POSRI Issue Report

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포스코경영연구원

팬데믹 이후 메가트렌드와 미래 철강산업

(Post-Pandemic Megatrends and Their Influence on the Steel Industry)

POSRI 미래 메가트렌드 리서치 시리즈, 2023년 1월 11일

고준형, *Ph.D.* | 대표이사 원장, 포스코경영연구원

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팬데믹 이후, 4대 메가트렌드는 사회·경제에 지속적인 빅 체인지 유발

기후변화

- 모든 분야에 지속적으로 영향을 미치는 슈퍼 메가트렌드

기술진보

- 탄소중립·부의 불균형·질병 확산 등 인류 문제해결을 위해 발전하는 기술

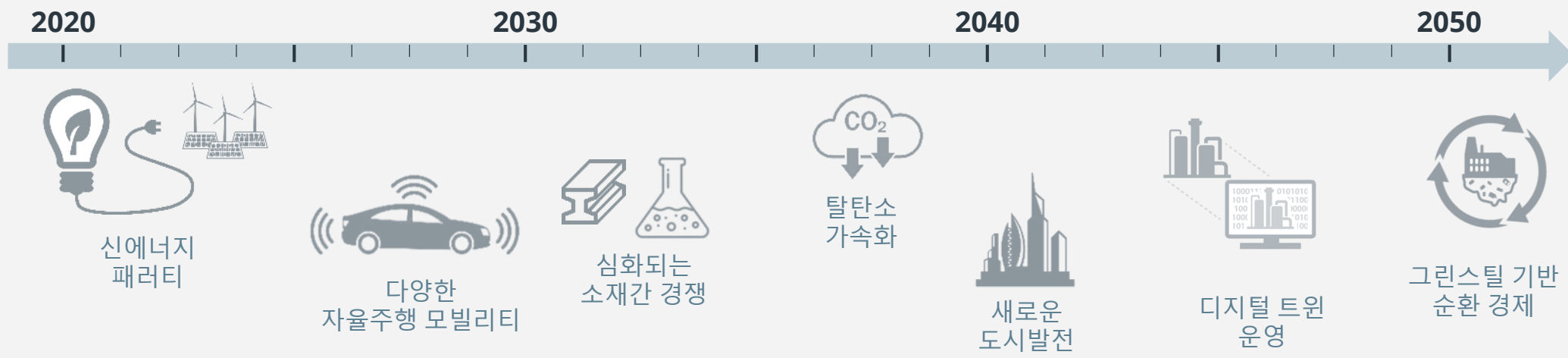
사회경제적 변화

- 인구학적 변화 - 고령화, 신세대의 영향력 증대, 개인 선호의 이전

지정학적 리밸런싱

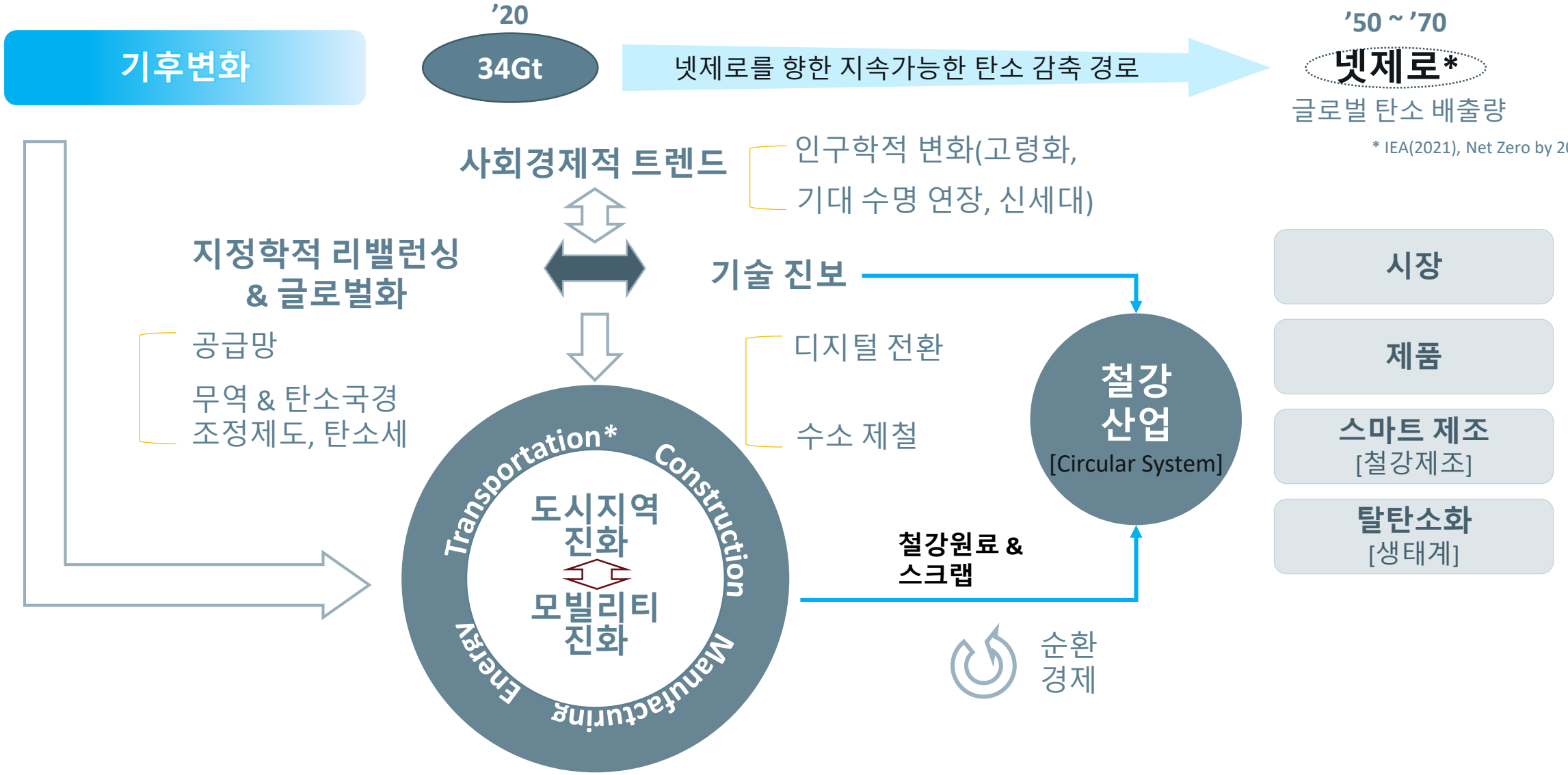
- 다극화된 세계질서, 공급망 재편, 에너지·기술·환경 등 다양한 이슈에 대한 패권경쟁

혁신적 관점 ↔ 지속가능성 관점



향후 30년 내 글로벌 철강산업 환경의 변화와 도전은?

넷제로 시대 글로벌 철강업 환경



1] 팬데믹 이후의 패러다임 (Post-pandemic landscape of the globe)

- **4대 메가트렌드는 미래 사회·경제에 지속적인 빅 체인지를 유발할 것임**

  - (기후변화) 경제·산업구조 변화를 넘어 글로벌 기술패권과 역학관계 변화 초래
  - (기술혁신) 혁신기술은 소재와 에너지를 클린화하고 재순환해 탈탄소 실현
  - (사회경제적 변화) 고령화, 신세대의 사회내 경제적 영향력 증대
  - (지정학적 리밸런싱) 글로벌 공급망, 탄소가격시스템, 교역구조 전환 예상

  → **메가트렌드는 도시/모빌리티 진화를 통해 미래 철강산업의 구조변화 영향**

2] 도시발전의 미래 (Future of urban development)

- **도시 진화는 에너지, 인프라, 모빌리티 허브로서 저탄소 기조가 강화되면서 그린건축, 분산전원, 친환경모빌리티 중심의 미래 철강수요의 양적/질적 변화의 모멘텀이 될 전망**

  - (건설) 친환경 니즈 강화, 디지털 3D 기술, 친환경 합성소재 수요 증가, 철강수요 메인 드라이버 역할
  - (모빌리티) 친환경/편의/안전 니즈, UAM(urban air mobility), Hyperloop/퍼스널 모빌리티 신규 수요
  - (에너지) 분산전원의 집적화, 신재생에너지/수소 생태계 인프라 창출로 철강 수요 확대

3] 철강기술의 미래 (Future of steelmaking technology & metallic balance)

- **탈탄소 기술발전은 가속화되면서 현재 주류 제법들이 대체, 전환될 전망**
  - 철강업 탄소중립 경로: 프로세스 최적화(~'30) → 탄소감축 가속화(~'50)
  - 철강업 미래 경쟁우위는 연원료 저가소싱과 에너지효율 설비 확보에 좌우
- **수소 기반의 청정 철강제법 전환으로 철원 밸런스도 중장기적으로 큰 변화**
  - 선철 수요는 감소세로 전환 반면, 철스크랩과 직접환원철 수요는 큰 폭 증가
- **자원순환 경제와 지정학적 재편에 대응해 철강재의 안정적 공급 중요**
  - 철강업내 포함 전후방 Value Chain에서 자원순환성(circularity) 확보 관건
  - 지정학·지경학적 변화를 뛰어넘어 미래 안정적인 철강 공급망 유지 필요
- **한편, 디지털전환 확산으로 철강 제조(자동화 → 디지털 트윈) 및 철강 Biz. 프로세스** (마케팅, 물류 등 실제업무의 가상화)**에도 혁신적으로 적용**

4] 비전과 아젠다 (Vision and agenda for global steel industry)

- **(비전) 미래 철강산업은 친환경소재를 제공해 인류 사회의 지속적인 성장에 기여해야 하며 비전 달성을 위해 4대 분야의 노력을 경주할 필요**
  ① Growing along the market, ② Material solution provider, ③ Smart & digital manufacturer, ④ Carbon neutral ecosystem
- **(2050년 철강산업 미래상) 제로에너지 빌딩, 그린 모빌리티, 신재생에너지 인프라 등 미래 도시에서 필요한 자원순환적이고 친환경적인 철강 소재의 중요성은 미래에도 계속될 것임**

새로운 도시 유형, 그린 모빌리티, 재생 에너지 인프라로 구성된 사회에서도 순환적이고 친환경적인 철강의 중요성은 지속

"철강의 현대 사회의 필수 소재. 철강의 주 수요처는 빌딩과 인프라이고 운송수단의 중요 소재. SDS 시나리오는 파리 협약에 부응하는 이행경로 전망."
(IEA, 2020)

Source: POSRI, MEEG

Post-Pandemic Megatrends and Their Influence on the Steel Industry

POSRI's Future Megatrend Research Series, January 11th, 2023

Dr. Jun H. Goh | President and CEO, POSCO Research Institute

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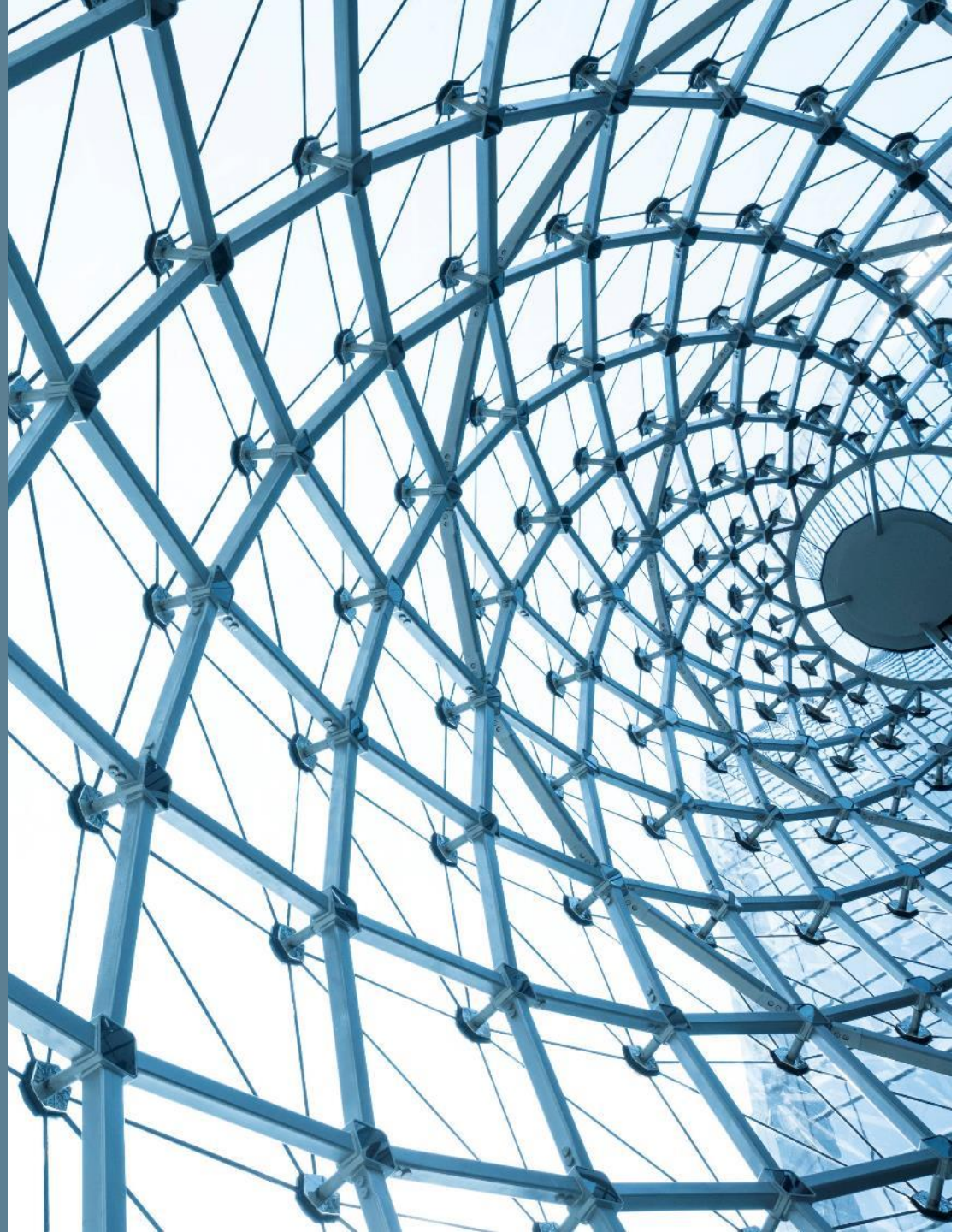
•Some materials are brought and modified from POSRI's presentation on behalf of worldsteel MegaTrends Evaluation Expert Group(MEEG) at worldsteel Board meeting(Oct. '22)
•The contents inside are not the official opinions from POSRI and worldsteel.



Contents

Four megatrends accelerated after pandemic, triggering enormous changes

Climate Change

- Super megatrend constantly influencing all sectors

Technological Progress

- Address the issues such as carbon neutrality, wealth inequality and spreading disease

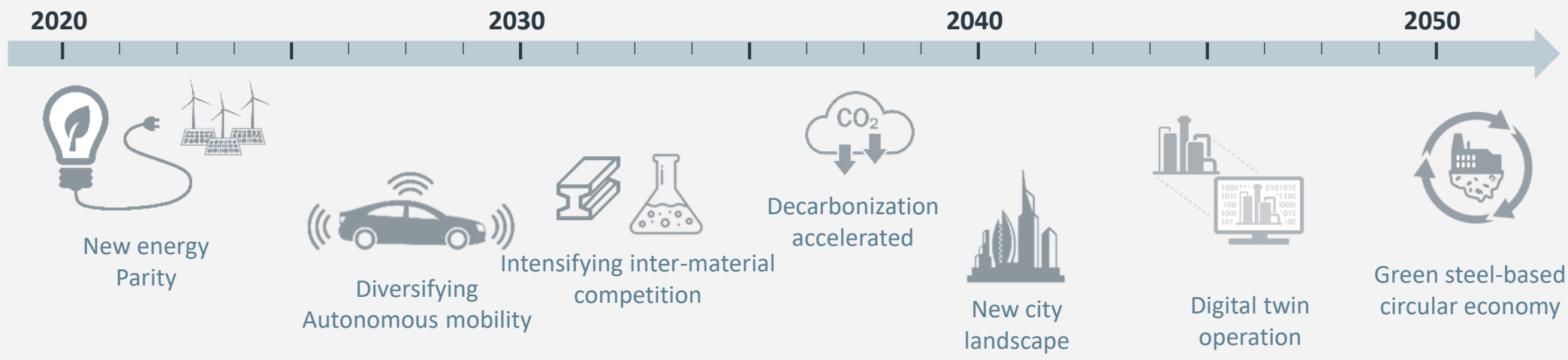
Socioeconomic Changes

- Demographic shift - Aging population, bigger role of new generations, shifting individual behaviors

Geopolitics

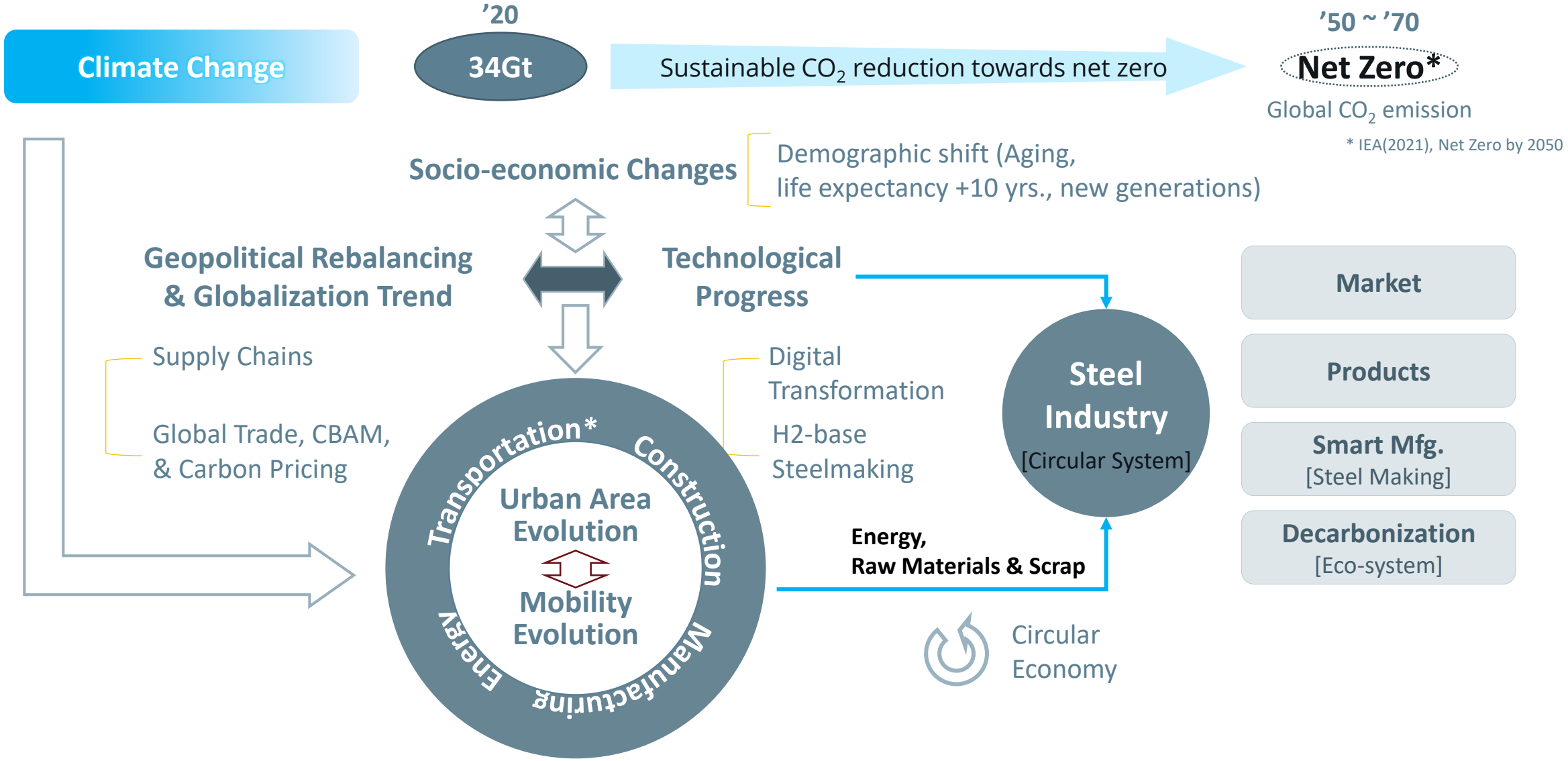
- Hegemonic competition to multi-polar world order & energy·tech divide

Innovation perspective ⟷ **Sustainability perspective**



How will the landscape change and what challenges will the steel industry face next 30 years?

Framework for pictures of the future(PoF) of the steel industry in the net-zero era



* Automobile, Aerotaxi, hyperloop, Shipbuilding, etc.

Post-pandemic landscape of the globe

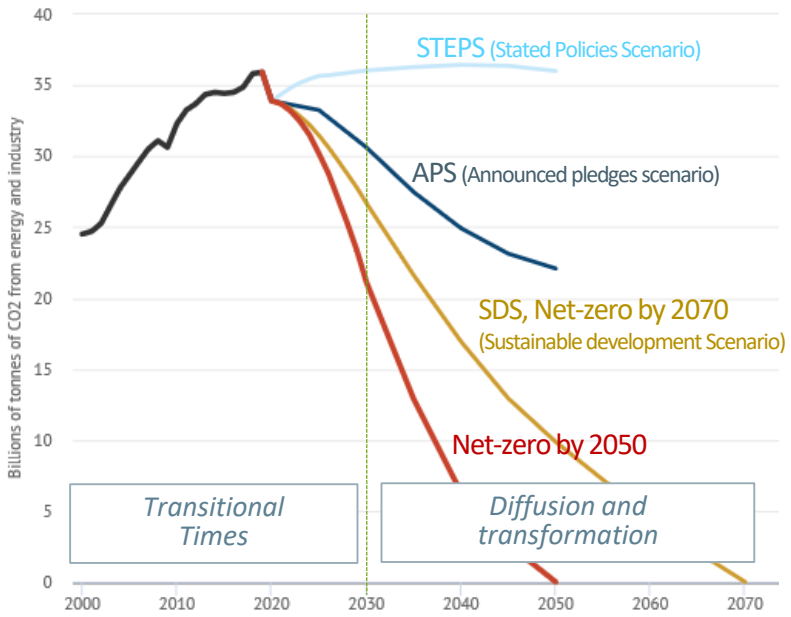
Climate change brings about changes to all sectors such as economy, society, politics, and technology

❖ Global net zero initiatives change not only economic and industrial structure, but also global technological standards and geopolitical hegemony

Global Decarbonization Pathways

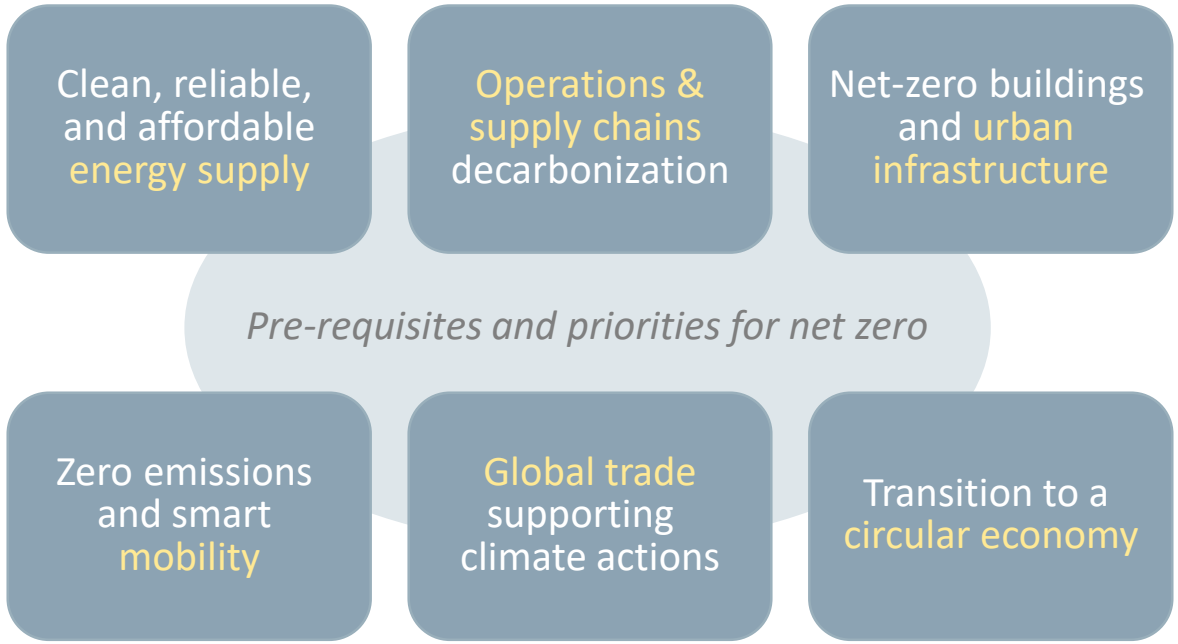
Transitional times (2020~2030): Power decarbonization, innovative tech. development

Diffusion and transformation (~2050/70): Non-power decarbonization, clean e. & innovative tech. diffusion



Is Net-Zero Really Possible?

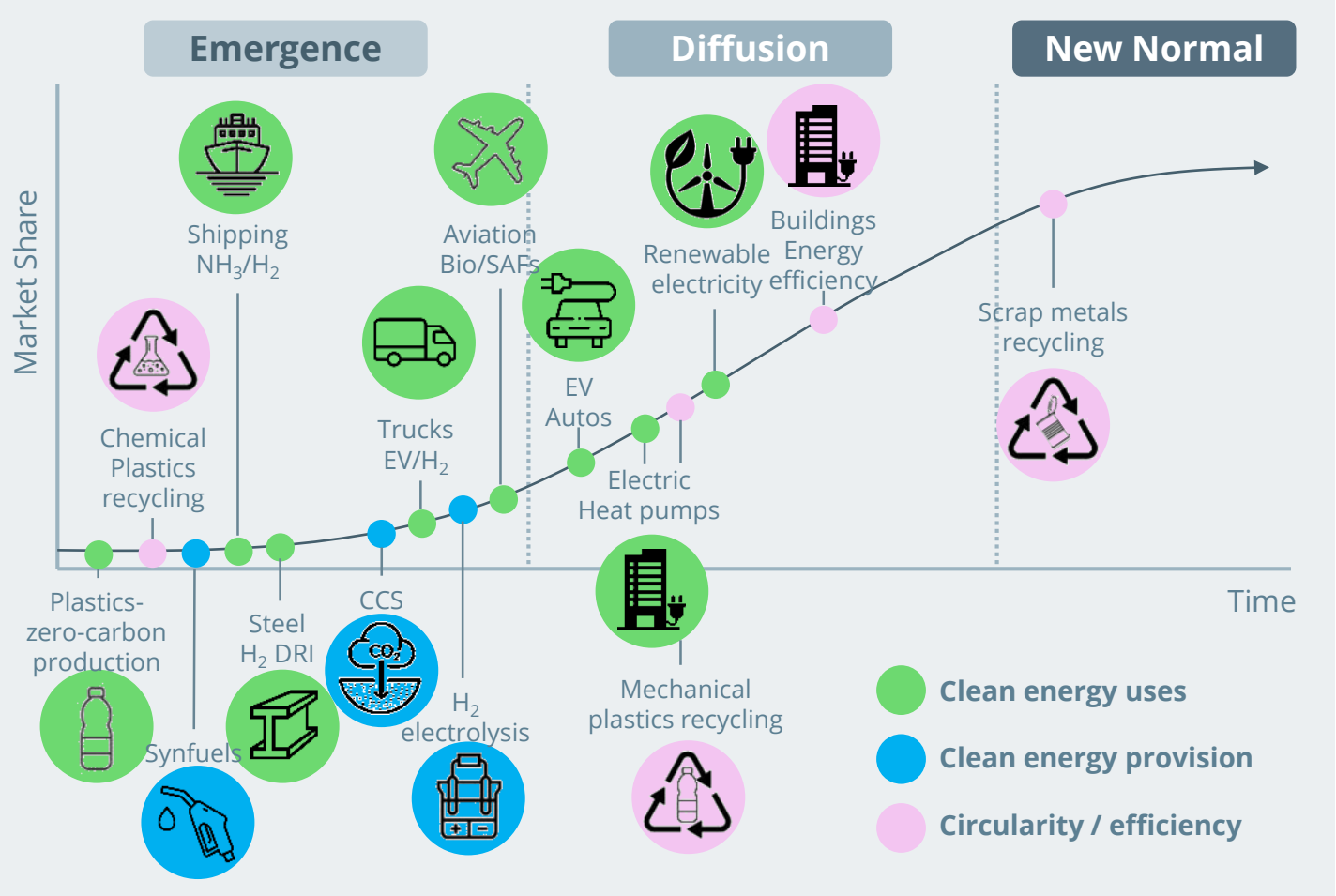
International society's net zero momentum by 2030 and clean energy infra. investment and progress will determine success of net zero emissions by 2050



Source: IEA(2021), Net Zero by 2050, https://www.carbonbrief.org/iea-renewables-should-overtake-coal-within-five-years-to-secure-1-5c-goal/

Innovative technologies help to clean and recirculate materials & energy to realize decarbonization transition

❖ 3 stages of technological innovation: ① Emergence of new tech., ② Large-scale diffusion, ③ Commercialization as a new normal
→ Technological innovation progress by phase and economical viability can realize transition to a net-zero society



❖ Areas of technological innovation

Clean energy & material uses	- Transport: aviation, shipping, trucking etc. - Industry: steel, cement, chemicals, aluminum etc. - Buildings: commercial building, housing, - Agriculture
Clean energy provision	- Green power - E-fuel: hydrogen - Bio energy - CCS, CCUS, CCUTS etc.
Circularity / efficiency	- Industry recycling: chemical plastic, scrap metal recycling etc. - Building efficiency

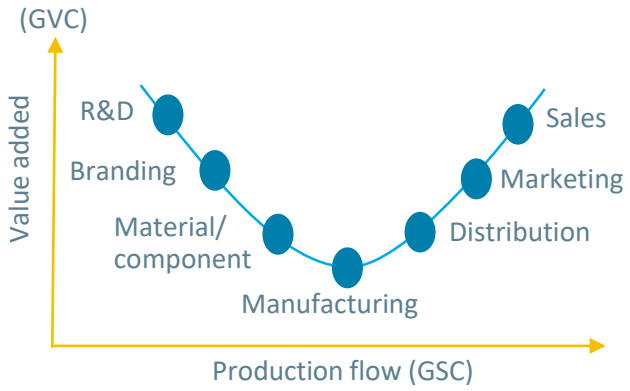
Source: Making Mission Possible, ETC(2020)

Changes are expected in supply chain, carbon pricing and trade structure in the process of geopolitical rebalancing

- ❖ Rising uncertainty in transition to multi-polar world order (ex: US-China conflict, Russia-Ukraine war)
- ❖ Intensifying hegemonic competition for various issues like tech., environment and energy, beyond military & economic interest

① Security in supply chains

- Importance of stable sourcing of core tech. & components/parts growing bigger with heightened economic security and carbon neutrality after pandemic



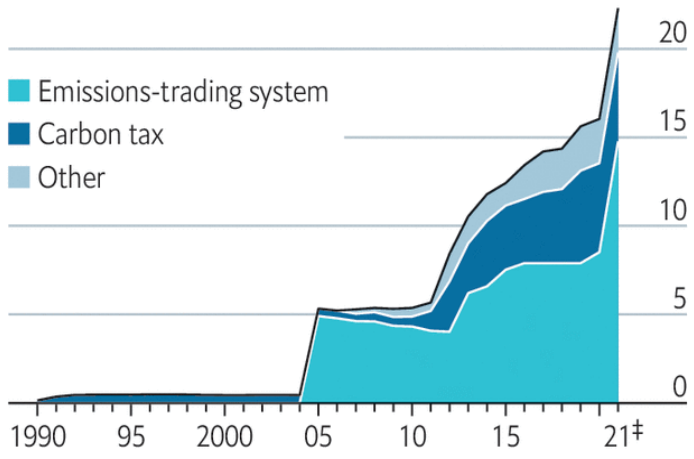
* Global value chain is value-added-led concept, global supply chain is supply/production flow-led concept

② Expanded impact of carbon pricing

- Cross-border measures (ex. CBAM) in line with adoption of carbon tax & ETS

Carbon-pricing initiatives

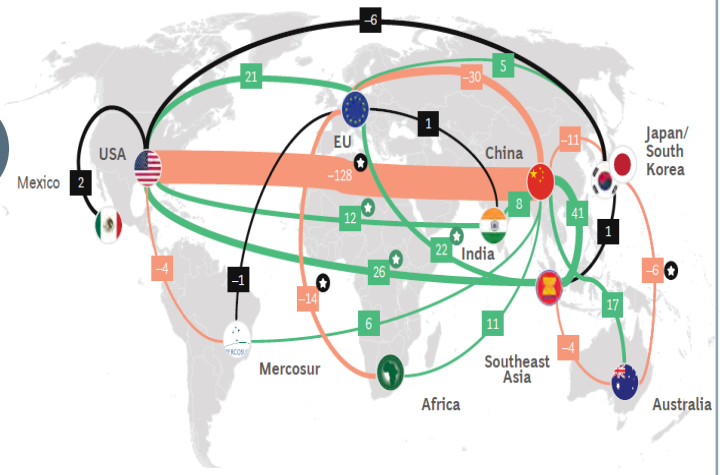
(% of annual global greenhouse-gas emissions covered)



23% as of '21

③ Structural change in global trade

- Contracted global trade with changing supply chains, but robust intra-trade



<-3%
-3~3%
>3%

- Color of arrow represents percentage change from 2019~2023F
- Width of arrow represents volume change in trade flows 2019~2023F

Source: KIEP(2021), World Bank(2022), BCG(2020)

Future of urban development

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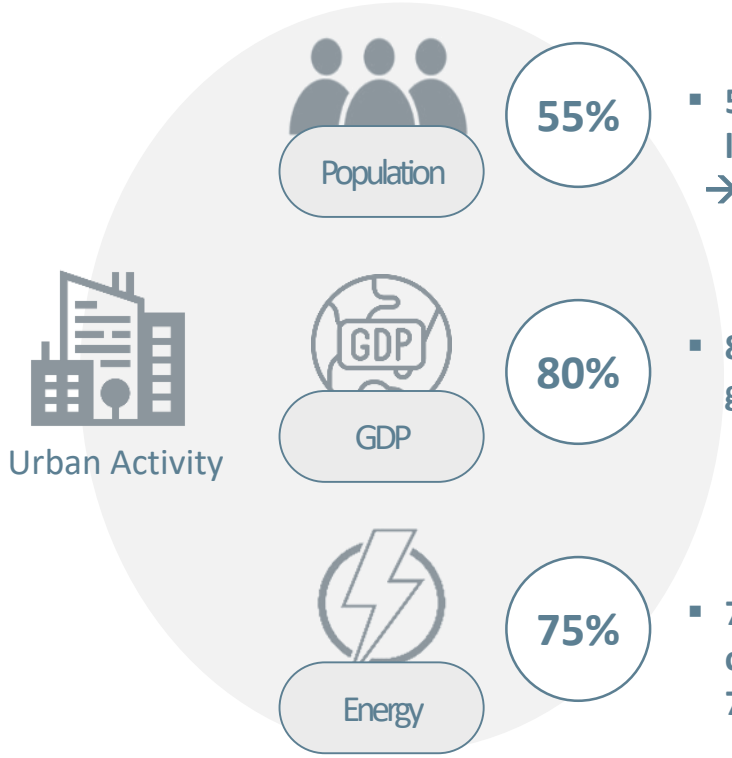
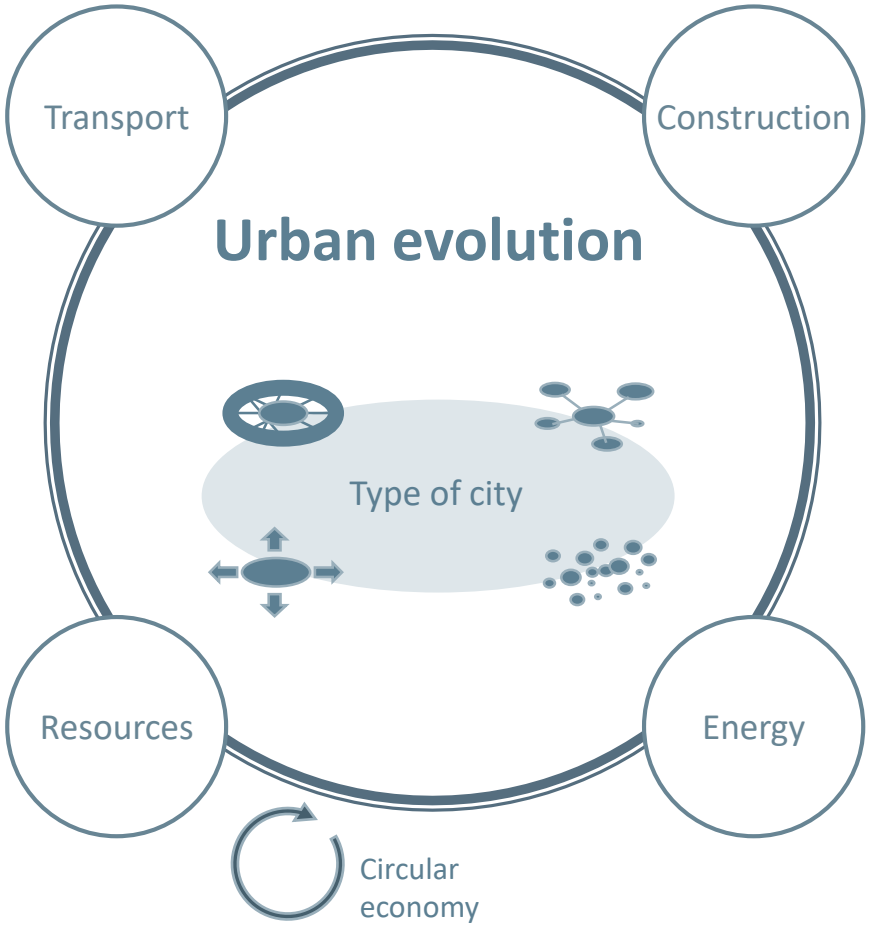
Why cities are important?

A city is a hub where energy, materials and infra. are utilized and interconnected with each other through mobility, logistics, and networks

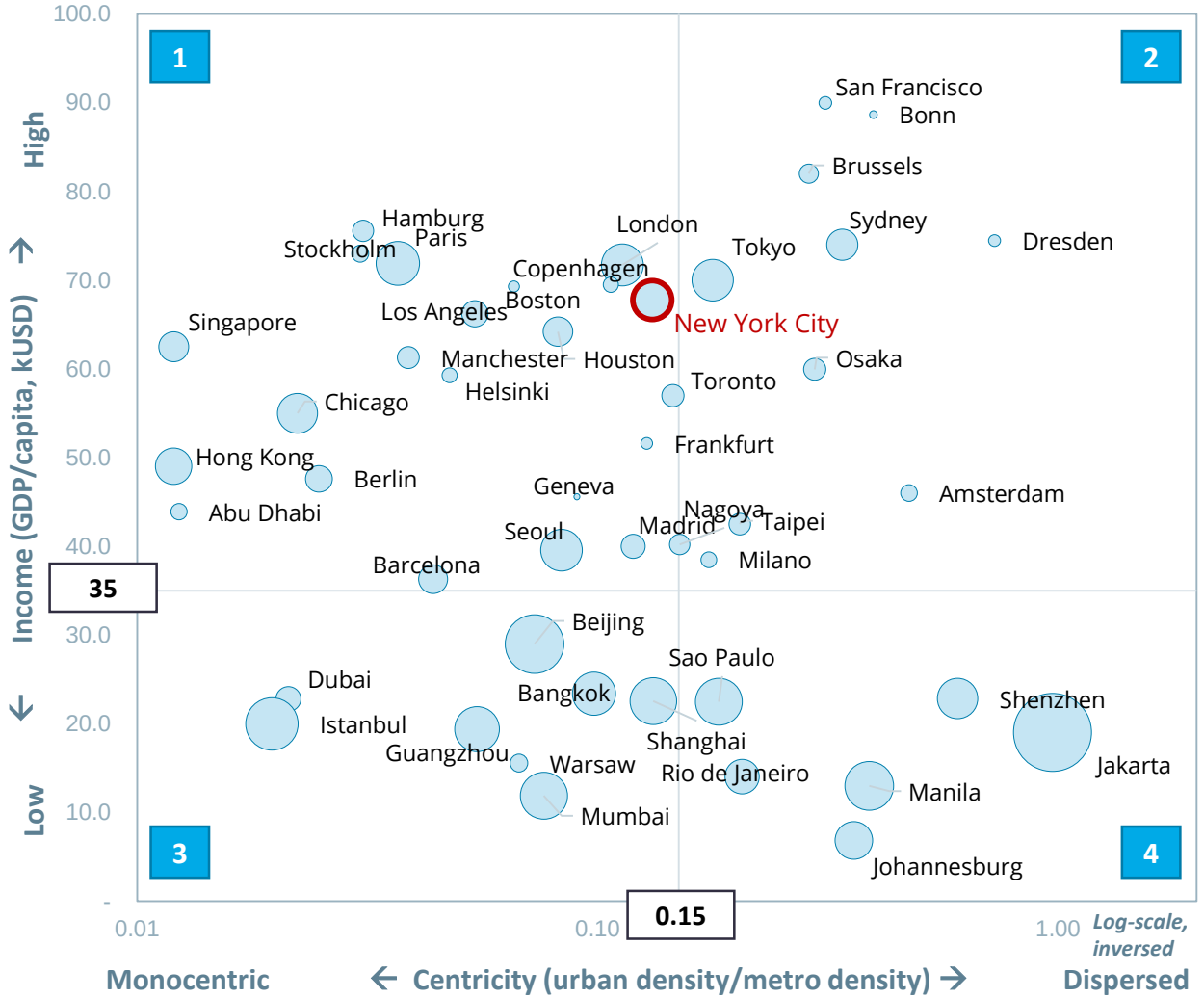


- 55% of global population live in cities ('21) → 68% ('50)
- 80% of global GDP generated in cities
- 75% of final energy consumption and 70% of CO_2 emissions



Source: UN, World Bank Urban Development

Global cities can be categorized into 4 archetypes by income and volume density



1 Advanced Metropolises

✓ **New York, London, Paris, Hong Kong**

- Large urban area, public transport
- Sprawling metropolitan area

2 Prosperous low-density cities

✓ **SF, Amsterdam, Brussels, Bonn**

- Wide-spread/small but rich cities
- Car-centric, Intercity transport

3 Expanding mono-centric cities

✓ **Beijing, Bangkok, Mumbai, Istanbul**

- Fast-growing Asian/S.American cities
- Public transportation development

4 Developing scattered cities

✓ **Johannesburg, Manila, Rio de Janeiro**

- Large developing urban areas
- Poor transportation access

Urban area density = Urban population / Urban area

Metro area density = Metro population / Metro area

Source: POSCO Research Institute(POSRI), modified by worldsteel MEEG (Megatrends Evaluation Expert Group)

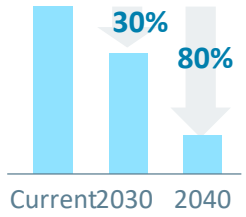
Differentiated changes in construction, mobility, and energy landscape are expected in each city archetype

Advanced Metropolises

- High Income
- High-density

New York

New York's CO_2 emissions goal



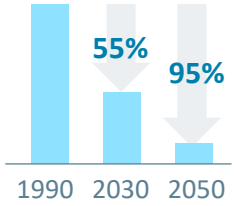
- 20% energy cut from public bldgs., high efficient design for new skyscrapers
- Fossil fuels prohibited in mega construction (2035)
- Sustainable mobility (walk, bicycle, public transport) above 80% (2050)

Prosperous low-density cities

- High Income
- Low-density

Amsterdam

Amsterdam's CO_2 emissions goal



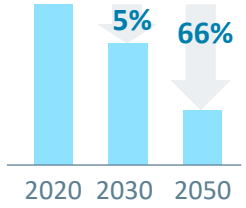
- Polycentric transition of cities with eco-friendly urban center
- Zero-carbon land and sea freight within 10 years
- Transition to a "Circular-City" by 2050, re-circulation of all consumption resources

Expanding monocentric cities

- Low Income
- High-density

Beijing

Beijing's CO_2 emissions goal



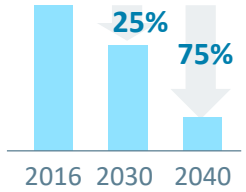
- 2060 carbon neutral plan (Xi Jinping in UN General Assembly, Sept. '20)
- 'Energy Revolution' for carbon neutrality
- Plants relocated outside Beijing, whereas product design, SW/AI industry will gather in the city center

Developing Scattered cities

- Low Income
- Low-density

Johannesburg

Joburg's CO_2 emissions goal



- Carbon neutral by '50, ease of high carbon intensity
- Land use diversity, narrowing of divide, encouraging social mix
- Green conservation, biodiversity protection, sustainable city

* The detailed information of each city planning roadmap for 2050 is provided in the appendices

Future construction, mobility & energy landscape differ by city archetypes

Type of city	Advanced Metropolises	Prosperous low-density cities	Expanding mono-centric cities	Developing scattered cities
	✓ New York, London, Paris, Hong Kong	✓ SF, Amsterdam, Brussels, Bonn	✓ Beijing, Bangkok, Mumbai, Istanbul	✓ Johannesburg, Manila, Rio de Janeiro
Construction	• High density city and low density suburb	• Infra, network planed first & developed later	• High rise, high density city (compact, efficient land use)	• Low rise cheap housing, unmanaged development
Mobility	• Public transport + private car (intra-city connectivity)	• Public transport+ active mobility	• Public transport such as bus and taxi	• Poor public transport access (intercity bus)
Energy	• Complex power grid system	• Independent, dispersed energy production & consumption	• Compact energy consumption for residential and commercial buildings	• Obsolete grid system, insufficient power system

Keywords: Green, smart, compact cities and digitalized construction

❖ Eco-friendliness, safety, healthcare and tech. expand new construction markets and promote construction innovation

✓**Construction & infrastructure going green & Smart**

- Vertical forest (urban farm)
  - sky gardens
- Net zero energy buildings
- Smart city management

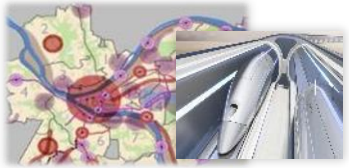
✓**City from energy consumer to energy producer**

- Metropolitan power generation replaced by suburb green energy

- Wind farm in suburb
  : bladeless wind turbines
- Building integrated PV (solar walls and roofs)

✓**Polycentric City with intercity connection**

- Hub & spoke btw urban center & satellite cities



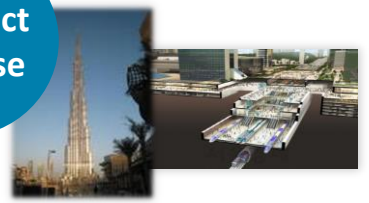
- Hyperloop & UAM terminal
- Intercity roads & railway infrastructure

Future construction trend

- Green/ Smart infra.
- Clean energy use
- Network city
- Compact land use
- Digital/ 3D model

✓**Land use efficiency with skyscraper & underground city**

- Energy saved with less commute & logistics time



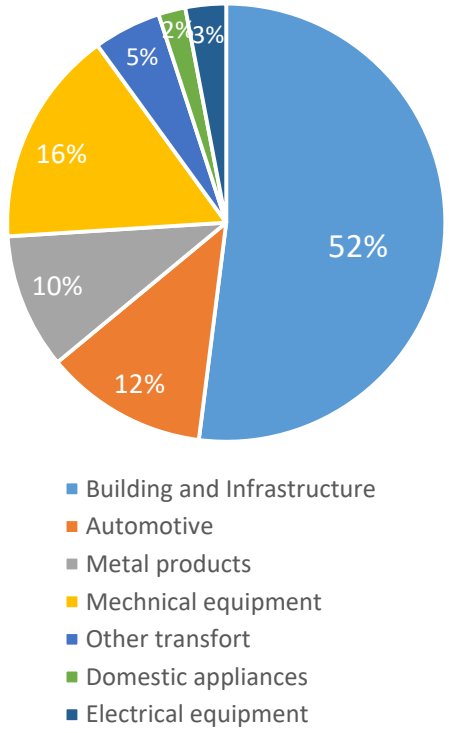
- Mixed used urban areas
- Underground complex development
- High-rise above 500m as a symbol of city

✓**MMC (Modern Methods of Construction) as a booster for construction innovation**

- Growing importance of serious accident risks, eco-friendly & contactless construction and new tech. at construction site
- MMC emerged as alternative to conventional way of construction, as it redefined as pre-assembly (incl. prefab, modular)

Construction uses more than half of global steel, but the current steel market share in construction is still low

Steel use by industry
(Global steel use 1,768 Mt)

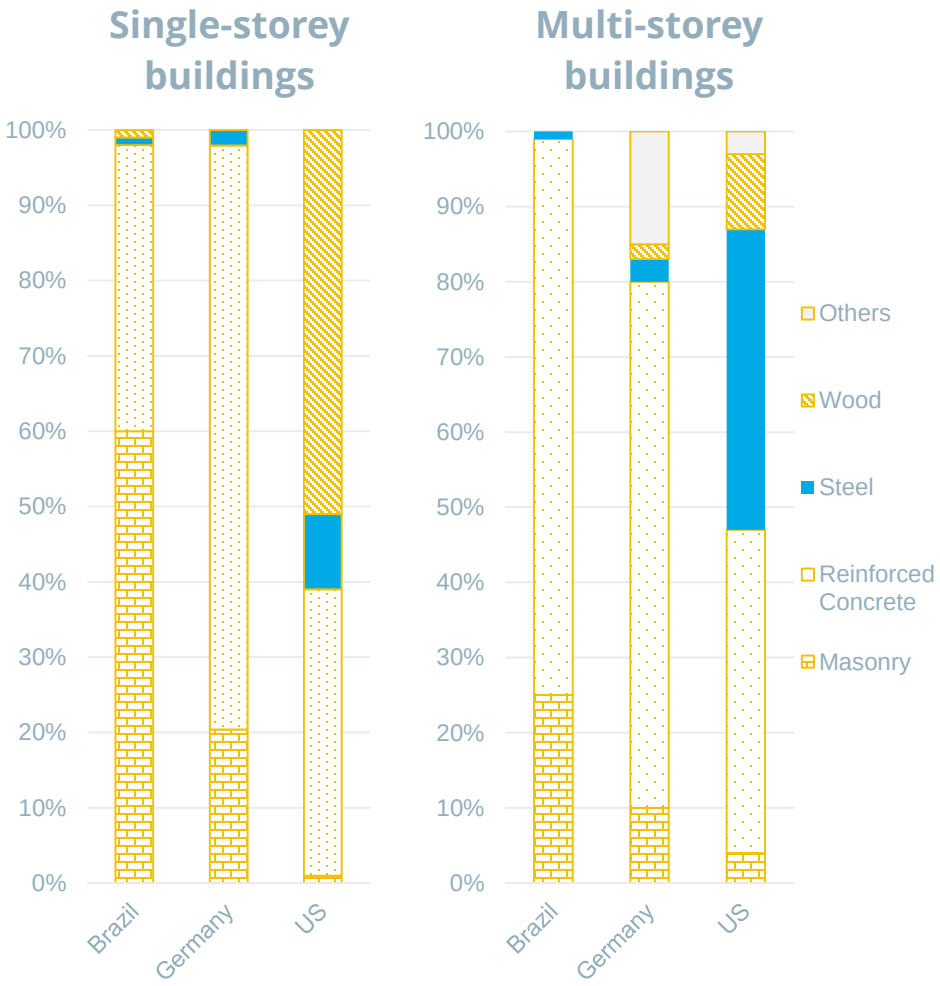


Construction market segment and its market size (% of total)		Steel market share within each market (% of total)	Segment contribution to steel market share (% of total)
Building (70%)	Residential (40%)	10%	4.00
	Commercial & Business (15%)	40%	6.00
	Industry (15%)	60%	9.00
Infrastructure (30%)	Bridge (5%)	20%	1.00
	Road (10%)	5%	0.50
	Railway (5%)	40%	2.00
	Airport (3%)	15%	0.45
	Port (7%)	25%	1.75
		Steel market share in global construction industry	24.70

Source: worldsteel, “The Opportunity of Constructsteel” (2022 POSCO Forum), modified by POSRI

Construction materials for buildings differ by region, but steel is still important

- Material use differentiated by region, culture, demographics, and architectural styles; constant use of steel structure (reinforced concrete and steel frame); some changes with rising importance of eco-friendliness



REINFORCED CONCRETE

Durability, high compressive strength	Carbon footprint weight

MASONRY

Material availability, durability	Labor-intensive Heavy materials - brick, stone, blocks

STEEL FRAME

Lighter & stronger, easy fabrication in different sizes	Structural support, limitation of flexibility, floors

WOOD FRAME

Cost-effective, Less energy used, i.e. low carbon	Limited supply, durability

STEEL STRUCTURES

Relatively light, fast-build, easy fabrication, high volume	High maintenance cost, high carbon footprint

Source: MEEG Assessment, Statista, US data from AISC for buildings higher than 4 floors

Development of construction materials

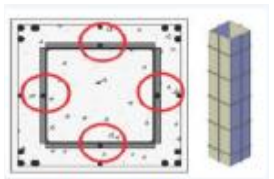
[Future construction materials]

- **Low carbon/carbon neutral steel and concrete are the two materials that have the potential to effectively reduce the embodied carbon in constructed structures**
- Alternative materials are being developed, but development will take time
- And they are likely to have severe cost and volume limitations

Steel-concrete composite structure

Composite slabs

Composite beams



Composite columns

Steel-Timber Composite Structure

Timber-steel Composite (TSC)

Metal Profiles Control With Wood Vaneers

Steel-timber Composite building

Steel-Other material Composite Structure

Wall panel with mineral wool

Slab with PIR (polyisocyanurate)

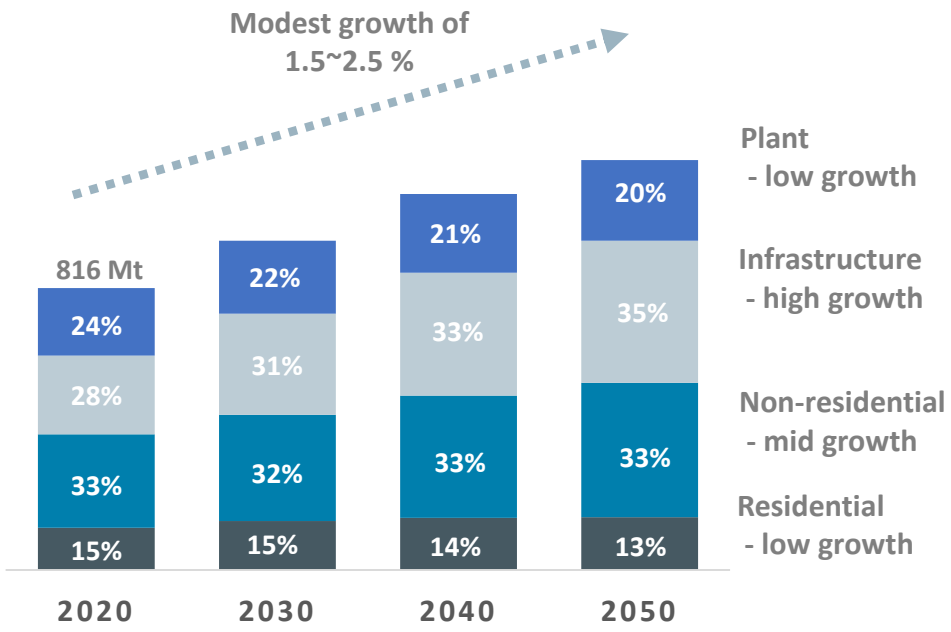
Tiled composite Panel system

Source: MEEG Assessment, KIAEBS, Study on the Future of Urban Areas and the Construction Sector

Steel demand for construction still to grow with its eco-friendliness and easy composition w/ other materials, though competing w/ concrete and future materials

❖ Trends in modular building design, digital 3D construction, and fast growing infrastructure(in particular, the construction of energy & EV infrastructure, hyperloop, etc.) with high steel intensity points to continuous growth in steel use in construction

[Steel demand potential by construction type (Mt)]



Steel demand growth depending on future construction growth & steel intensity

(vs. average)	Residential	Non-residential	Infra.	Plant
Steel intensity	Low	High	High	High
Construction growth	Low	Mid	High	Low
Steel demand growth	Low	Mid	High	Low

Source: IHS Markit (Construction investment), worldsteel, POSRI

Eco-friendly mobility with increased convenience, safety & accessibility for citizens

Complete street

✓ **People-friendly street**

- Accessibility & safety for various traffic modes

- Active mobility (walking and biking)
- Higher accessibility to public trans. & personal mobility
- Safety (low-speed design)

Source : U.S. Department of Transportation

Mobility hub

✓ **Dispersed hubs of hyperloop, UAM & subway**

- Intersection where various transport modes cross each other

- Shared car parking
- Connected to personal mobility
- Integrated transport terminal

Source : Hyundai Motor Company

15-minute city / Innovative logistics city

✓ **Lifestyle zone with 15 minutes access**

- No need for long-distance travel

- Dispersed education, healthcare, shopping & leisure facilities
- Last mile mobility (robot delivery, autonomous shuttle)
- Travel time and distance ↓

Source : Autonomy Paris

Eco-friendly mobility

✓ **Less traffic, electrification of cars & public trans.**

- Expansion of shared mobility and EV infra.

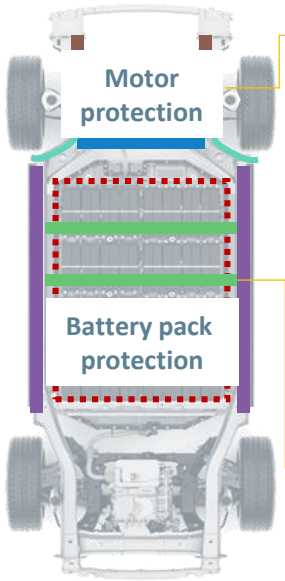
- EVs & electric bus
- EVs & personal mobility charging station

Despite fierce competition for light-weight materials, steel maintaining strong advantage with its clean process, recyclability and economic features

Reinforcement through electrification

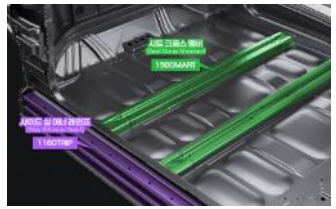
✓ **Reinforcement to protect battery pack & motor**

- Hot power fusion (HPF), aluminum profile



▪ **Forward collision avoidance**

✓ Side member to protect motor, front side rail to dash reinforcement to protect battery and seats



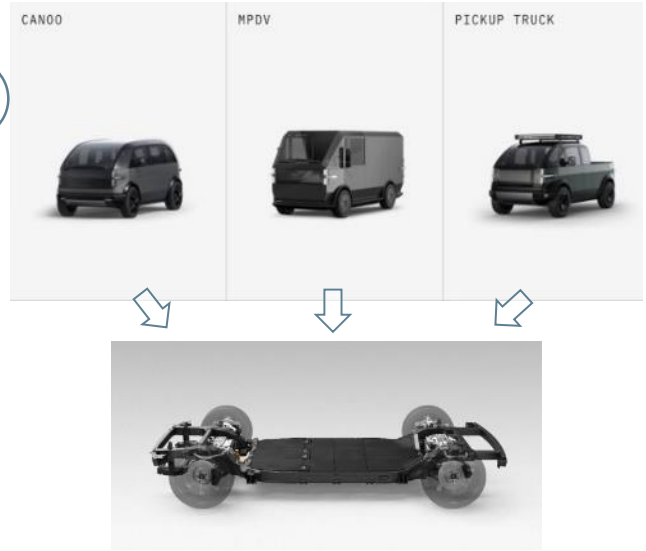
▪ **Battery pack protection**

✓ Side seal reinforcement for side collision, cross member reinforcement to hold up the flooring and prevent torsion

Change by modular design

✓ **Platform for purpose built vehicle (PBV)**

- Various PBVs on common platform
- Autonomous shuttle & robot taxi platform
- Ladder frame for SUVs & pickup truck



Automotive materials future

✓ **Material diversification**

- Steel taking upper hand with rising importance of clean process and recycling
- Rising share of light-weight materials

【 Steel demand for the automotive sector, mil. tonnes 】

164	210	219
2020	2030	2040

Source : POSRI forecast

【 Carbon emission per material kg, CO_2-kg/material-kg】

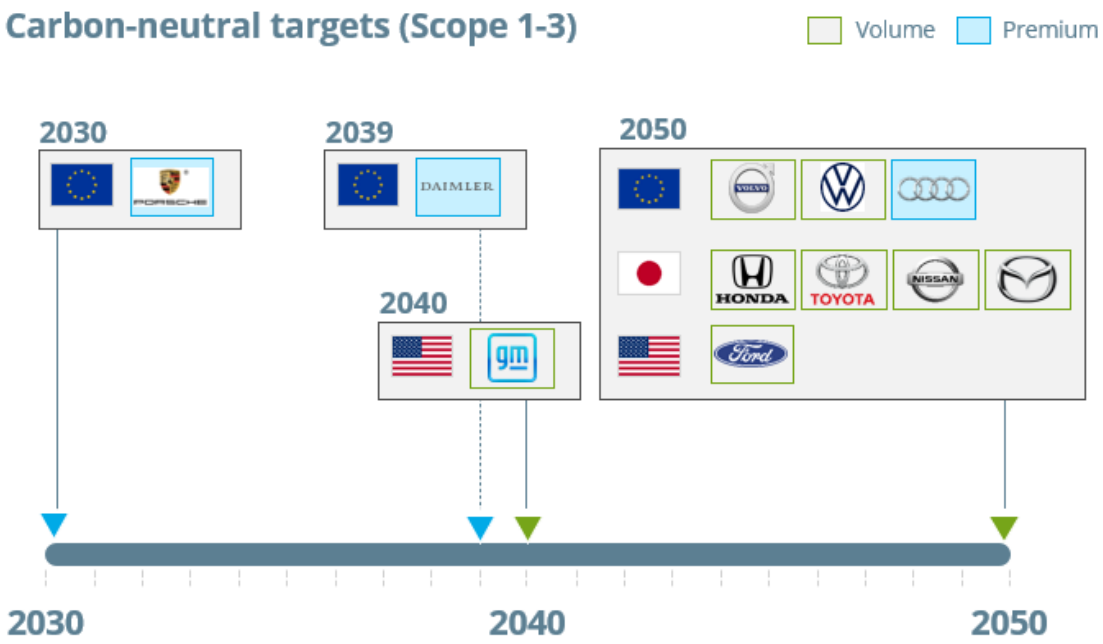
2.3	8.9~16.5	15~22
Fe	Aluminum	CFRP

Source : Aluminum Association('13), worldsteel('10), Nikkei auto

Lightweight material portion (of aluminum and plastics) may rise as EVs and AVs need longer range

Steel still stays as a mainstream material as it has superior cost competitiveness with lower carbon footprint and recyclability

Automotive sector's demand for low carbon products might be expected to surge



Focus end-segment	Example product	Emission split, in % of total emissions	
Automotive	ICE	15-25	75-85
	BEV	25-35	65-75

Raw material emissions | Other emissions (incl. use phase and other scope 3 emissions)

Source: McKinsey, 2021, study commissioned by worldsteel

Increasing environmental pressures, CO_2 costs
Generational change towards responsible preferences

Greater policy focus on mobility as an easier to decarbonize sector

Increasing focus on embodied carbon as use phase is decarbonized

Steel to be most important material decarbonization lever for automotive industry

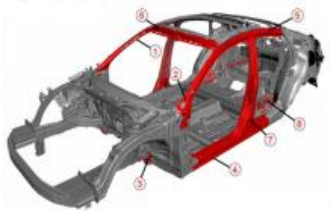
Automotive likely to be a first mover for low-carbon materials demand

OEMs committing to carbon-neutral targets (premium OEMs starting by 2030, volume OEMS largely targeting 2050)

Steel is taking another step forward with new materials, processes and applications

1 Enhanced Materials

Hot Stamped Parts (Mitsui)

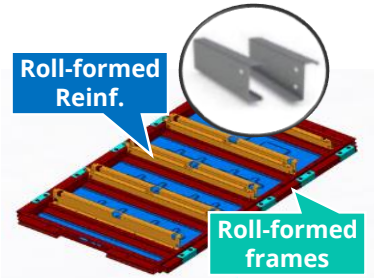


Hot Stamping Applications in BIW (Honda Civic)

✓**3rd generation steel and hot stamped materials**
Applications for side impact reinforcement to become popular as safety standard for passengers and protection strategy for battery pack becomes more important (Side sill, B pillar)

2 New Process & Applications

Roll-formed steel parts in BIW (Ford Mach E)



Applications in battery packs (POSCO)

✓**Developing new processes for new applications**
Roll forming process to become a new norm to compete with aluminum profile applications – Similar rigidity, but cost-effective
Other technology like tailor welded blanks and roll stamping also developed

3 Composite Materials

Steel-polymer composite Solutions (MSC, TATA)

Steel-polymer composite Applications in BIW (Ford)

✓**Composite materials developed for lightweight applications**
Steel-polymer composite has advantage in lightweight applications with excellent acoustic properties, also cost-competitive compared to other lightweight materials

Future urban energy represented by decarbonization, distributed system and tech. innovation

Impact Factors

✓**Extreme weather**

- Highest frequency of extreme weather events for past 7 years compared to past 200 years[2)]

✓**Inefficient E. system**

- Inefficiency of capital-intensive invest.
  (long payback period, low profitability)
- **Overlapped public e. biz.**
  *Small, creative, private biz. needed

✓**Link to tech. innovation**

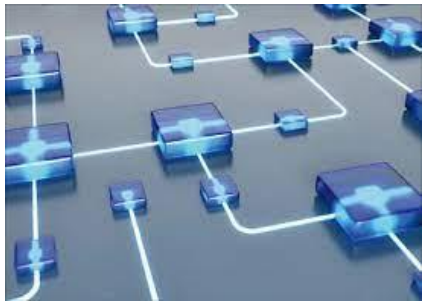
- Conventional E + [CCUS, H2, nuclear fusion] tech. innovation linked
- Smartization

Future Trends of Urban Energy[1)]

1 Decarbonized energy

- **Rapid shift to decarbonized energy**
  (Replacing fuels for power generation and commercial use)
- **Decarbonized future energy**
  (Hydrogen, ammonia, nuclear fusion)

2 Agglomerated city clusters



- **No more heavy energy system**
  (Shift to a hub cluster system)
- **Smart micro grid expanded**
  (Agglomeration of distributed transmission NW)

3 Energy tech. innovation

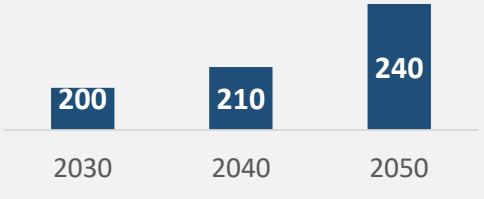
- **Optimal energy supply-demand**
  (Digital Twin, meta-verse)
- **Test bed proving future tech.**
  (R&BD[3)] incl. space-based solar power & wireless transmitter)

Note1) Forbes(2022), IEA(2022), EIA(2022) etc.
Note 2) WMO
Note 3) R&BD(Research & Business Development)

Eco-steel for energy expanded with durability, high strength, corrosion- & heat-resistance, zero carbon and economic feasibility

Wind Power Generation

【Annual new wind capacity, GW】



120~180 tonnes of steel per MW

Turbine Motor

✓ Electrical steel used in rotating machine for wind turbine

Turbine Bearing

✓ High strength bearing used in rotating support for wind turbine

Tower

✓ Vibration, collision, and low-temperature resistant steel for tower

Solar Power Generation

【Annual new solar capacity, GW】

35~45 tonnes of steel per MW

태양열 판넬 지지 구조물

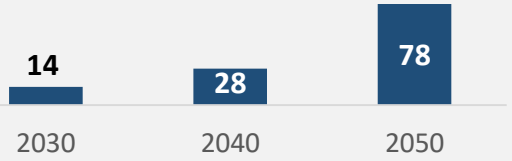
PosMAC 제품구성

Solar Power Panel Foundation

✓ Lightweight solar foundation with high corrosion resistance

Hydrogen Ecosystem

【Hydrogen market size, Exajoules】



Produce

✓ CCUS CO_2 capture
✓ Steel for water electrolysis

Delivery

✓ Steel for hydrogen line pipe
✓ Storage tank steel for liquid H_2

Storage

✓ High-pressure tank steel for hydrogen storage
✓ Low-temperature liquefied hydrogen storage tank steel

Use

✓ Fuel cell metal separator
✓ Storage tank steel wire for fuel cell EVs

Source : https://www.ren21.net/wp-content/uploads/2019/05/GSR2022_Full_Report.pdf, Hydrogen Council / McKinsey

Pattern of steel use differ by city type – steel use saturates in developed cities whereas construction, mobility and energy material hike in developing cities

Advanced metropolis

London, Barcelona, Berlin, Boston, Chicago, Frankfurt, Hamburg, Helsinki, Hong Kong, Houston, Los Angeles, Madrid, New York, Seoul, Singapore, Tokyo, Stockholm, Manchester, Nagoya

Prosperous low-density cities

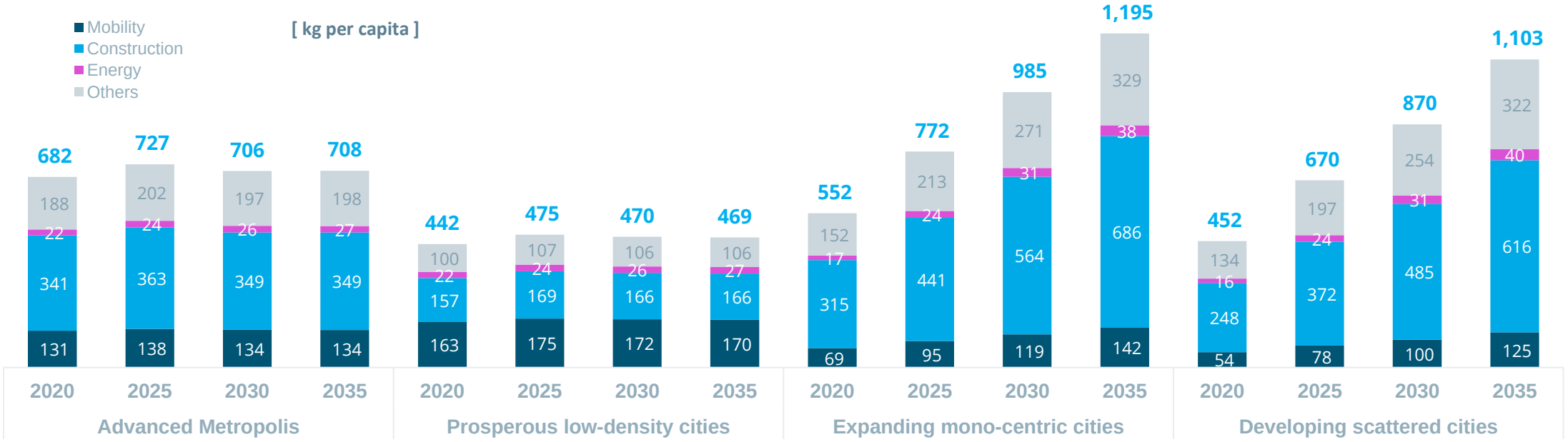
Amsterdam, Osaka, San Francisco, Sydney, Bonn, Dresden

Expanding mono-centric cities

Bangkok, Beijing, Guangzhou, Kolkata, Mumbai, Rio de Janeiro, Sao Paulo, Tianjin, Shanghai

Developing scattered cities

Jakarta, Johannesburg, Shenzhen



Note: estimated by POSRI

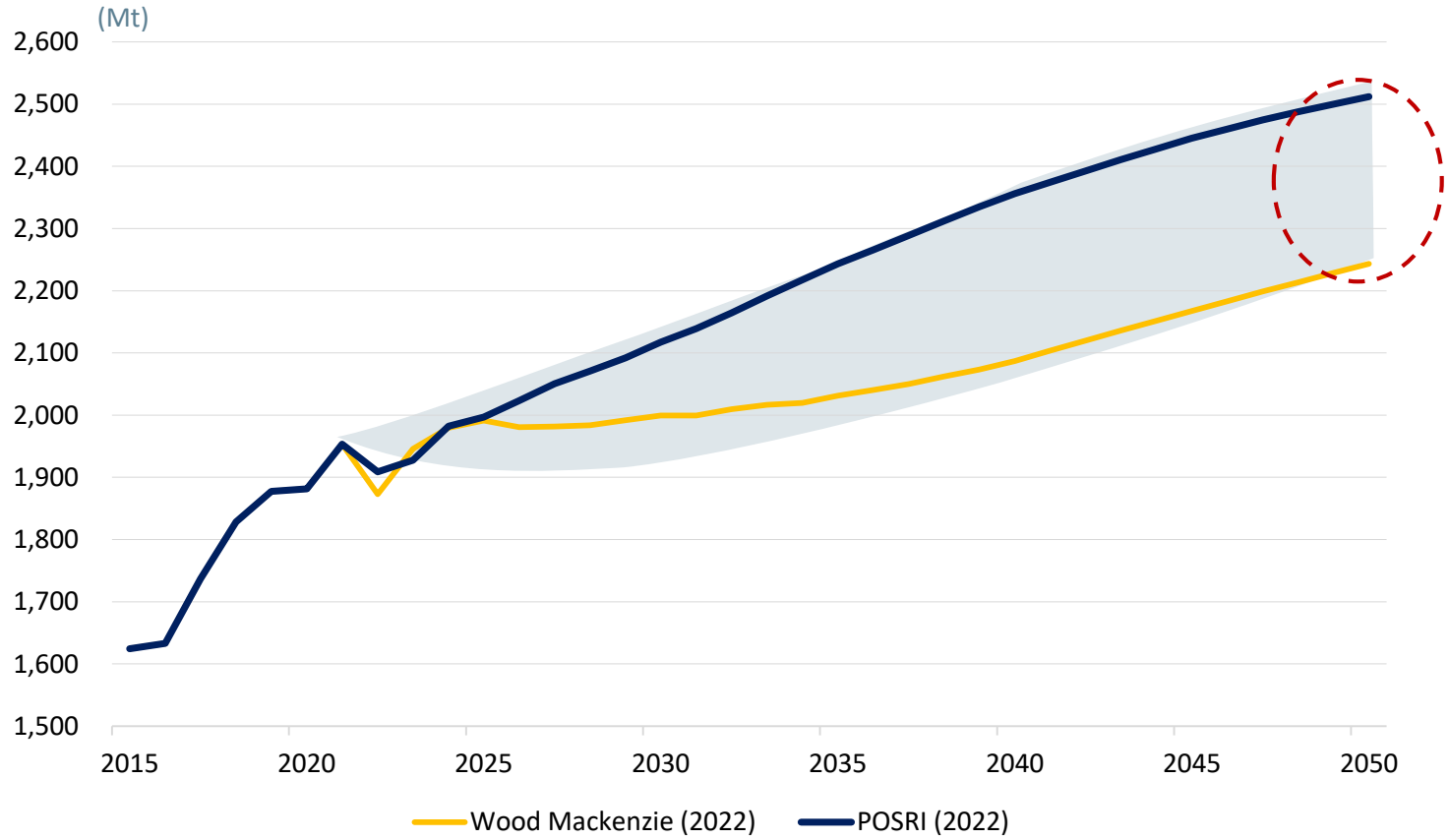
Future of steelmaking technology and raw material requirement

posco RESEARCH INSTITUTE

Long-term global steel production required to meet both market demand and carbon reduction standard

❖ Despite carbon neutrality trend, crude steel production to reach 2.2-2.5 bil. tonnes by '50 with modest growth of steel demand

[Global crude steel production forecast]



Global crude steel production ('20-'50)

❖ **Various institutions :** Project modest growth of about 1% annually next 30 years to 2.2-2.5 billion tonnes in '50. China's crude steel production to peak between '25~ '30

❖ **Wood Mackenzie** : Forecasts China's crude steel production peaking in '20 to reach 804 Mt by '50 under zero carbon initiative ('70), and India's and SEA's production to replace China's after '40

Source : Wood Mackenzie('22.6.), POSCO Research Institute(POSRI, '22.9)

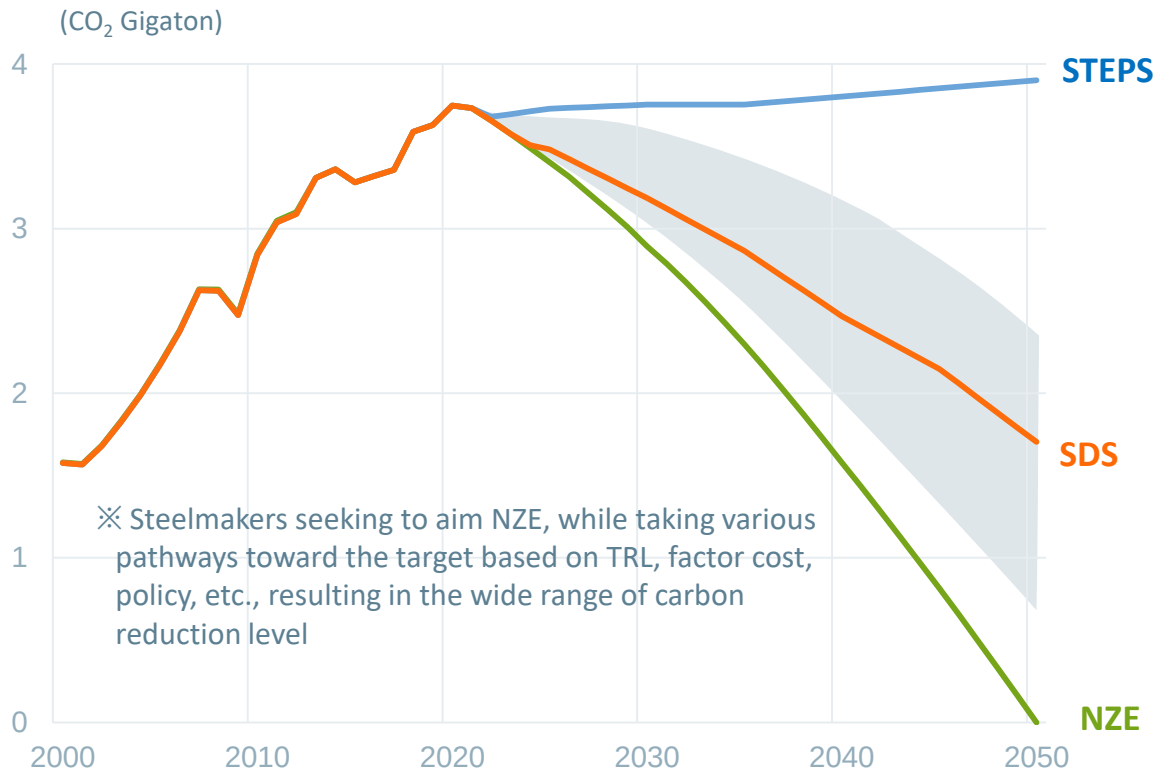
How will decarbonizing pathways of steel sector be drawn?

❖ Each scenario has different conditions for the steel industry's carbon reduction goal by volume and timeline

- 'Carbon reduction' is major premise & goal; various factors (TRL*, production factor cost, regional and policy factor) to be considered

* Technology readiness level (TRL) of green steelmaking technology

[Carbon reduction scenarios for global steel industry]

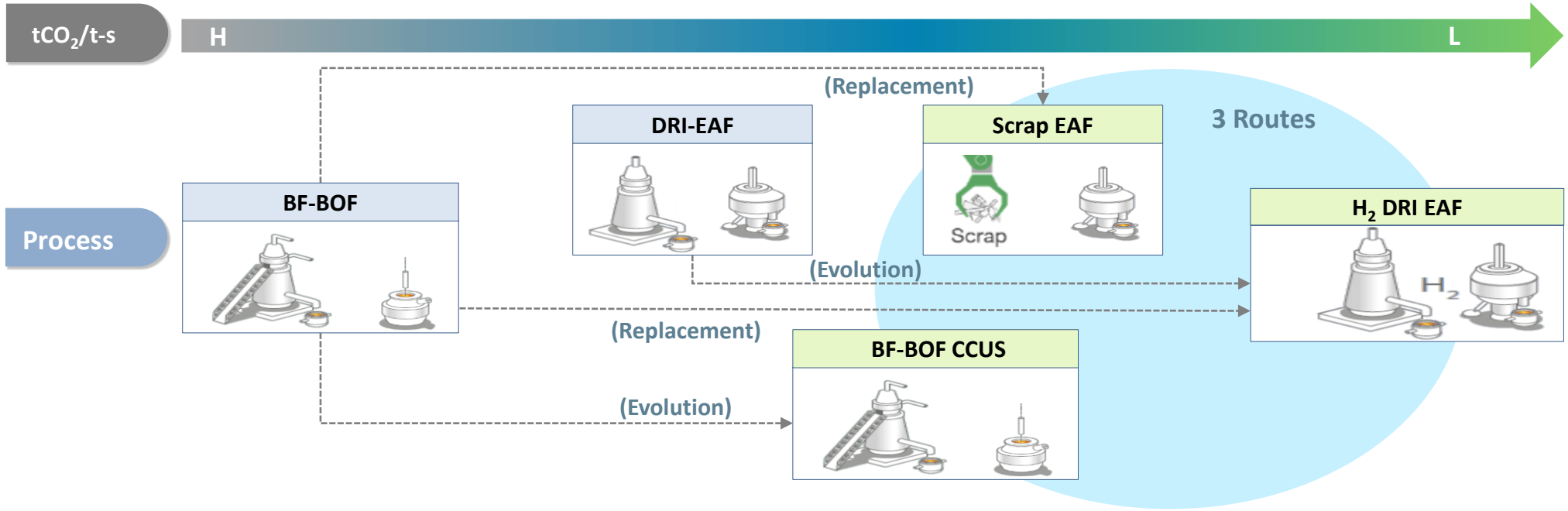


※ Source : IEA(2020), POSRI(2022)

Note: STEPS(stated policies scenario), SDS(sustainable development scenario), NZE(Net-zero emissions)

3 routes of steelmaking process to promote carbon neutrality

- Carbon reduction method by timeline : Process optimization (~'30) → Carbon reduction (~'50) → Carbon neutral ('50~)
- Cost advantage is the top priority for steel industry → Future competitiveness to be determined by low-cost sourcing of raw materials & energy and high energy efficiency of facilities

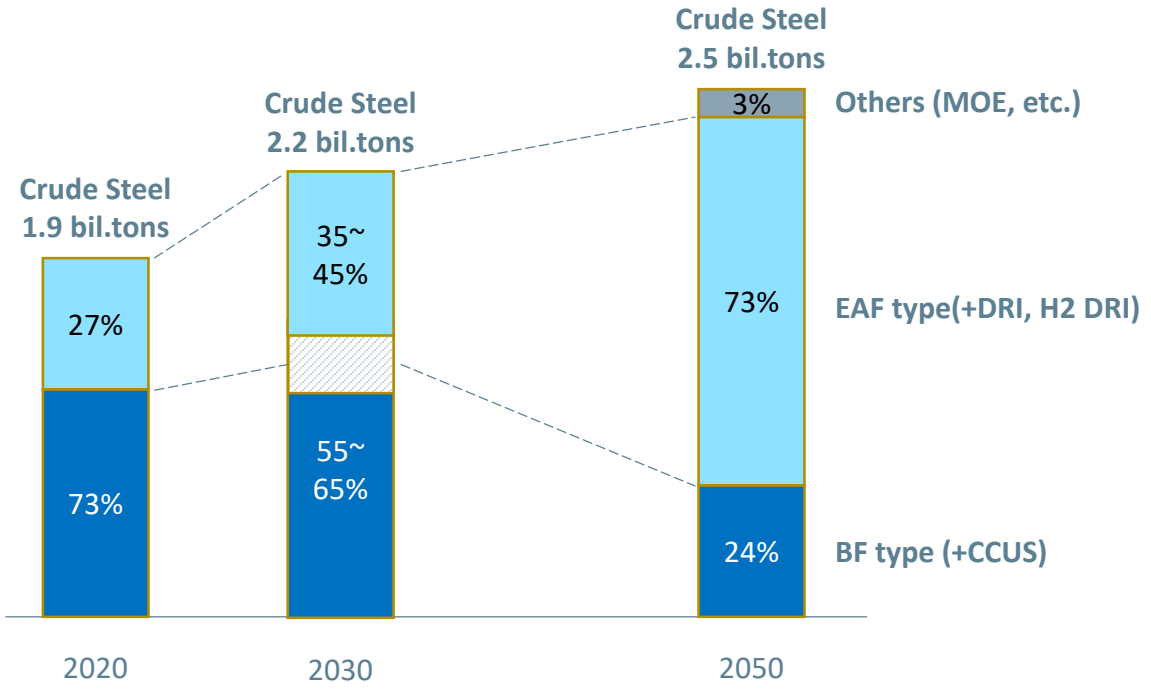


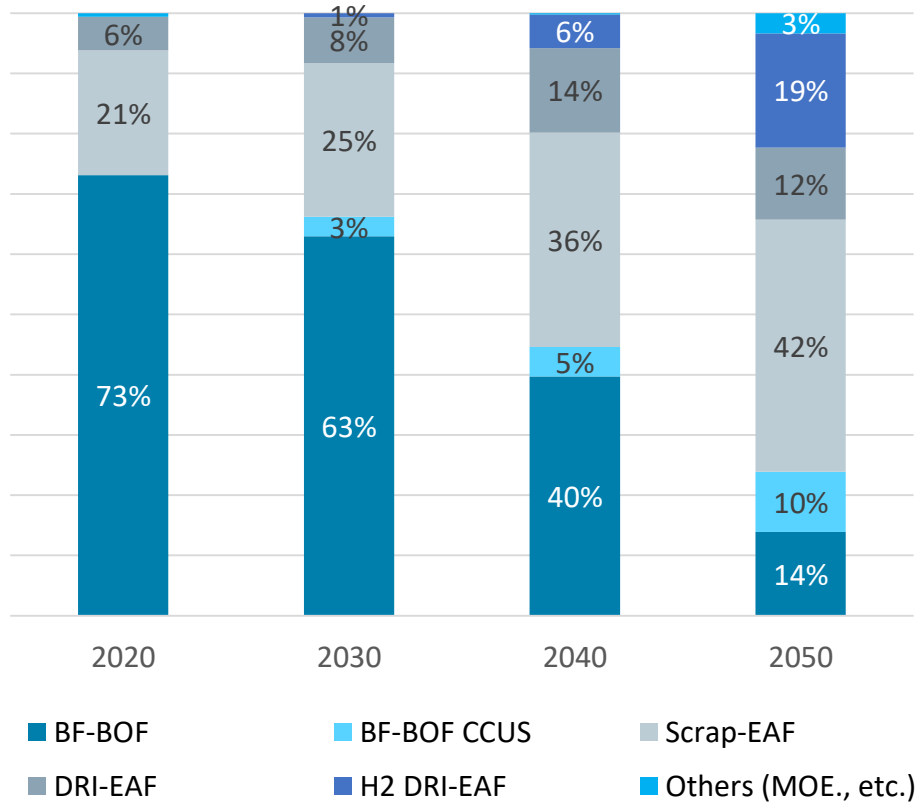
	BF-BOF	DRI-EAF	BF-BOF CCUS	Scrap EAF	H_2 DRI EAF
K S F	**Facilities going bigger and consolidated**	**Natural gas procurement cost**	**Economic feasibility for CCUS tech.** (power use, capture rate)	**Scrap sourcing cost, thin-slab casting & rolling**	**Green energy procurement, operation efficiency, & unit scale-up**
Future issues (Competitive edge)	Carbon tax, Coal price volatility	Carbon tax, NG price volatility	Commercial feasibility, CO_2 removal rate	Stable supply of renewable E., Limit in high-end steel quality	Stable supply of DR pellet, Limit in 100% H_2 operations

EAF to become a dominant steelmaking process in medium to long term

- Rising share of EAF processes : ①Scrap-EAF (21% → 42%), ②H2-DRI-EAF (0%→ 19%), ③DRI-EAF (6%→ 12%)
- Due to the abundant accumulation of scraps worldwide and the effects of CO2 reductions, scrap-EAF capacity will continue to expand, bolstered by the rapidly expanding H2-DRI-EAF structure

[Projection on Global steelmaking process by types (2020~2050)]



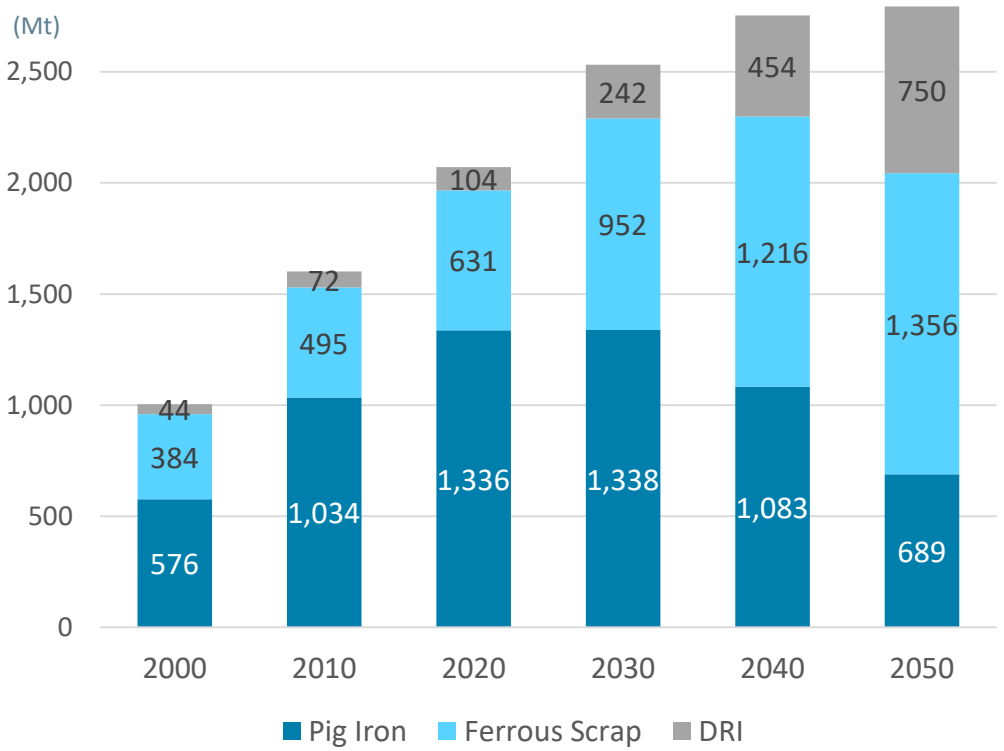


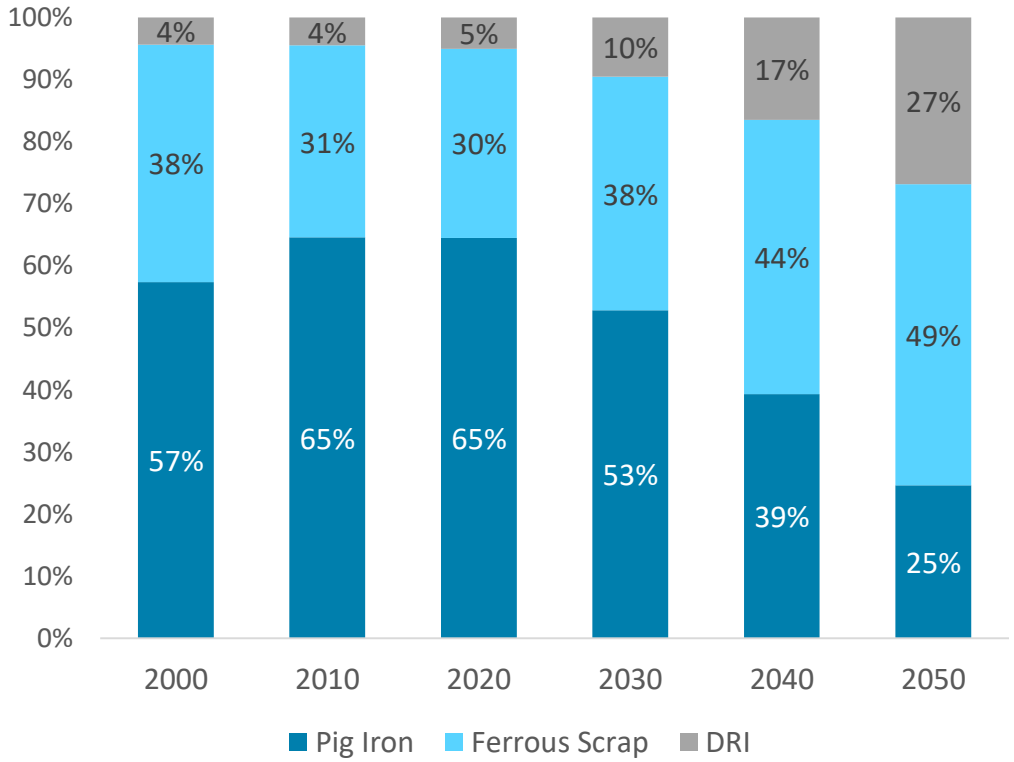
Note: Projection by POSCO Research Institute(POSRI)

Raw material requirement in mid- to long-term expected to change greatly

- In the long-term, demand for DRI and steel scrap expected to rise while demand for pig iron to fall
- Demand for DRI expected to increase rapidly with its share rising from 5% in '20 to 27% in '50

[Projection on Global Demand of Steelmaking Raw Materials: volume & share]

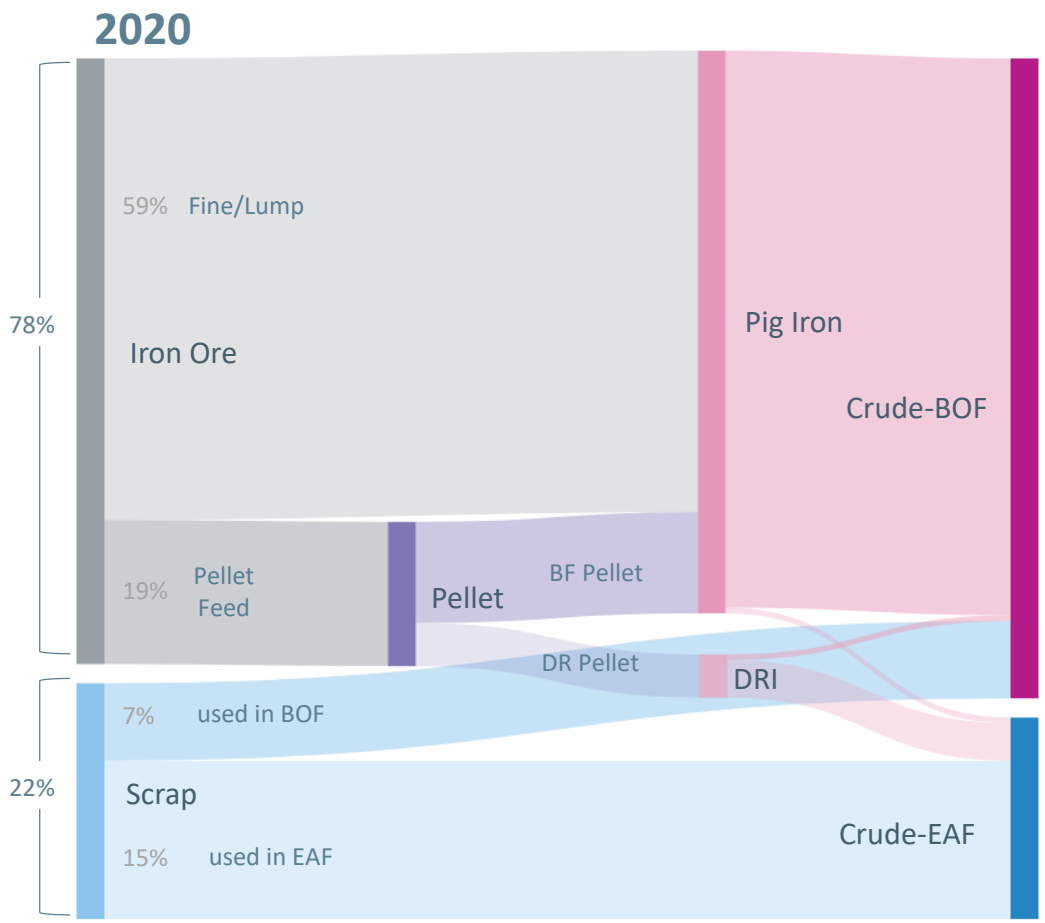


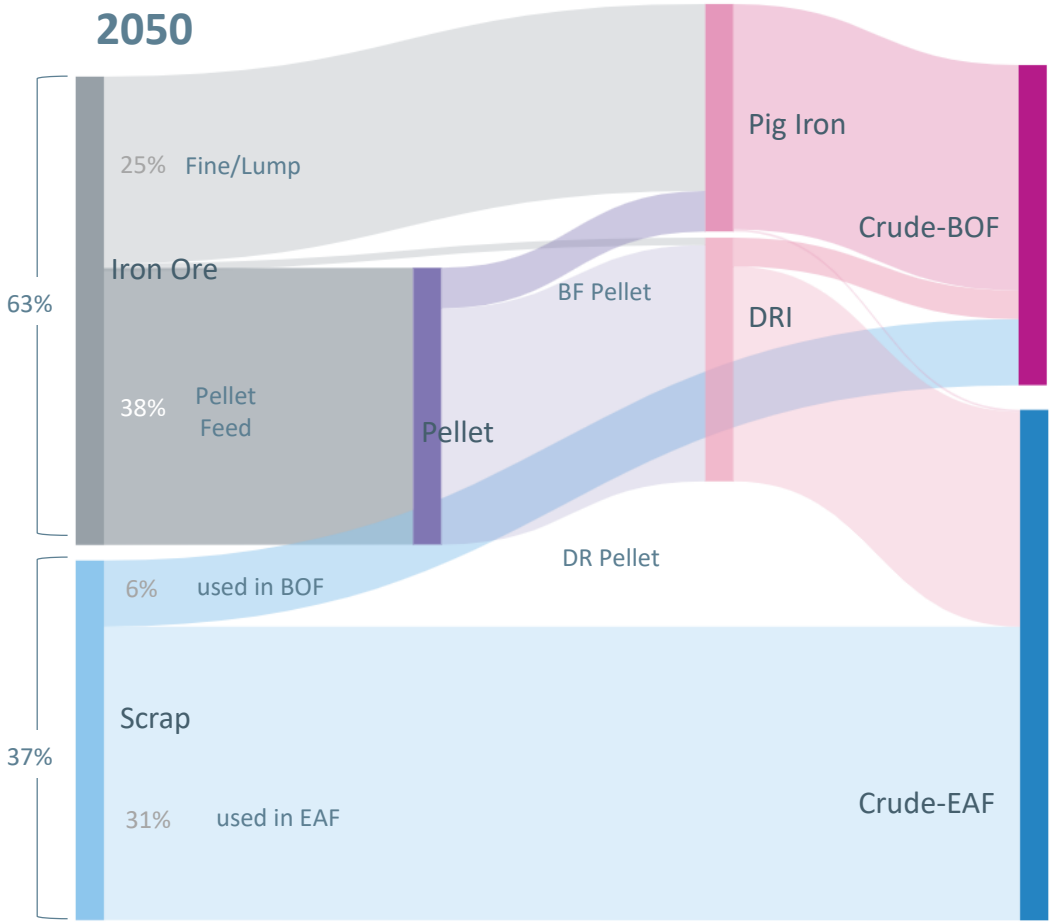


Note: Projection by POSCO Research Institute(POSRI)

Steelmaking Materials' Sankey Diagram (2020→ 2050)

- With efforts for carbon reduction, proportion of ferrous scrap to rise from 22% ('20) to 37% ('50), while iron ore to decline from 78% to 63%
- New decarbonizing technologies such as hydrogen reduction to trigger more DRI production and to raise proportion of pellet feed from 19% ('20) to 38% ('50), resulting in significant changes in iron ore mining structure





Note: POSCO Research Institute(POSRI, 2022.9): Share is based on simple metric tonne without considering Fe grade and loss rate

Steel as a key material to the transition to a circular economy

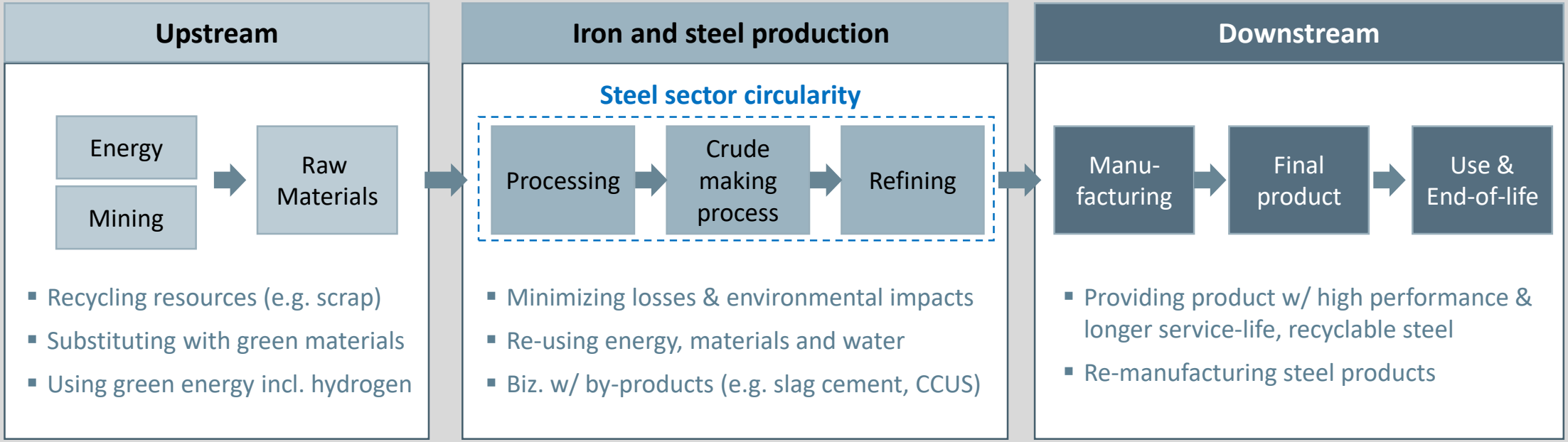
AS-IS

- **Linear Economy**: Natural resources are turned into products that are ultimately destined to become waste. This process is summarized by "**take, make, waste**".

TO-BE

- **Circular Economy**: Creating a closed-loop economic system that involves the process of '**reuse, remanufacturing, recycling and reduce**' in pursuit of no waste

The circular economy and the steel industry value chain



Shifts in geopolitics leading to fundamental changes in materials procurement, production and markets

AS-IS

- **Optimizing costs, maximizing profits**: **Supply chains of steel** have been grown in **length**, seeking for lower labor and input costs. **Complex and fragmented** supply chains became fragile to external shocks

TO-BE

- **Ensuring sustainability**: Make supply chains more **secure, reliable and resilient** to increasing geopolitical challenges

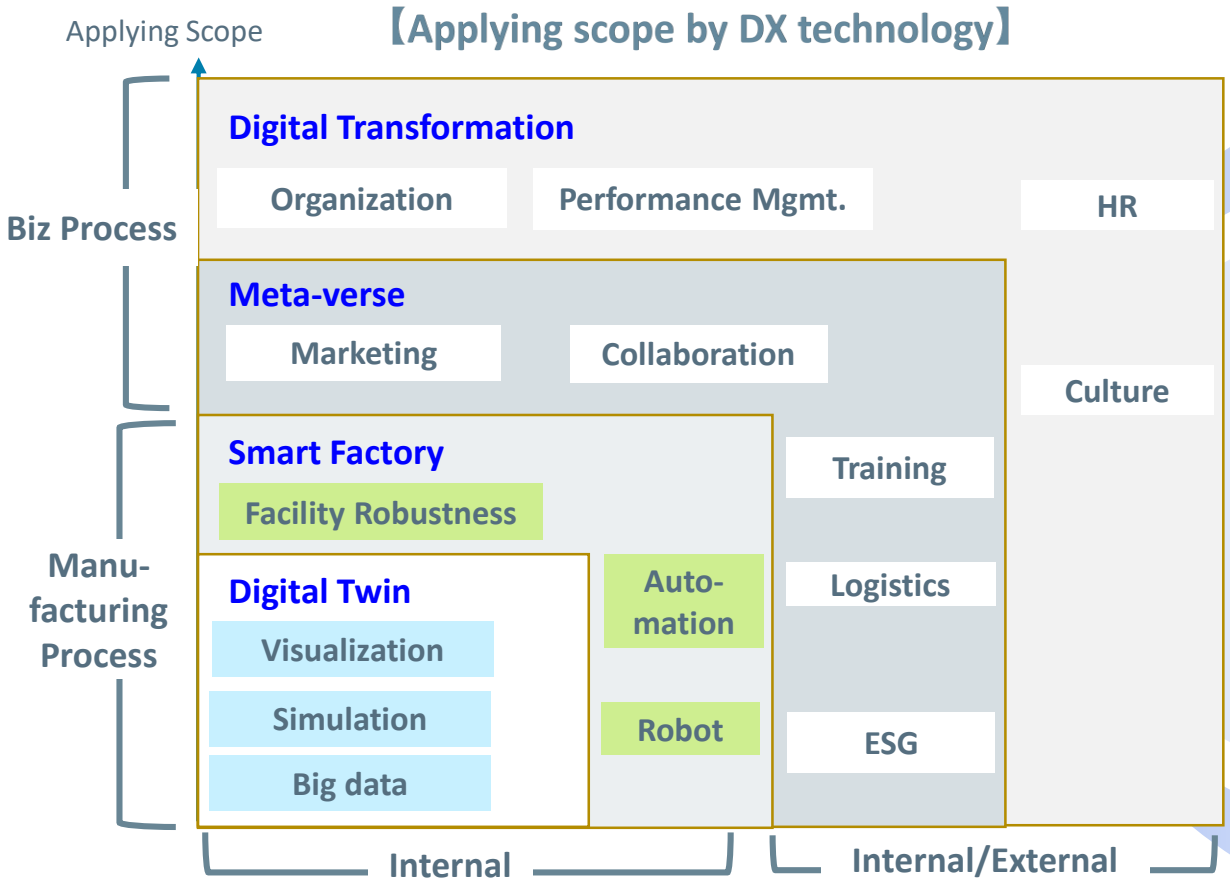
Geopolitical Competition

- **Bigger States**
  - Industrial policies (**Incentives to domestic industries**)
- **Localization/ Regionalism**
  - Local content requirement
  - Re/Near-shoring
  - **Economic blocs**
- **New Trade Policies**
  - **Carbon/ESG related trade measures**
  - Trade restrictions to critical materials

Supply Chain of Steel	Looking Forward
Materials	▪ Lowered high dependency on single supplier ▪ Making procurement decisions reflecting challenges of geo-politics & economics
Production	▪ Re-locating facilities to the location with low risks ▪ Prod./invest. in the location near market & raw materials ▪ Adopting green electricity & tech. in production process
Markets	▪ Enhancing cross-border competitiveness by providing more competitive products such as low-carbon steel products ▪ Tightening partnership with customers & within blocs

Digital Transformation(DX) in steel ecosystem accelerated after pandemic

- Key development direction of digital transformation is the online-led real-virtual world integration
- Manufacturing process : Evolved into digital twin which is virtual representation of real world entities, together with automation- and intelligence-centered smart factories
- Business process : With emergence of meta-verse, virtual world turning into the actual working space for companies



Source : A.T. Kearny ('22)

Steel's future competitiveness depends on real-virtual world integration

→ **Accelerating real-virtual world integration change the ways of process control, safety mgmt. & customization**

Process	▪ Data + Skilled workers' experience → AI + Simulation
Safety	▪ Training + Process management → Zero Risk System
Customization	▪ No change when schedule is fixed → flexible production upon order change

Evolved to Digital Twin with data connected among unit processes and Virtual Factory integrating all processes

AS-IS

- Limited adoption of digital twin as it is difficult to track a certain point due to changing properties of continuous process
- Human controlled operations by drawing optimal value from unit process through big data analysis and AI modeling

TO-BE

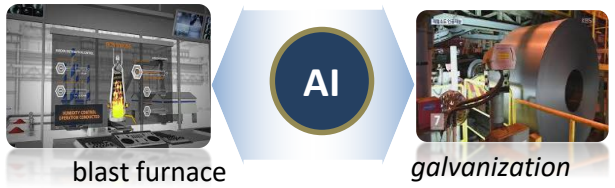
- Evolution by phase to virtual factory controlling whole processes with accumulated process data
- Through digital twin-based real-time simulation, real-time monitoring and optimal auto-control of all events at sites

Unit Process

- Digital Twin on Single Process

Improve quality, reduce costs in a single process

IoT + Big Data + AI



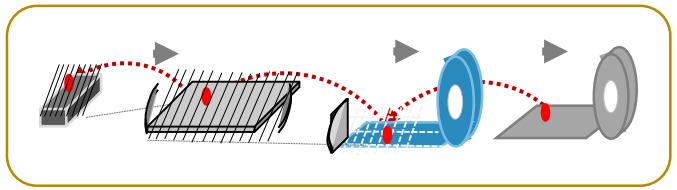
Human controlled operation, with big data & AI analysis

Process Thru

- Digital Twin between Multiple Processes

Data Trace Between Processes & Factories → *Find optimal patterns*

Deep Learning + Augmented AI



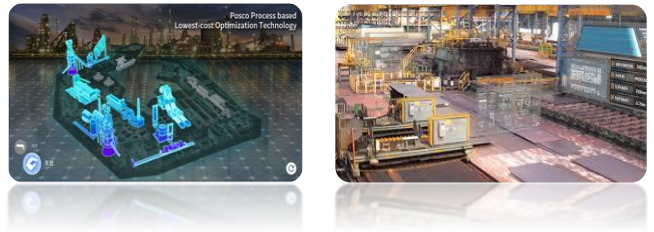
Skilled worker control → Replaced by machine learning-based optimal pattern control

Virtual Factory

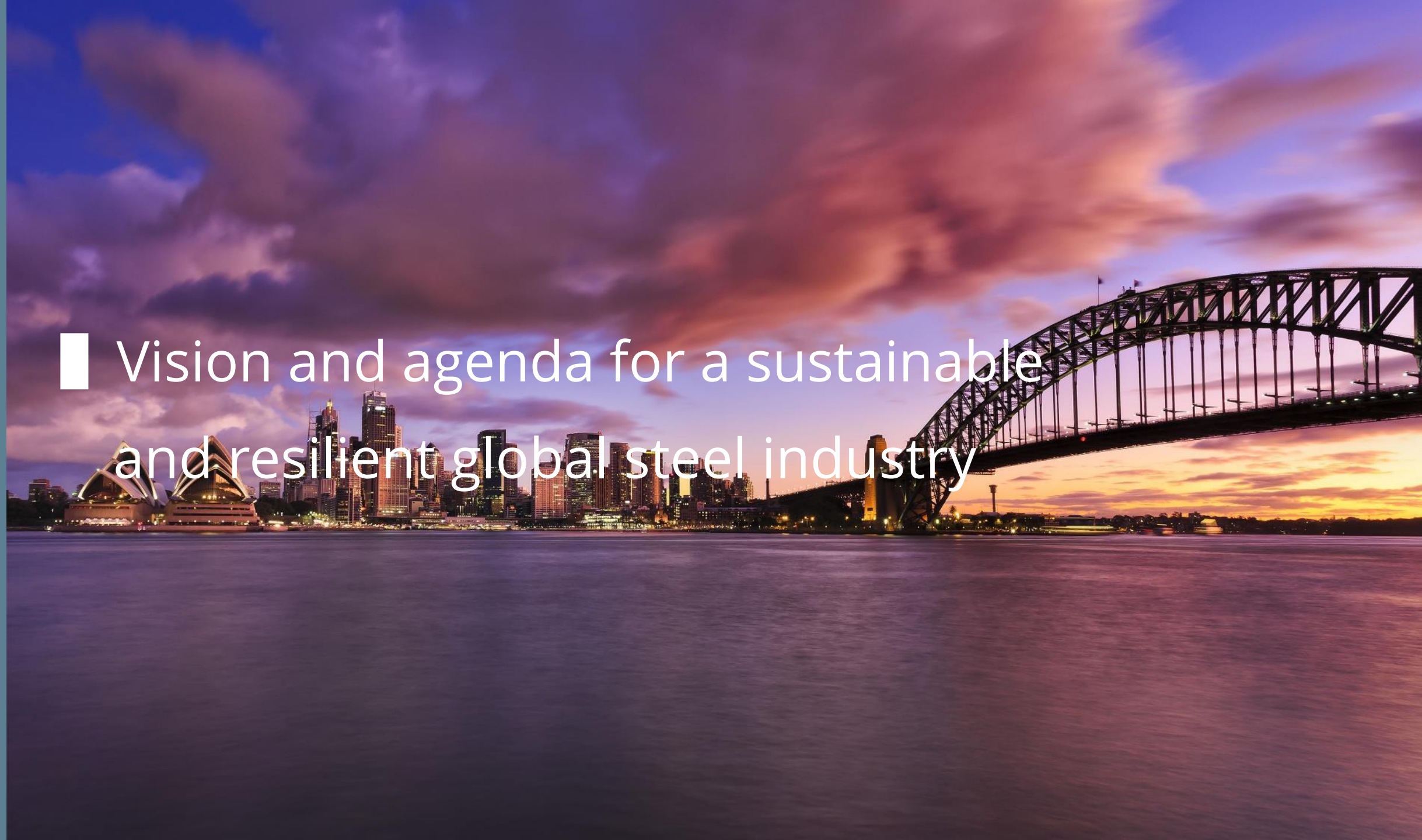
- Digital Twin through Whole Manufacturing Process

Real-Time Virtual Simulation → Full Optimized, Robotized Operation

Robot + Digital Twin



Unmanned Operation without failure & malfunctioning

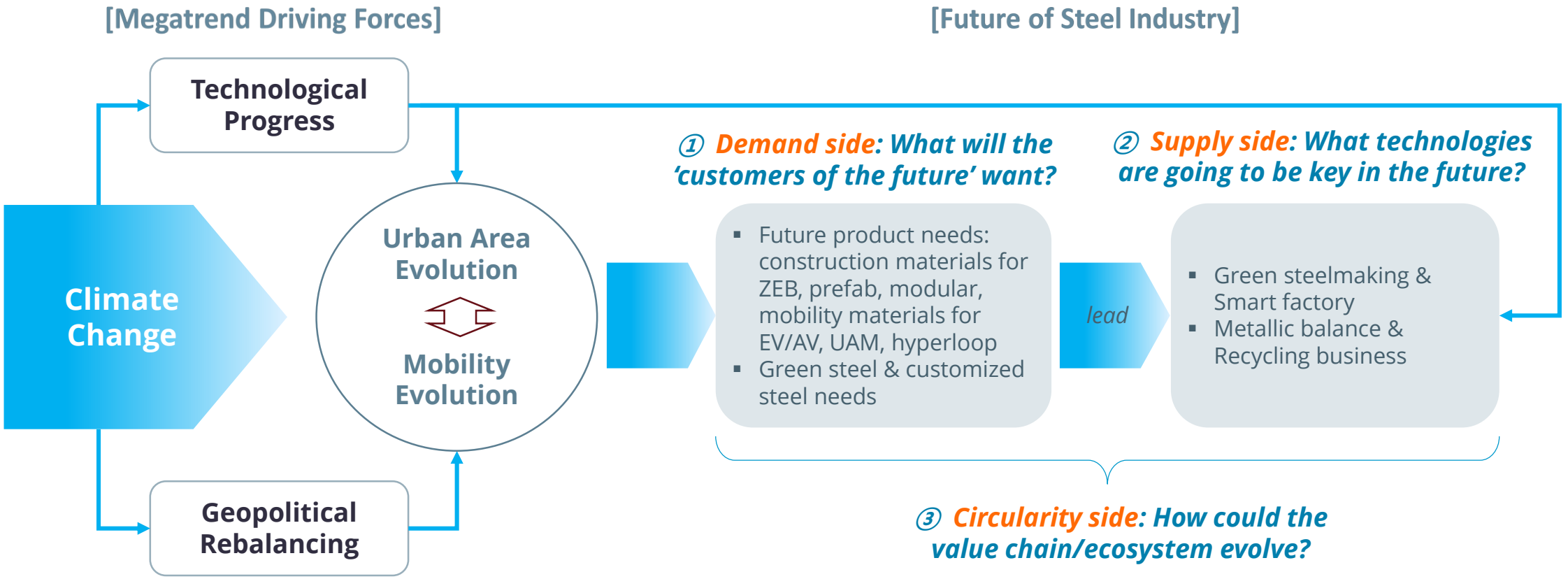


Vision and agenda for a sustainable and resilient global steel industry

posco RESEARCH INSTITUTE

How steel business will thrive under rapidly changing urban area and mobility landscape?

Sustainable and resilient steelmaker: Eco-friendly and digital producer of smart, green and customized solutions

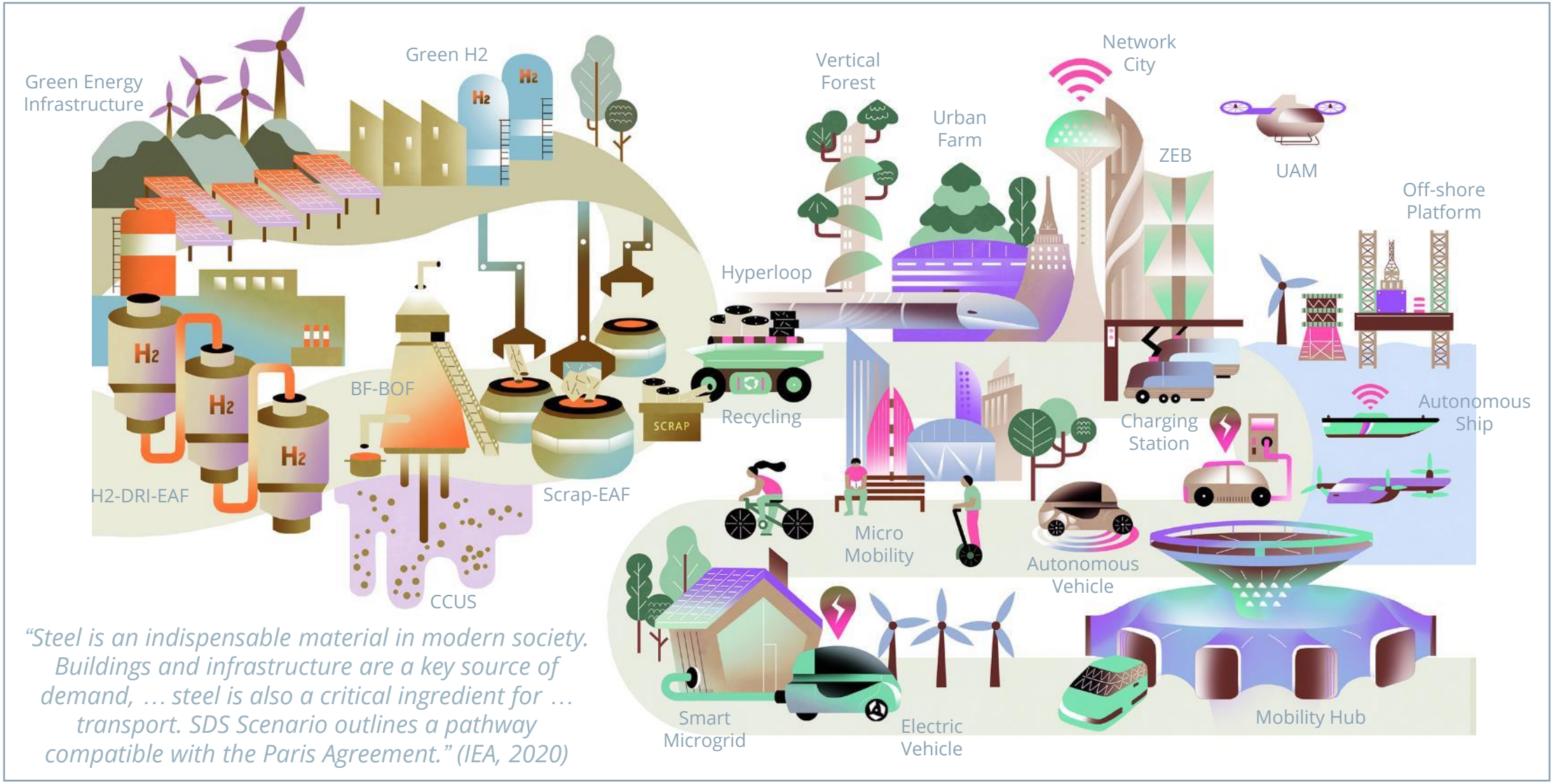


The vision of the future steel industry is to contribute to the sustainable growth of human society by providing eco-friendly materials

Sustainable & Resilient Steel Industry

	Market	Products	Smart Mfg. [Steel Making]	Decarbonization [Ecosystem]
1 **Vision** *"where should we go?"*	**Growing along the market**	**Material solution provider**	**Smart & digital manufacturer**	**Carbon neutral ecosystem**
2 **Agenda** *"How can we get there?"*	• **Develop construct., auto, and energy steel demand** along the evolving future city archetypes • **Appeal the market with steel's superior performance** – lightness, high-strength with low-carbon footprint • **Digitally driven customized market-oriented technology solutions** • **Meet the changing standards of the market** of fair competition and innovation	• Diverse and competitive **material solutions to meet customers' needs** in the future • **Partnering with** construction, auto, energy vendors to develop products • Providing **multi-material solutions** as joining and process technology evolves • **R&D with newly-emerging polymers** industries towards future product development	• **Expand smart factory capabilities** - Smart safety devices, AI-based customized production, V/C integration • **Building digital ecosy**stem by data sharing with business partners and applying open & transparent technology • **Applying meta-verse tools** to develop new solutions, enhance processes and measure carbon footprint	• Intra- and inter-industry open networking data platform towards green steelmaking • **Build up green steel value chains from upstream**(scrap, DRI, renewable energy, hydrogen) **to downstream in a circular economy** • **Promote dialogue** over decarbonization **btw. private and public sectors** to cross-border over regional blocs

Circular and eco-friendly steel flows into new city landscapes, green mobility, and renewable energy infrastructure



"Steel is an indispensable material in modern society. Buildings and infrastructure are a key source of demand, … steel is also a critical ingredient for … transport. SDS Scenario outlines a pathway compatible with the Paris Agreement." (IEA, 2020)

Source: POSRI, MEEG

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If you have any comment and suggestion on this presentation, please feel free to send an e-mail to Dr. Jun H. Goh (‘jgoh@posri.re.kr’).

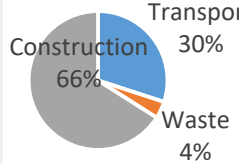
Appendix 1. Case Study – ① Advanced metropolises: New York

Advanced Metropolises

- High Income
- High-density

New York

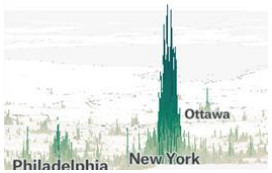
% of GHG emissions



- ➢ **20% energy cut from public bldgs., high efficient design for new skyscrapers**
- ➢ **Fossil fuels prohibited in mega construction (2035)**
- ➢ **Sustainable mobility above 80% (2050)**

Construction

◆ High-density high-rise with green areas



Dense Population

Open High-rise

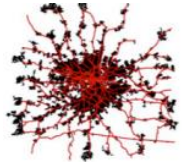
Cons-truction
- ✓ **Utilized to protect ecosystem**
  - Encouraging green bldg. & support for renewable-based remodeling

Road
- ✓ **Suitable for active mobility**
  - Recyclable materials, rainfall control

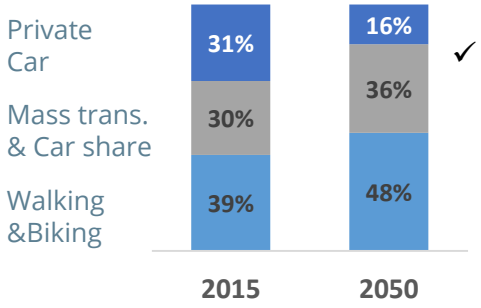
Infra.
- ✓ **Self-power generation from rooftop and suburb PVs**
  - 80% of urban green space for farm

Mobility

◆ Transport NW to ease congestion and pollution



- Mass trans. Complex road NW - ✓ **Complete Streets** Public transport+ Active Mobility



✓ Sustainable mobility to increase from 69% to 84% by ‘50

Energy

◆ More renewables, R&D for infra. tech.

De-Carboni-zaztion
- ✓ **30% cut by ‘30, 80% cut by ‘50**
  - Less dependence on fossil fuels (Facility modernization)
  - Expansion of North Atlantic Wind Energy Area

De-Centrali-zation
- ✓ **Expansion of distributed power grid**
  - One-stop approval, PVs for distributed power
  - Feed-in tariff, ESS

Inno-vation
- ✓ **R&D in urban energy infra.**
  - Support for clean e. (hydrogen)
  - Recycling tech. development (wastewater treatment plant)

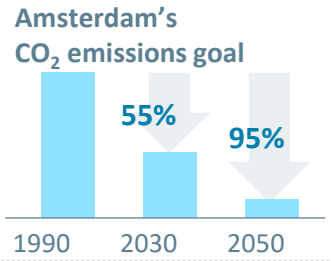
Source: PlaNYC 2030 – A Greener Greater New York, OneNYC – Efficient Mobility

Appendix 1. Case Study – ② Prosperous low-density cities: Amsterdam

Prosperous low-density cities

- High Income
- Low-density

Amsterdam



- ➢ **Polycentric transition of cities with eco-friendly urban center**
- ➢ **Zero-carbon land and sea freight within 10 years**
- ➢ **Transition to a "Circular-City" by 2050, re-circulation of all consumption resources**

Construction

◆ **Sparse, low density population**

Sparse Population

Open Mid-rise

Cons-truction

✓**Green infra., biodiversity design**
- Green space within 10 minutes

Road

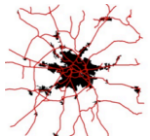
✓**Polycentric city to cut traffic load**
- Mainline railways, roads, transit centers

Infra.

✓**Wind-led sustainable energy design**
- Maximum use of wind/solar power

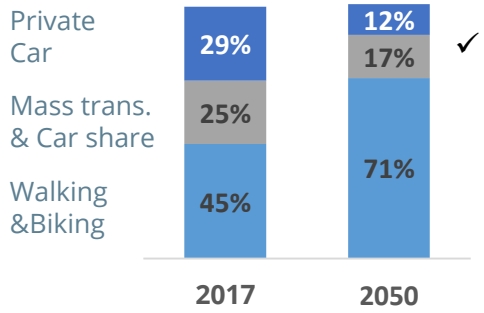
Mobility

◆ **Less transfer in 15-min. living areas**



- Suburb trans.
- Mass trans.

✓**City block & Active mobility**
- Walking & biking



✓Sustainable mobility to increase from 70% to 88% by '50

Energy

◆ **Expanded renewable e. and green city**

De-Carboni-zaztion

✓**Net-zero, sustainable city by '50**
- 60-90% of EV fuels replaced by renewables('40)
- 50% less raw materials & materials

De-Centrali-zation

✓**UPV* and suburb wind farm**
- PVs for every available city roofs
. Renewables for 80%('30), all houses ('50)

* UPV : Urban photovoltaics

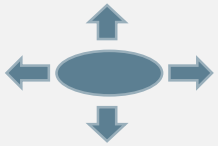
Inno-vation

✓**Green façade, green roof**
- Greening of rooftops & public space to reduce urban heat stress

Source: Amsterdam Green Infrastructure Vision 2050

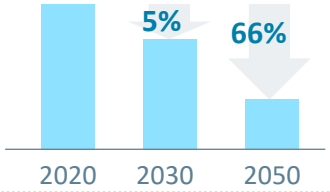
Appendix 1. Case Study – ③ Expanding monocentric cities: Beijing

Expanding monocentric cities



- Low Income
- High-density

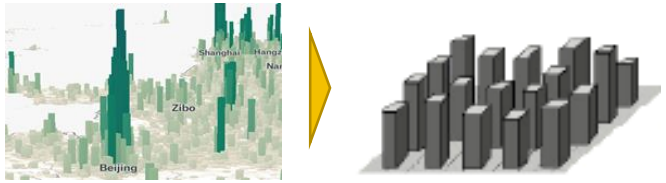
Beijing's CO_2 emissions forecast



- **2060 carbon neutral plan (Xi Jinping in UN General Assembly, Sept. '20)**
- **'Energy Revolution' for carbon neutrality**
- **Plants relocated outside Beijing, product design, SW/AI industry**

Construction

◆ **From grey city to colorful city**



Dense Population → Compact High-rise

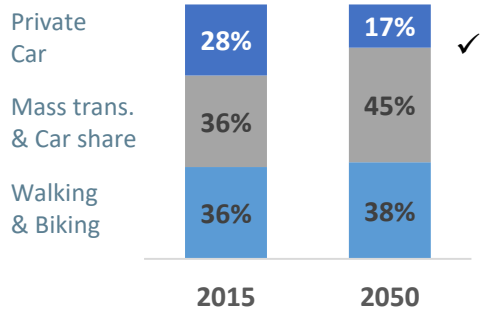
Cons-truction	✓**Mosaic → Kaleidoscopic land use** - Innovation & lifestyle zones
Road	✓**Energy efficiency↑with increased urban transport** - Integration of residential and lifestyle zones with MoD* design
Infra.	✓**Sponge city with smart tech.** - Rainwater management, basis for 'Digital Beijing'

Mobility

◆ **Traffic congestion eased with digital tech.**

- Ring roads
- Mass trans.

✓**Mobility on Demand**
- Autonomous driving tech. & digital economy



✓Sustainable mobility to increase from 72% to 83% by '50

Energy

◆ **Energy innovation for carbon neutrality**

De-Carboni-zaztion

✓**Renewable e. up to 60% by '60**
- Renewables + natural gas + electricity for new demand
- Fossil fuels↓: Coal 61%→7%('60)

De-Centrali-zation

✓**Smart grid expanded from city center to suburbs**
- Center ('25)→ City border ('35)→ Rural ('50)
- Distributed power system, mini gas generators

Inno-vation

✓**Digitalization by reconfiguring power system**
- Eco-friendly raw materials, CCS tech.
- Wireless power transmission tech.

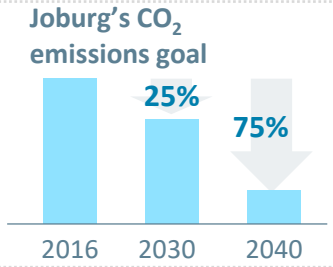
Source: MEGA-TRENDS AND THE NEED FOR NEW CITY BUILDING APPROACHES IN THE PEOPLE'S REPUBLIC OF CHINA
* MOD (Mobility on Demand)

Appendix 1. Case Study – ④ Developing scattered cities: Johannesburg

Developing Scattered cities

- Low Income
- Low-density

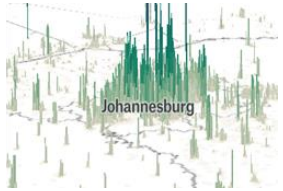
Johannesburg



- ➢ **Carbon neutral by '50, ease of high carbon intensity**
- ➢ **Land use diversity, narrowing of divide, encouraging social mix**
- ➢ **Green conservation, biodiversity protection, sustainable city**

Construction

◆ **Compact polycentric city**



Scattered Population

Open Midrise

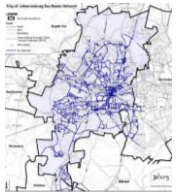
Cons-truction
- ✓ **Increased urban density, prevention of overpopulated adjacent cities**
  - Public housing & infra. expanded

Road
- ✓ **Improved to raise accessibility from satellite cities**
  - Active mobility infra. in urban center

Infra.
- ✓ **Facility, infra. expanded to community**
  - Maximized use of invest. for residential convenience

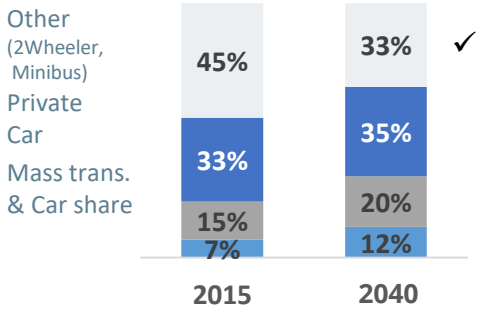
Mobility

◆ **Traffic congestion eased with digital tech.**



- Mass trans.
- Accessibility from the outer

✓ **Renewable-based eco-mobility**
- Active mobility



✓ Sustainable mobility to increase from 22% to 32% by '50

Energy

◆ **Half of energy from renewables ('40)**

De-Carboni-zaztion
- ✓ **Net-zero energy for all ('50)**
  - Reduction of industry's coal use
  - 50% rooftop PVs by '30

De-Centrali-zation
- ✓ **Distributed power system**
  - Renewables facilities on city borders
  - 20% renewables for commercial, 15% for residential ('50)

Inno-vation
- ✓ **Smart grid & ESS**
  - Distribution of smart meters
  - Zero emissions for new bldg. ('30) and existing bldg. ('50)

Source: JOBURG 2040 Growth & Development Strategy

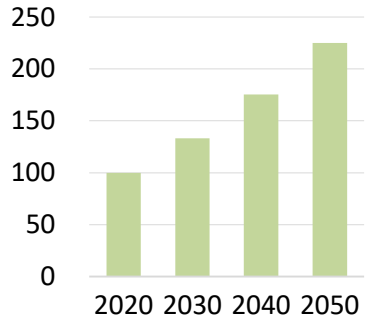
Global steel demand to grow CAGR 0.9% in '20-'50 to reach 2.35 bil. tonnes by '50

- Construction: Modest growth at CAGR above 1~2% in urbanization trend
- Mobility: Despite continued growth in automotive production, steel demand to fall slightly after '40 with slowing steel share of auto materials
- Energy: Slowing energy investment expected after accelerated investment during the next 15~20 years to achieve carbon neutrality

[Steel-consuming Industry]

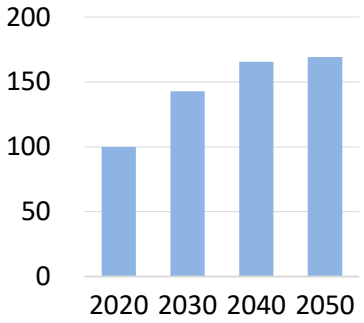
(2020 = 100)

Construction Investment



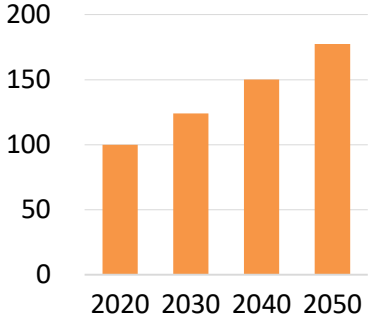
Source: IHS Markit, POSRI

Automotive Production



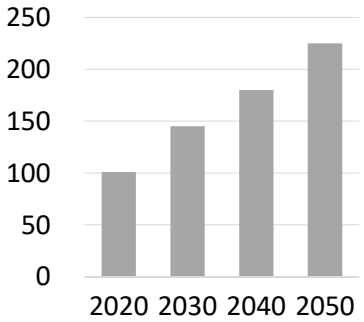
Source: Wood Mackenzie

Energy Investment



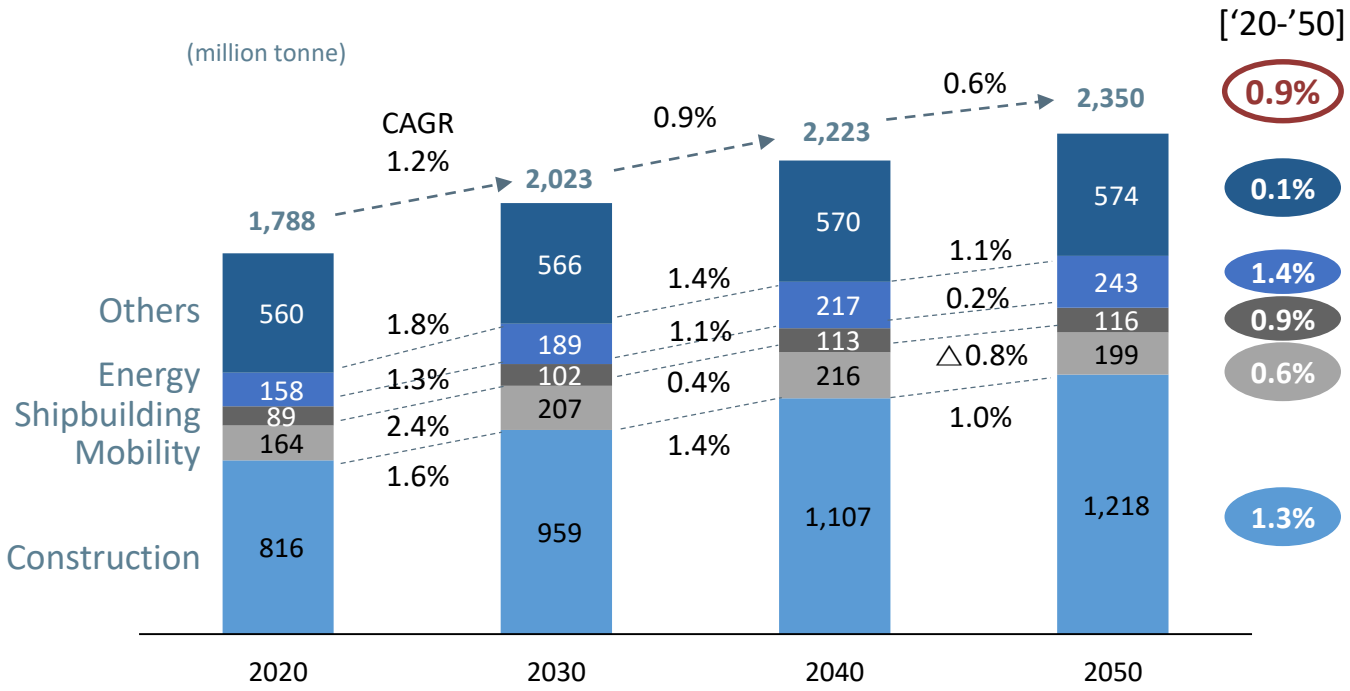
Source: IHS Markit, POSRI

Ship Demand



Source: OECD

[Steel demand forecast]



Mobility: Calculated by multiplying CRU & Wood Mackenzie's automotive production forecast by steel unit requirement per car unit
Construction: Calculated by multiplying IHS Markit's construction spending forecast by steel intensity per amount
Energy: Calculated by multiplying IHS Markit's energy investment forecast by steel intensity
Others: Calculated by multiplying IHS Markit's industrial production forecast by steel intensity