FY2022
Supply-Demand Survey of Mineral Resources to Achieve Carbon Neutrality

— Demand Outlook for Mineral Resources —

10 November, 2022

The Institute of Energy Economics, Japan

Summary of Supply-Demand Survey for CN-Related Mineral Resources

- The Institute of Energy Economics, Japan (IEEJ) has been commissioned to conduct "the FY2022 Demand-Supply Survey of Mineral Resources to Achieve Carbon Neutrality". With the support of JOGMEC, IEEJ was in charge of demand, while supply was handled by JOGMEC and Mitsubishi UFJ Research and Consulting, the subcontractor.

- Conducted an analysis of the supply-demand balance of mineral resources related to carbon neutrality (CN).
  → Comparison of demand and supply over time, Comparison of cumulative demand and reserves (USGS) + supply of recycling (- 2050)

- [Analysis coverage]
  CN Technology: Renewable energy, stationary storage batteries, electric vehicles, fuel cell vehicles, water electrolysis, etc.
  (Also takes into account the decrease in mineral resources use due to the substitution of conventional technology. Demand for non-CN use is also taken into account.)
  CN Mineral Resources: Copper, Lithium, Nickel, Cobalt, Graphite, Silicon, Dysprosium, Neodymium, Platinum, Palladium, Rhodium, Vanadium

Methodology for forecasting demand of CN-related Mineral Resources

Demand for CN-related minerals is estimated using the “bottom-up approach" that multiplies the amount of technology introduced and the mineral use intensity.

Mineral demand = Newly introduced CN technology each year x Mineral use by type per technology unit + Demand other than CN technology

- Use intensity: Set from various documents such as the International Energy Agency (IEA) and the Commonwealth Scientific and Industrial Research Organization (CSIRO). The intensities are **constant during the forecast period**.

- Amount of technology introduced: Referred from the "**IEEJ Outlook 2023**". Set two scenarios.

Reference Scenario (REF): A scenario in which past trends continue into the future.
Advanced Technologies Scenario (ATS): A scenario in which the introduction of CN technology is accelerated due to strengthening of energy and environmental policies, etc.

- Demand for minerals other than CN-related technology: Rough estimate with a fixed intensity per population.

Analysis coverage (mineral / CN-related technology) and use intensity

		Copper	Lithium	Nickel	Cobalt	Graphite	Silicon	Dysprosium	Neodymium	Vanadium	Platinum	Palladium	Rhodium
Onshore wind	t/GW	2,880	-	430	-	-	-	2	28	-	-	-	-
Offshore wind	t/GW	8,000	-	270	-	-	-	15	235	-	-	-	-
PV	t/GW	2,820	-	-	-	-	3,980	-	-	-	-	-	-
Geothermal	t/GW	-	-	120,300	-	-	-	-	-	-	-	-	-
Hydro	t/GW	1,050	-	30	-	-	-	-	-	-	-	-	-
Nuclear	t/GW	1,480	-	1,300	-	-	-	-	-	-	-	-	-
Coal thermal	t/GW	1,150	-	700	200	-	-	-	-	-	-	-	-
Gas thermal	t/GW	1,090	-	-	-	-	-	-	-	-	-	-	-
Stationary LIB	t/GWh	340	120	531	173	881	-	-	-	-	-	-	-
Stationary VRF	t/GWh	-	-	-	-	-	-	-	-	2,920	-	-	-
Automotive LIB	t/GWh	340	120	531	173	881	-	-	-	-	-	-	-
PLDV ICV	t/1000unit	15	-	-	-	-	-	-	-	-	0.000453	0.001499	0.000154
PLDV HEV	t/1000unit	17	0.1	0.5	0.2	1.1	-	0.036	0.324	-	0.000453	0.001499	0.000154
PLDV PHEV	t/1000unit	22	1.1	4.7	1.5	8.1	-	0.060	0.540	-	0.000453	0.001499	0.000154
PLDV BEV	t/1000unit	32	6.0	26.5	8.7	44.4	-	0.060	0.540	-	-	-	-
PLDV FCV	t/1000unit	19	0.1	0.7	0.2	13.4	-	0.060	0.540	-	0.020000	-	-
HDV ICV	t/1000unit	30	-	-	-	-	-	-	-	-	0.000907	0.002999	0.000309
HDV HEV	t/1000unit	35	0.2	1.1	0.3	2.2	-	0.072	0.648	-	0.000907	0.002999	0.000309
HDV PHEV	t/1000unit	43	2.1	9.3	3.1	16.2	-	0.120	1.080	-	0.000907	0.002999	0.000309
HDV BEV	t/1000unit	63	12.0	53.1	17.3	88.8	-	0.120	1.080	-	-	-	-
HDV FCV	t/1000unit	38	0.3	1.3	0.4	26.9	-	0.120	1.080	-	0.040000	-	-
Water electrolysis	t/GW	229	-	423	0	-	-	-	-	-	0.010000	-	-

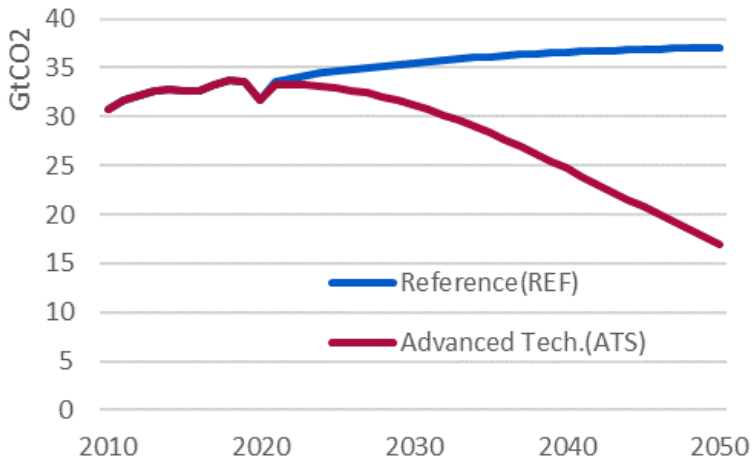
Sources) IEA, “The Role of Critical Minerals in Clean Energy Transitions”, CSIRO, “Critical Energy Minerals Roadmap” etc.

Note) PV: Photovoltaic, LIB: Lithium-ion battery, VRF: Vanadium redox flow battery, PLDV: Passenger light duty vehicle, HDV: Heavy duty vehicle, ICV: Internal combustion engine vehicle, HEV：Hybrid electric vehicle, PHEV; Plug-in hybrid electric vehicle, BEV：Battery electric vehicle, FCV: Fuel-cell electric vehicle

Scenarios in IEEJ Outlook

	Reference Scenario	Advanced Technologies Scenario
	Reflects past trends with technology progress and current energy policies, without any aggressive policies for low-carbon measures	Assumes introduction of powerful policies to address energy security and climate change issues with the utmost penetration of low-carbon technologies
Socio-economic structure	Stable growth led by developing economies despite slower population growth. Rapid penetration of energy consuming appliances and vehicles due to higher income.	
International energy prices	**Oil** supply cost increases along with demand growth. **Natural gas** prices converge among Europe, North America and Asia markets. **Coal** price decreases due to request for decarbonization.	All prices decrease along with decrease in demand due to progress in energy saving and request for decarbonization
Energy and environmental policies	Gradual reinforcement of low-carbon policies with past pace	Further reinforcement of domestic policies along with international collaboration
Energy and environmental technologies	Improving efficiency and declining cost of existing technology with past pace	Further declining cost of existing and promising technology

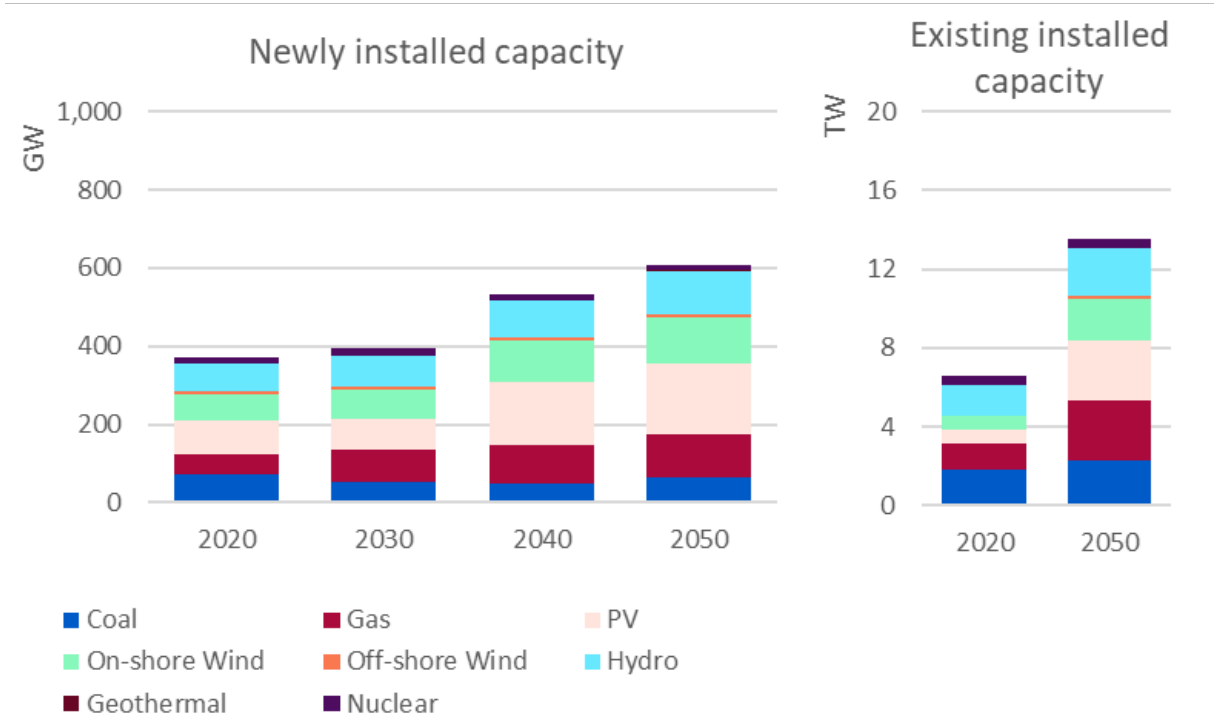
Global energy-related CO_2 emissions



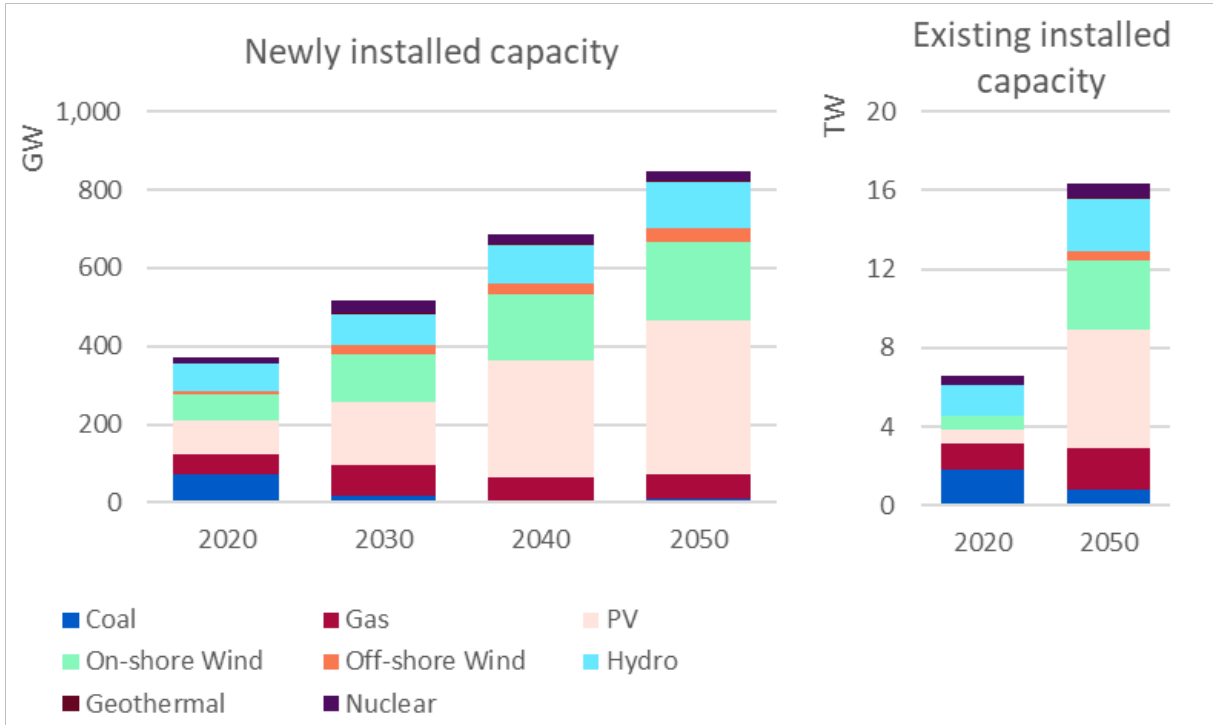
Source) "IEEJ Outlook 2023"

Outlook for CN power source

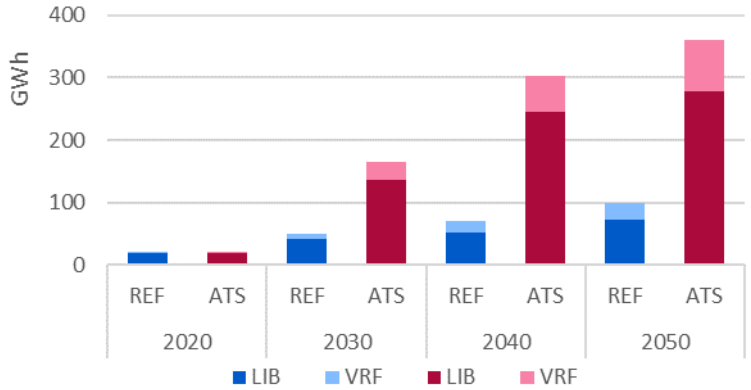
Reference Scenario (REF)



Advanced Technologies Scenario (ATS)



Stationary storage batteries

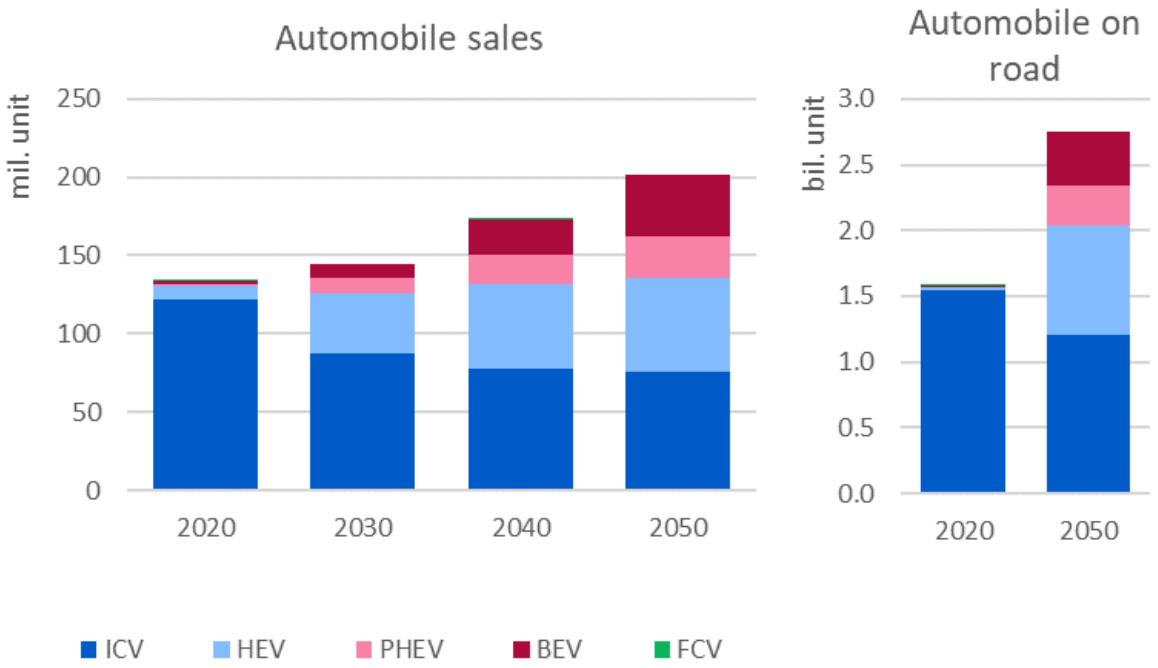


- In REF, renewable energy and thermal power generation meet the increasing electricity demand.
- In ATS, renewable energy and nuclear power meet it. Their introduction amount is about twice that of REF.
- The introduction of stationary storage batteries increases due to the spread of variable renewable energy.

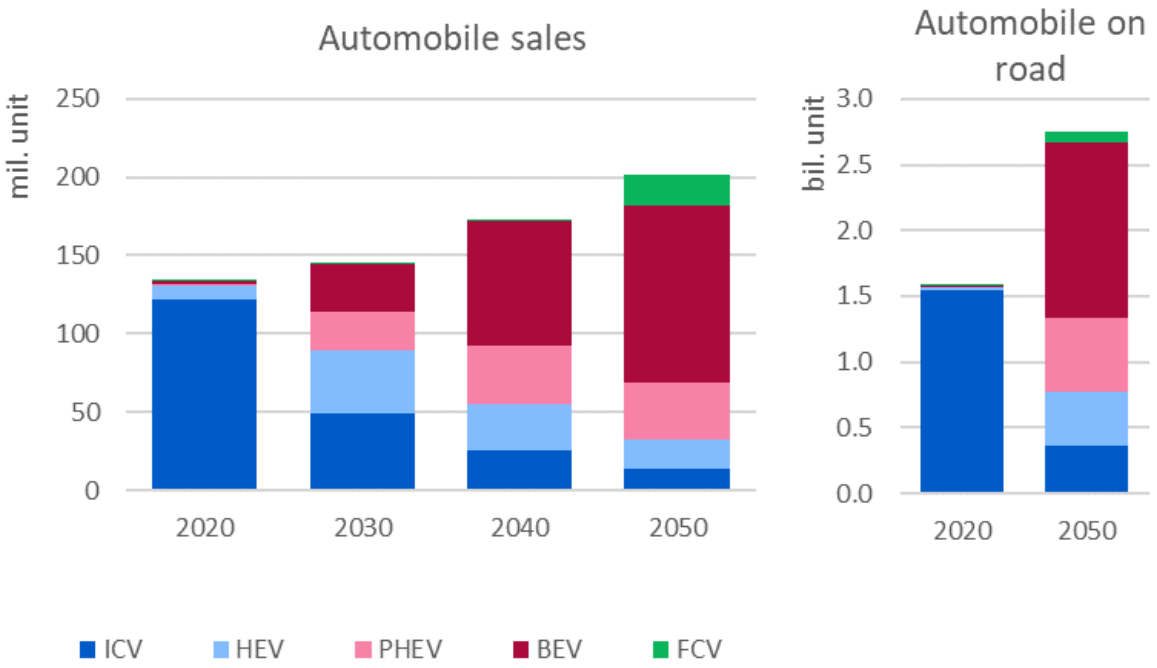
Source) "IEEJ Outlook 2023"

Outlook for electric vehicles

Reference Scenario (REF)

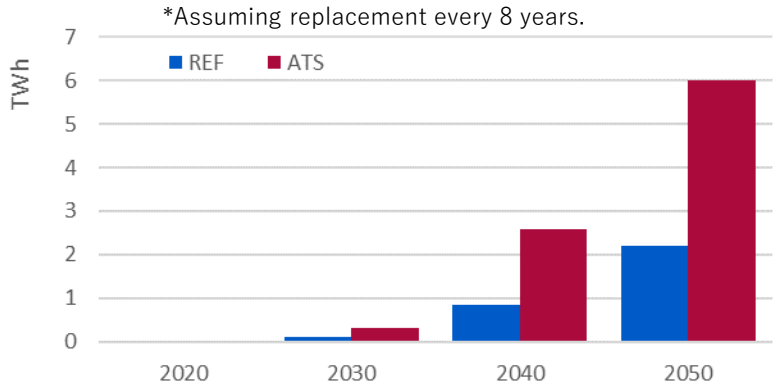


Advanced Technologies Scenario (ATS)



Note) ICV: Internal combustion engine vehicle, HEV：Hybrid electric vehicle, PHEV; Plug-in hybrid electric vehicle, BEV：Battery electric vehicle, FCV: Fuel-cell electric vehicle

Replacement battery

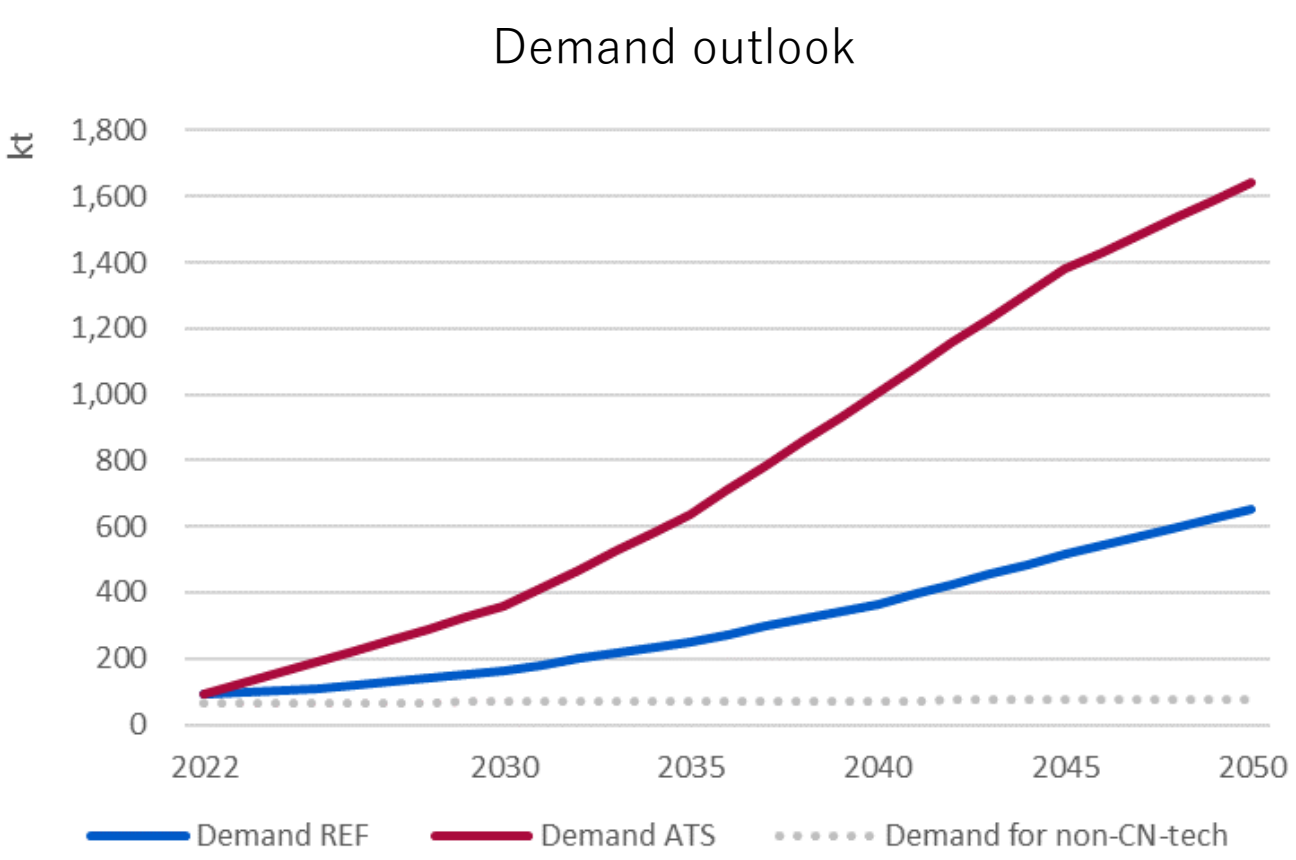


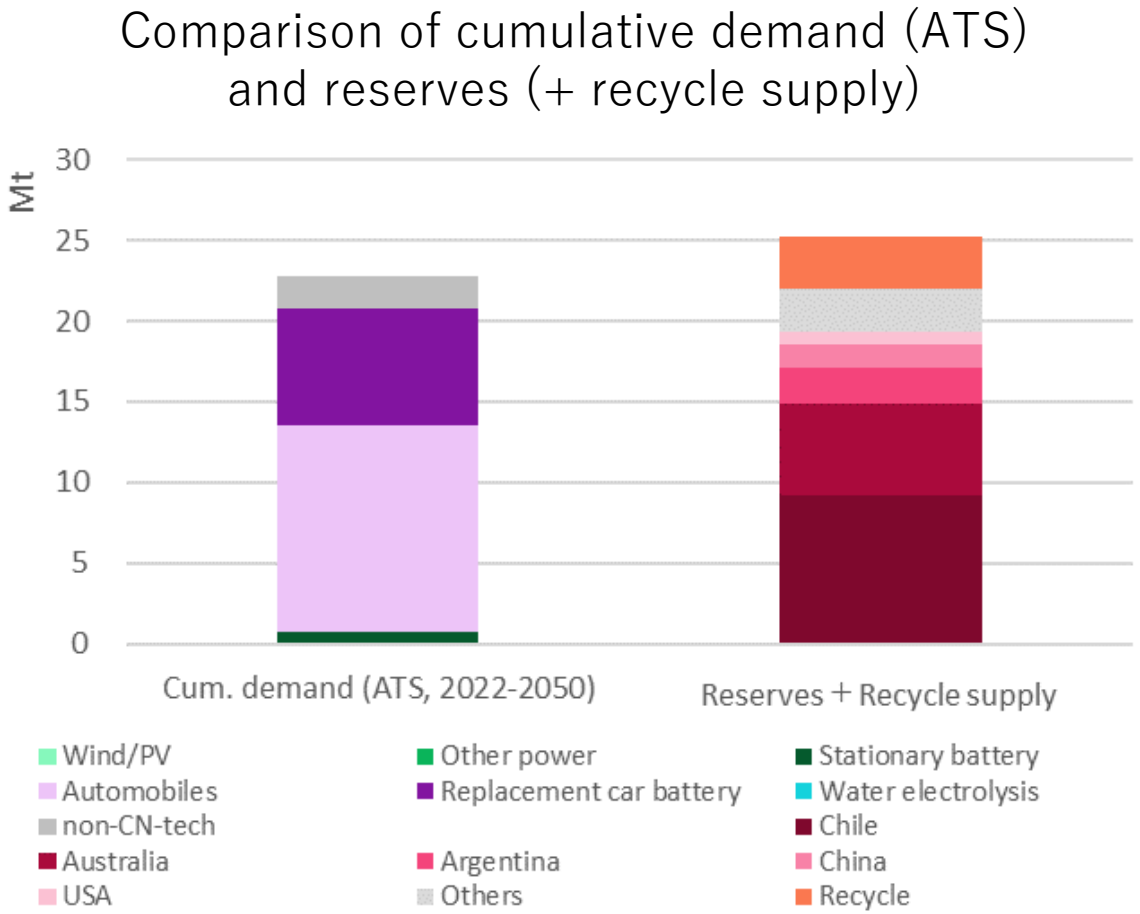
- In REF, ICVs and HEVs are the mainstream.
- In ATS, BEVs are the mainstream. After 2040, FCVs start to be introduced.
- Demand for replacement battery increases along with the spread of electric vehicles.

Source) "IEEJ Outlook 2023"

Results of mineral demand outlook

Lithium (Li)



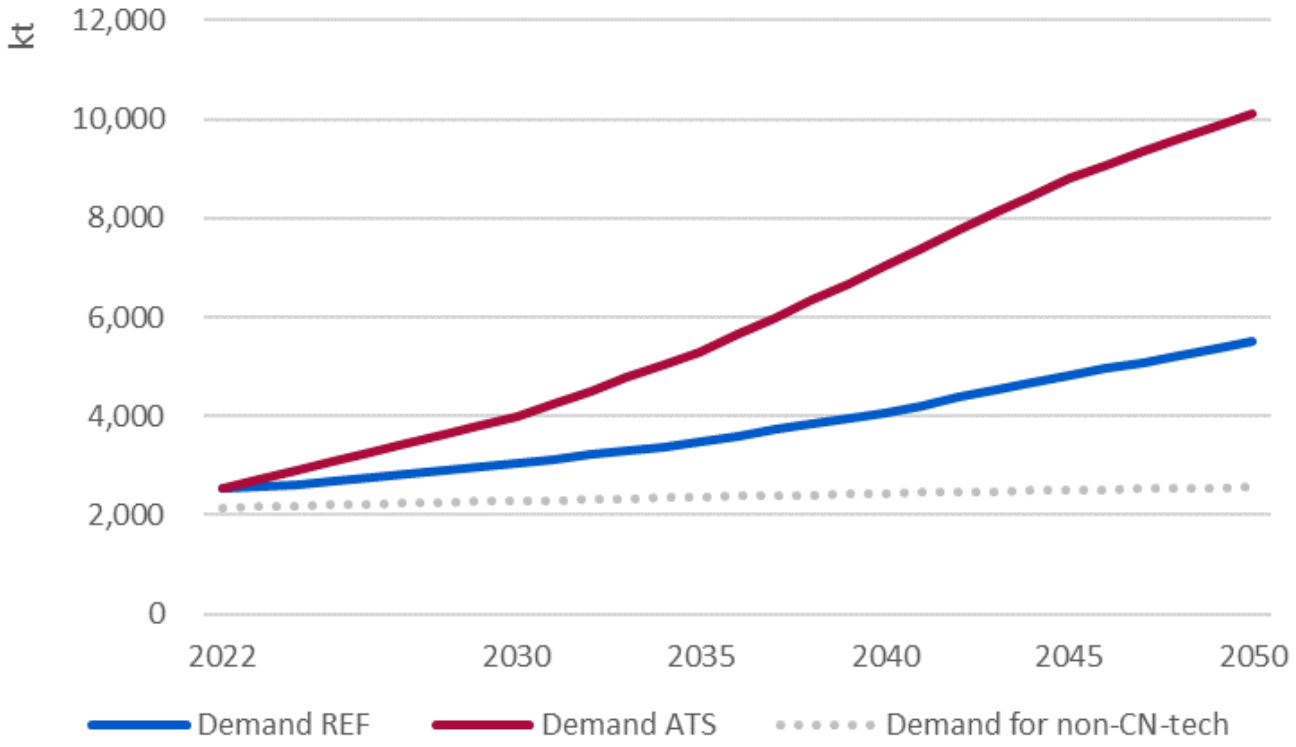


- Lithium is mainly used in batteries, and demand grows significantly along with electric vehicles.
- In ATS, where the electrification of automobiles is greatly advanced, demand increases by more than 10 times by 2050.
- Cumulative demand in ATS is slightly lower than reserves (+ recycle supply).

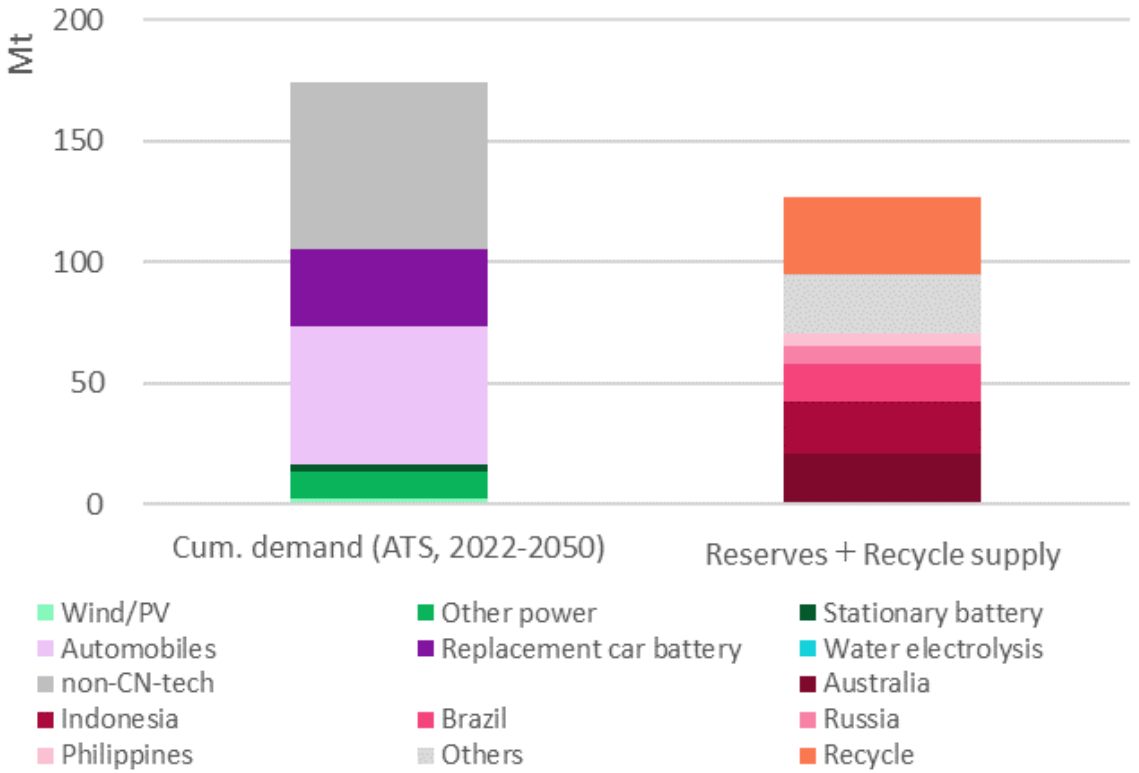
Note) Reserves are estimated from USGS, etc. Reserves fluctuate depending on economic efficiency, etc.

Nickel (Ni)

Demand outlook



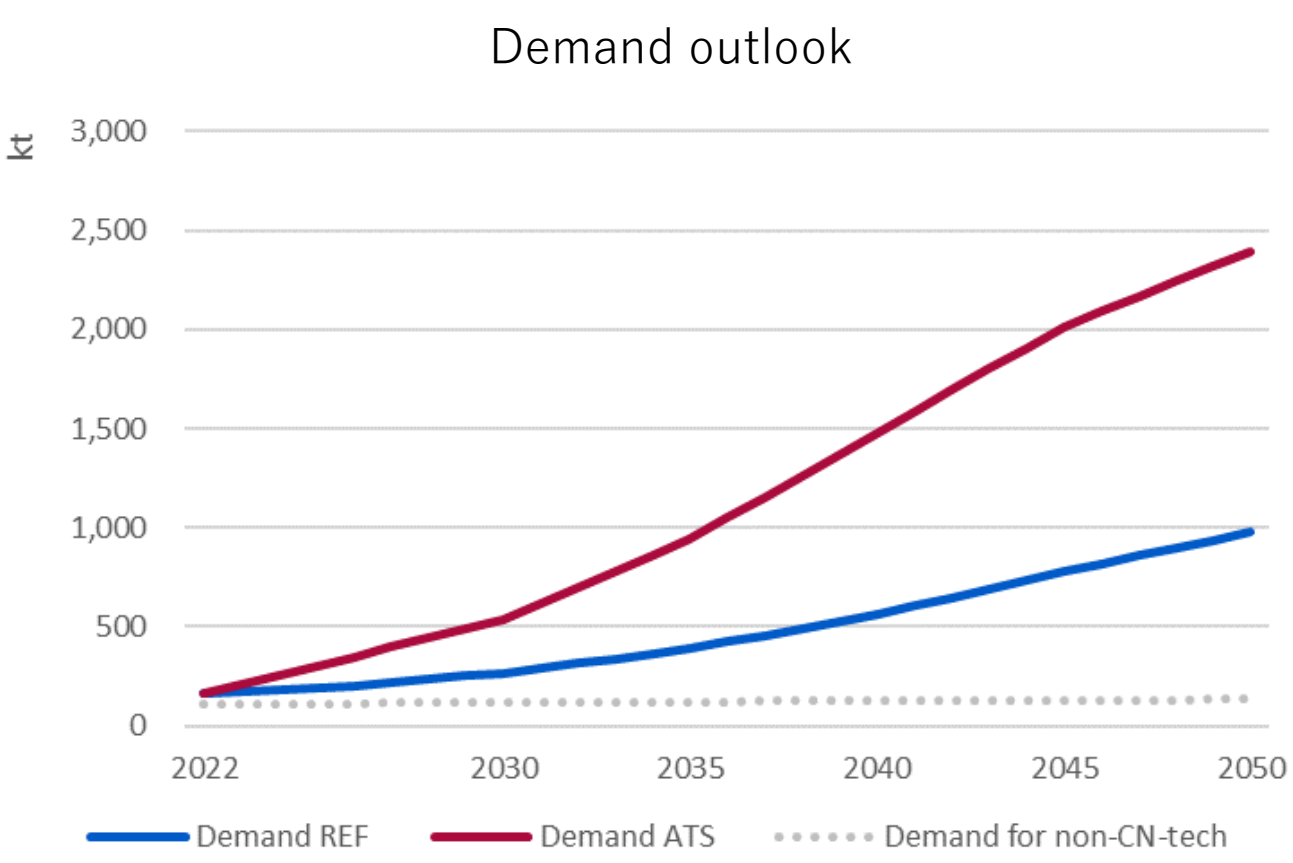
Comparison of cumulative demand (ATS) and reserves (+ recycle supply)

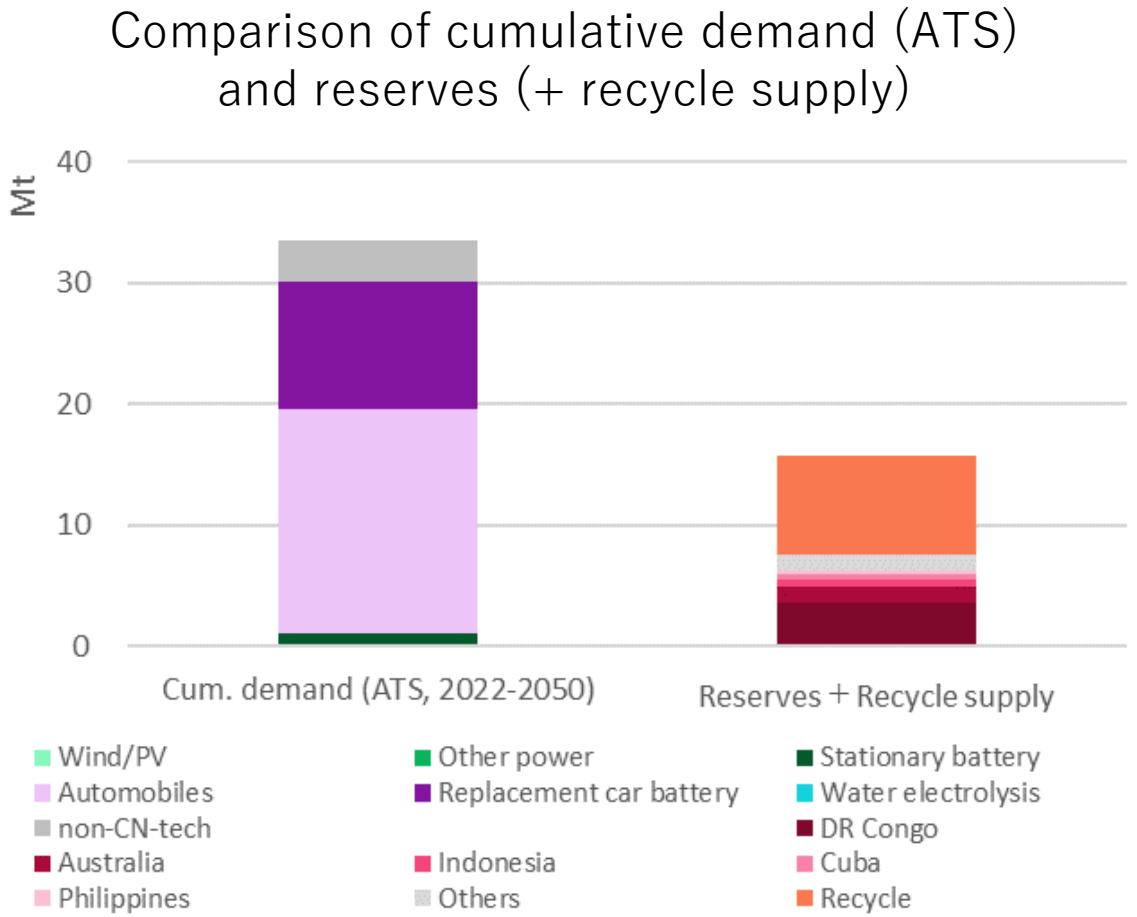


- Outside of main application, stainless steel and heat-resistant steel, Nickel is used for lithium-ion batteries and geothermal power in CN technologies.
- In ATS, where the electrification of automobiles is greatly advanced, demand increases by around 4 times by 2050.
- Cumulative demand in ATS exceeds reserves (+ recycle supply).

Note) Reserves are estimated from USGS, etc. Reserves fluctuate depending on economic efficiency, etc.

Cobalt (Co)

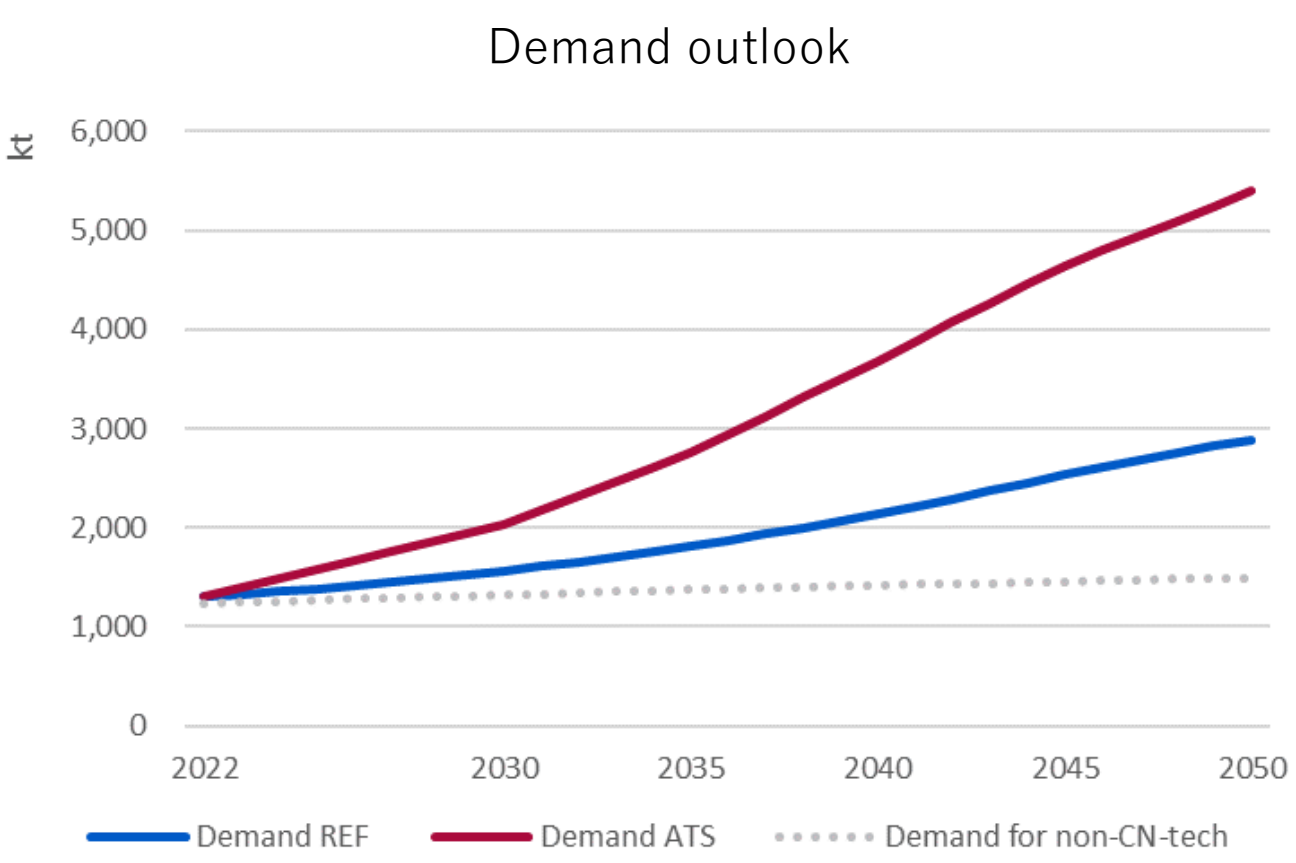


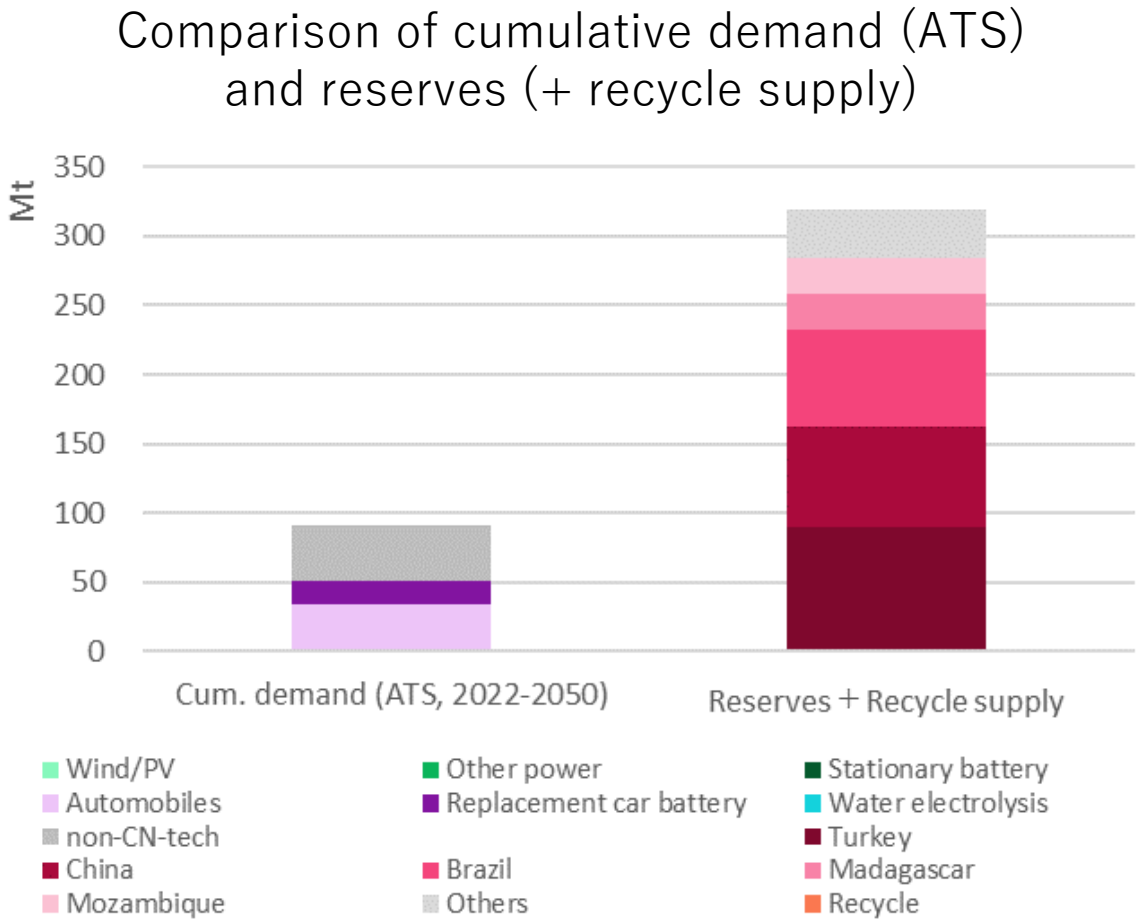


- Outside of special steel application, Cobalt is used as a positive electrode material for lithium-ion batteries.
- In ATS, where the electrification of automobiles is greatly advanced, demand increases by more than 10 times by 2050.
- Cumulative demand in ATS exceeds reserves (+ recycle supply).

Note) Reserves are estimated from USGS, etc. Reserves fluctuate depending on economic efficiency, etc.

Natural graphite (C)

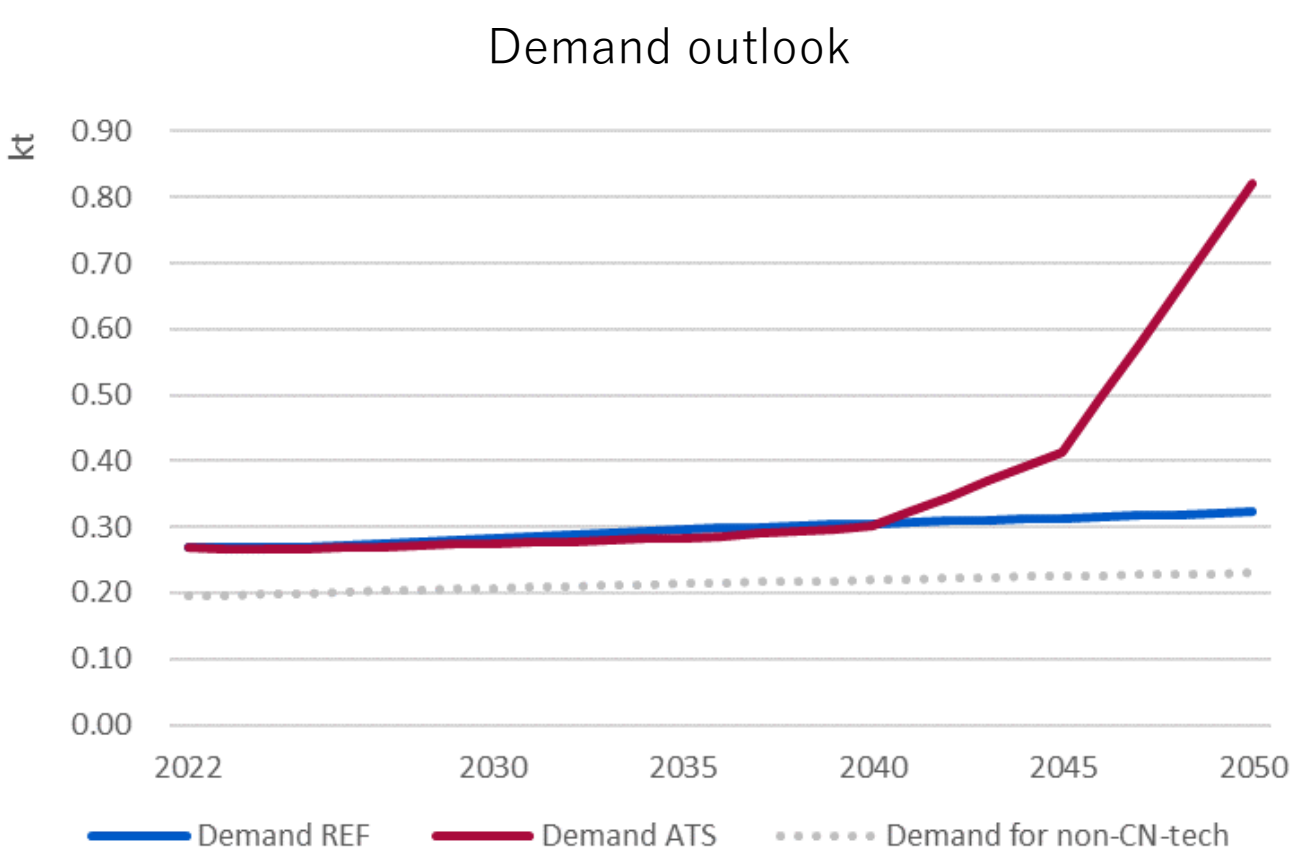


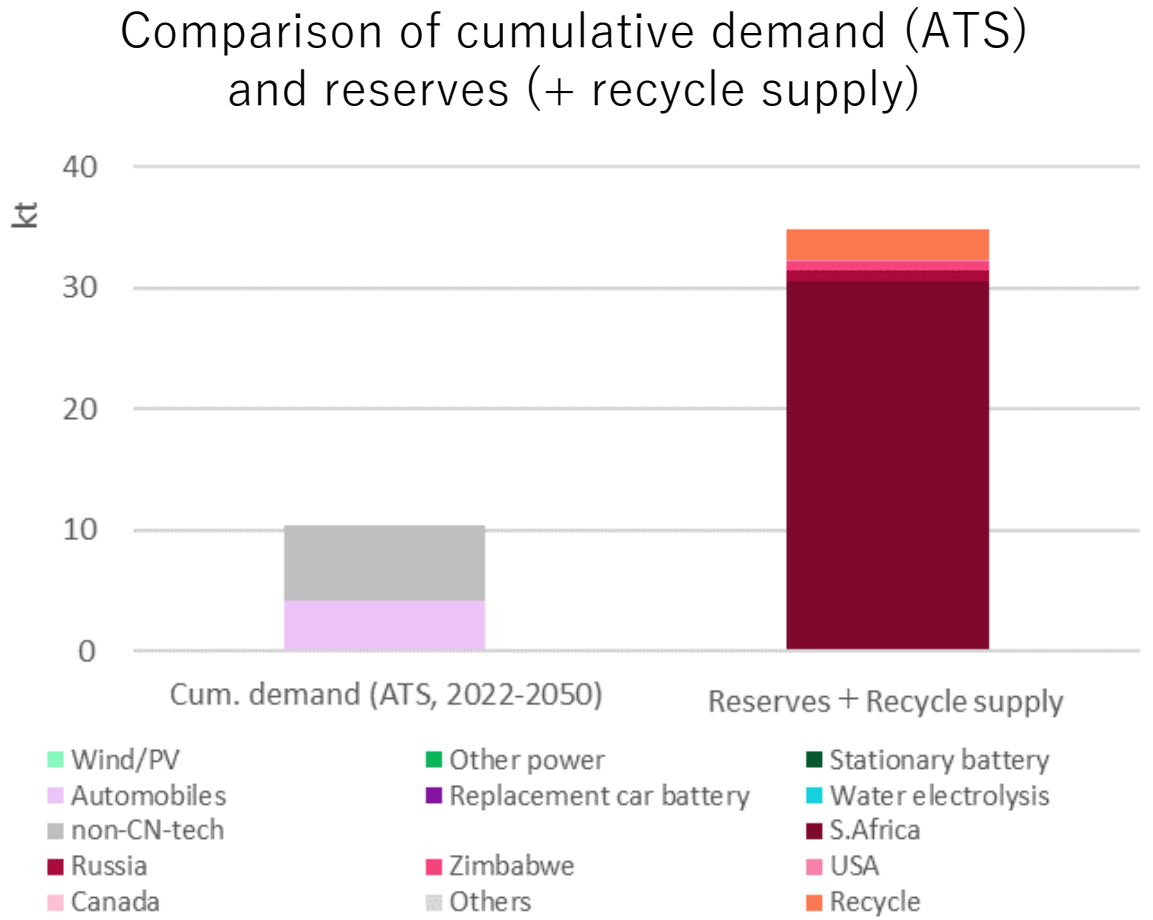


- Graphite is used in metal crucibles, molds, electric furnace electrodes, etc. and used in lithium-ion batteries in CN technologies.
- In ATS, where the electrification of automobiles is greatly advanced, demand increases by more than 4 times by 2050.
- Cumulative demand in ATS is much lower than reserves (+ recycle supply).

Note) Reserves are estimated from USGS, etc. Reserves fluctuate depending on economic efficiency, etc.

Platinum (Pt)

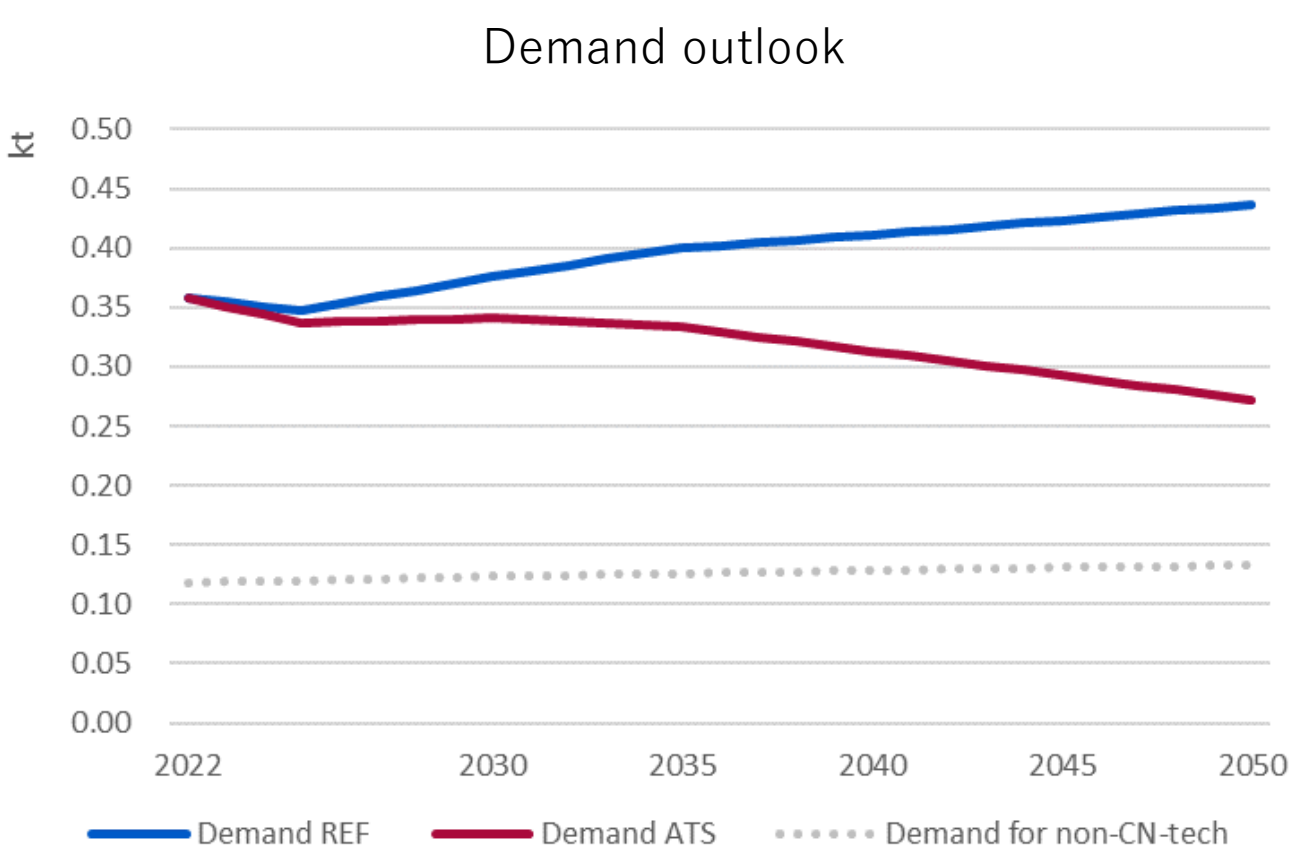


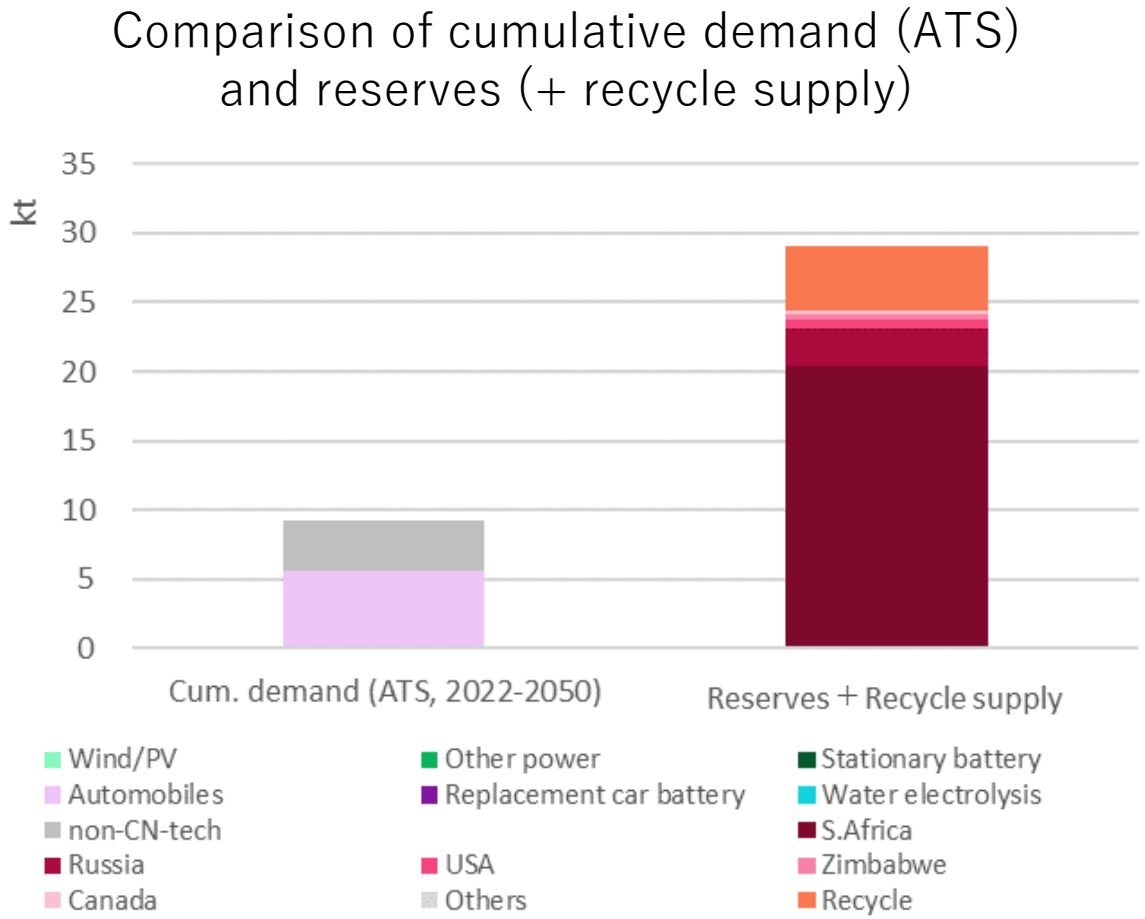


- In CN technologies, Platinum is used as an exhaust gas catalyst for automobiles now, will be used as an electrode catalyst for fuel cells and water electrolysers.
- In ATS, its demand for vehicles with internal combustion engine declines, but the demand for fuel cell vehicles increases significantly from 2040 onwards.
- Cumulative demand in ATS is much lower than reserves (+ recycle supply).

Note) Reserves are estimated from Hughes, et.al, and Platinum Group Metals, etc. Reserves fluctuate depending on economic efficiency, etc.

Palladium (Pd)

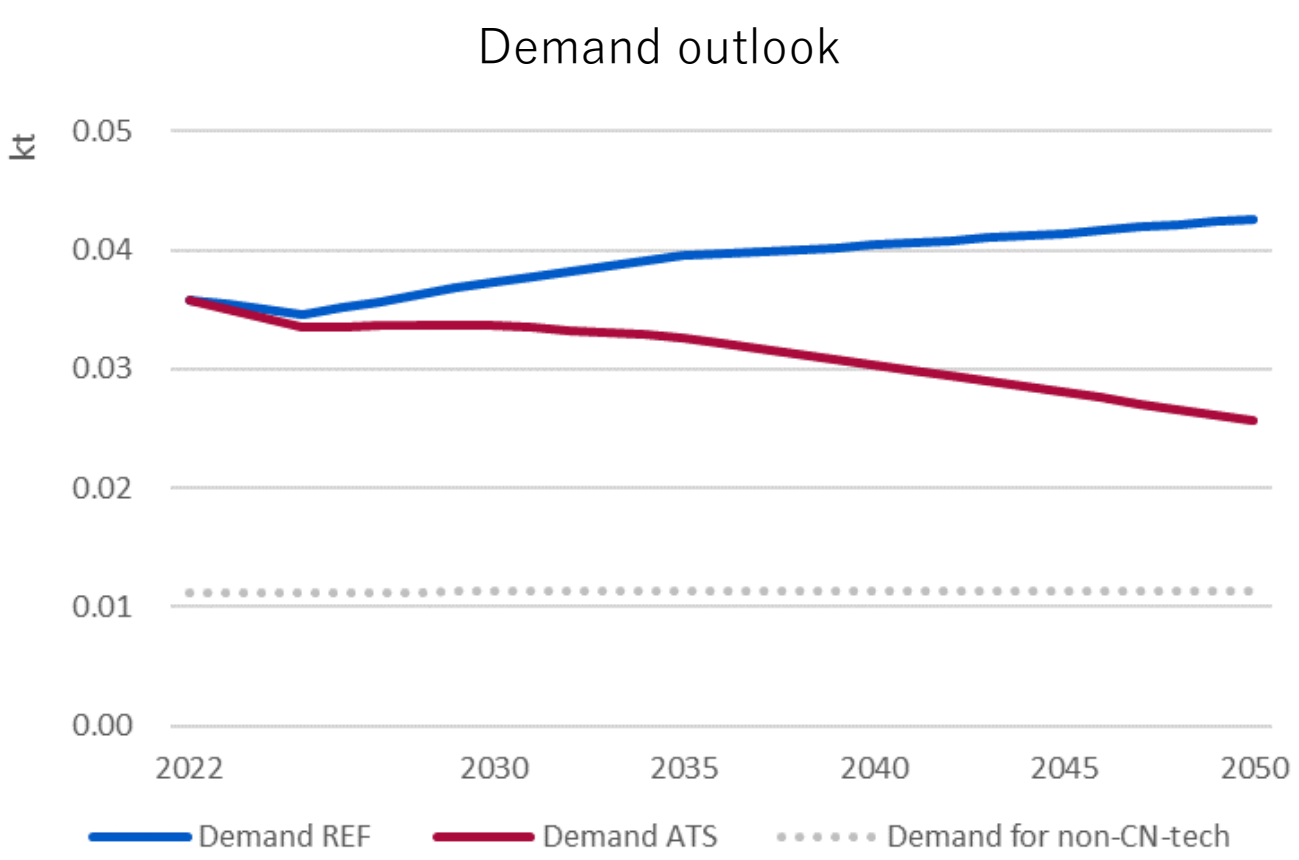


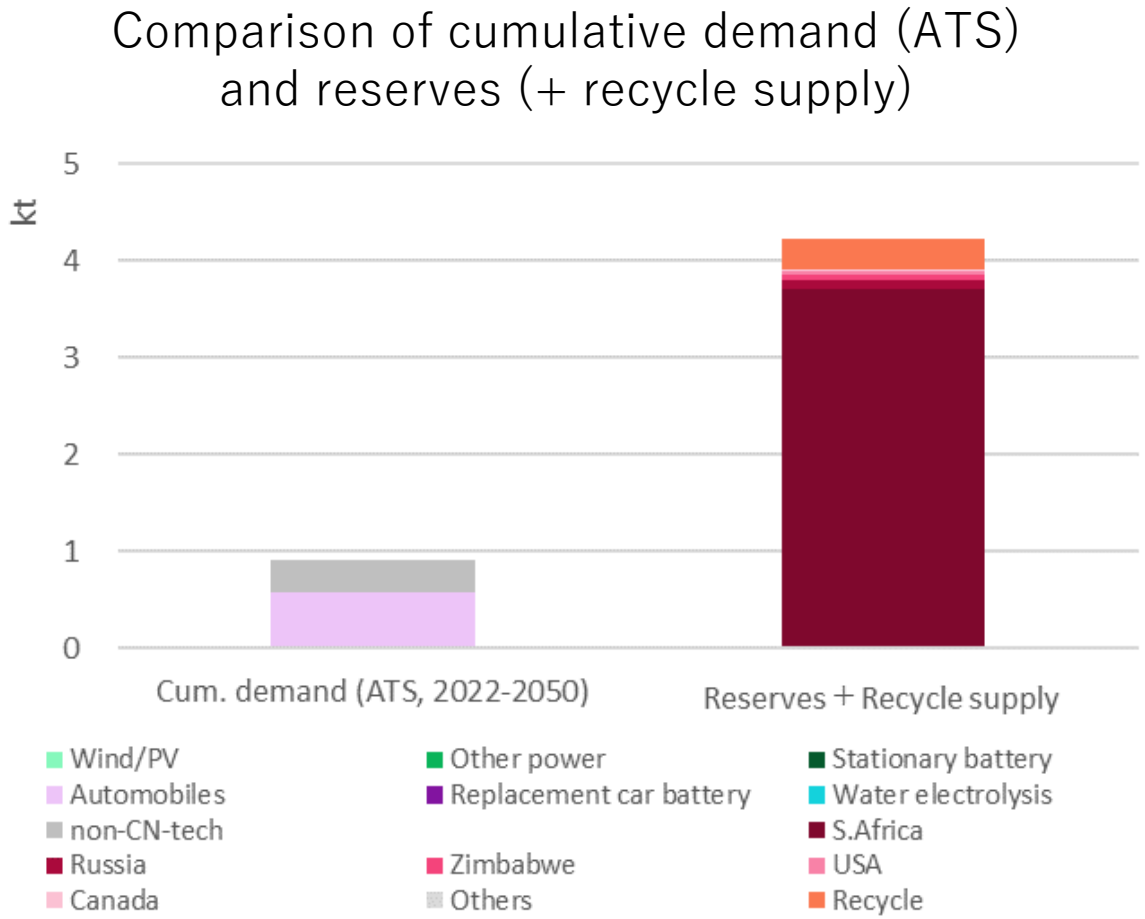


- In CN technologies, Palladium is used as an exhaust gas catalyst for automobiles.
- Demand in ATS, which has fewer vehicles with internal combustion engine, is lower than that in REF, and remain flat and then gradually decrease.
- Cumulative demand in ATS is much lower than reserves (+ recycle supply).

Note) Reserves are estimated from Hughes, et.al, and Platinum Group Metals, etc. Reserves fluctuate depending on economic efficiency, etc.

Rhodium (Rh)

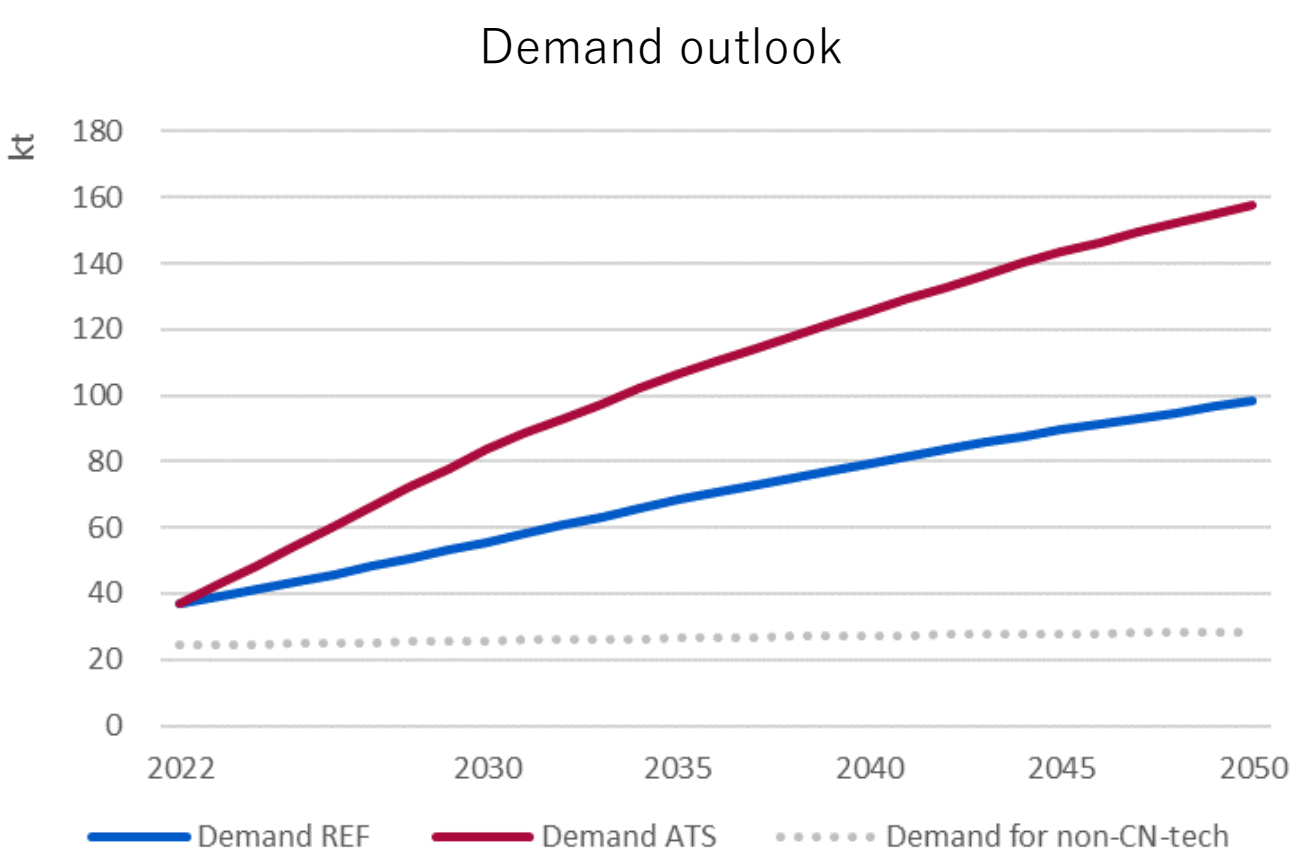


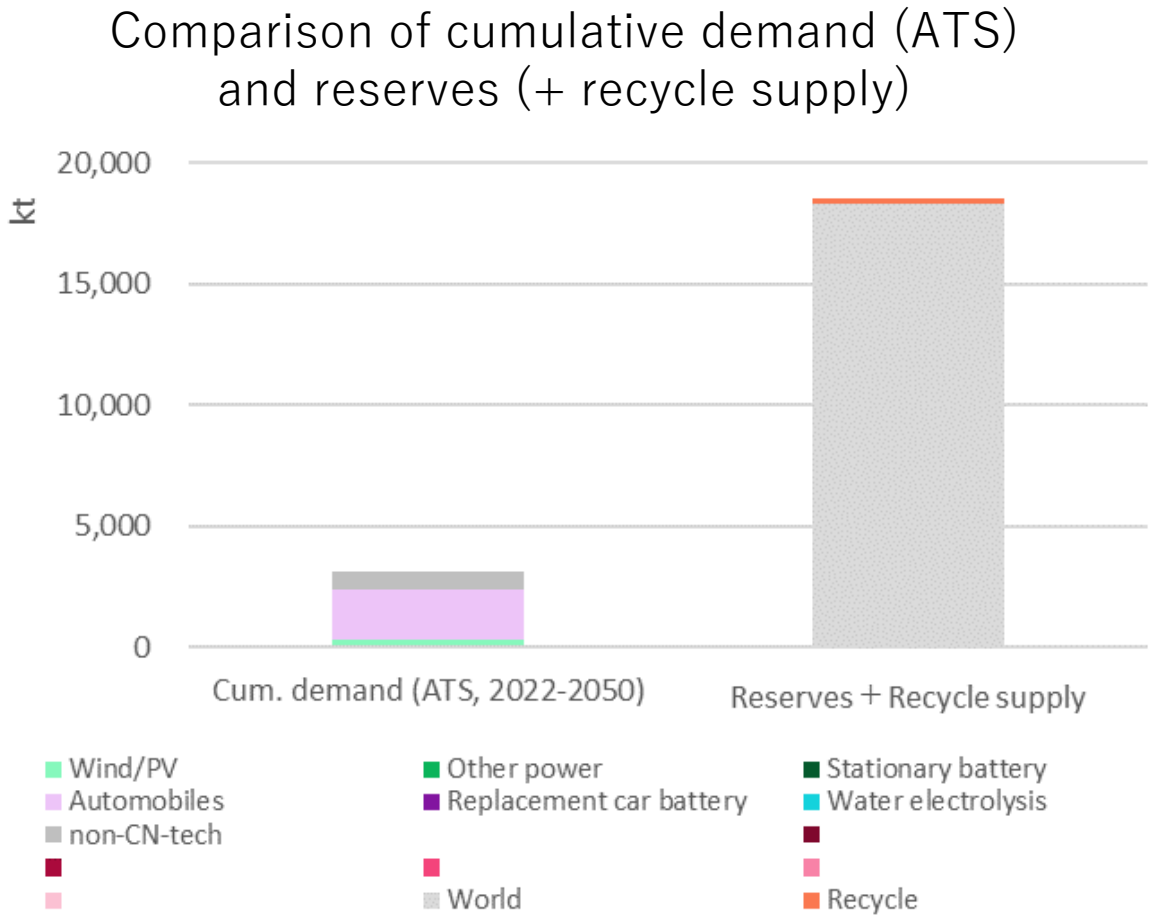


- In CN technologies, Rhodium is used as an exhaust gas catalyst for automobiles.
- Demand in ATS, which has fewer vehicles with internal combustion engine, is lower than that in REF, and remain flat and then gradually decrease.
- Cumulative demand in ATS is much lower than reserves (+ recycle supply).

Note) Reserves are estimated from Hughes, et.al, and Platinum Group Metals, etc. Reserves fluctuate depending on economic efficiency, etc.

Neodymium (Nd)

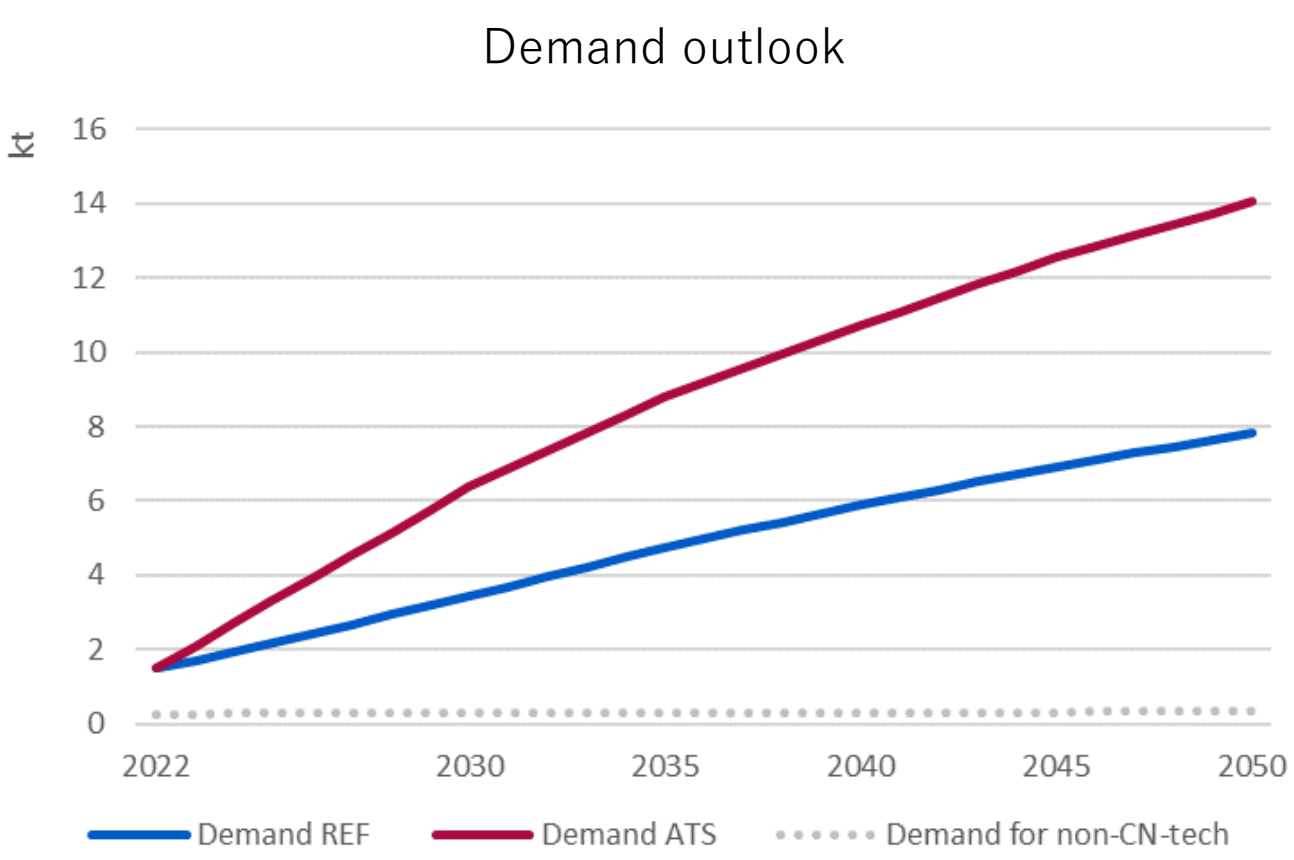


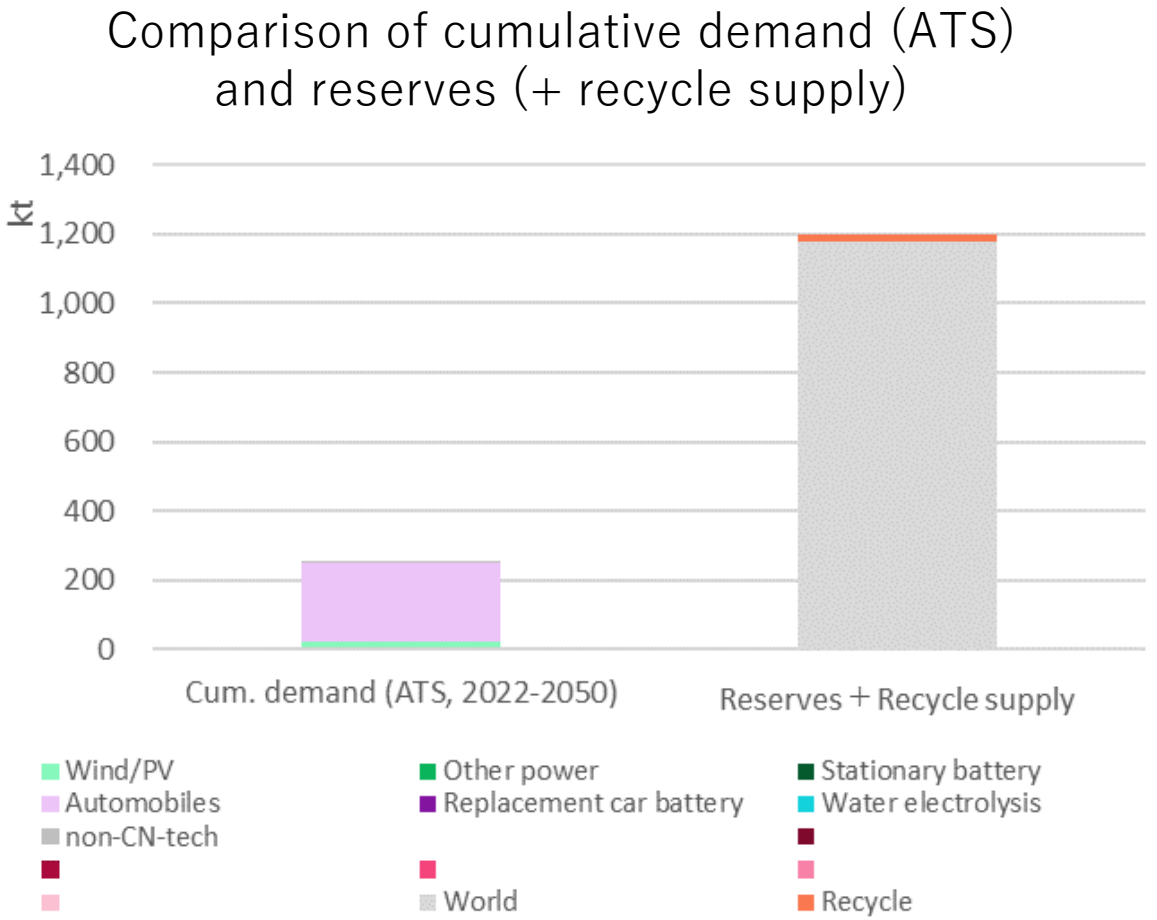


- Neodymium is used in the magnets in the motors of electric vehicles and the generators of wind power, in CN technologies.
- In ATS, demand increases by around 4 times by 2050.
- Cumulative demand in ATS is much lower than reserves (+ recycle supply).

Note) Reserves are estimated from USGS, etc. Reserves fluctuate depending on economic efficiency, etc.

Dysprosium (Dy)

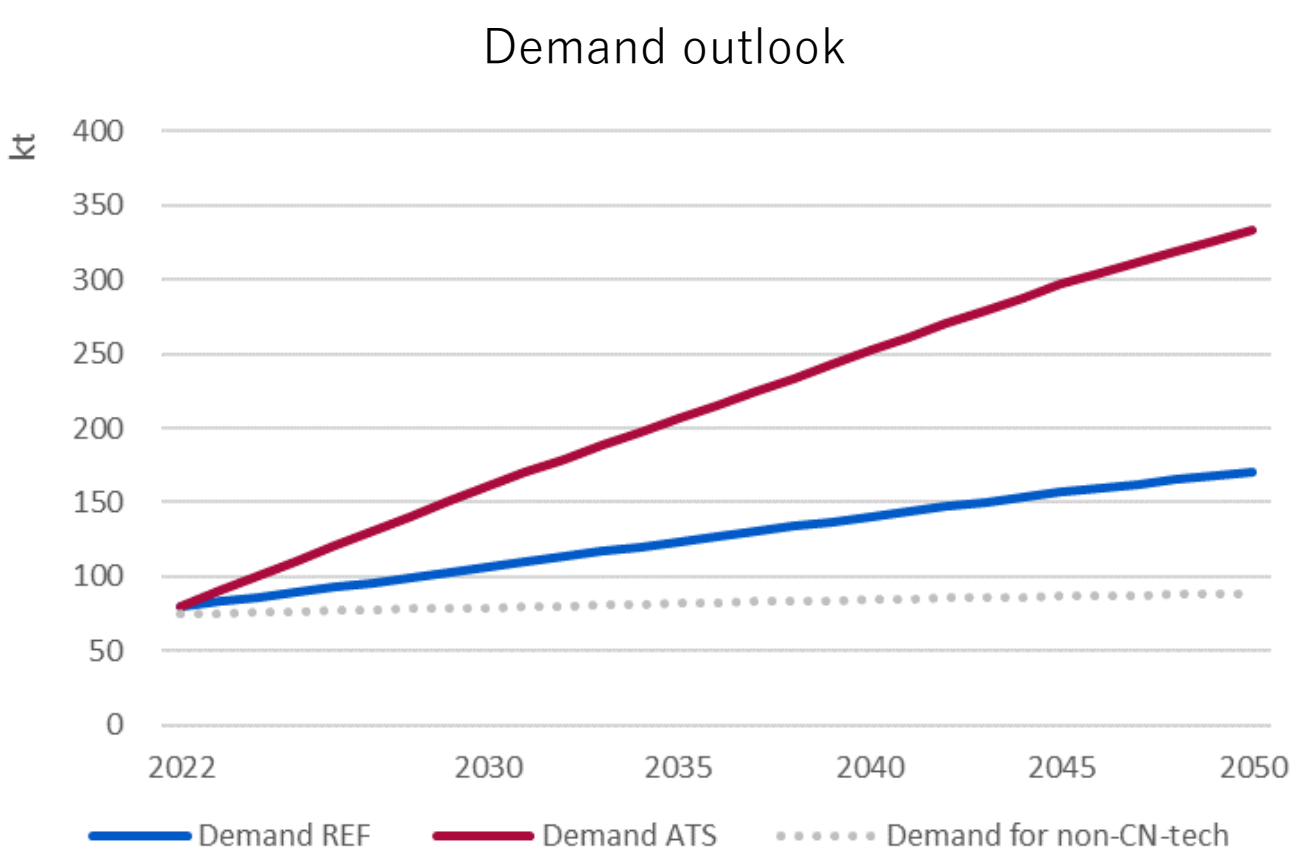


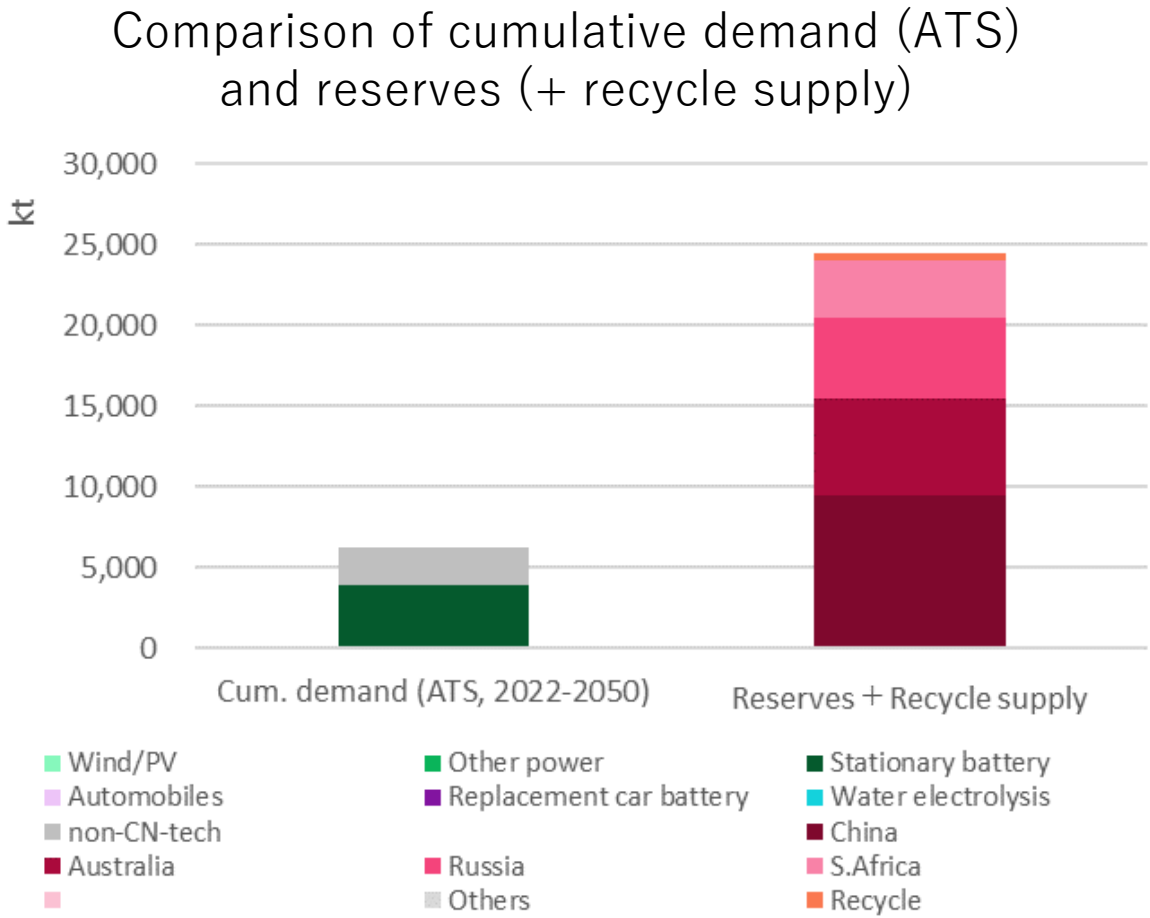


- Dysprosium is used in the magnets in the motors of electric vehicles and the generators of wind power, in CN technologies.
- In ATS, demand increases by more than 10 times by 2050.
- Cumulative demand in ATS is much lower than reserves (+ recycle supply).

Note) Reserves are estimated from USGS, etc. Reserves fluctuate depending on economic efficiency, etc.

Vanadium (V)

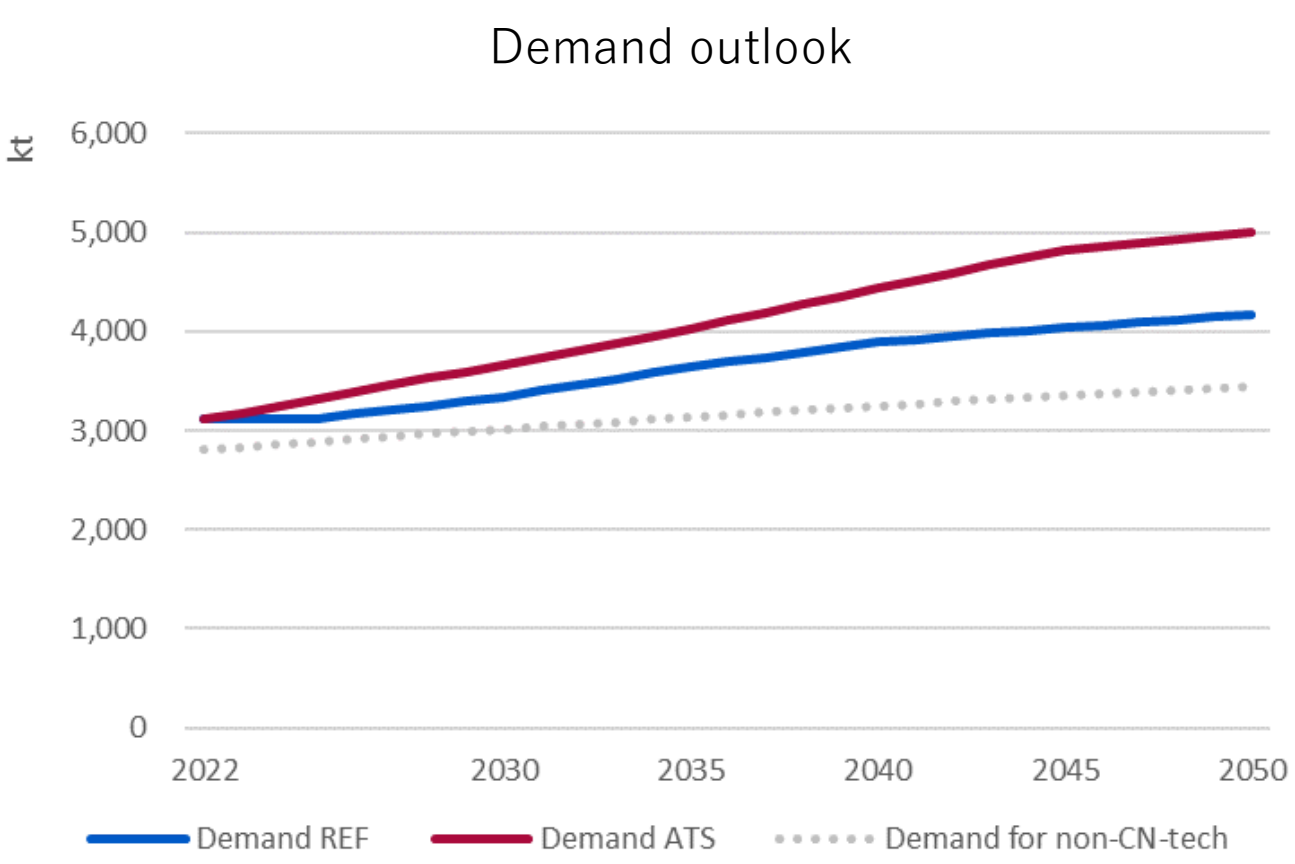


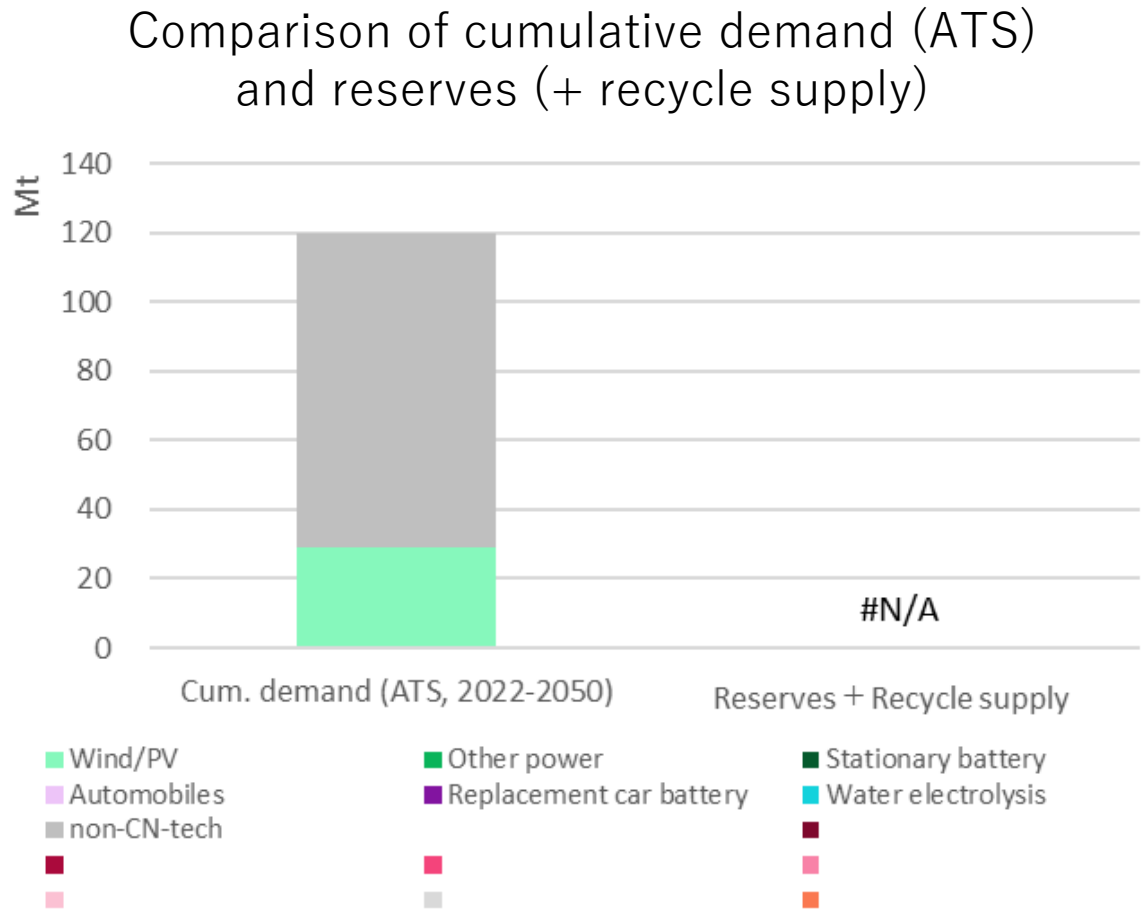


- Vanadium is used as an additive to steel, and will be used in the electrolyte of redox flow batteries in CN technologies.
- In ATS, where variable renewable energy are more popular, demand increases by around 4 times by 2050.
- Cumulative demand in ATS is much lower than reserves (+ recycle supply).

Note) Reserves are estimated from USGS, etc. Reserves fluctuate depending on economic efficiency, etc.

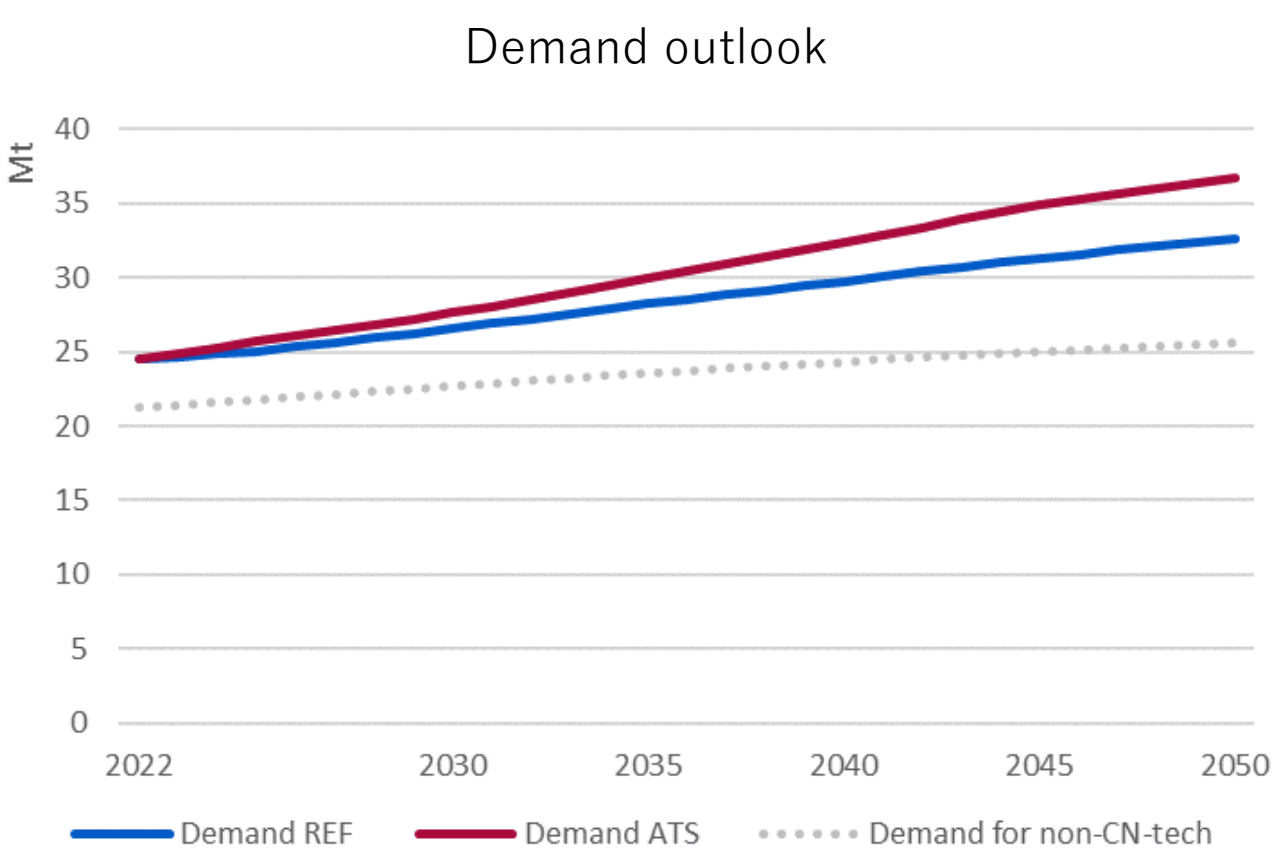
Silicon (Si)

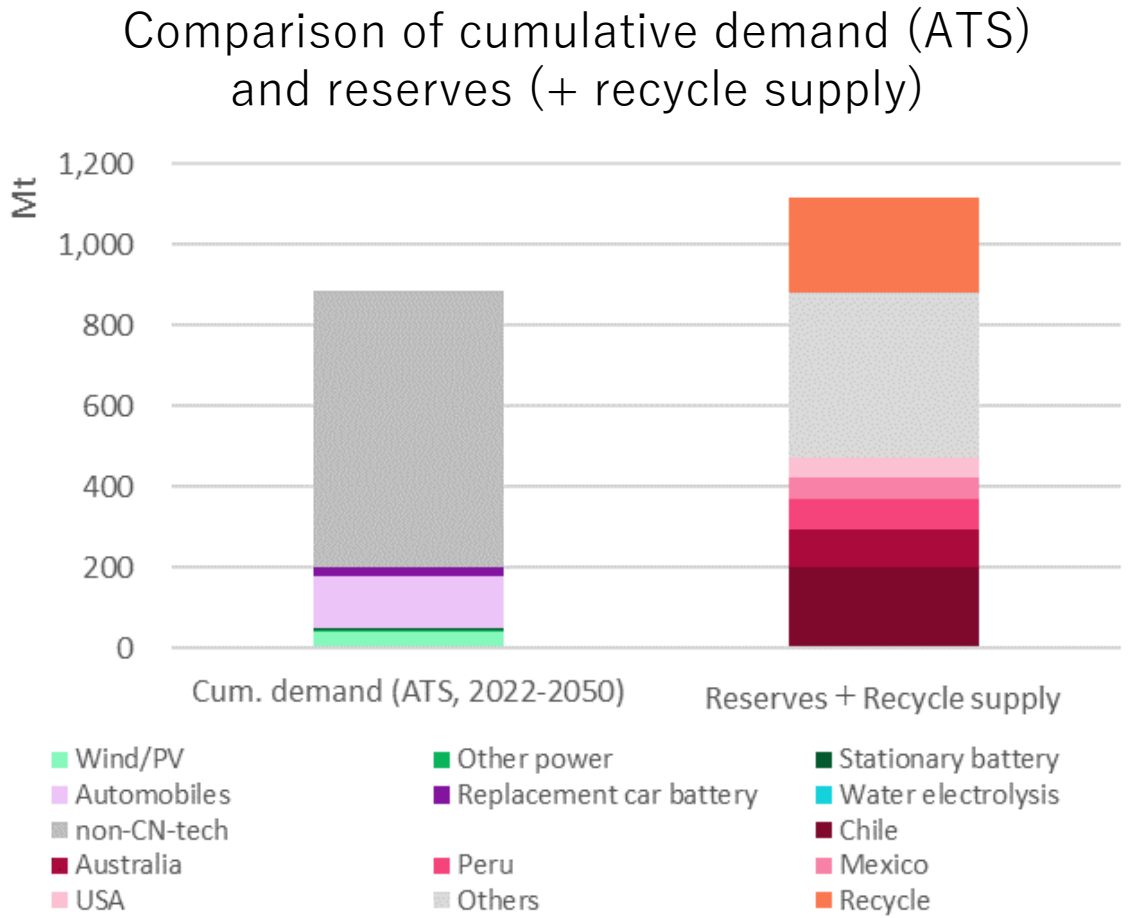




- Silicon is used in various applications, and it is used in photovoltaic panels in CN technologies.
- Demand increase significantly as photovoltaic power generation spreads.
- Silicon is the second most abundant element after oxygen, and its resources are extremely large. No concern about tight supply and demand when looking at the resource as a whole.

Copper (Cu)





- Copper is used in various applications, and there is a lot of demand outside of CN technologies.
- Demand increases significantly along with wind and PV power, electric vehicles, and batteries.
- Cumulative demand in ATS is slightly lower than reserves (+ recycle supply).

Note) Reserves are estimated from USGS, etc. Reserves fluctuate depending on economic efficiency, etc.

Summary of Mineral Demand Outlook

- Mass-scale introduction of CN technology will greatly induce the demand for minerals.

Silicon: photovoltaic
Lithium, Nickel, Cobalt, Graphite: electric vehicles (batteries)
Platinum: fuel cell vehicles
Neodymium, Dysprosium: wind power generation, electric vehicles (motors)
Vanadium: redox flow battery

- Require technological development to reduce the use intensity for mineral resources whose cumulative demand exceeds reserves.

Minerals where demand exceeds reserves: Nickel, Cobalt

Note) The mineral use intensities are set to be constant during the forecast period.
Reserves may fluctuate depending on economic efficiency, etc.