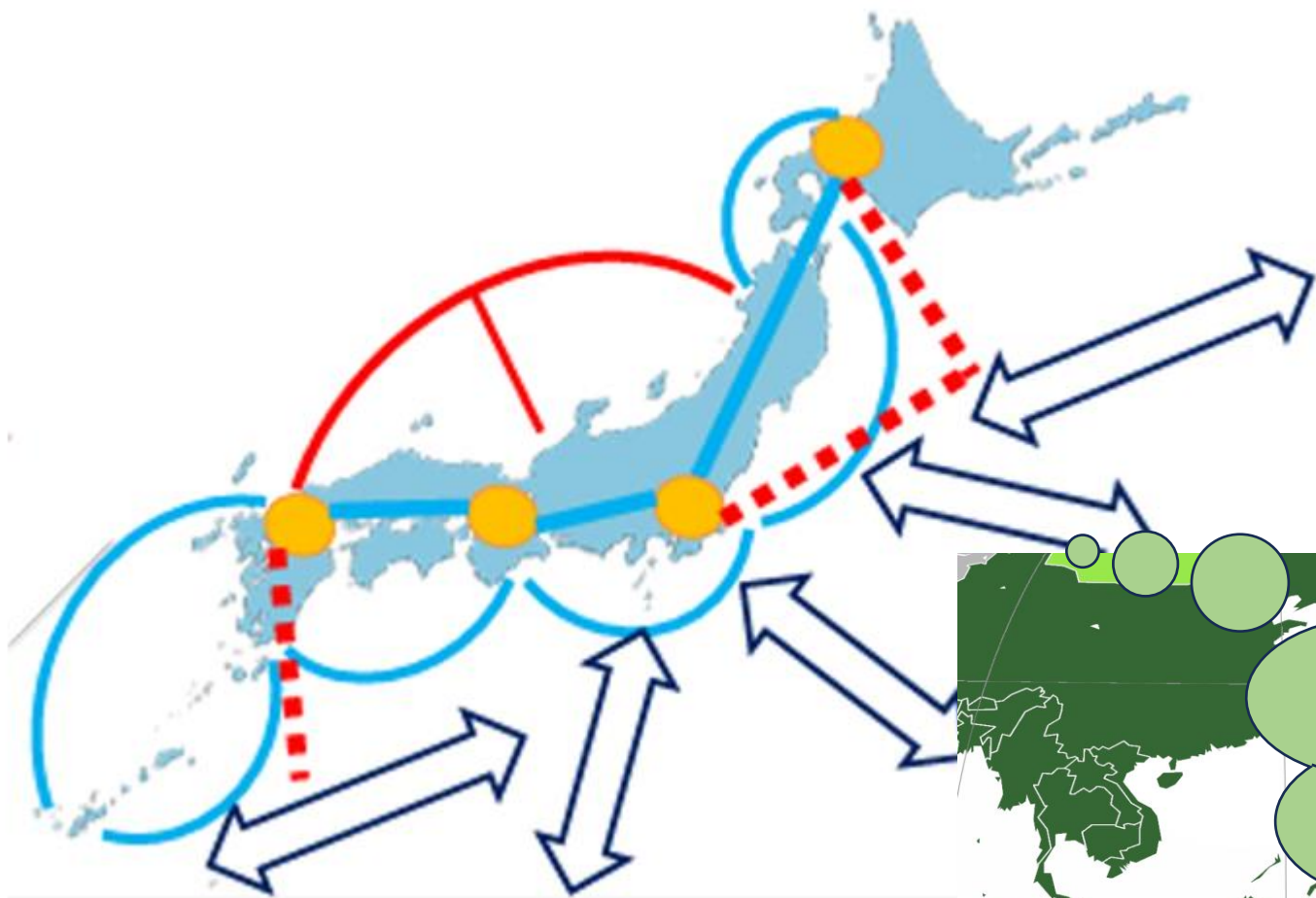
1. 陸ファイバー : 既存
2. C-Lion Subsea Cable  
→ Amsterdam, London, Zurich, etc.,
3. atnorth(Helsinki) と連携 (含量子 IQM&VTT)
4. Microsoftが3つのDCを Helsinkiに新設を発表



visited September 20(Wed), 2023

- 電気代： **1/5 ~ 1/7** !!!
  - ✓ 30 € MWh (5-7円/kWh) from PPA
  - ✓ 日本 35円/kWh
  - ✓ Carbon **“Negative”** も発生
- **製紙工場の跡地を再利用**
  - ✓ 工場の躯体をそのまま利用
  - ✓ 250MWの(既存)電力引き込み
  - ✓ **100% 再生可能エネルギー電力**
- 地域冷暖房システムへの 熱供給
  - ✓ 夏季も販売可能(病院や宿泊施設等)
  - ✓ 大きな **税制優遇(22 € → 0.6 € /MWh)**
  - ✓ 拡大予定
- 北極海ケーブル(FNF)は前提
  - ✓ 2027年 サービス開始の予定



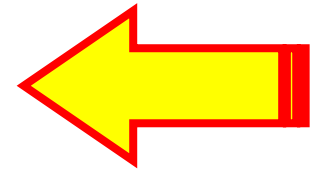


We need **“Global”** collaboration and cooperation

# ~When we Think about the Earth~

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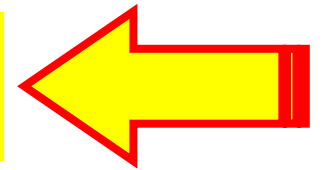
**Moon** 1,000 msec.



Inter-Continent: 200-300 msec.

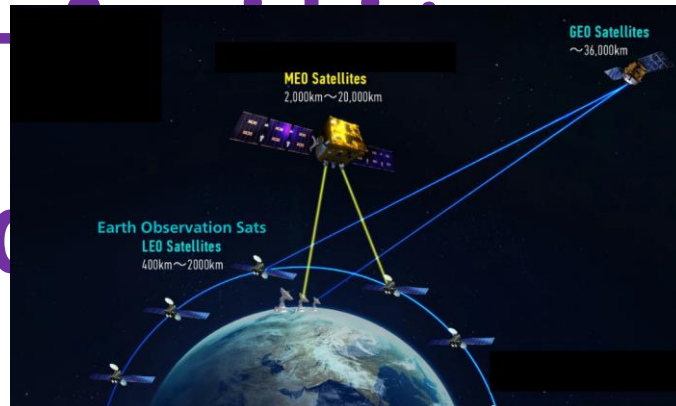
Domestic: 30- 50 msec.

**LOE satellite** 3- 30 msec.

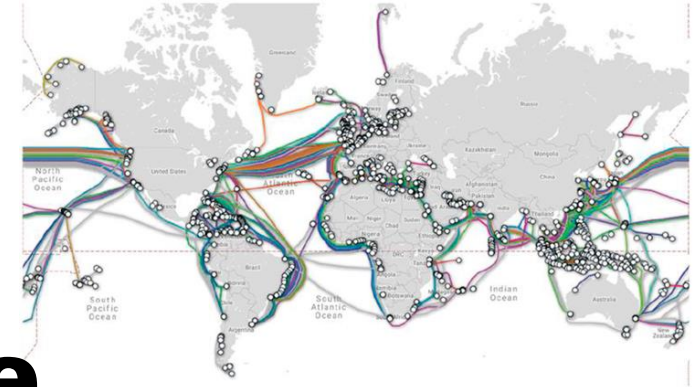


Intra-Continent: 2- 3 msec.

② Mal-... of Renewal Energy



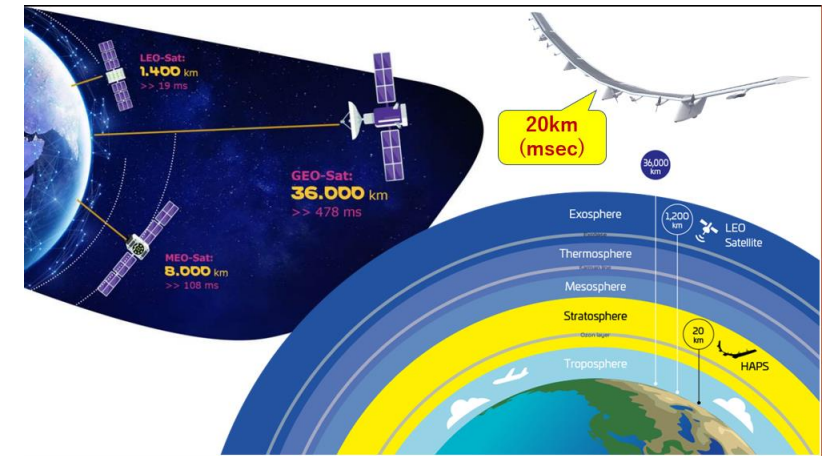
# Infrastructure of Beyond 5G



## 1. Global Internet infrastructure

(a) Terrestrial

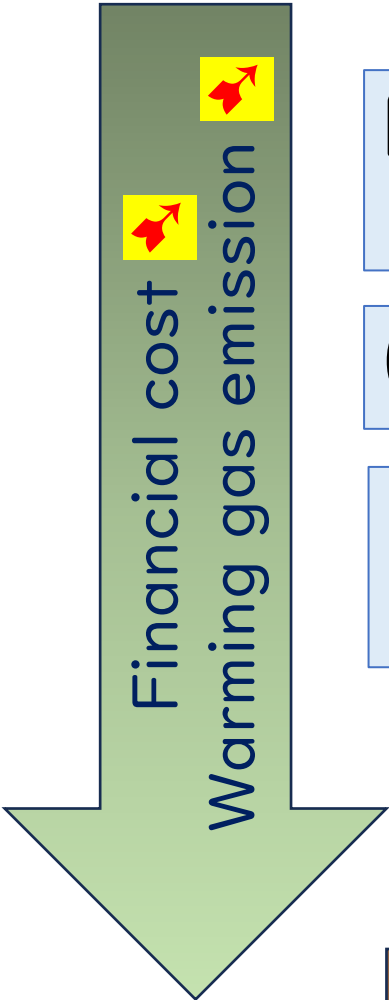
(b) Non Terrestrial



## 2. Energy consumption

(a) Radio AP and front hole

(b) Data Center

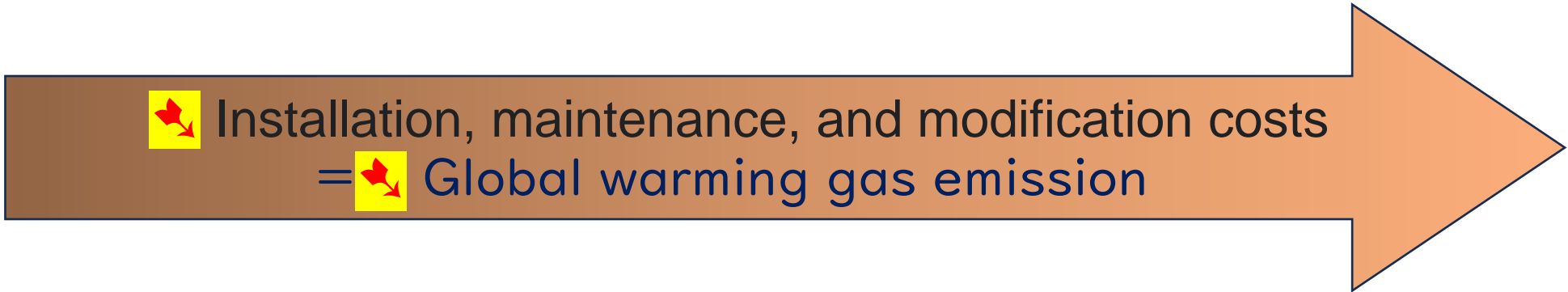


Railway, Road vs Air/Sea Port vs {n/a}  
(train) (vehicle) (airplane) (ship) (drone)

Optical fiber vs Cellular radio vs Satellite/WiFi

Synchronous vs Local grid vs Mobile  
(Japan) (USA/EU) (EV Power grid)

【Surface】 【{fixed}Point】 【{mobile}Point】



Once again...

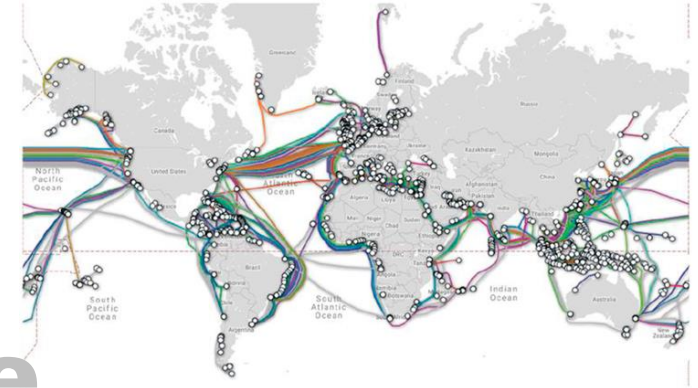
# 【Message 2/2】

Transfer cost . . . . .  
= **E**nergy **P**roductivity...

**M**aterial >> **E**lectricity >> **D**igital bits  
(**P**ower) (digital **F**unction)

**x0000** : **x00** : **1**

# Infrastructure of Beyond 5G



## 1. Global Internet infrastructure

(a) Terrestrial

(b) Non Terrestrial

## 2. Energy consumption

(a) Radio AP and front hole

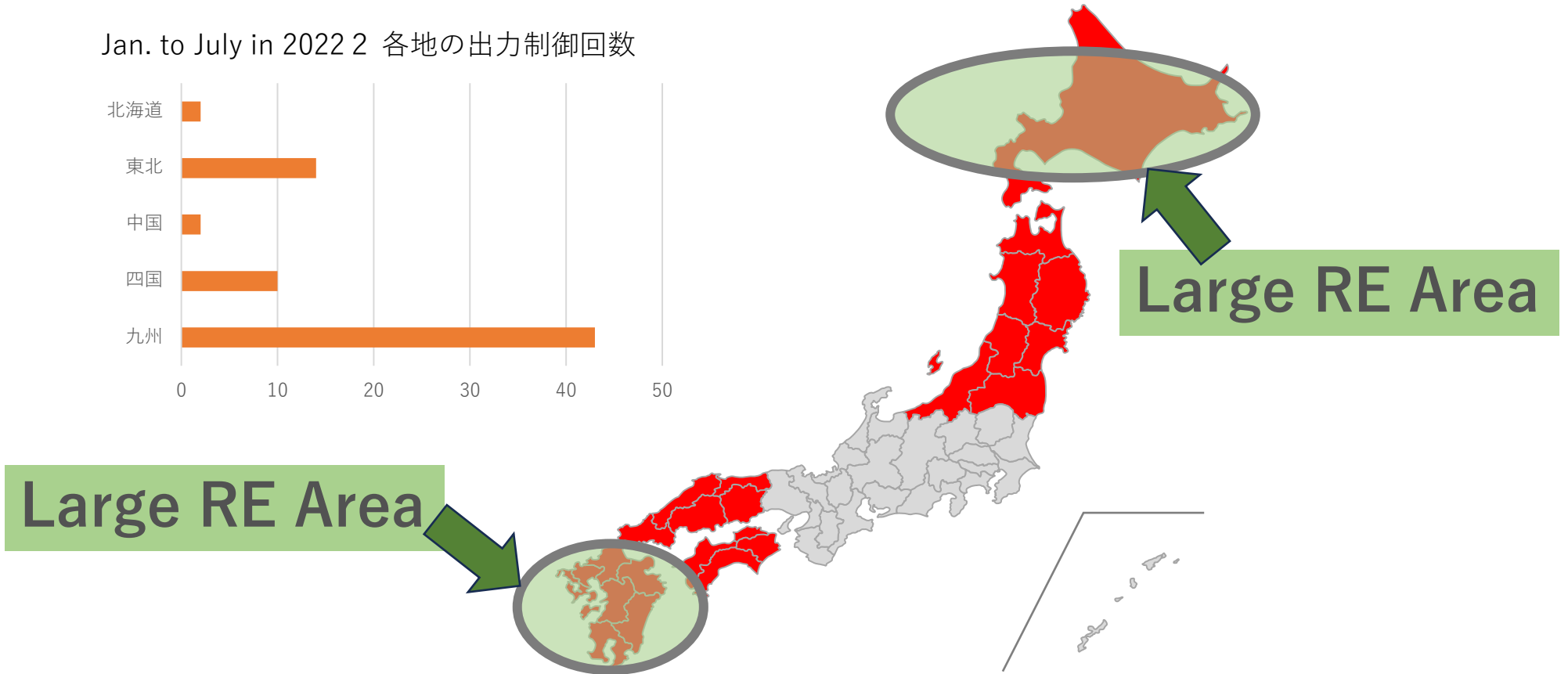
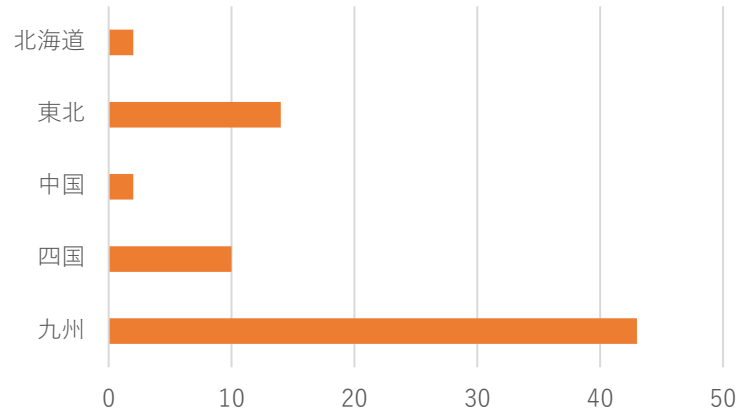
(b) **Data Center with Power Grid**



# Electrical Power shortage in spring and winter in Japan

- 2022年再エネ出力制御は四国・中国・東北・北海道電力管内に拡大

Jan. to July in 2022 各地の出力制御回数



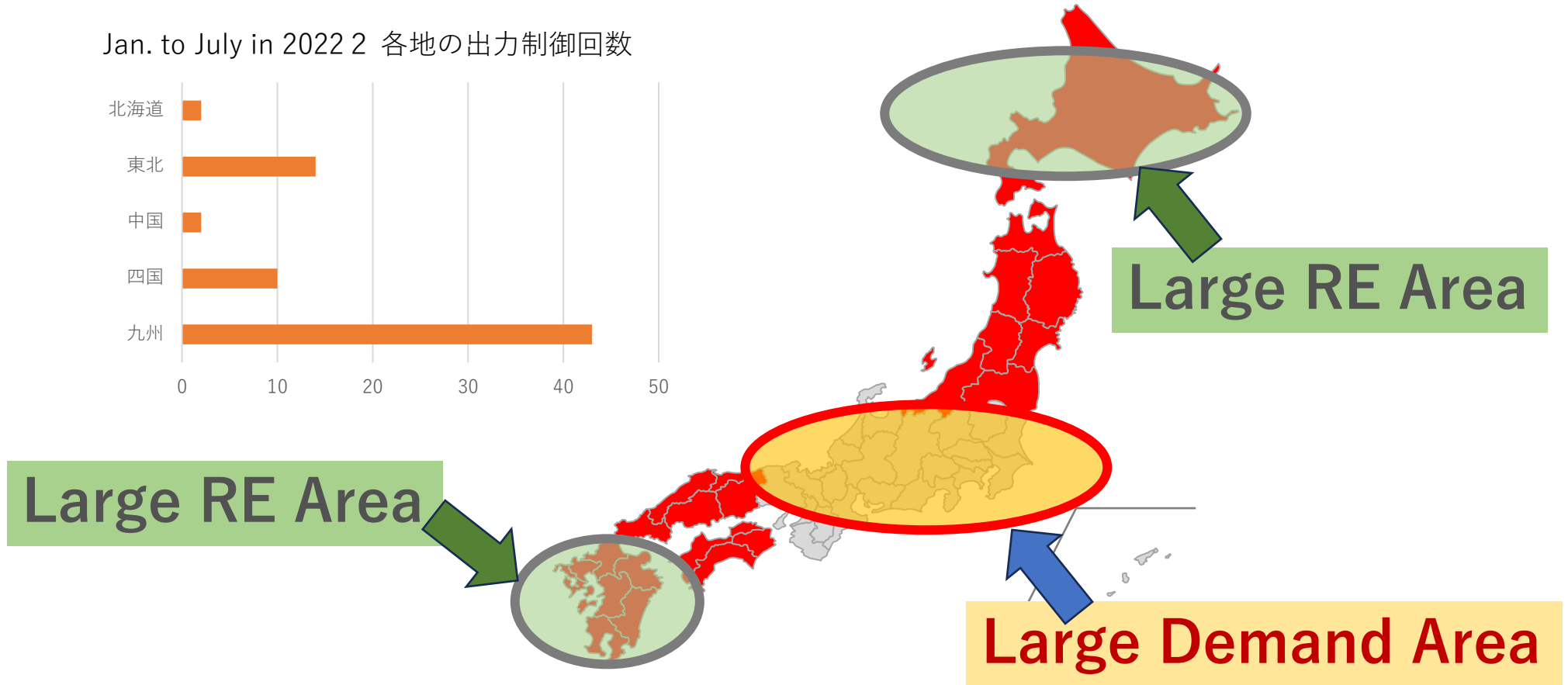
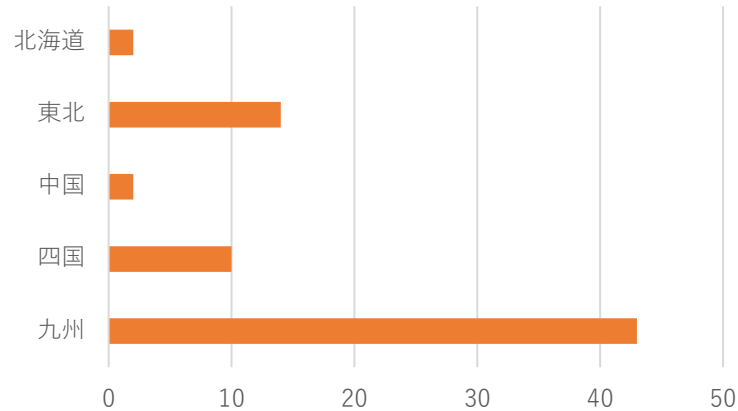
【資料】 ビットメディア 代表取締役社長 高野 雅晴 氏  
第4回イベント（2022年9月28日）  
「データセンターの地域エネルギー貢献」



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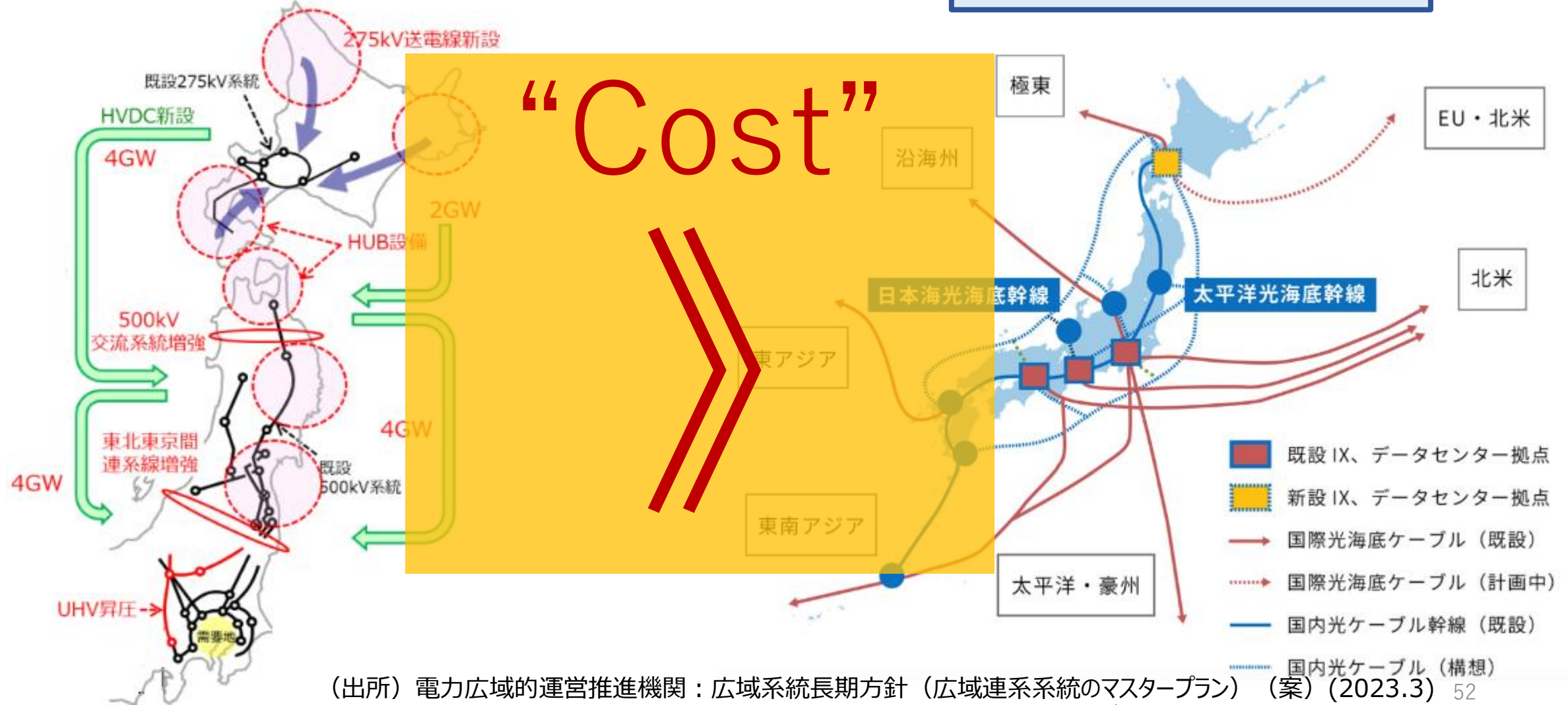


【資料】 ビットメディア 代表取締役社長 高野 雅晴 氏  
第4回イベント（2022年9月28日）  
「データセンターの地域エネルギー貢献」

# As a デジタル田園都市国家構想(Digital Garden City Initiative)

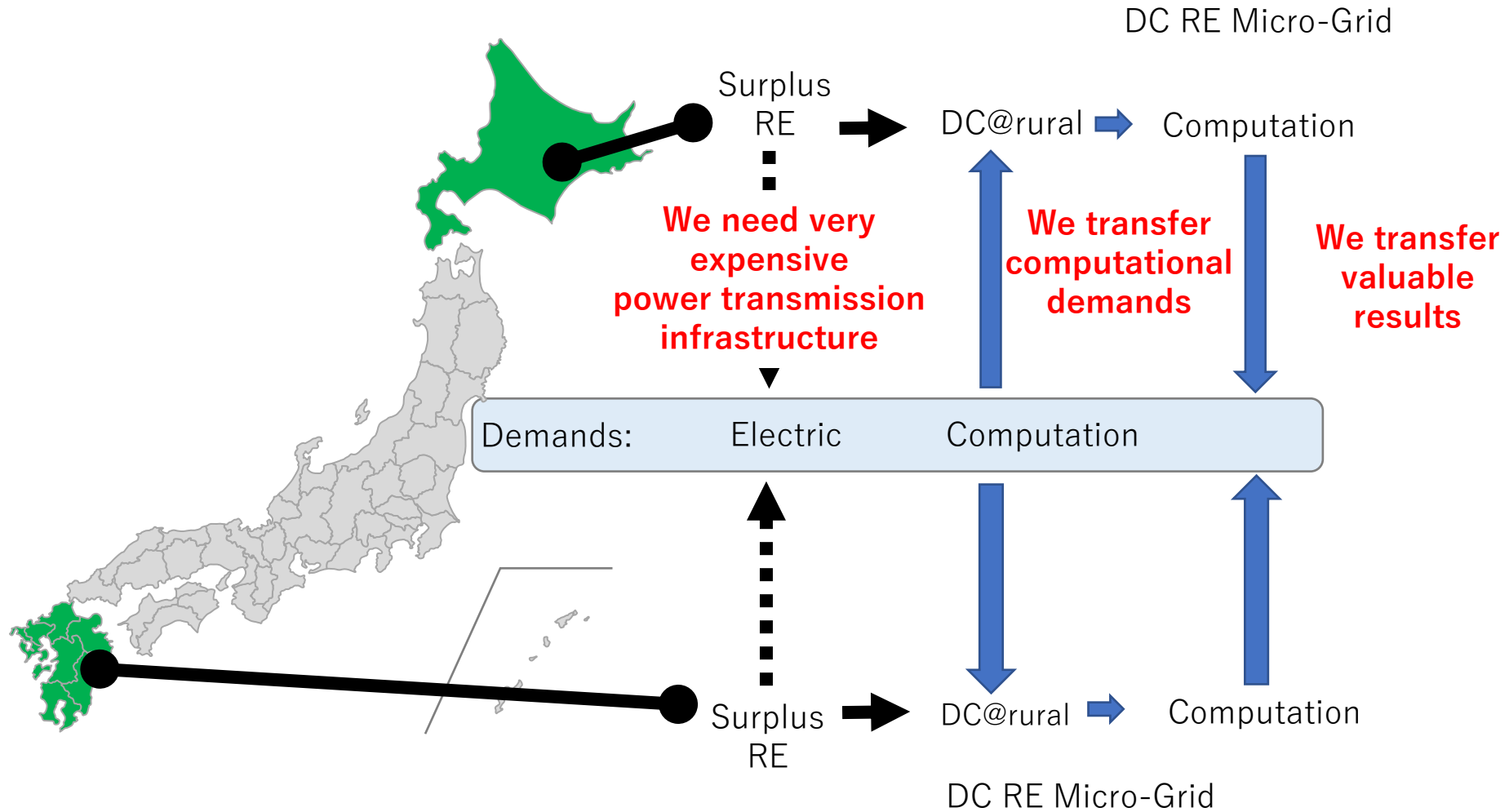
Electric Power

Information



(出所) 電力広域的運営推進機関：広域系統長期方針（広域連系システムのマスタープラン）（案）（2023.3）  
北海道ニューピアデータセンター研究会提言書：「北海道をデータセンターのパラダイスに」（2022.4）

# Data Center in rural area can help !!!

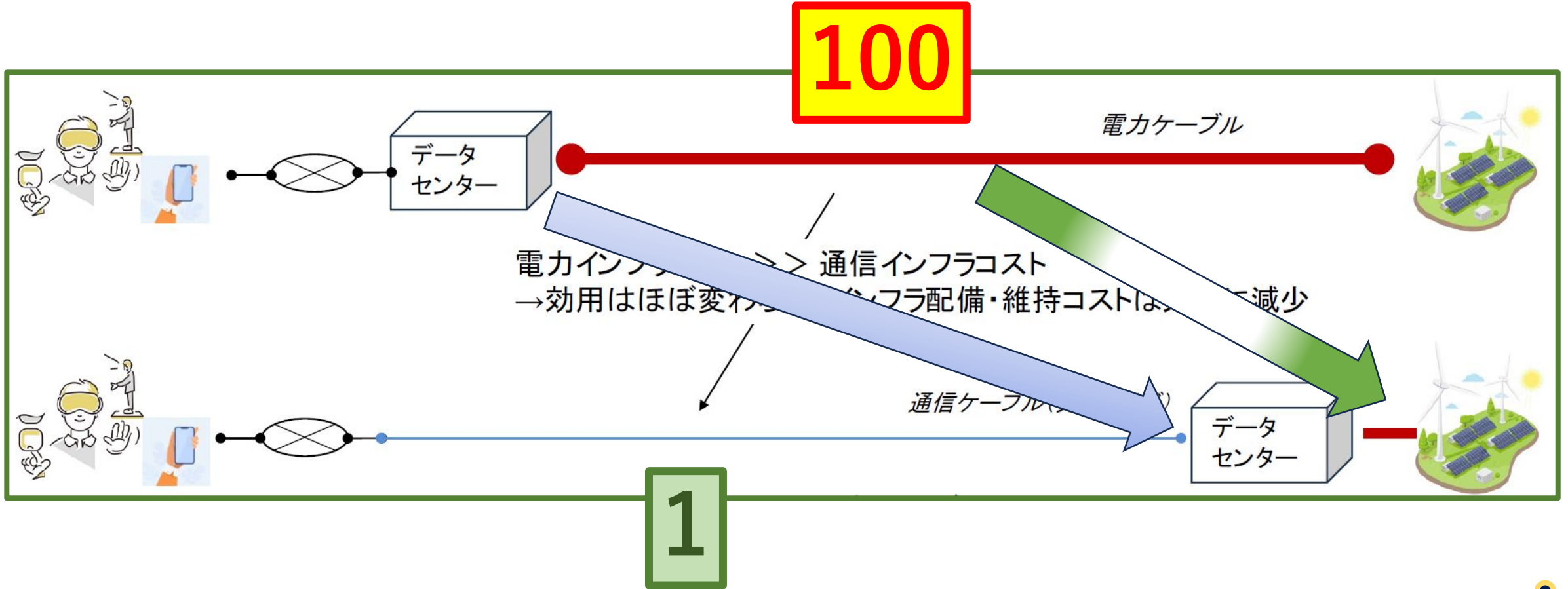


【資料】 ビットメディア 代表取締役社長 高野 雅晴 氏  
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# Practical implementation Focusing on AI and Big Data Processing !!

1. Only for HPC/GPU service  
→ not serious PKIs
  - ① Latency
  - ② Service outage time
2. Cooperation with power grid company { @北陸 }  
→ DR: Demand Response
  - ①  $\Delta$ kW (=critical shortage)
  - ② kWh (=Daily operation)





By Digital Twin

# Carbon Neutral by **EP-x00** (Energy Productivity)

	<b>Of IT</b>	<b>By IT</b>
<b>AS IS</b>	<ul style="list-style-type: none"><li>● <b>Virtual Machine</b></li><li>● <b>Huge Memory &amp; Processor</b></li></ul>	<b>Digital Twin</b> (CPS; Cyber Physical System) with <b>LoD</b>
<b>TO BE</b>	<b>Electron</b> → <b>Photon</b> → <b>Quantum</b>	<b>Cyber First</b>