DENSO
Crafting the Core

Technology Development toward 2035

Yoshifumi Kato
Senior Executive Officer & CTO
DENSO Corporation

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Society envisioned by DENSO

Social issues

Global warming, resource shortages, population increase, aging, etc.

Factors that will shape society by 2035

- Strong momentum toward a recycling-oriented society focusing on renewable energy to protect the global environment
- Advancement of cyber-physical systems based on ICT
- Public demand for resilient social systems after experiencing the pandemic, disasters, war, and deepening social divide
- Diversifying values due to the emergence of regional differences as the pendulum swings between globalization and localization

DENSO

Society envisioned by DENSO in 2035

Create a recycling-oriented society which mainly uses renewable energy and realize safe and highly valuable **mobility** and **manufacturing**.
Place top priority on **keeping social activities going** and **meeting diverse values and sense of well-being**.

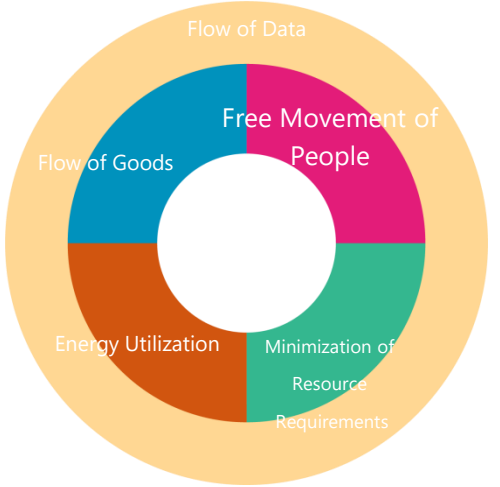
Approach

DENSO's expertise lies in the **mobility of people and goods** as a mobility company, **optimization of energy and resources** as a manufacturer, and **data generation and management** as an inventor of the QR Code.

We conduct analyses based on **"The Five Flows"** in line with the envisioned society, and create what is needed by developing technologies and finding new partners.

- Free Movement of People
- Flow of Goods
- Energy Utilization
- Minimization of Resource Requirements
- Flow of Data

“The Five Flows” on which DENSO is working

Value proposition			Goal
Safe and valuable mobility	Free Movement of People	Achieve mobility that meets diverse values by eliminating negative aspects of mobility (traffic accident fatalities)	
	Flow of Goods	Achieve environmentally-friendly and people-friendly mobility of goods by eliminating waste and losses	
Environmentally friendly manufacturing	Energy Utilization	Spread DENSO’s carbon-neutral manufacturing to society and realize an energy recycling society	
	Minimization of Resource Requirements	Achieve sustainable manufacturing of products using limited resources to minimize the environmental impact	
Connect the flows to maximize value	Flow of Data	Connect all the flows using detailed data Connect drivers with vehicles and infrastructure	

Connect all the flows by the flow of data to create a well-being cycle society

Free Movement of People & Flow of Goods

Safe and valuable mobility

Advanced driver assistance/automated driving

- Development of GSP3* with enhanced safety performance
- Annual production of millimeter-wave radar sensor: 8.3 million units
- Annual production of vision sensors: 6.2 million units

*Global Safety Package 3

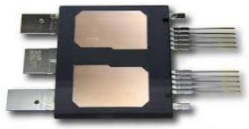
Millimeter-wave radar sensor

Vision sensor

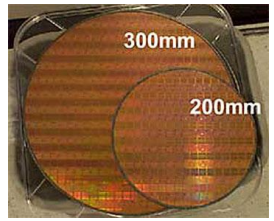
Electrification

- Annual production of inverters: 3.1 million units
  Cumulative global production exceeded 20 million units in December 2021.
- DENSO will collaborate with USJC on manufacturing automotive power semiconductors.

Power control unit (inverter)



Power semiconductor



Large-diameter wafer

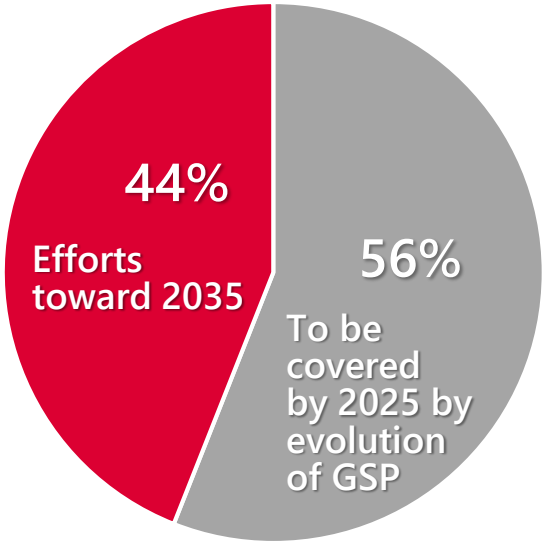
Free Movement of People: Safer mobility with greater peace of mind

Usual driving | Before crash: Active safety | Immediately before crash: Crash safety | During/immediately after crash: Mitigation of damage caused by crash | After crash: Emergency call

GSP3

Expansion of support ← → Improvement in safety performance

Traffic fatalities covered by the system (1,755 cases)

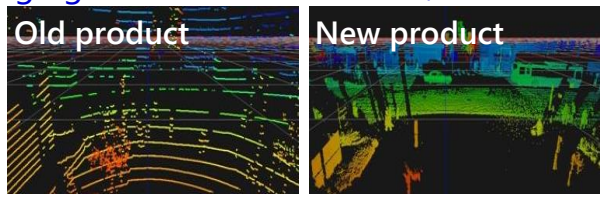


* Calculated based on ITARDA's analysis of accidents in 2018
Injury: deaths, principally implicated party: passenger cars (standard motor vehicles/light motor vehicles) only, excluding car-train accidents

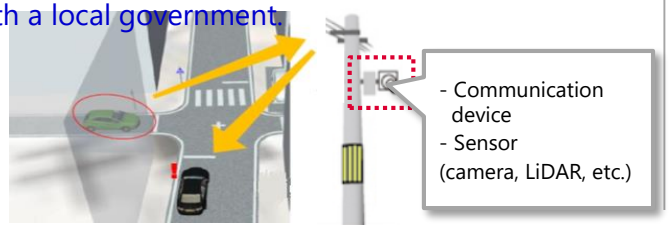
Efforts toward 2035

Before crash/immediately before crash:

Development of high-performance sensors
Recognition of hazards around the vehicle by increasing the distance and angle
Imaging millimeter-wave radar, SPAD-LiDAR



Development and demonstration of a vehicle-infrastructure cooperative system
Recognition of hazards in blind spots that cannot be detected by vehicle sensors
Commencement of demonstration tests in collaboration with a local government



Usual driving:

Coordination between a driver assistance system and HMI

- Development of algorithms that integrate the situation around the vehicle with the driver's condition to improve safety by analyzing the driver's condition, skills, and tendencies
  - January 2023: Establishment of the Safety Systems Business Unit through integration of the AD&ADAS Business Unit and the Cockpit Systems Business Unit
  - October 2022: Commencement of collection of basic driving data from 3,000 drivers through a project funded by the Toyota Mobility Foundation

Fully automated driving:

Reinforcement of collaboration with a development manufacturer of Level 4 automated driving in anticipation of the spread of ride-sharing services of automated driving cars
April 2019: Equity participation in Uber-ATG (currently Aurora Innovation)

Increase safety by analyzing the driver's behavior and promote development toward fully automated driving

Free Movement of People : In search of new value required of mobility

Mobility experience (family trips, etc.) → Acquisition of driver's license → First driving → Daily driving → Changes in driving skills → Return of driver's license → Support for mobility

Maximize the value of mobility

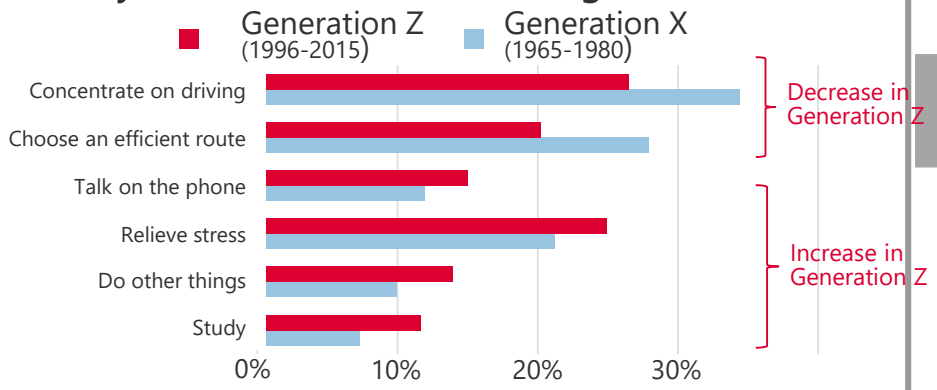
Q: How did you perceive mobility during the Covid-19 pandemic?

A ticket to freedom or a time eater?

A ticket to freedom: **73%** A time eater: **27%**

Source: A survey on "100 questions about the signs of change" in Web DENTSU-HO

Q: What do you want to do while driving?



Source: DENSO's independent global survey on 6,400 individuals

Offer mobility that meets diverse values

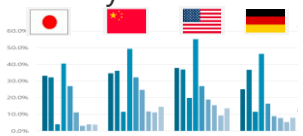
Understanding of values

A global survey on values

Creation of a mobility concept based on a hypothesis of the future image of consumers and feedback to global operations

Strengthen marketing capabilities

By country



By generation

Provision and evaluation of experience value

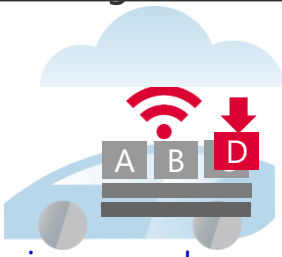
Exhibition of a concept model at an experiential retail store to receive feedback from users and identify their desired values

November 2022: Usability evaluation of the cabin space at b8ta Tokyo (Shibuya)

Vehicle adaptation depending on the mobility life cycle and driver's generation

Evolution of the electronic platform and software

1) Analyze the value of mobility based on the vehicle data linked to individuals
2) Propose personalized functions
3) Update software by OTA



Reconfiguration of the electronic platform, training of software engineers, and reskilling (mechanics → software)

Propose functions that offer value depending on the mobility life cycle and generation, and strengthen the electronic platform and software development capabilities

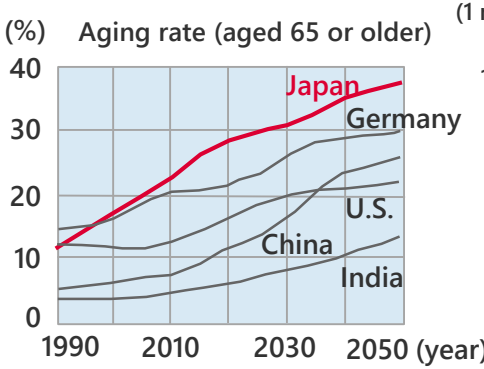
Flow of Goods

Producer → First one mile (collection) → Cargo collection center → Trunk road → Expressway → Trunk road → Delivery center → Last one mile (delivery) → Consumers

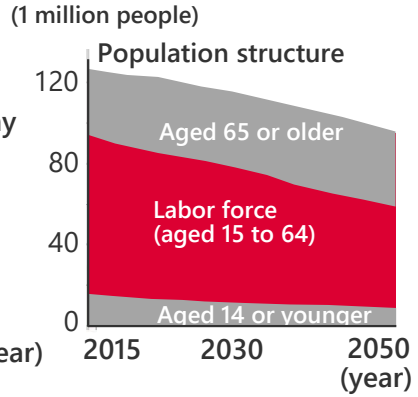
Long distance/many hours

Shortage of drivers/increase in parcels

Worldwide population aging



Labor shortage



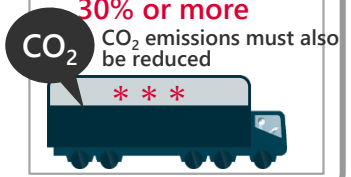
Shortage of truck drivers by 2028

Shortage of **278,000** drivers

1/4 of cargo cannot be transported

Empty cargo on return trips: **30% or more**

CO_2 emissions must also be reduced



Basic strategy

To solve the imminent issue, the combination of **automated driving** with an **advanced operation system** is a realistic solution

Automatic driving

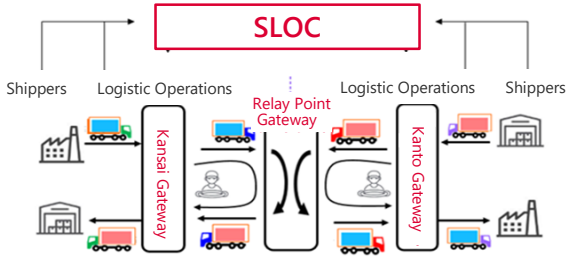
Collaboration with Aurora Innovation+ Development of automated driving for small vehicles

Introduce automated driving to multi-modal transport and achieve seamless connection

Operation system

Shuttle Line Of Communication

Eliminate many hours of operations and empty cargo on return trips by exchanging containers at gateways



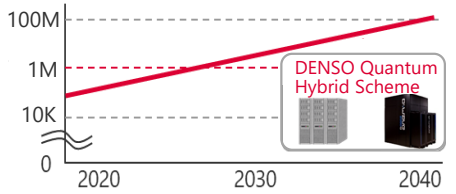
https://www.denso.com/global/en/driven-base/project/sloc/

Quantum computing

Find the optimal solution in terms of human resources, goods, and time by utilizing quantum computing

Example:
Trucks: 1,000
Cargo: 60,000 parcels
Delivery centers: 100 locations
↓
More than 1 million variables

Estimation of evolution



Realize a people-friendly "Flow of Goods" that keeps society running by using multimodal automated driving and an advanced operation system

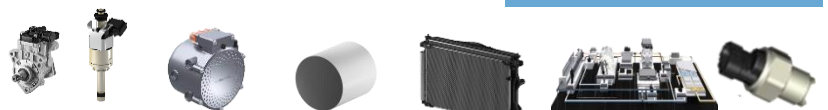
Energy Utilization & Minimization of Resource Requirements

Environmentally-friendly manufacturing

Electrification, internal combustion engines (ICEs), and thermal technologies

Application of automotive products and technologies to achieve carbon neutrality at plants and in society

Electrochemical reaction	Materials, processing	Detection, thermal/energy management



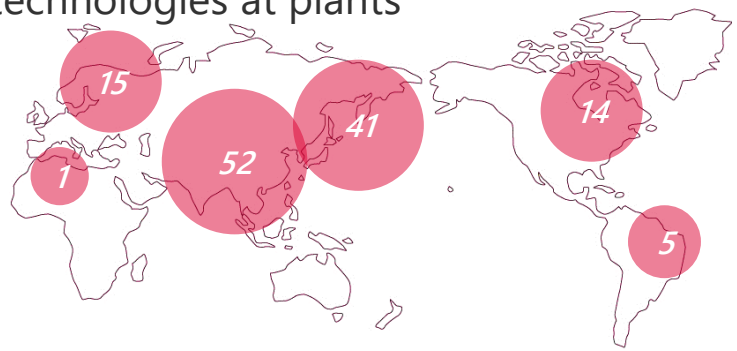
ICE/thermal (chemical reaction) | Electrification | Catalyst technology | Cooling technology | Energy management system | Sensor

Robotics

High-quality, highly-durable robots and equipment used in various applications

Manufacturing at 130 plants around the world

Manufacturing know-how and skills refined through over 70 years of operations since founding and demonstration of technologies at plants



Energy Utilization

Generate → Use → Store/return → Use (recycling)

CO_2, surplus renewable energy, heat

Energy circulation system

Generate
Adjustments using renewable electricity on the grid and energy creation depending on the situation in respective regions

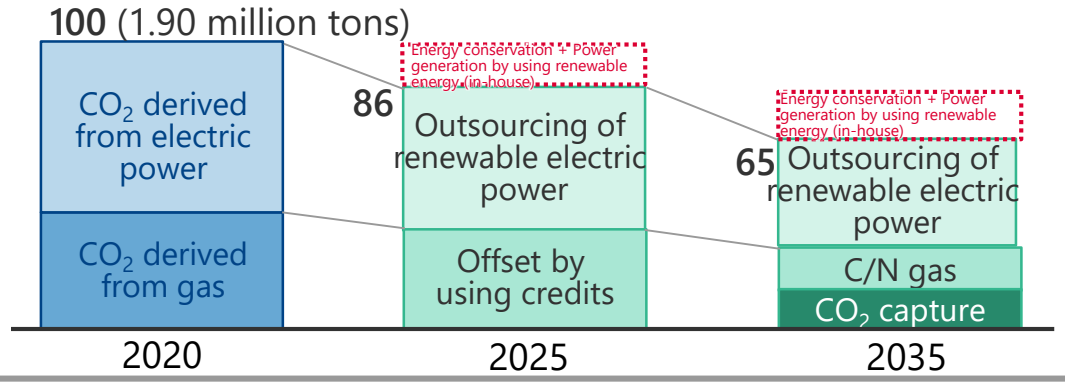
Use
Thorough energy conservation by visualizing energy using the flow of data

Store
Electricity
Hydrogen
Fuel (methane/liquid fuel)
Battery V2X/VPP
SOFCs/SOECs
CO_2 circulation

Conversion to electricity (thermoacoustic, etc.)

Return
Heat
CO_2
Emissions/air capture
Resources
Conversion to carbon (artificial photosynthesis)

Carbon-neutral basic strategy for manufacturing



Efforts in energy use

In-house plant → Deployment to other manufacturers and society

September 2020	Commencement of CO_2 circulation demonstration	Return: CO_2 Store: methane
October 2021	Introduction of live gas at plants	Use: methane
February 2022	V2X linkage	Store: electricity
2023 and beyond	Introduction of SOFCs/SOECs	Store: hydrogen

CO_2 circulation demonstration plant at the Anjo Plant

TOYOTA CHUKEN

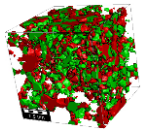
Joint development with Toyota Central R&D Labs

Hydrogen generation technology

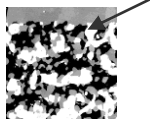
Develop efficient energy conversion materials by optimizing the structures of materials on the atomic level

Submicron level Control of electrode structures + Nanometer level Control of atomic structures

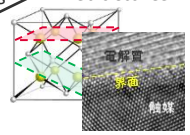
Electrode design



Control of microstructures of porous ceramics



Design and control of atomic structures



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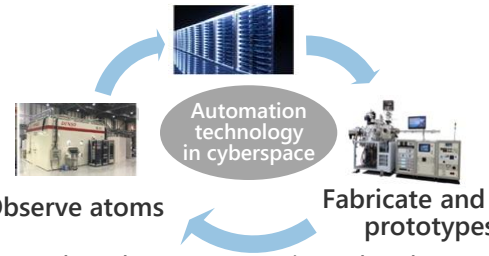
Advanced material technology

Improve the hydrogen generation efficiency by controlling the structures of ceramic materials on the nanometer level

Look for structures



Thermal management technologies

Develop thermoacoustic technology to convert heat into electricity using ceramic technology

Develop and spread technologies that effectively utilize renewable energy to realize carbon-neutral plants

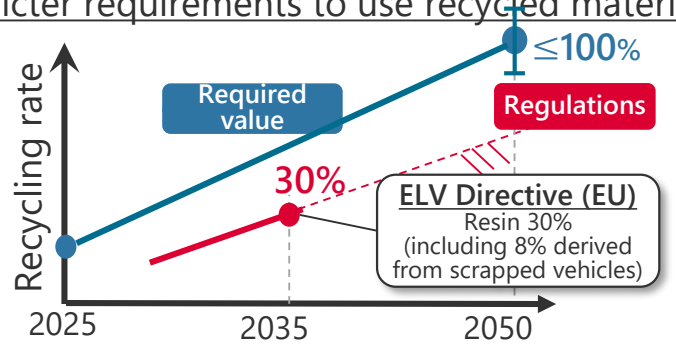
Minimization of Resource Requirements

Materials → Parts → Assembly → Use → Disposal

Recycle ← Dismantling ← Recovery

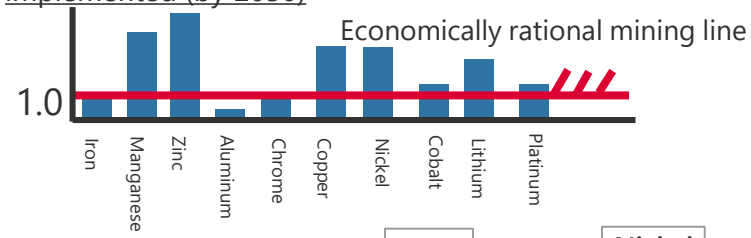
- High efficiency
- Low cost
- Meet regulations/requirements

Stricter requirements to use recycled material



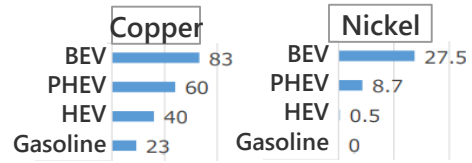
Resource depletion: consumption when no measures are implemented (by 2050)

Source: National Institute for Materials Science (NIMS)



Consumption of resources per vehicle (kg)

Source: Agency for Natural Resources and Energy



Commencement of efforts to build an ecosystem in collaboration with recycling industries

Application of manufacturing technologies and know-how

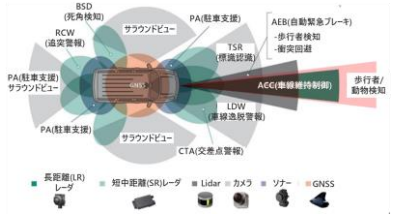
Development of means, structures, and materials suitable for disassembly and recycling based on **reverse engineering** in manufacturing

Materials → Parts → Assembly → Recycle ← Dismantling ← Recovery

- Recycle: - Recycling to make up for deterioration; - Recycling to reinforce the strength
- Dismantling: - Modules and structures suitable for dismantling; - Safe and low-energy disassembly procedure

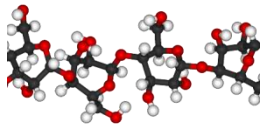
High-purity dismantling

Inexpensive extraction of high-purity materials based on **precision dismantling and sorting** by leveraging robotics and recognition/judgment technologies for automated driving

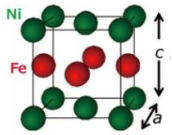


Development of alternative materials

Development of environmentally-friendly new materials **derived from biotechnology and free of rare earth materials**, to make up for the shortage of materials



Cellulose nanofibers, an alternative to glass/talc



Creation on the atomic level Iron-Ni magnet

Build an ecosystem in collaboration with recycling industries and establish an economically rational "Minimization of Resource Requirements" based on respective regional situations

Flow of Data

Connect the flows to maximize value

QR Code

Invented by DENSO in 1994, the QR Code is widely used around the world. Various types of QR Code have been developed to meet customers' needs.

Regular QR QR in QR SQRC

2020 QR Code certified as an IEEE Milestone
2022 QR Code won the IEEE Corporate Innovation Award

QR Code readers

QR Code readers are utilized in manufacturing and logistics industries, etc. around the world, as well as daily life (e.g., settlement using smartphone apps).

Blockchain

Blockchain prevents counterfeiting by allowing users to monitor data.
The lightweight algorithm can run on simple devices.

Flow of Data

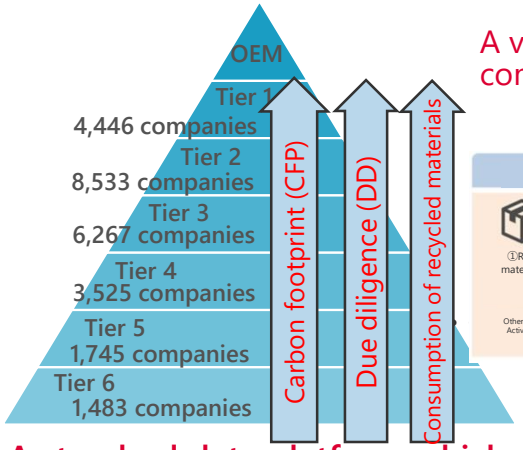
Example of battery traceability

Resources manufacturers | Materials manufacturers | Battery manufacturers | Automakers | Users | Dealers | Secondary-use companies | Users | Battery recyclers | Materials manufacturers

Data flow

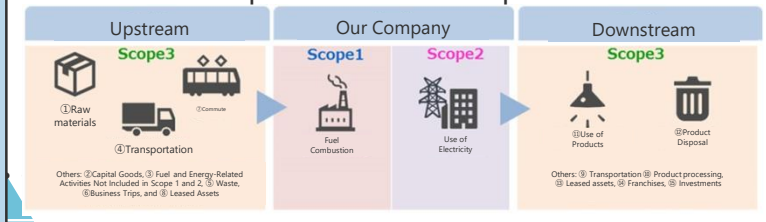
Ecosystem of the automotive industry in Japan

Source: "FY2020 White Paper on Small and Medium Enterprises" published by the Small and Medium Enterprise Agency



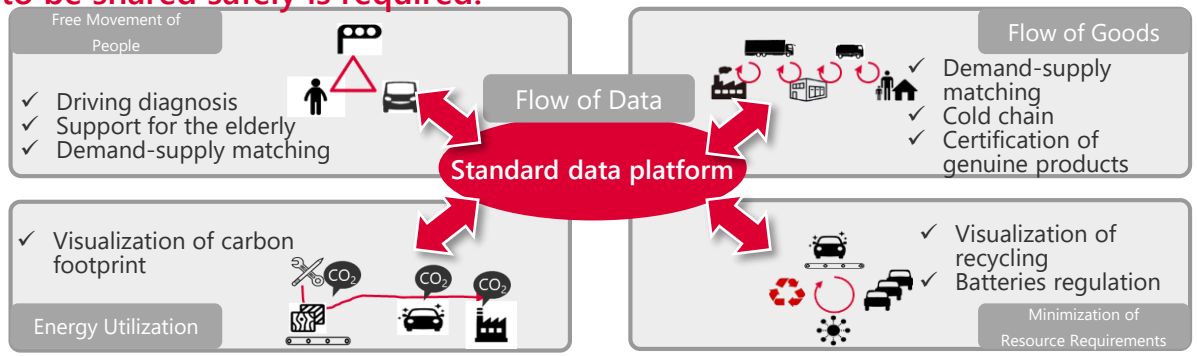
A very long and broad supply chain of about 26,000 companies

Example of carbon footprint



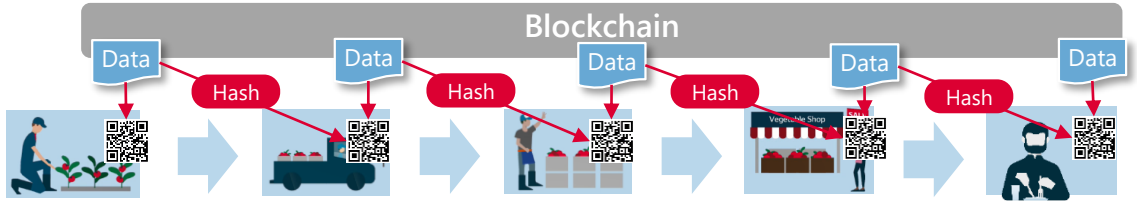
Source: Green Value Chain Platform of the Ministry of the Environment

A standard data platform which can be used easily by anyone and enables data to be shared safely is required.



Traceability system

Provide a mechanism to trace the flow of goods and services by combining the QR Code and block chain and connecting the supply chain information



Build a battery traceability system for electric vehicles

Visualize the battery manufacturing flow for electric vehicles on the supply chain

Started to build a system with NTT Data in September 2022

- Carbon footprint (Energy Utilization)
- Human rights and environmental due diligence (Minimization of Resource Requirements)

Manufacture of batteries → Automotive industry → Other industries

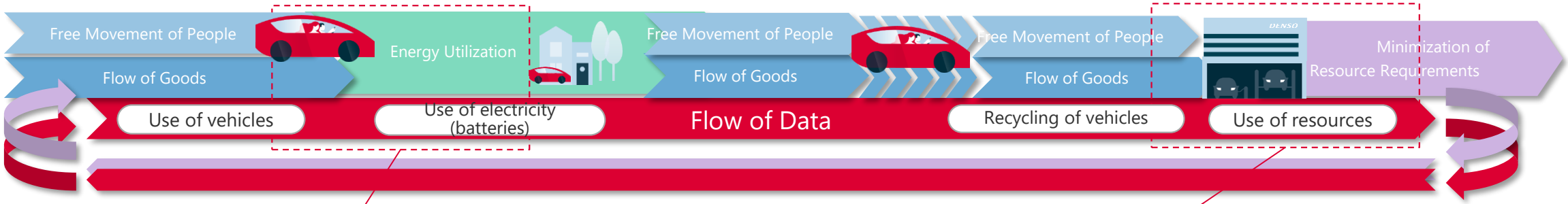
Standard data platform

Promote collaboration with Catena-X (a data platform in Europe)

Pursue "Flow of Data" technology that can be deployed to CFP, DD, and other industries, starting with battery traceability

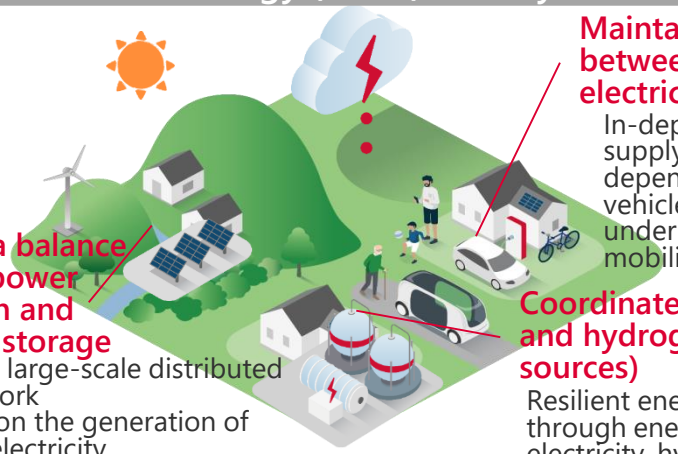
Value derived from connecting the five flows

Connect all the flows by the flow of data to monitor and support the entire lifecycle of vehicles and the next lifecycle after recycling



Carbon-neutral city

Effectively utilize vehicle batteries to use only renewable energy (100%) in daily life



Maintain a balance between mobility and electricity storage

In-depth charging/power supply control depending on usage of vehicles without undermining flexible mobility

Maintain a balance between power generation and electricity storage

Control of a large-scale distributed power network depending on the generation of renewable electricity

Coordinate the use of electricity and hydrogen (and other energy sources)

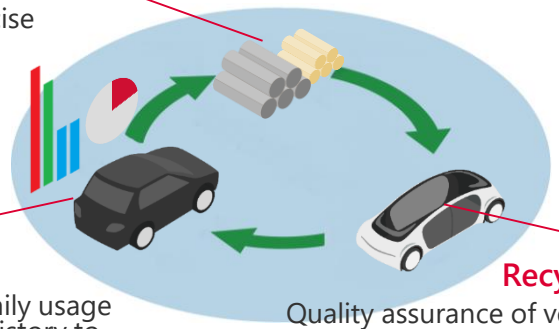
Resilient energy infrastructure through energy circulation (e.g., electricity, hydrogen)

Vehicles recycled from vehicles

Fully recycle vehicles (100%) to provide vehicles that can be reliably used by the next generation

Materials history

Quality assurance of materials through precise recycling based on driving history



Driving history

Detailed recording of daily usage and repair/restoration history to ensure the value of vehicles

Recycling history

Quality assurance of vehicles by recycling vehicles using optimal materials based on materials history

Expand “recycling of vehicles” to “recycling in society” to create a well-being cycle society

Future that DENSO will create

Value proposition			DENSO's efforts	Vision for commercialization
Safe and valuable mobility	Free Movement of People	Achieve mobility that meets diverse values by eliminating negative aspects of mobility (traffic accident fatalities)	・Coordinate driver assistance systems with Human Machine Interface (HMI) ・Develop an electronic platform to update software depending on personal needs	・Offer high-performance driver assistance systems and promote their spread by reducing costs ・Offer electrification systems for various applications ・Commercialize solutions to optimize free movement of people and flow of goods
	Flow of Goods	Achieve environmentally-friendly and people-friendly mobility of goods by eliminating waste and losses	・Develop automated driving for small vehicles ・Achieve optimization by quantum computing	
Environmentally friendly manufacturing	Energy Utilization	Spread DENSO's carbon-neutral manufacturing to society and realize an energy recycling society	・Develop an energy circulation system ・Develop highly efficient energy conversion materials	・Commercialize energy circulation systems for plants ・Achieve expansion and deployment to systems for communities
	Minimization of Resource Requirements	Achieve sustainable manufacturing of products using limited resources to minimize the environmental impact	・Develop dismantling, recycling, and material technologies ・Develop an ecosystem in collaboration with partners	・Commercialize recycling of vehicles in collaboration with recycling industries. ・Externally sell a precision automatic dismantling system
Connect the flows to maximize value	Flow of Data	Connect all the flows using detailed data Connect drivers with vehicles and infrastructure	・Develop a battery traceability system ・Develop a standard data platform and acquire/utilize accurate data in collaboration with partners	・Commercialize cross-domain services using the standard data platform as the core

Reorganization in January 2023 to accelerate commercialization

New organization: Social Innovation Business Development Function Unit

- Digital Solution Development Dept.
- Circular Economy Development Dept.
- FA Business Development Div.
- Food Value Chain Business Development Div.

Build a large flow with partners in the industry to create a well-being cycle society

DENSO

Crafting the Core