TOSHIBA

Toshiba Group Technology Strategy

-Creation of new value through infrastructure services-

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Executive Officer Corporate Vice President and CTO Toshiba Corporation December 3rd, 2020





- **1** Toshiba Group's Vision
- **2** Infrastructure Services that Solve Social Issues
- **3** Cutting-edge Technologies
- **4 R&D Structure & Investment**
- 5 In Closing



Toshiba Group's Vision

- Toshiba Next Plan overview
- Social issues & macro trends
- CPS technology that solves social issues
- Technology strategy basic policy



Overview of the Toshiba Next Plan – Growth in 3 Phases

Shift focus to growth, deploy infrastructure services, and become a CPS technology company



Social Issues and Macro Trends

Global warming, extreme weather - Decarbonization -



Government promotion of decarbonization policies^{*1} 1 trillion EUR invested in "European Green New Deal"^{*2} Accelerated expansion of renewable energy

Natural disasters, infrastructure deterioration - Reinforcing Infrastructure-



The number of natural disasters has increased 1.5 times since 2000 Total damage in 2019 is about 15 trillion yen⁻³

Spread of new virus infections - Responding to the New Normal -



The World Health Organization declares the COVID-19 pandemic, and predicts it will be prolonged ⁴. Automation and labor saving accelerated as new lifestyles are adopted and social systems change.



Declining birth rates and aging populations, healthy life expectancy ~ Advanced medical care, preventive medical care ~



Spread of genetic testing ⁵ (1 in 11 people in the US, expanding the global market for diagnosis and testing); launch of therapeutic drugs

Trends in leading cutting-edge technologies ~ Quantum technologies ~



Application of leading cutting-edge technologies that control the behaviour of electrons and photons with high precision and utilize the quantum effect. (Quantum cryptograpy, Quantum computing, etc) 1: Prime Minister Suga's General Policy Speech https://japan.kantei.go.jp/99_suga/statement/20 2010/_00006.html

*2: NEDO (New Energy and Industrial Technology Development Organization) From "Overseas Trends Following the Corona Crisis" https://www.meti.go.jp/shingikai/energy_enviro nment/green_innovation/pdf/001_05_00.pdf

*3: FY2020 Ministry of Land, Infrastructure, Transport and Tourism white paper https://www.mlit.go.jp/statistics/file000004.html

*4: https://www.who.int/emergencies/diseases/ novel-coronavirus-2019

*5: https://thednageek.com/dna-tests/

CPS Technology that Solves Social Issues

Create infrastructure services that tackle social issues with TOSHIBA's unique CPS technology based on our abundant knowledge and achievements in the infrastructure business



Basic Technology Strategy Policy

Create infrastructure services and data services based on TIRA by utilizing AI/IoT technologies and Edge components & devices

"Cyber" Policy

Further advance CPS using digital twins that utilize AI & domain knowledge to accumulate and analyze data, and feed it back to the "Physical" space



Provide open infrastructure services & data services based on Toshiba IoT Reference Architecture

"Physical" Policy

Differentiate CPS by collecting data with Edge component devices and linking with "Cyber" space

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Infrastructure Services that Solve Social Issues

2-1 Initiatives for Infrastructure Services

- Decarbonization
- Reinforcing Infrastructure
- •New Normal

2-2 Base Technology that Supports Infrastructure Services



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"Committed to People, Committed to the Future" Using the abundant knowledge and technology we have cultivated in the past to solve social issues



Initiatives for Infrastructure Services



Initiatives for "Decarbonization"

Promote decarbonization throughout the energy chain with competitive system components and digital technologies based on AI & domain knowledge



Initiatives for "Decarbonization"

Promote decarbonization with a strong track record and high technological potential



- Top^{*1} share of mega solar installation in Japan
- ${}^{\bullet}$ The world's highest efficiency of new solar energy ${}^{^{\star}\!_2}$

Geothermal

• Top class^{*5} globally in power generation turbines

Energy Management

Grid & VPP

Japan No.1

WW Top tier

 Top high-voltage substation equipment^{*6} and system computer^{*7} in Japan

• Established Toshiba Next Kraftwerke

WW No.1

Storage



- Top power generation facility^{*3} in Japan (including FIT)
- Top variable speed pumped storage power plant^{*4} globally

Wind

- Preparing offshore wind power bid
- Planning to produce cutting-edge wind turbines in Japan

CO₂ Utilization

CCUS^{*9} Japan First

- Commenced operation of CO₂ separation and recovery demonstration facility in Omuta, Fukuoka
- Top level globally in rapid charge-discharge performance with SCiB[™] rechargeable batteries
- Largest P2G (hydrogen) facility globally, FH2R^{*8} in Fukushima Prefecture

Green Mobility & Energy Saving



• Energy-saving railway drive system that consumes 27% less electricity than before (SCiB[™], VVVF inverter with all-SiC, PMSM)

CO₂ Recycling

P2C <sup>
* D2##</sup>
気候変動アクティョン <sup>
環境大臣表彰</sup>

- Established high-throughput CO₂ resource recovery technology capable of commercial level processing
- *1: EPC operators with capacity of exceeding 2MW which launched operations by May 2019 (Source) RTS Corporation
- *2: Perovskite solar panel; biggest in size and highest efficiency among film-based modules
- *3: Based on the number of units, (Source) Toshiba
- *4: Based on the number of plants, (Source) Toshiba
- *5: Based on facility capacity, (Source) Toshiba
- *6: Voltage of over 154kV, (Source) Toshiba
- *7: Load dispatching center system, (Source) Toshiba
- *8: Fukushima Hydrogen Energy Research Field (technology development project with NEDO (New Energy and Industrial Technology Development Organization), Tohoku Electric Power Co., Inc., Iwatani Corporation, Tohoku Electric Power Network Co., Inc., and Asahi Kasei Corp.)
- *9: CCUS Carbon dioxide Capture, Utilization and Storage

Initiatives for "Decarbonization"— VPP (Virtual Power Plant)

Achieve widespread use of renewable energy and balance electricity supply and demand through optimal control technologies for distributed resources and unique forecasting technologies that utilize AI



Cutting-edge technologies that will achieve "Decarbonization"

• Lightweight

Transparent

• Flexible

Driving decarbonization with Toshiba's "Generate," "Transfer," "Store" and "Use smartly" technologies



S Renewable power generation

Tandem-type solar cells

Light-weight mobility installation expected with conversion efficiency that exceeds Si





Perovskite thin-film solar cells

Can be applied to places where solar cells could not be installed

Large-area film-type with the world's highest energy conversion efficiency

New Energy and Industrial Technology Development Organization (NEDO) commissioned business



VPP (Virtual Power Plant)

Prediction technology

Developed renewable power generation quantity and demand prediction technology that combines weather information and Toshiba's original AI technology

Demand forecasts

Sparse modelling, ensemble learning

Sponsored by TEPCO HD S "1st Electricity Load Forecasting Technology Contest" 1st prize (2017) Al utilization

PV Power generation forecast

Energy

Management

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Sponsored by TEPCO HD and Hokkaido Electric Power Company "PV in HOKKAIDO" Grand Prix Winner (2019) **Al utilization** Estimated the performance and panel angle of power generation equipment

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Operational Improved the accuracy of power saving volumes by analyzing operational data



Cutting-edge technologies that will achieve "Decarbonization"

Driving decarbonization with Toshiba's "Generate," "Transfer," "Store" and "Use Smartly" technologies



Energy Management

Achieve frequency adjustment with long-life, highly reliable SCiB[™] Storage batteries

SCiB™



Reliability (Life • Safety)

Developed NTO^{*1} cathode and demonstrated about 1.5 times capacity (prototype cell)

* 1: Niobium-titanium oxide

Next-generation technology Aqueous rechargeable batteries

- Developed an Aqueous Li-ion rechargeable battery not classified as a dangerous product under Japan's Fire Service Act
- Can be charged/discharged over 2,000 times





Produce, store and supply 1,200 Nm³ (rated operation) of hydrogen an hour



Fukushima Hydrogen Energy Research Field

New Energy and Industrial Technology Development Organization (NEDO) commissioned business

Power to Chemicals (P2C)

CO₂ Recycling

気候変動アクション

還境大臣表彰

Recycling CO₂ using renewable energy, etc. Commercial level processing is possible with cell stacking





Power Electronics

First application of a voltage-sourcedconverter-to-HVDC system in Japan



Energy Management

(commenced operation March 28, 2019)

VSC (Voltage Sourced Converter) HVDC link system using low-loss power semiconductor devices (IEGT^{*2}) to reduce converter size *2: Injection Enhanced Gate Transistor

Railway drive system

Green Mobility

Uses VVVF inverter with all-SiC devices to reduce energy loss and reduce equipment size





VVVF*3 Inverter

- * 3: Variable voltage variable frequency control
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Can operate even at -30°C

Initiatives for "Reinforcing Infrastructure"

Provide infrastructure services in preparation for disasters and deterioration with competitive system components and digital technology based on AI & domain knowledge



Initiatives for "Reinforcing Infrastructure" -Weather Disaster Prevention Solutions-

Contribute to the realization of disaster-resistant social infrastructure with weather prediction technologies and by forecasting heavy rainfall in advance using weather radars



Cutting-edge Technologies for "Reinforcing Infrastructure"

Advanced physical and digital technologies that accurately responds to disasters and infrastructure deterioration



Multi parameter – phased array weather radar

Forecast localized heavy rain up to 30 minutes ahead and provide disaster prediction information

Observe rain clouds within an 80km radius in 3D in 1 minute



Quickly understand rain cloud characteristics and accurately observe rain volumes at the same time by combining multi-parameter radar and phased array radar



Provide highly accurate weather forecasting services by AI analysis of meteorological and hydrological data

Meteorological data x AI





Low power multi-hop network

Relay and Collect data from inaccessible places, such as mountainous regions

Power saving wireless equipment that can operate for a long time with batteries and solar panels



Infrastructure health monitoring

Judge deterioration of infrastructures such as bridges from AE^{*} sensors etc.



deteriorating areas

This content includes that obtained from research work commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

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* Acoustic Emission © 2020 Toshiba Corporation

Initiatives for the "New Normal"

Promote the remote capabilities and automation required in our new normal by competitive systems and components, and digital technologies based on AI and domain knowledge

Factories

Ensure business operation and supply chain resilience

Smart manufacturingVR/AR



Office Communications

Health and safety, protecting people

- Social distancing: non-contact, non-face-to-face
- Remote work & remote training
- Remote security



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Logistics

E-commerce

Automation, labor saving

non-contact

- Intelligent robots
- Autonomous control, automated driving
- Work progress management
- Support for wide product range

- Cashless
- Smart receipts
- Marketing
- Consumption stimulation

Initiatives for the "New Normal": 1. Smart Manufacturing

Build a strong supply chain with manufacturing industry solutions Meister™ series based on Toshiba manufacturing knowledge, and improve factory management efficiency

Build a strong digitized supply chain Promote remoting and automation

Manufacturing IoT

O&M IoT

The Meister™ series brings together Toshiba's manufacturing knowledge and know-how, and has been used and improved through numerous iterations



Motion **Factory RPA** "Marionette Control" capture **RPA: Robotic Process Automation** Offline Externa equipment Control terminal signals PC image information **Explicit knowledge of** Automation of manual skilled work operation Field measurement **Meter reading AI** technologv Inspection robot 3D measurements Drones **Efficiency and automation Converting plants** of inspection work into 3D data

Digitization technology that realizes remote capabilities

and the automation of manufacturing and O&M sites

Initiatives for the "New Normal": 2. Logistics Solutions

Achieve scalable automation and labor savings with intelligent logistics robots and integrated warehouse management services



Initiatives for the "New Normal": 3. Smart Receipts^{*1}

Achieve 3 non-contacts by utilizing the POS track record, where we have the No.1^{*2} market share in Japan Co-create the future by transforming purchasing data into something of value



*1: "Smart Receipt" is a registered trademark of Toshiba TEC Corporation *2: http://www.dssr.jp/news.html

Initiatives for the "New Normal": 4. Technologies to Tackle COVID-19

Contribute to safety/security in daily life and communication settings



Social distancing

Auto subtitling system ToScLive™

E-learning cloud services Generalist[®]/LM

Human traffic detection technology SMART EYE SENSOR MULTI

Group density estimation technology

(image recognition AI technology)

Quickly subtitle spoken words, including technical terms, in an easy-to-read format

Easily create teaching materials and support the shift from group teaching to e-learning.

Detect and control flows of people in a smart facility

Quickly and precisely count crowd in public spaces, at event, incidents, etc.



UV sterilization & virus control equipment

Corona countermeasures app (ifLink community activities) Reduce risk of infection in public facilities such as trains and buses, schools and commercial buildings

Achieve ventilation with CO₂ sensing



Base Technology that Supports Infrastructure Services - Al and Security -



AI Technology to Support Infrastructure Services

Stable infrastructure operation, manufacturing quality maintenance and improvement, AI development for the new normal

Requirement 1 Data linkage & utilization



e.g. Infrastructure maintenance and operational support

Realize optimal maintenance work by utilizing data collected from infrastructure, product specification and maintenance data



VPP, reinforcing infrastructure

Requirement 2 Collaboration with people



e.g. Defect analysis in semiconductor plant

Analysis time reduced to 1/8 by operating an AI system that presents cause of defect candidates



Smart manufacturing

Requirement 3 Edge processing



e.g. Image recognition for logistics robots

High-speed processing to individually recognize randomly piled objects

Object recognition engine "BiSeg[™]*"





* Viet Pham, et al., "BiSeg: Simultaneous Instance Segmentation and Semantic Segmentation with Fully Convolutional Networks," 28th British Machine Vision Conference, 2017.

Logistics solutions

Security Technology to Protect Infrastructure Services

Support infrastructure security lifecycle management

Requirement 1 Defence & Prevention

Achieve secure communications as though on a dedicated line, easily and in any environment

Block threats to infrastructure legacy devices that are difficult to replace or update (CYTHEMIS[™])



Requirement 2 Monitoring & Detection

Monitor infrastructure without affecting control system operation, detect threat of intrusion

IDS^{*1} and unidirectional security gateway for control systems

Security solutions IT System OT System Risk assessment solutions Defensive solutions Monitoring & detection solutions Incident response solutions Education & training solutions Education & training solutions

Requirement 3 Response & Recovery

Minimize recovery time in the unlikely event of an incident

Achieve "risk visualization" and "automated response" by utilizing threat intelligence and SOAR^{*2}



Total support from risk assessment through to

security solution construction, operation & maintenance, security monitoring & response

*1: Intrusion Detection System *2: Security Orchestration, Automation and Response *3: Industrial Control System – Security Operation Center



Cutting-edge Technologies

- Precision Medicine
- Quantum Cryptography
- Simulated Bifurcation Machine™



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Initiatives for Cutting-edge Technologies

Utilize open innovation and promote development of cutting-edge technologies



Biotech

Materials

Quantum cryptography



Participation in the Cross-ministerial Strategic Innovation Promotion Program (SIP)

Group density estimating Al



Our unique deep learning method analyzes crowds projected in camera images at high speed and with the world's highest level of accuracy

Disease risk prediction AI

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Joint development with SOMPO Holdings, Inc.

Quantum branch machine



Participation in Exploratory Research for Advanced Technology (ERATO) and New Energy and Industrial Technology **Development Organization (NEDO) project**

Facial recognition AI



Joint development with Nippon **Television Network Corporation**

Japonica array



Joint research with Tohoku University

Simulated Bifurcation Machine™

CEATEC

New Normal **Solutions Section** Semi-Grand Prix

Biodegradable

liposome

Joint research with Shinshu

University and IDDK



Provide services from Groovenauts Inc., etc.

Identify failure factors from sources with missing data



Joint research with the Institute of Statistical Mathematics

Micro RNA



Joint research with National Cancer Center Hospital and Tokyo Medical University

Quantum computing



Participation in the Quantum Innovation Initiative Council

Scalable DNN



Joint research with RIKEN AIP

Collagen nanofibers



Joint research with Tokyo Medical and Dental University © 2020 Toshiba Corporation 29



Precision Medicine - Disease Risk Prediction AI and microRNA

Wide provision of preventive solutions and early detection opportunities



Precision Medicine— Biodegradable Liposomes and Heavy Ion Beam Cancer Treatment Equipment

Provide patient-friendly diagnosis and treatment



Quantum Cryptography

Provide theoretically unbreakable cryptographic communication technology and bring innovation to society's IT infrastructure

High-speed

Achieves key distribution speed exceeding 10 Mbps at a distance of 10 km

Photon detection noise reduction control circuit that achieves high speed





Stable

Stable operation by minimizing the disturbance impact with feedback control technology



Interoperability

ETSI, the European standardization organization completed standardization of a key delivery API, and we have ensured operation on various systems in cooperation with third-party organizations

ETSI GS QKD 014 V1.1.1 (2019-02)



Group Specification ETSI GS QKD 014, "Quantum Key Distribution (QKD); Protocol and data format of RESTbased key delivery API" (2019)

Network compatible

Possible to utilize existing optical fiber

Real-world demonstration of multiplexing standard fibre-optic communication and quantum cryptography, and cryptographic key relay utilizing a network function



Quantum Cryptography

From FY2020, proactively expand business in Japan and overseas, and drive practical application of quantum cryptography

Quantum cryptography system integration



Quantum key distribution services

UK

Started joint demonstration project with BT

Japan

Received order for demonstration project from NICT

USA Participated in Verizon demonstration with QXC

Toshiba Digital Solutions Corporation has received an order for a demonstration project from National Institute of Information and Communications Technology (NICT) Overseas, final demonstrations of commercial technology with 3^{*1} US and European companies are underway

*1: OXC and Verizon in USA and BT in Europe

Cryptographic key delivery services platform In order to realize end-to-end secure cryptographic communication across networks, a quantum cryptography system that realizes long-distance and high-speed quantum key distribution, and a cryptographic key distribution layer based on international standards^{*2}, have been built into the platform



*2 : Toshiba promotes standardization activities in collaboration with other organizations and companies

Simulated Bifurcation Machine[™]

Solve combinatorial optimization problems at world beating speed and scale using Toshiba's original algorithm, the result of research in quantum computing



Software

- No special hardware required
- Works with commercially available CPUs, GPUs, and FPGAs
- Can be run in the cloud or on-site



- Calculate answers to combinatorial optimization problems*1 across various industries at high speed
- Dramatically improve efficiency and productivity in numerous industries, such as logistic routing, optimal power distribution, and pharmaceutical research

Large-scale

- Easy to scale up due to parallel computing algorithm
- Demonstration decoding of the 1million spin^{*2} maximum cut problem



High-speed

Solutions Section

Semi-Grand Prix

- Computable in real time due to parallel computing algorithm
- About 1000 times faster^{*3} than SA^{*4} a popular existing method



AWS Compatible Paid PoC-compatible cloud services started

on AWS^{*5} ('20/09)

Azure Compatible

Microsoft Azure Quantum services scheduled to be available from 2021

Strengthening cooperation Continue cooperation to solve problems such as in finance and drug discovery, etc.*6

*1: Problems where it is difficult to find the optimal solution due to the huge number of combinations; *2: Unit size of Ising problem; *3: 100,000 spin and full coupling problem. Science Advances 5, eaav2372 (2019); *4: Approximate solution for simulated annealing combinatorial optimization. Method used as standard in conventional applications. Isakov et al., Comput. Phys. Commun. 192, 265 (2015); *5: Amazon Web Service; *6: Fixstars, Nextremer, Groove Notes, Zenrin Datacom, YDC

Recent Major Awards from External Parties

Energy Conservation Grand Prize - METI Minister's Award^{*1} Minister of the Environment's Award for Activities to Mitigate Global Warming^{*2}

"Railroad drive system using electricity storage and high efficiency electric motors"

Ichimura Prize in Industry for Outstanding Achievement^{*3}



HIRA SCIE

"Development and practical application of large rechargeable batteries using lithium titanium oxide negative electrode"

Minister of Education, Culture, Sports, Science and Technology - Science and Technology Award (Development Category)^{*4}

"Development of long-life large rechargeable battery with excellent input/output performance and safety" "Development of superconducting magnet with excellent safety and contribution to helium resource conservation"

Climate Change Action Minister of the Environment^{*5}

"Development of CO₂ recycling technology utilizing artificial photosynthesis technology" "Initiative for meteorological disaster prevention with multi-parameter phased array weather radars"



^{今和2年度} 気候変動アクション 環境大臣表彰



"IEEE Milestone" certification^{*6}

World's first commercial and home inverter air conditioner



Minister of Economy, Trade and Industry Award, New normal solutions category Semi-Grand Prix award^{*7} in CEATEC AWARD 2020



Minister of Economy, Trade and Industry Award





New Normal Solutions Section Semi-Grand Prix

microRNA detection technology

Simulated Bifurcation Machine™

Derwent Top 100 Global Innovators 2019-2020

Selected by US research firm Clarivate Analytics Recognised as one of the world's 100 most innovative companies and research institutes for nine consecutive years

- *1 : https://www.toshiba.co.jp/infrastructure/news/20200129_2.htm
- *2 : https://www.toshiba.co.jp/infrastructure/news/20191202.htm
- *3 : https://www.toshiba.co.jp/rdc/detail/2006_03.htm
- *4 : https://www.toshiba.co.jp/about/press/2020_04/tp_j1401.htm
- *5 : http://www.toshiba.co.jp/about/press/2020_10/pr_j3002.htm
- *6 : https://www.toshiba-carrier.co.jp/news/press/201104/
- *7 : https: //www.ceatec.com/ja/outline/outline02_01.html



R&D Structure & Investment



R&D Structure to Accelerate Creation of Infrastructure Services

Promote research and development of CPS technologies and cutting-edge technologies through a global R&D structure that strengthens the infrastructure services & data services businesses and creates new businesses

Toshiba Corporation	Corporate Research & Development Center	Global R&D organizations	
	Corporate Manufacturing Engineering Center	<text><list-item><list-item></list-item></list-item></text>	
	Software Technology Center		
	Digital Innovation Technology Center		
Toshiba Energy Systems	Energy Systems Research and Development Center		
Toshiba Infrastructure Systems & Solution	Infrastructure Systems Research and Development Center		
Toshiba Electronic Devices & Storage	Electronic Devices & Storage Research & Development Center		
Toshiba Digital Solutions	Software System Technology Development Center		
Toshiba TEC	Research & Development Center	© 2020 Toshiba Corporation (737	

New R&D Building Overview

New R&D building to accelerate rapid progress toward becoming a CPS technology company

Scheduled to start operation in FY2023



Establishment of new building, and R&D points

Fusion of technologies from different fields

Such as AI, data processing, components, materials, etc.

System of Systems

business model realization

Information security technology

that is highly reliable and infrastructure-specific

Improvements in software development productivity & profitability, as the foundation of the services business

Find problems & build services

through dialogue with customers and business divisions

R&D Investment

Strengthen R&D for infrastructure services and data services

Technologies focused on Total investment plan: ¥900B R&D portfolio Infrastructure services (FY19-23) **Strengthening R&D for** & Data services Others **Infrastructure services & Data services Digital Solutions Devices & Storage Retail & Printing** 23%→36% (+13pts) Energy systems • Decarbonization: VPP, distributed power supply response (FY19→FY25) **Energy Systems** Infrastructure System • Renewable energy, storage battery system demand and supply adjustment 2,000 • GHG emission reductions, power plant diagnosis Others 7% ← Infrastructure systems • Plant operation automation / operation optimization 10% Advanced research 1,500 1,500 • Intelligent robots, AI 20% and base 22% • Equipment diagnosis predictions technologies 29% **Devices** & 11% 10% Digital solutions **Products** 1,000 1,000 • Smart manufacturing 27% Big data, IoT platform, quantum cryptography 28% Infrastructure Industry / business solutions systems 500 500 Retail Smart receipts, POS business solutions, maintenance efficiency improvements 36% Infrastructure (AI utilization, automation) 26% Services & Data 23% 0 Services 0 Building solutions FY18 FY19 FY20 FY21 FY22 FY23 **FY19 FY20 FY25** * Excluding Toshiba memory

R&D Investment—Related to Renewable Energy

Strengthen development of renewable energy-related technologies toward decarbonization

Renewable energy-related R&D: ¥17B (FY20: R&D expenditure approximately 10% of net sales) Further strengthen in the future







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Trends in leading cutting-edge technologies - Quantum technologies -



Toshiba Group's Vision

Cyber

(D) YO

Physical



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Systems

TOSHIBA

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