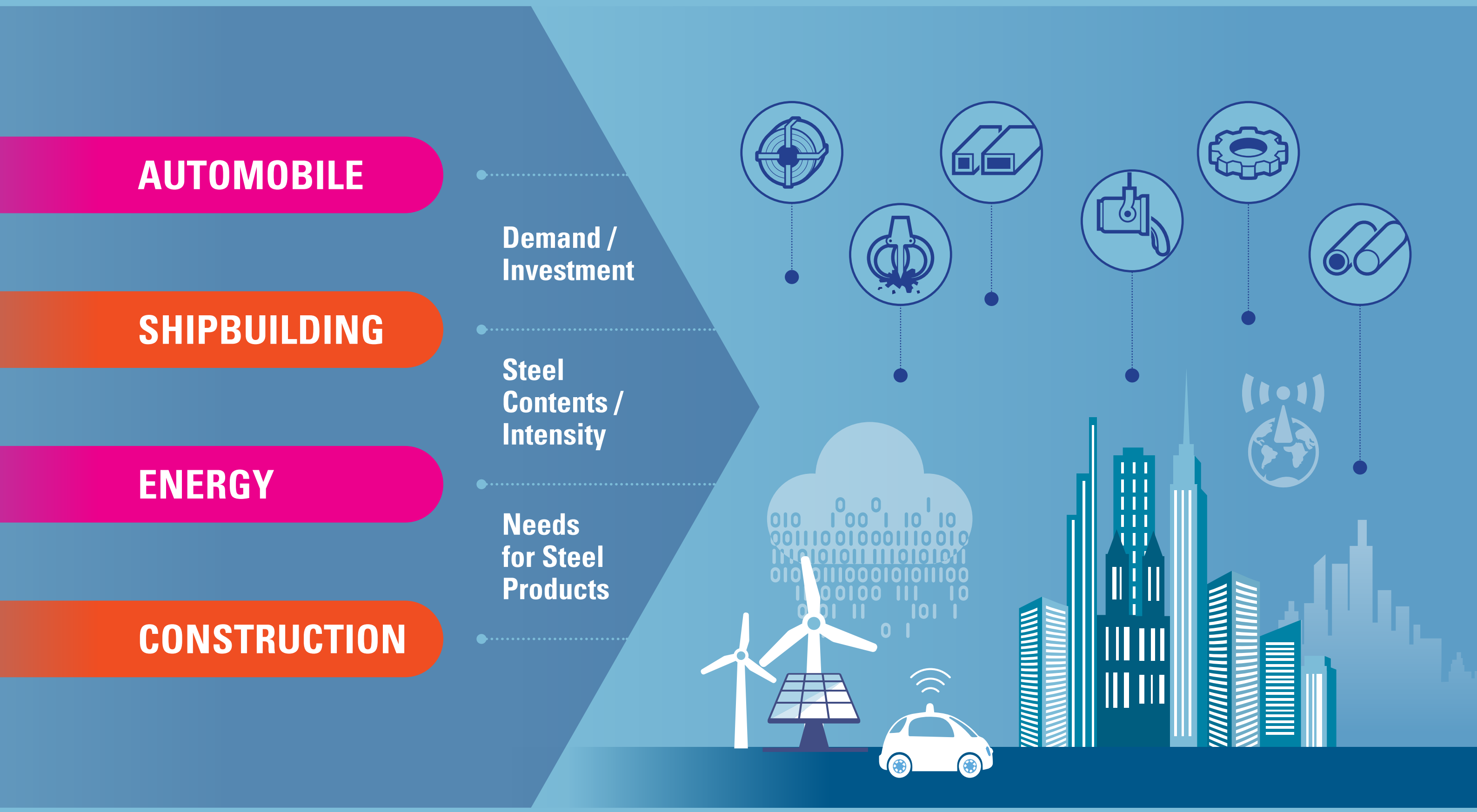
On the Cover

# Future Megatrends

## in Steel-consuming Industries and Their Impact on the Steel Industry

**ONGOING AND EMERGING MEGATRENDS** Source: POSCO Research Institute


AUTOMOBILE
SHIPBUILDING
ENERGY
CONSTRUCTION
Demand / Investment
Steel Contents / Intensity
Needs for Steel Products

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# Future Megatrends and the Steel Industry

## What is a megatrend?

To understand future megatrends, the definition and characteristics of megatrends must first be made clear. Megatrends are a long-term process of transformation with a broad scope and dramatic impact. They are considered powerful factors shaping future markets.[1] Megatrends have three main characteristics through which they are distinct from other trends: their time horizon, reach, and intensity of impact.[2] Companies can gain insight into what areas will emerge or grow in the future by analyzing and predicting future megatrends. In doing so, they are able to uncover clues for business portfolios, new future businesses, and R&D themes.

1 Z-punkt GimbH, a German consulting firm for strategic foresight consulting

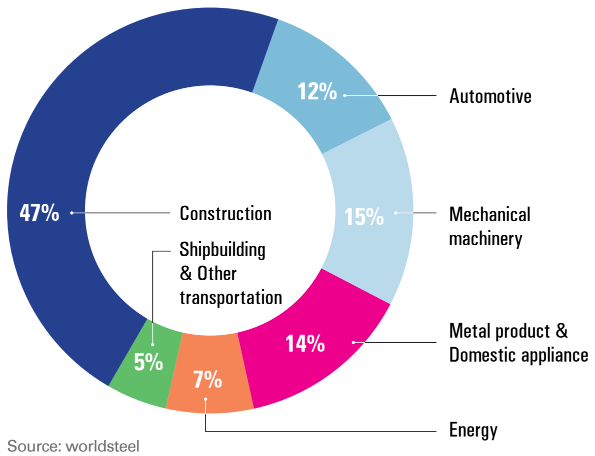
2 Firstly, megatrends can be observed over decades. Quantitative, empirically unambiguous indicators are available for the present. They can be projected—with high probabilities—at least 10 years into the future. Secondly, megatrends have a comprehensive impact on all regions and actors—governments and individuals and their consumption patterns, but also businesses and their strategies. Finally, megatrends fuel fundamental, multidimensional transformations of all societal subsystems, whether politics, society, or the economy.

## Ongoing trends in the steel industry

This article deals purely with megatrends which will significantly impact the future steel industry rather than general megatrends. In this article, megatrends with a great influence over the steel industry are divided into ongoing trends and emerging trends, considering the lapse of time. The time horizon of 20 to 30 years is considered here to reflect new megatrends—worsening global warming and the spread of the Fourth Industrial Revolution—which bring fundamental changes to global industrial structures.

Looking back on the last 50 years of the global steel industry, the expansion of steel-consuming industries has driven the growth of the steel industry. In order to review the history of quantitative growth from the perspective of steel demand, the share of steel demand within each industry should first be considered. The largest consumer of global steel is the construction industry, which absorbs nearly 50% of global steel production. This industry accounts for a large share of the global economy. As urban infrastructure such as commercial and residential buildings, bridges, and pipelines has been

**Figure 1. Global Steel Demand Share by End-use ('07-'15 average)**




Source: worldsteel

installed in major cities worldwide, steel demand for construction has continued to increase. The second and third largest steel-consuming industries are the machinery industry and the metal products/domestic appliance industry, which consume about 15% and 14% of global steel, respectively. These industries have relatively many end-user companies, therefore an indivisual company purchase a small volume of steel but require a wide range of steel products. Next, the automotive industry accounts for 12% of global steel demand. The automotive industry has experienced increasing demand for auto sheet and wire rod, such as for exhaust pipes and inner and outer automobile panels. The shipbuilding, other transportation and the energy industries combined account for 12% of global steel demand. These industries consume only a few types of steel products, but do so in large amounts. Table 1 shows the annual average proportion of steel demand by industry over the nine years from 2007 to 2015.

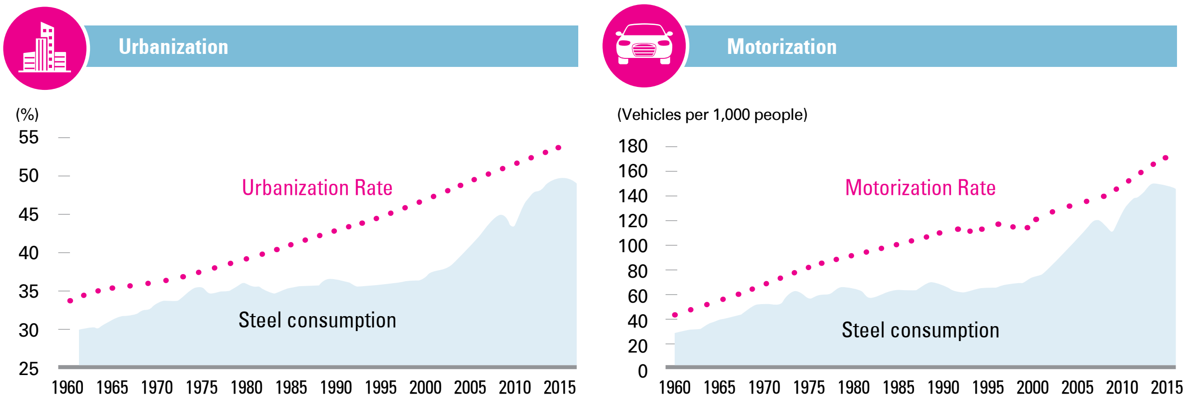
The steel industry has been propelled by four main drivers of steel-consuming industries: urbanization, motorization, globalization, and industrialization. First, urbanization is the most important construction trend impacting the steel industry. Closely intertwined with rising population and incomes, the number of urban dwellers has increased steadily. In 1960, only 33.7% of people worldwide resided in urban areas (1.02 among 3.03 billion people), but by 2015, 54% of the world's population was urban (3.96 among 7.33 billion people).[3] Second, the key trend for

3 UN World Urbanization Prospects (2014 Revision)

**Table 1. Characteristics of Megatrends**

| Characteristics | Details |
|---|---|
| **Time horizon** | Can be observed over at least 10 years |
| **Reach** | Have a comprehensive impact on every sector of society (including policy authorities, customers, and companies) |
| **Intensity of impact** | Megatrends deeply and extensively influence technology, society, the economy, politics, and the environment |

**Figure 2. Four Main Drivers for Steel-consuming Industries**




Source: worldsteel, World Bank, POSCO Research Institute
Note: The right axis abbreviated denotes annual global steel consumption

the automotive industry is motorization. Led by high income earners, the motorization rate (vehicles per 1,000 people) generally grows gradually at the introductory stage[4] but rises rapidly during the growth stage as cars become popular among general customers responding to rising incomes and improved road infrastructure. This is called the stage of mass motorization. Car ownership rose ten-fold over the period from 1960 to 2015, from 127 million to 1,262 million units, bolstered by increased household incomes and a relative decline in car prices. The global rate of motorization (vehicles per 1,000 people) also increased significantly, from 42 units to 172 units over the same period, indicating that the era of full-scale motorization has arrived. Third, globalization is the most important trend for the shipbuilding industry, on the ground that globalization is characterized by increased trade between countries.[5] After World War II, the global trade environment gradually improved thanks to voluntary cooperation among member countries of the General Agreement on Tariffs and Trade (GATT, 1948) and World Trade Organization (WTO, 1995). As a result, the export-to-GDP ratio increased profoundly, from 12% in 1960 to 30% in 2015. Finally, under the influence of rapid industrialization, the machinery and domestic appliance industries have sparked global steel demand. These ongoing megatrends will continue to affect the steel industry in the future.

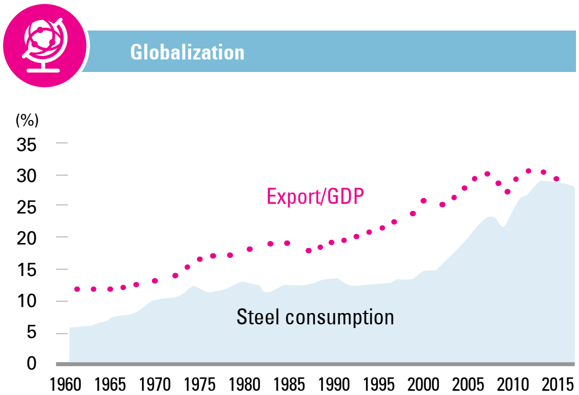
4 Automobiles are durable goods with a lifecycle similar to that of general goods (introductory, growth, maturity, and decline stages).

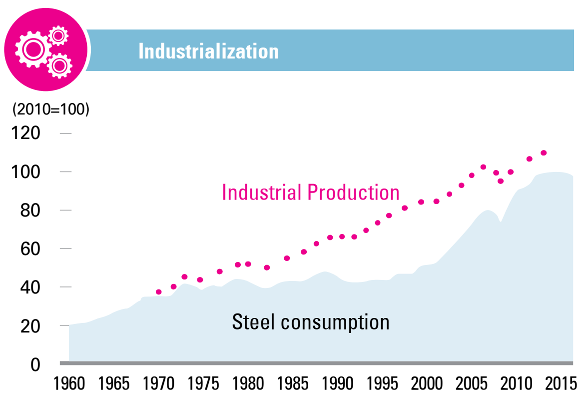
5 The International Monetary Fund (IMF) identified four basic aspects of globalization: trade and transactions, capital and investment movement, migration and movement of people, and the dissemination of knowledge.

## Emerging trends for the steel industry

Together with these ongoing megatrends, global climate action and the Fourth Industrial Revolution are the emerging trends that will affect the future of the steel industry.

At the 2015 United Nations Climate Change Conference held in Paris, known as COP21 or CMP11, all 196 Parties agreed to adopt the Paris Agreement. It creates a new legally-binding framework for coordinated international efforts



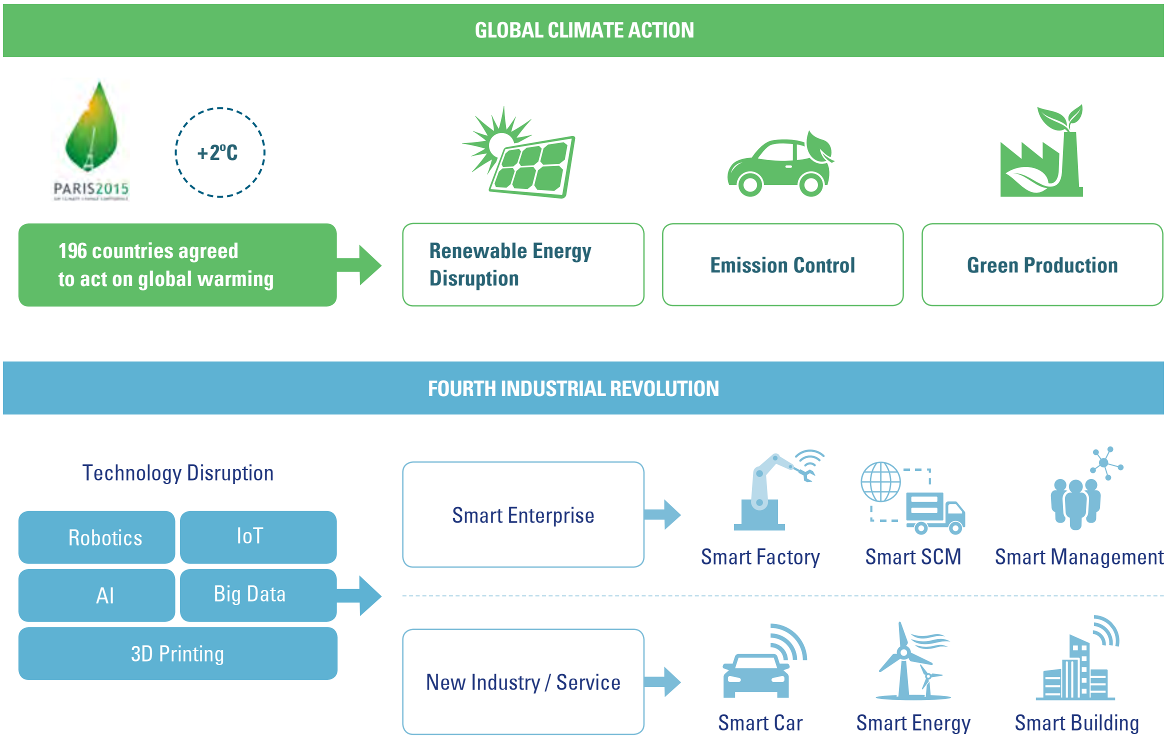




to tackle climate change. Since then, global climate action has accelerated although U.S. President Donald Trump's decision to withdraw from the Agreement would damage its solidarity. This will promote the development of innovative renewable energy, $CO_2$ emission controls, and green production. The Paris Agreement is meaningful in two ways. First, it has an expanded scope of application. The Kyoto Protocol was applicable in only 37 industrialized countries and the European Community, while all 196 Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are subject to this Agreement. Second, it includes a long-term target: Keeping global temperature rise well below two degrees Celsius above pre-industrial levels or limiting the temperature increase even further to 1.5 degrees Celsius. To meet these goals, global greenhouse gas emissions are to be reduced to at least 10% below 2010 levels by 2030 and 55% by 2050. Therefore, the Agreement will have a long-term impact on the steel industry in terms of demand, products, and production process.

The Fourth Industrial Revolution, the second emerging trend, is accelerating based on key technologies such as IoT, big data, and AI. With the progression of these technologies, companies will convert themselves into smart enterprises, pursuing smart factories and smart management. As a result, new industries and services such as smart cars, smart energy, and smart buildings will all gain ground. This will bring about profound changes in the steel industry by both direct and indirect means: an indirect impact on steel demand through steel-consuming industries and a direct impact on steelmaking process. For smart factories, production costs will be reduced due to increased work efficiency, reduced waste, and swifter decision-making.[6] In addition,

6 According to a survey by PwC in 2016 (cost reduction effects for five years, 2016-2020), smart factories contribute to an annual cost reduction of USD 54 billion.

Figure 3. Emerging Trends Reshaping the Future of the Steel Industry




knowhow for smart factories will become explicit knowledge.

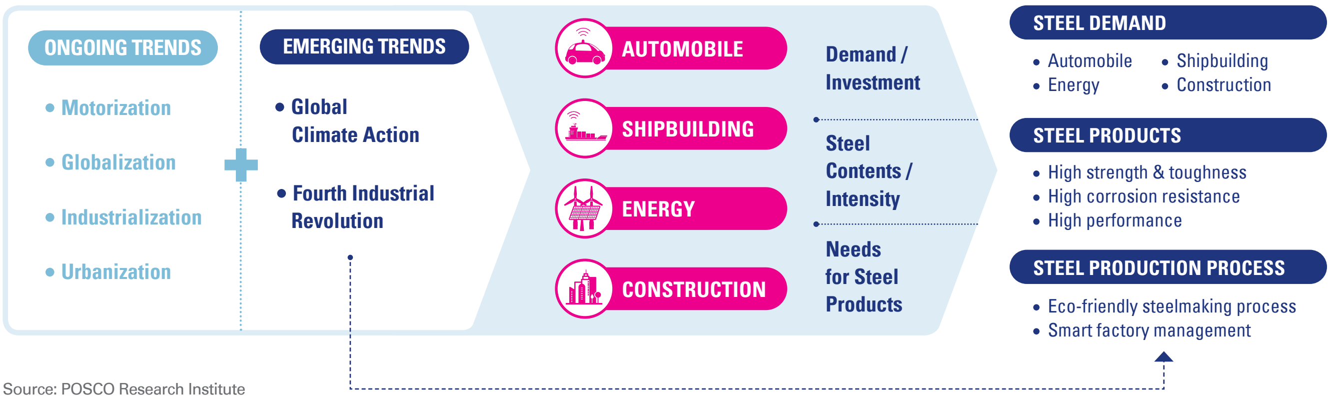
These emerging trends will impact the ongoing trends, resulting in a multiplier effect, which refers to a ripple effect through which changes in one factor transform another. In this article, two factors—climate change and the Fourth Industrial Revolution—will be closely intertwined with ongoing trends and become a driver of change. In other words, the two emerging trends of concerted action on global warming and the Fourth Industrial Revolution will have a significant impact on the future of the ongoing trends of urbanization, motorization, globalization, and industrialization.

## Impact of Megatrends on the Steel Industry

The ongoing and newly emerging trends will in combination change the landscape of steel-consuming industries and ultimately impact the entire steel ecosystem.

Changes in megatrends will influence both product/investment demand and steel content, the 'steel intensity' in respective industries. First, in the case of the automotive industry, global demand for new cars will increase over the long term apace with widespread motorization; however it will not grow to the degree that might have been expected given the impact of

**Figure 4. Impact on the Steel Industry**




Source: POSCO Research Institute

autonomous driving technologies and the rise of the sharing economy. Steel content per vehicle is expected to decline as automobile materials become lighter and stronger owing to stricter fuel efficiency standards, electrification, and safety concerns. Second, in the shipbuilding industry, the current oversupply situation will run its course until 2025. However, the shipbuilding market will grow after this point due to the expansion of global trade and rising demand for vessel replacement. Steel intensity by ship's tonnage will fall continuously as vessels become larger and lighter, and it will further decline with the rise of electric propulsion and unmanned and autonomous ships. Third, the trend of urbanization will cause global construction investment to rise continuously over the long term. However, the steel intensity of construction investment will continue to decline given that for smart and green cities software requires greater investment than steel. Fourth, in the energy industry, global energy investment will continue to increase thanks to rising populations and economic development in emerging countries. The steel intensity of energy investment will be sustained by rising investment in transmission and distribution (the sector with high steel intensity), despite declining investment in energy infrastructure (the sector with low steel intensity). These impacts on product/investment demand and steel intensity will eventually affect future steel demand.

As new megatrends develop, there will be a considerable shift in customer needs for steel products. In particular, demand is rising for high strength and toughness, high corrosion resistance, and high performance steels. Under global climate action the steel industry will continue to develop energy saving and recycling technologies and new eco-friendly steelmaking process. The 4th Industrial Revolution will profoundly change the future of the steel industry. The steel industry will move beyond plant automation, toward smartization across all process using smart technologies. Through this smart transformation, the global steel industry will create new values.

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# Understanding **the New Mobility Paradigm**

## The evolution of the car industry

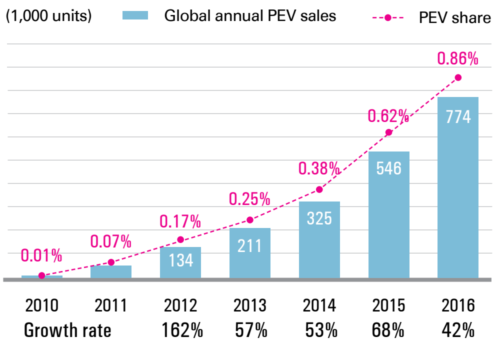
Based on its appearance, the Consumer Electronics Show (CES) held in January of 2017 might have been described as a 'Car Electronics Show.' Starting out 50 years ago as an electronics show for displaying home appliances, the CES has emerged as major arena for IT competition. Recently, however, it seems to be evolving into an automotive showcase. The Detroit auto show (NAIAS), once the mecca of the automobile world, was held in the same month but seems to have lost its sparkle compared to the CES. In April 2017, Tesla, the definitive maker of electric vehicles (EVs), overtook Ford and GM in terms of market cap to further undermine the position of the Motor City. It is fair to state that the center of attention in the automotive industry has shifted from Detroit to Silicon Valley as IT companies such as Google spin-off Waymo, graphics processing units maker Nvidia, and microprocessor fabricator Intel are actively working to develop autonomous driving technologies.

The popularization of cars began in the 1920s when the Ford Model T first hit the road. The automobile market of the time was so lopsided that carmakers were able to offer customers only a single color option (black). Today this unbalanced consumption structure has shifted to a more customer-oriented market in which car buyers can choose from a vast range of brands, dozens of models, and thousands of options. The automobile industry must manage further innovation through the rise of new mobility services. Such mobility services allow the production of a car customized to a single individual, and can even blur the lines between what is shared and what is owned. Driving the fundamental changes in this industrial structure is the exponential advancement of technologies such as AI, Big Data, IoT, and 3D printing that together comprise the Fourth Industrial Revolution. These deep changes are most evident in the automotive industry.

## The rise of electric vehicles

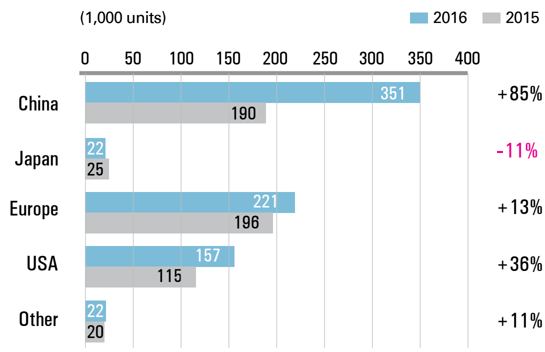
Tesla was the first company to begin pulling down

**Figure 1. Plug-in Electric Vehicle Sales Trend**




Source: EV-Volumes

**Figure 2. Plug-in Sales and Growth Rate**




Source: EV-Volumes

the entry barriers into the traditional automotive industry. When others were still doubtful as to whether EVs could gain ground in the market, Tesla was releasing electric luxury cars with sleek designs and elevated performance comparable to sports cars: Model S sedans and Model X sport utility vehicles. The company is now heading toward the 200,000 sales milestone.[1] Tesla delivered 25,000 cars in the first quarter of 2017 alone and plans to release the more affordable Model 3 in July of this year. Tesla is now surely on a par with traditional automakers in many regards. The Renault-Nissan Alliance, although further from the spotlight than Tesla, had sold a total of 425,000 EVs worldwide by 2016, contributing greatly to the popularization of the category. The company is taking steps to appeal to a broader audience with a wide range of lineups, including the Nissan Leaf (which has topped 250,000 in total sales), Renault Zoe, and Mitsubishi Outlander.[2] Moreover, China is also gearing up for the EV competition. Backed by robust support from the Chinese government, more than 350,000 EVs were sold in China last year alone, roughly half of the global total. With this fast-growing trend, global plug-in vehicle sales reached 773,600 units in 2016, 42% above the total for 2015.[3] Although EVs currently account for less than 1% of the overall market, they should become as competitive as internal combustion engine (ICE) vehicles by around 2020, and will be increasingly preferred by customers.

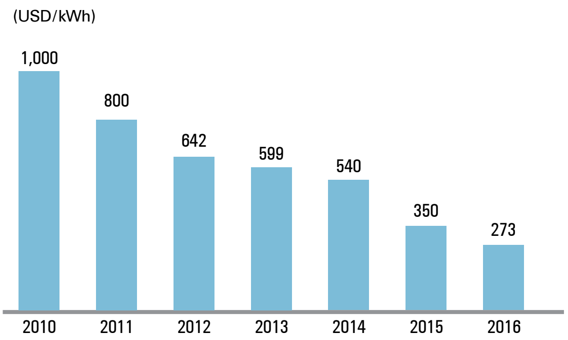
The success of Tesla has awoken traditional carmakers. Major global automobile companies are rushing to develop their own EVs. As the first among the major players, GM has rolled out an affordable, second-generation all-electric vehicle, the Chevrolet Bolt. It has doubled the battery capacity of the first-generation plug-in hybrid Volt and achieved a range of 380 km on a single charge. By solving the most significant barrier, it has significantly improved driver convenience. The USD 30,000 price tag after subsidies is also competitive compared to ICE vehicles.

1 "Tesla Beats Estimate With 25,000 Deliveries as Model 3 Nears", Bloomberg, April 3, 2017

2 "Renault-Nissan maintains dominance in global electric car market", driveEV.net, February 8, 2017

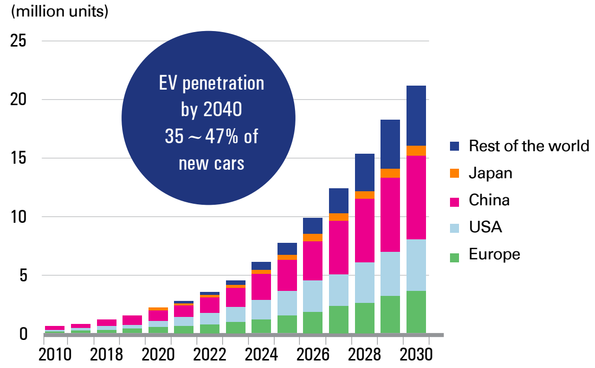
3 "Global Plug-in Sales for 2016", EV-Volumes.com

**Figure 3. EV Battery Pack Price Trend**




Source: Bloomberg New Energy Finance Summit, April 25, 2017

**Figure 4. EV Sales Forecast by Region**




Source: Bloomberg New Energy Finance

This price competitiveness can be attributed to the rapid decline in battery costs: The average battery pack has fallen in cost from over USD 1,000/kWh in 2010 to USD 273/kWh in 2016. By 2030, it is expected to drop below USD 100/kWh. This means that EVs capable of surpassing 300 km on a single charge could possibly be produced for less than ICE vehicles. The effect of the widespread acceptance of EVs is clearly evident in Norway. Thanks to tax incentives, EVs there have reached at a price point similar to ICE vehicles, and their market share has surged dramatically from 1.4% in 2011 to 29% in 2016. Assuming charging infrastructure is available, the global EV market should expand rapidly. Bloomberg New Energy Finance forecasts that the market share of plug-in EVs will top 35% by 2040.[4]

4 "Bloomberg New Energy Finance Summit", M. Liebreich, BNEF, April 25, 2017

## One step closer to the age of robotic vehicles

Driverless cars were once a subject of science fiction, but today they have already hit the road. High-end luxury brands such as Mercedes-Benz, Audi, and Hyundai Genesis EQ900 come equipped with Advanced Driver Assistance Systems (ADAS), such as Adaptive Cruise Control (ACC) which automatically adjusts vehicle speed to help maintain a safe distance from vehicles ahead, and a Lane Keeping Assist System (LKAS) which prevents motorists from drifting out of a lane. Some countries are attempting to legalize Auto Emergency Braking (AEB) to combat collisions on the roads. This kind of driver assistance is classified as Level 1 or 2 driving automation for on-road vehicles. The development of automated driving systems is currently underway, spanning from Level 3 (conditional automation) to Level 5 (full automation). Waymo's fleet of autonomous vehicles (AVs) has logged more than three million miles on public roads since 2008. Tesla is outperforming other companies by producing automated vehicles equipped with its Level 2 Autopilot. In 2016, Tesla announced that all of its cars will feature the autonomous driving hardware necessary for full Level 5 autonomy.[5]

**Table 1. Automated Driving Level Definitions**

| SAE level | Name | Narrative Definition | Steering and Acceleration/ Deceleration | Monitoring of Driving Environment | Fallback Performance of Dynamic Driving Task | System Capability (Driving Modes) |
|---|---|---|---|---|---|---|
| Human driver monitors the driving environment | | | | | | |
| 0 | **No Automation** | Full-time performance by the **human driver** of all aspects of the **dynamic driving task**, even when enhanced by warning or intervention systems | Human driver | Human driver | Human driver | n/a |
| 1 | **Driver Assistance** | **Driving mode**-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the **human driver** perform all remaining aspects of the dynamic driving task | Human driver and system | Human driver | Human driver | Some driving modes |
| 2 | **Partial Automation** | **Driving mode**-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the **human driver** perform all remaining aspects of the **dynamic driving task** | System | Human driver | Human driver | Some driving modes |
| Automated driving system ("system") monitors the driving environment | | | | | | |
| 3 | **Conditional Automation** | **Driving mode**-specific performance by an **automated driving system** of all aspects of the dynamic driving task with the expectation that the **human driver** will respond appropriately to a **request to intervene** | System | System | Human driver | Some driving modes |
| 4 | **High Automation** | **Driving mode**-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a **human driver** does not respond appropriately to a request to **intervene** | System | System | System | Some driving modes |
| 5 | **Full Automation** | Full-time performance by an **automated driving system** of all aspects of the **dynamic driving task** under all roadway and environmental conditions that can be managed by a **human driver** | System | System | System | All driving modes |

Source: SAE International

The automobile industry is expected to reach Level 5 autonomy by around 2020. To this end, the cost of expensive components must first be reduced. High-speed computers for processing autonomous driving are priced at minimum over USD 10,000. Key sensors, such as Light Detection and Ranging (LiDAR) are also expensive, coming in at somewhere from thousands to tens of thousands of dollars. There are additional obstacles as well. Outside of advanced countries, it is difficult to set up basic infrastructure such as precision 3D mapping and 5G wireless communications among cars and with road infrastructure. In addition, lanes should be designated for exclusive use of AVs during the transition period. Regional road conditions and driver characteristics should also be considered. Companies have been pursuing various efforts to overcome these obstacles. Relatively affordable radar and camera sensors are being used to reduce AV costs. Companies are developing autonomous driving technologies that mimic human driving using deep learning to allow autonomous driving without 3D mapping or 5G wireless communications.

Self-driving cars will bring about several positive effects. First of all, automobile accidents will be reduced. Nearly 1.3 million people die annually in car crashes around the globe, 95% of which are caused by human error. Tesla has even pointed that driving by humans could be considered reckless behavior in the

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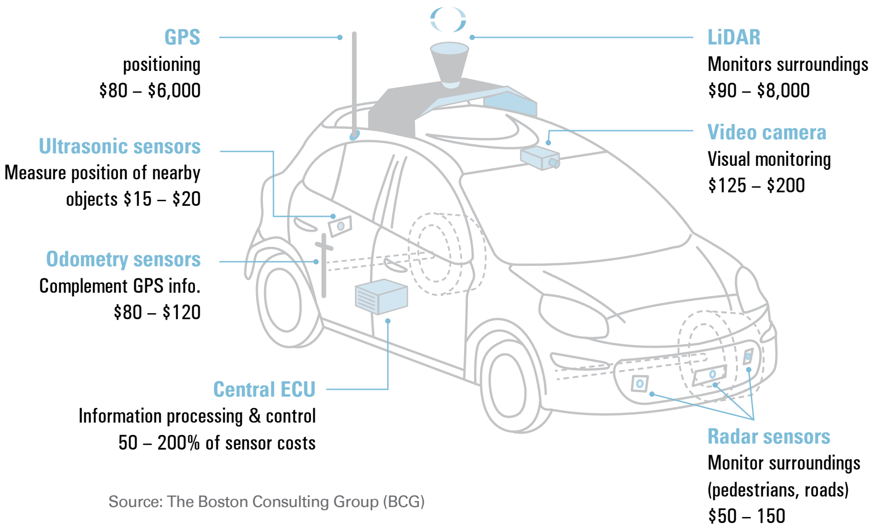
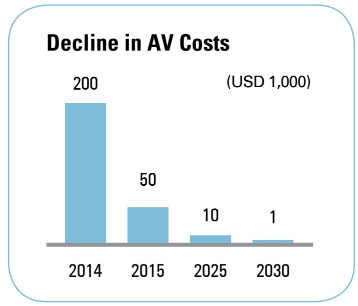
The US National Highway Traffic Safety Administration (NHTSA) has defined five different levels of autonomous driving. SAE International identifies six levels of driving automation from 0 (no automation) to 5 (full automation).

**Figure 5. Autonomous Vehicle Equipment**







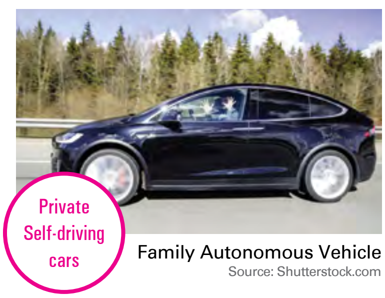

Source: The Boston Consulting Group (BCG)

near future. For this reason, companies including Waymo and Ford are even removing the steering wheel, brake, and accelerator pedals to ensure fully autonomous driving without human intervention. Self-driving cars are energy-effective and reduce collisions. They will also benefit those who are unable to drive a car, including young people, people with disabilities, and the elderly.

## Imagining future mobility

Despite the 130-year history of cars, there is much room for improvement, particularly in terms of engine efficiency and utility. In response to climate change, highly-efficient EVs are becoming increasingly widespread and resources are being used more effectively via car sharing. The combination of autonomous driving technology and car sharing will in turn bring about profound changes. In 2015, the International Transport Forum (ITF) at the OECD selected Lisbon, Portugal as a case study for a simulation on the effects of the sharing economy. In a rather aggressive scenario in which all motorized trips were carried out by high-capacity autonomous public transportation, 90% of vehicles could be removed from the streets while delivering nearly the same level of mobility as before. Although this scenario is based on the premise that all residents use car sharing and are not reluctant to share a ride

**Figure 6. Types of Autonomous Vehicles**




Family Autonomous Vehicle
Source: Shutterstock.com


Shared Autonomous Vehicle
Source: nuTonomy.com

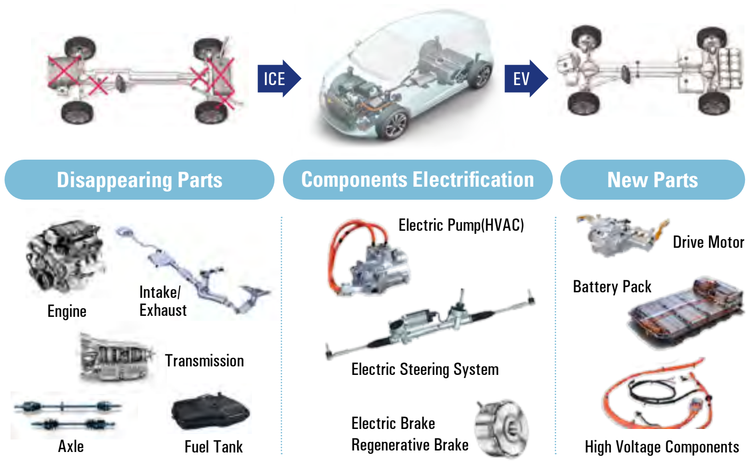

Pooled Shared AV
Source: Shutterstock.com

with strangers, the effect of even partial sharing mobility will reduce the need for parking spaces, which account for about 30% of large cities, and road networks, thus allowing a more pleasant and convenient environment for people.[6]

The Boston Consulting Group (BCG) has projected that autonomous driving technology will result in the replacement of conventional taxis with robo-taxis, and that the cost of a ride in such a robo-taxi would be lower than that in a conventional cab.[7] Traveling short distances as part of daily routines for commuting to work or school, or for shopping would be accomplished by robo-taxi rather than in privately-owned vehicles. As most trips are currently taken by one or two people and autonomous cars require no driver's seat, cars in the future can be made smaller. This explains why Google's pod and NuTonomy's robo-taxi in Singapore are compact cars. Ten-seat mini-buses would be practical for short-distance commutes by those who share destinations or travel routes. If IT technology advances enough to offer commuters door-to-door service without causing inconvenience to other commuters, traditional public transportation can be replaced by autonomous public transportation.

Attitudes toward car ownership are gradually shifting as well. Under rapid urbanization, road networks are becoming increasingly complicated. With the development of public transportation and the more widespread use of cars, car ownership is less considered a status symbol. At this juncture, the sharing economy is gaining momentum, giving rise to Uber, a ride-sharing platform with a nearly USD 66 billion valuation.

**Figure 7. EV Platform**




Source: POSCO Research Institute

Uber plans to provide cheaper rides to more customers by taking advantage of self-driving cars. If autonomous driving technology reduces labor costs and door-to-door autonomous public transportation is available for the cost of conventional public transportation, car ownership is certain to become less meaningful.

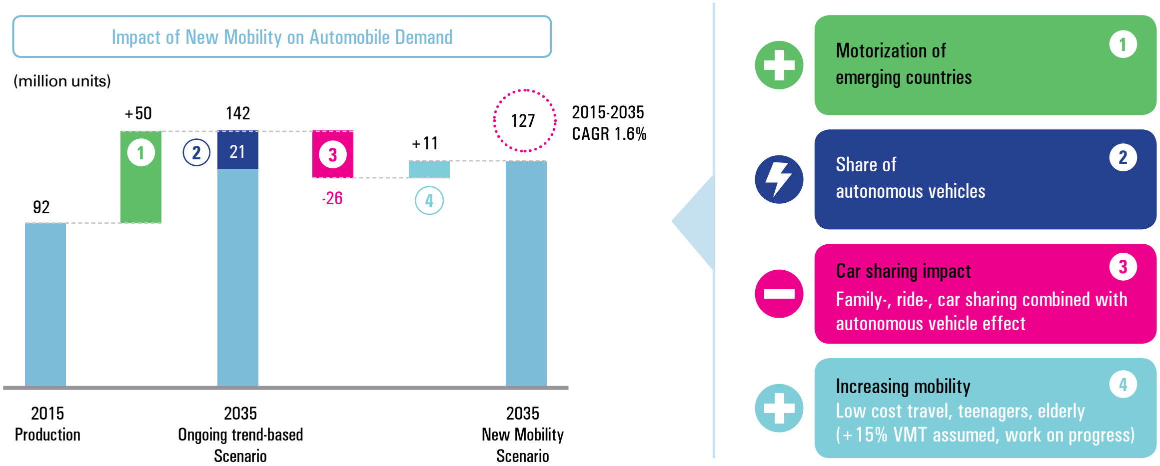
## Changes in needs, changes in materials

The sophistication of EVs and autonomous driving technology and the spread of the sharing economy will transform automobile demand, and subsequently the related materials. EVs do not require as many auto parts as do conventional ICEs. In particular, metal parts such as powertrain components—the engine, vehicle intake and exhaust system, and transmission—will be replaced by batteries, motors, and electronic parts. As cars are made lighter to improve driving range, alternative materials such as aluminum and CFRP are being used in some luxury lineups.

6 "Urban Mobility System Upgrade", OECD-ITF, April, 2015

7 "Revolution in the Driver's Car Seat", Boston Consulting Group, April 3, 2015

**Figure 8. Automobile Market Forecast**




Source: Modified by POSCO Research Institute (based on IHS Markit data)

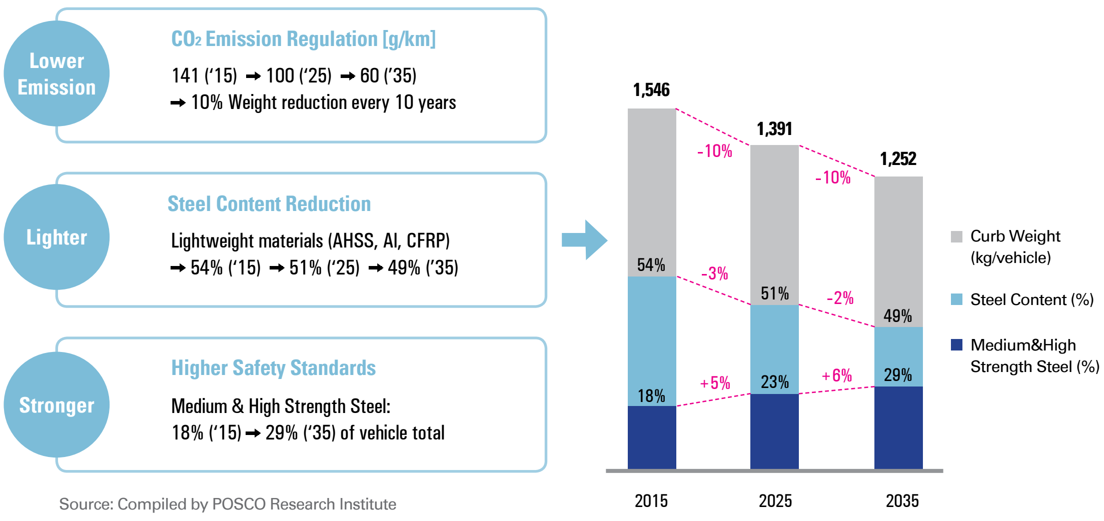
Self-driving cars will significantly influence automobile demand. While some controversy exists, many research outcomes suggest that automobile demand will decline with the rise of self-driving cars. If this becomes a reality, the steel industry will have to withstand a double impact of falling automobile demand and the threat of alternative materials.

Global sales of passenger cars will increase from 89 million units in 2016 to over 100 million units by 2023. This expansion is mainly the result of growth in emerging markets, including China and India. A number of institutions forecast that if this trend continues, global passenger car sales will increase to 130 million units by 2035. However, such forecasts are bound to change with the significant development of self-driving technology and the visible effects of sharing mobility. According to results from car sharing enterprises such as ZipCar and Uber, as well as from the University of Michigan Transportation Research Institute (UMTRI) and Barclays, each shared vehicle is expected to replace between nine and twenty new cars.[8] Assuming that shared vehicles run more than traditional vehicles and have a shorter replacement period; however, POSCO Research Institute projects that the shorter replacement period will reduce this only by two to three new car sales. If robo-taxi and mini-bus fares fall to the level of conventional public transportation, groups more vulnerable to transportation exclusion, such as the young and people with disabilities, will be highly likely to buy cars and use robo-taxis, leading to an increase in mobility demand. Therefore, the projected impact still remains to be seen.

Higher fuel economy standards are being implemented in the USA and Europe to combat climate change. A timeline has been created for reducing $CO_2$ emissions from the current 140g/km to about 100g/km within a decade and to 60g/km within two. The USA has prepared well for fuel economy standards, mainly by the U.S. Environmental Protection Agency (EPA) under the Obama administration, setting the Corporate Average Fuel Economy (CAFE) standards to

8 "Disruptive Mobility", Barclays Capital, July 20, 2015

**Figure 9. Material Composition of a Car and Steel Content Per Vehicle**




Source: Compiled by POSCO Research Institute

improve from the current 34.1 mpg to 54.5 mpg (miles-per-gallon) by 2025. Despite the unpredictability surrounding potential attempts by the Trump administration to ease this restriction, it will be difficult to profoundly change this limit. To comply with these fuel economy standards, ICEs must be improved, electrified, and lightened. According to the technical assessment report (TAR) by the EPA, cars will have to become lighter by about 10% every decade in order to comply with the CAFE standards. However, car body strength and price should not be compromised in order to satisfy higher safty standards. For these reasons, steel materials, which account for nearly half of auto parts, cannot be significantly reduced. The steel industry is also actively developing lighter and stronger steel materials such as advanced high-strength steel (AHSS) to replace traditional general steel. The industry will be able to maintain competitiveness in the future.

Some believe that plastic cars will come to occupy the roads with the advent of EVs and self-driving cars. However, the era of plastic cars still seems to remain in the distant future.[9] The rapidly increasing energy density of EV batteries (EVBs) will offset the weight of car bodies. EVBs pose a risk of fire, so they still require strong materials such as steel. Steel materials are also price competitive. Therefore, steel remains attractive for EVs. The same is true for self-driving cars. Although IHS Markit has made a rather aggressive forecast that self-driving car sales will reach 21 million units per annum by 2035 (about 20% of total sales), it is estimated that only 8% of cars on the roads will be self-driving by that year. This suggests that self-driving cars will share the roads with human drivers, making it all the more necessary to build cars strong enough to withstand accidents. This means that steel will remain an important material for cars. The future of autonomous cars is so unpredictable that no institution has released a forecast with strong conviction. Close attention must continue to be focused on the rapidly changing environment surrounding electric vehicles and self-driving cars.

9 "Autonomous vehicle sales forecast to reach 21 mil. globally in 2035", IHS Markit, June 6, 2016

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# Will the Shipbuilding Industry Flourish Again?

## Shipbuilding industry is highly influenced by environmental issues and technological advances

The shipbuilding industry is greatly influenced by increases in seaborne trade, the lifecycle of ships, changes in regulations, and advancing technology. After the first-ever of its kind set sail in 1956, container ships emerged as a popular new type of vessel following the recessions of the 1970s. Undergoing a continuous process of development, they have become one of the most important kinds of vessels on today's oceans. Thanks to the development of container ships, a growing need for replacement of ships built during the 1970s boom, and new regulations such as double-hull requirements for oil tankers, the shipbuilding industry underwent an additional boom in the 2000s. Similarly, advancing technology and a rapidly shifting business environment will bring considerable changes to the shipbuilding industry in the future.

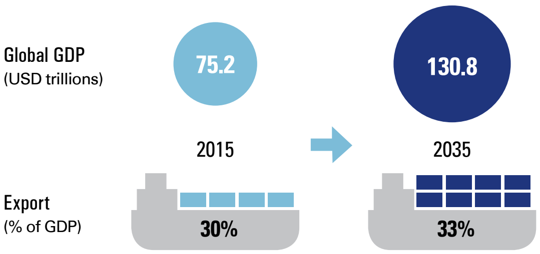
## Shipbuilding industry to be recovered in the long term, backed by global economic growth

There has been increasing concern that the world economy is facing a prolonged period of low growth following the 2008-09 financial crisis, influenced by slow growth in advanced countries and a Chinese economic slowdown. In 2016, Drewry, a British maritime research firm, expressed concern over a new "new normal" in which seaborne trade growth will continue to slow more so than expected[1] owing to reshoring in advanced countries and stringent protectionist measures. However, globalization is certain to gradually expand over the long term. In consequence, the export-to-GDP ratio is expected to rise moderately from 30% in 2015 to 33% by 2035.

The shipbuilding industry boomed in the 2000s, but the boom quickly turned to bust after the 2008-09 financial crisis, followed by massive counter-cyclical ordering. From 2008 to 2015, the shipbuilding industry was in oversupply, with an average annual new order volume of 77 million

1 Rahul Kapoor, "Diminishing returns?", TOC Asia Container Supply Chain Conference, April 20, 2016.

**Figure 1. Growing Global Trade**




Source: IHS Market, Roland Berger Trend Compendium, WTO

GT. This oversupply will linger until 2025, and the average annual volume of new orders will remain around 54 million GT over the next ten years. However, the shipbuilding market will then turn to an upswing with increasing growing global trade and rising demand for ship replacement. Shipbuilding orders will rise to the level of 95 million GT.

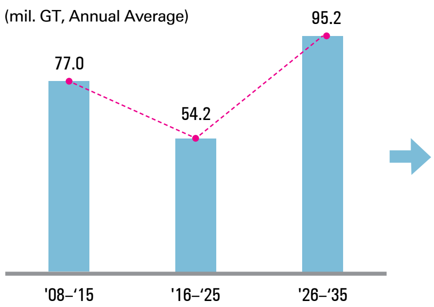
Moreover, demand for new and renewable energy will rise along with environmental issues, and demand for coal and oil will slow. Environmental concerns have positive impacts on the shipbuilding industry, such as the rise of $CO_2$ carriers and increasing demand for liquefied natural gas (LNG) carriers, but demand for conventional bulk carriers, such as coal and oil carriers, will potentially slow. Under such circumstances, demand for gas tankers and container ships will grow considerably.

## Rising demand for eco-friendly ships

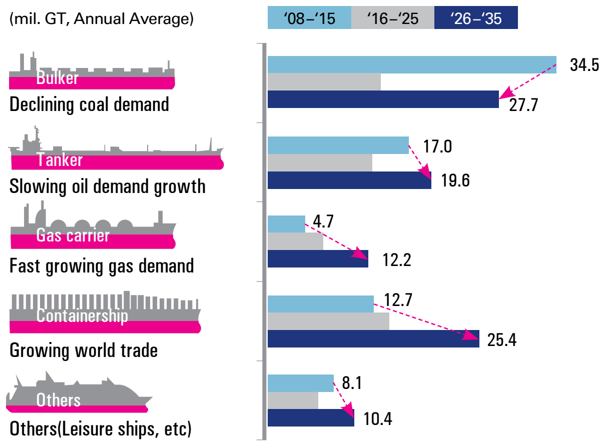
In 2016, the International Maritime Organization (IMO) decided to introduce more stringent SOx emission regulations. Under a new global cap, ships will be required to use fuel oil with a sulfur content of no more than 0.5% starting in 2020. Moreover, the IMO Tier III NOx emission limits took effect in 2016. Under these Tier III requirements, NOx emission levels for engines installed on vessels built (keel laying) on or after January 1, 2016 must be reduced to 3.4g/kWh if they are to operate in a designated Emission Control Area (ECA), including the North American Sea Area and United States Caribbean Sea Area. There is a further regulation that requires improved operational energy efficiency in order to reduce $CO_2$ emissions. If the Energy Efficiency Design Index (EEDI) is further strengthened, a 20-30% reduction of $CO_2$ emissions will be mandated by 2020-2030.

A wide range of technologies are being adopted to meet emissions regulations. More expensive low-sulfur fuel oil can be used, or engine scrubbers can be installed to reduce SOx emissions. Selective catalyst reduction (SCR) or exhaust gas recirculation (EGR) technologies are options that reduce the level of NOx. To lower both SOx and NOx emissions, ships can use more eco-friendly fuels such as LNG, methanol, and biodiesel. In the distant future, ships will utilize electric batteries or hydrogen fuel cells just as electric cars do today. Moving away from a heavy fuel oil (HFO) environment, ships will enjoy more technological options in a new era, such as installing ancillary devices for fuels or replacing conventional fuels with new alternatives.

**Figure 2. Global Shipbuilding Demand**




Source: POSCO Research Institute based on Clarkson data




Source: Clarkson, POSCO Research Institute

Image credit: Wikimedia commons

Which options will be preferred depends on fuel costs, installation and repair costs for facilities or equipment, areas of operation, and bunkering infrastructure for fuels. Although LNG-fueled ships are currently regarded as a positive solution, a number of considerations should be kept in mind. LNG-fueled ships require larger fuel tanks than do HFO-fueled ships. Furthermore, additional bunkering is required for long-distance round-trips. Ship owners prefer round-trips to be fully fueled since LNG prices vary by region. Fuel tanks large enough for round-trips would require considerable investment due to their expense and the reduction in shipping capacity resulting from their space demands. To address these concerns, ships require a totally new type of design. In the designs of the PERFECt (Piston Engine Room Free Efficient Containership) project,[2] an LNG-fueled ship runs on an electric motor instead of a main engine. Hyundai Heavy Industries and GE Marine have developed a design for a gas turbine-powered LNG carrier equipped with GE's COGES (Combined Gas turbine, Electric and Steam) system,[3] which is much lighter and more efficient than conventional engines. These examples indicate how a range of technologies will bring about differentiated and innovative types of ships.

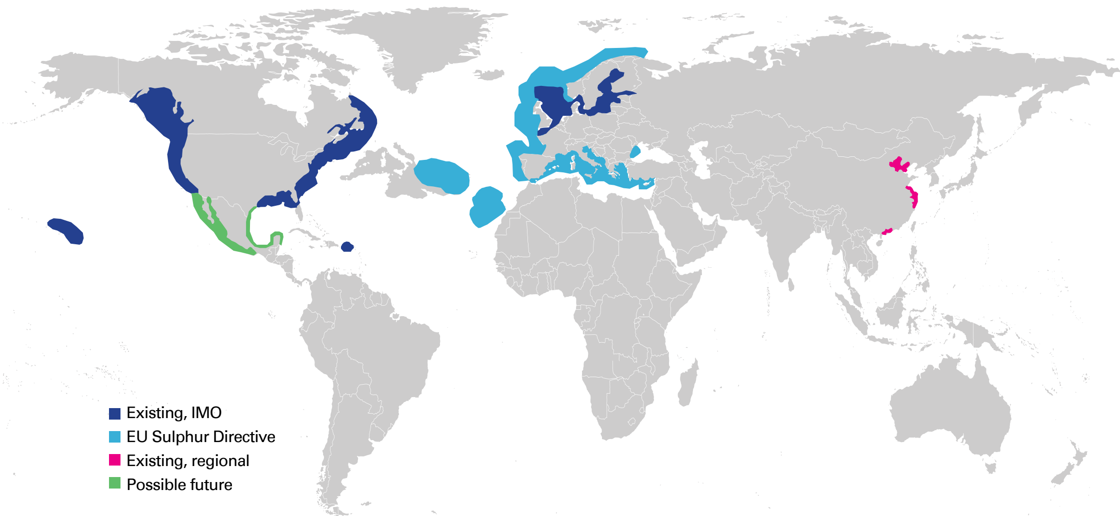
The more technologies that are available for adoption, the higher the related uncertainty becomes. In order to reduce this uncertainty, all possible technologies should be developed and examined. Green Ship of the Future, a Danish public-private partnership, is evaluating various technological alternatives for addressing environmental concerns and continuously conducts practical verification: retrofitting with an SCR or scrubber system and the economic feasibility of retrofit conversion to LNG propulsion.[4] New technologies can be more short-lived than the ships themselves with their life-cycle of more than 20 years. Therefore, ships should be equipped with more creative designs to allow easier conversion or application of various technologies. Consortiums or groups pursuing technological innovation will play a more

2 Gerd Würsig, "PERFECt–LNG feasibility study for a Piston Engine Room Free Efficient Containership", DNV-GL, October 27, 2015

3 Marine Insight, July 16, 2015

4 http://greenship.org/major-studies/

**Figure 3. Sulfur Emission Control Area**




Source: The International Council on Clean Transportation (ICCT)

important role in developing leading prospective technologies and debating technology standards. Just like what currently takes place in the ICT industry, traditional industries will be required to more actively discuss pertinent standards.

In addition, global warming will create an additional impact. The potential for using the North Pole route (NPR) is rising. The IMO Polar Code, which is a mandatory code for ships operating in polar waters, took effect on January 1, 2017. The NPR reduces the travel distance from Busan to Rotterdam by 32% (22,000 km → 15,000 km) compared to the conventional Suez Canal route, and cuts the travel time by up to 10 days (40 days → 30 days).[5] As a result, more ships will travel via the North Pole route, but the total capacity of the global fleet will fall.

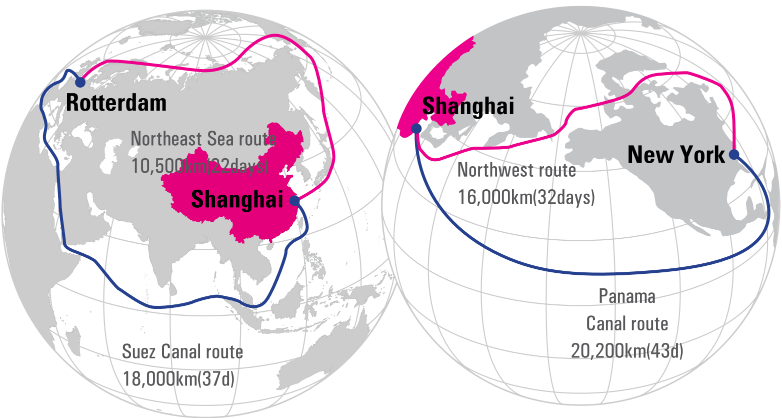
## Changes brought about by new technologies

Competition is consistently intensifying in the shipping market. Shipping companies will continue to seek economies of scale as a response to this increasing competition, and ships will subsequently become larger. There are limitations on the improvement of efficiency simply by scaling up the size of ships, so efficiency will have to be improved through the integration or optimization of value chains. Moreover, the world's leading ports, including Rotterdam in the Netherlands, Copenhagen in Denmark, and Hamburg in Germany, are attempting optimizations that would allow the entrance of ultra-large container ships and improve the efficiency of loading and discharging.

Such efforts do not end here. The Port of Rotterdam Authority has joined forces with Delft University of Technology to launch a Port Innovation Lab intended to discover new technologies and value for the maritime industry. Key enablers of the Fourth Industrial Revolution are being adopted in the shipbuilding and shipping industries. Preventive maintenance is already available, such as collecting operational data via sensors embedded in ships and monitoring the data via satellite communications at onshore control centers. This

5
Press release of the Ministry of Oceans and Fisheries, "MOF implements Polar Code this year," January 2, 2017

**Figure 4. North Pole Route (NPR)**




Source: visualcapitalist.com

enables ship owners to improve ships' operation rates and conduct real-time asset and shipment management.

Just like self-driving cars, remotely controlled or fully autonomous ships will become available in the future. Such autonomous ships can improve operational efficiency by ensuring optimal operation routes based on real-time weather and maritime conditions. Above all, the issue of crew shortages will be offset, leading to a decline in the labor costs that currently account for the lion's share of total operation costs. Crews today must face difficulties living on board for long periods, but working conditions will be significantly improved in the future when fleets are managed from onshore control centers. These changes are not limited to the crews on board. The designs of ships will fully evolve. With no crew to accommodate, the deckhouse and safety design can be eliminated, allowing future ships to be designed with a larger cargo capacity.

In 2016, Rolls-Royce released a plan to develop an autonomous unmanned ocean-going ship by 2035.[6] DNV-GL is developing an autonomous and fully battery-powered vessel, named ReVolt.[7] Shipbuilding companies in former shipbuilding powerhouses such as certain European countries and the USA can increase their prominence by improving their competitiveness using advanced technology. They will be able to raise value added through the development of key technologies for remotely controlled and unmanned ships, autonomous ships, and remote management. Korea is working to escalate the competitiveness of its shipbuilding and maritime industries through ICT convergence.[8] As existing shipbuilding giants prepare for a new era of change, competition will grow even more intense in the future.

Emerging technology will not only change ships. Shipyards will transform themselves into smart yards in order to improve productivity and safety. It will become more difficult to increase productivity through new technologies such as

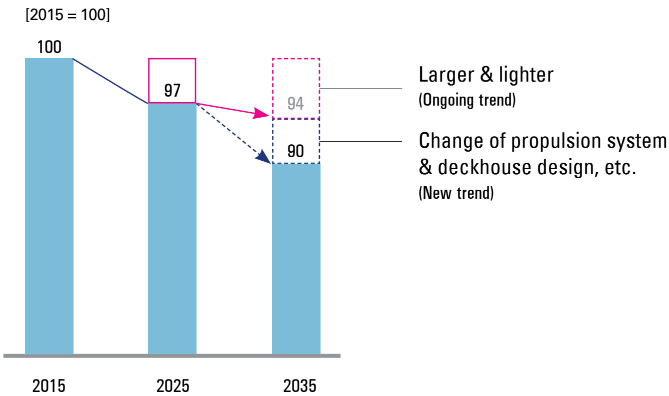
6 Rolls-Royce, "Autonomous ships The next step", 2016 (http://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/ship-intel/rr-ship-intel-aawa-8pg.pdf)

7 https://www.dnvgl.com/technology-innovation/revolt/

8 Press release of the Ministry of Science, ICT and Future Planning, "ICT Convergence to Increase Competitiveness and Take a Leap Second for the Shipbuilding and Maritime Industries," December 6, 2016

a mega-block construction method. However, virtual reality and augmented reality (VR/AR) will improve efficiency at work, and virtual 3D engineering technology will reduce design errors. Workers will be able to operate in a safer work environment using smart helmets. Difficult manual jobs that require high levels of concentration, such as welding, painting, and grinding, will be gradually taken over by robots, leading to an improvement in productivity and quality at work.

**Figure 5. Steel Intensity of Ship's Tonnage**




Source: POSCO Research Institute
Note: Steel intensity = Steel demand for shipbuilding/gross tonnage (GT)

## Qualitative changes in steel products and falling steel intensity

With the development of ultra-large container ships, LNG-fueled ships, electric ships, $CO_2$ carriers, polar ships, and environmentally–friendly equipment, the shipbuilding industry needs immediate qualitative changes. High-strength steel is a must for ultra-large and lighter ships, and high-strength low-alloy steel, such as POSCO's high-manganese steel, is required for safe and affordable LNG and $CO_2$ storage tanks. High-efficiency electrical steel sheets for electric propulsion motors will be required rather than forged and cast steel for massive main engines. Demand for low-temperature toughness steel will rise for polar operations. There will also be a demand for steel materials for various environmentally-friendly equipment and devices.

Such qualitative changes will influence steel intensity. As vessels become larger and lighter, the steel intensity of ship's tonnage will fall continuously, and then decline even further following the rise of electric propulsion, unmanned, and autonomous ships. Larger and lighter vessels will reduce steel intensity by 6% by 2035. If large diesel engines are replaced by electric motors after 2025, the weight of engines will be significantly reduced. No deckhouse is necessary for unmanned ships. With these, steel intensity will decline further by around 4%.

With the advent of the world's largest ship, the Mearsk Triple-E[9] container ship, 20,000 TEU-class container ships have been booming. Since then, related shipbuilders and steel companies have been leading the ultra-large container ship market. As more technologies are available to choose from, investment decisions are inevitably delayed. However, once the validity of a certain technology is established, it will soon come to lead the market. Shipbuilders and steel companies able to support various types of ships and technologies will enjoy considerable benefits in the future. Therefore, the steel industry should devise various solutions in partnership with the shipbuilding, shipping, and marine equipment industries.

9
http://www.maersk.com/en/hardware/triple-e

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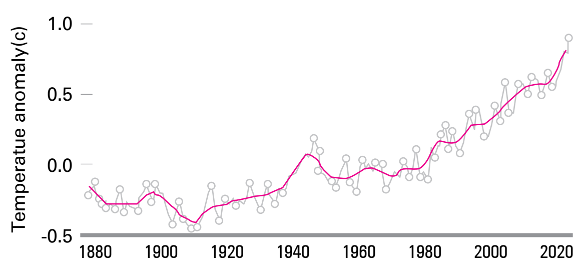
# Eyes on Energy Transition

## Global climate action

The year 2016 was the hottest ever recorded in the history of meteorological measurement, but 2017 is already poised to break its record. It seems that it will be difficult to combat climate change without a concerted global response. At the COP21, held in Paris in 2015, 196 Parties agreed to work together to hold the increase in global average temperature to below two degrees Celsius above pre-industrial levels or even to limit the rise to 1.5 degrees Celsius. Well aware of the potential severity of the impact of climate change, many countries across the globe are already reducing their coal use and sparing no efforts in providing policy support to new and renewable energy and to electric vehicles (EVs). These multi-year efforts have already started to pay off: global $CO_2$ emissions have fallen since 2014. However, it is still far short of what will be required in order to reach the two-degree target.

The International Energy Agency (IEA) forecasts an average global temperate increase of around 2.7 degrees Celsius by 2100, even with the implementation of existing global energy policies. Despite these concerns, global population growth and economic development are expected to drive energy consumption up. Even still, about 1.2 billion people will have no access to electricity in 2040. Today, humanity is caught in the dilemma of attempting to pursue both economic development and environmental protection.[1]

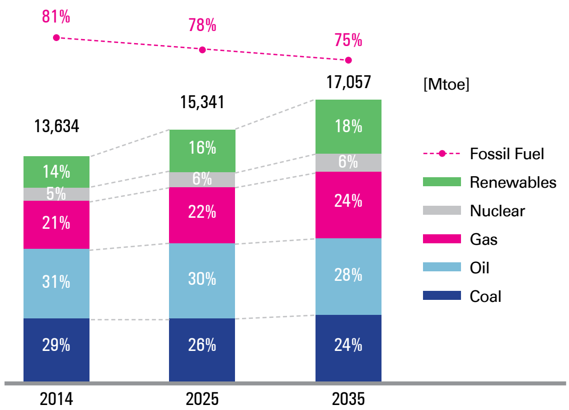
**Figure 1. Global Land-Ocean Temperature Index**




Source: NASA's Goddard Institute for Space Studies (GISS). Credit: NASA/GISS

1 World Energy Outlook 2016, IEA

**Figure 2. Primary Energy Demand by Fuel Type**




Source: World Energy Outlook 2016, IEA

## Peak oil demand still under debate

In October 2016, Fitch Ratings released a rather shocking report warning that EVs could send big oil companies into an "investor death spiral." Soon thereafter global oil giants including ExxonMobil, Royal Dutch Shell, and Total also published sobering projections that oil demand would peak by around 2020. Coal, the classic fossil fuel energy source, provides a related example of what could happen. The bankruptcy of the largest coal mining enterprise, Peabody Energy, has convinced many investors that the coal industry is in a death spiral and is expected to reach peak demand by around 2020.[2] In contrast, the natural gas market seems to be growing thanks to the development of shale gas and its replacement of coal. Opinions are mixed regarding peak oil demand. Some institutions are expressing a strong sense of urgency, as described earlier, while other long-term energy forecasters including BP and the International Energy Agency (IEA) expect that fossil fuels will still dominate through 2035-2040. In 2016, the IEA, in its New Policies Scenario (the central scenario), predicted that energy consumption will rise by 30% by 2040 compared to 2014, while the share of fossil fuels within primary energy consumption will fall from 81% to 74% over this span. Despite this decline, fossil fuels will expand in terms of quantity of consumption, and will continue to play a dominant role in the energy sector. However, these forecasts could be quickly turned on their head if a sudden transition were to occur, impacted by such variables as the rapid distribution of renewable energy, widespread use of EVs, and a fall in energy demand driven by increased efficiency.

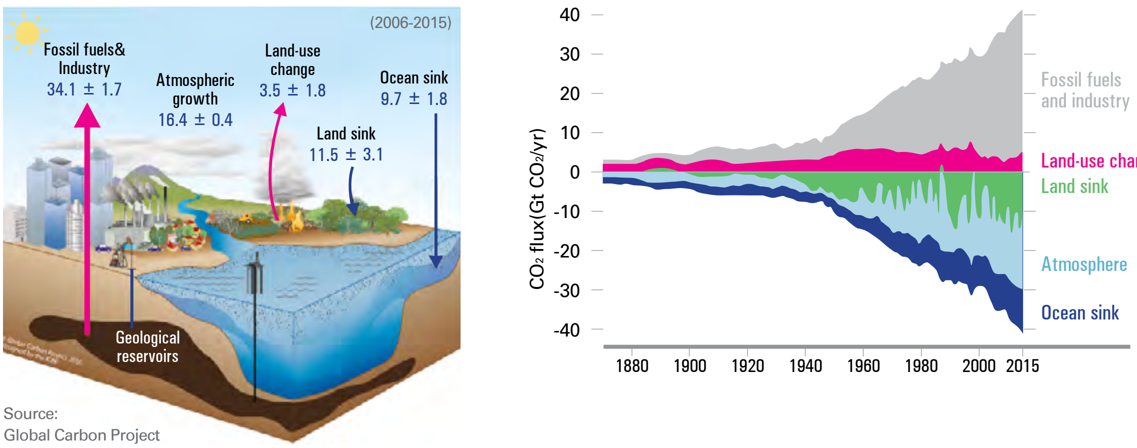
## Not "alternative," but "mainstream" energy

The atmospheric concentration of carbon dioxide should be maintained at 450 ppm to meet the two-degree Celsius target. This would allow the permissible carbon budget[3] to increase to

**2**
Oil Groups 'Threatened' by Electric Cars, Financial Times, October 19, 2016

**3**
The sum of all exchanges (inflows and outflows) of carbon compounds between the earth's carbon reservoirs (such as land mass and the atmosphere) in the carbon cycle.
(Source: Business Dictionary)

**Figure 3. Atmospheric $CO_2$ Balance and Historic Concentration Level**



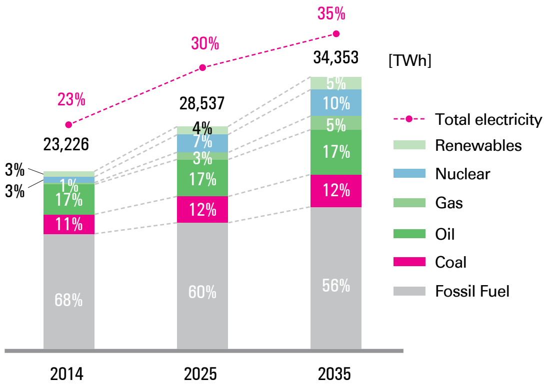

Source:
Global Carbon Project

about 800 gigatonnes of $CO_2$ ($GtCO_2$). According to the trend in the global carbon dioxide budget over the last decade, $CO_2$ fluxes from fossil fuel and industry emissions stand at 34.1 $GtCO_2$/yr, and those from land-use change emissions at 3.5 $GtCO_2$/yr, while $CO_2$ absorption from land sink is 11.5 $GtCO_2$/yr and that from ocean sink is 9.7 $GtCO_2$/yr. This means a 16.4 $GtCO_2$ annual increase in $CO_2$ emissions. Although it is assumed that this trend will continue, the two-degree target for 2100 cannot be achieved within 50 years. The earth will evade a disaster only if it reaches "carbon-neutral" (or 100% carbon reduction) by 2060.

As a response to global warming, renewable energy is increasingly being preferred. Wind power generated 140% of Denmark's electricity demand in 2015, and Germany broke a daily record for renewable energy by generating 85% of its power from renewable sources in April 2017. In the same month, the United Kingdom, the birthplace of the Industrial Revolution, generated a full day's electricity without coal. Global renewable energy capacity, mainly wind and solar power, increased from 20 GW in 2004 to 88 GW in 2010 and reached as far as 160 GW in 2016. Investment in renewable energy capacity, excluding large hydropower, has stood at twice that of fossil fuel generation over the last five years. The IEA has predicted that the share of renewables within global power generation is expected to rise from 23% in 2014 to 37% by 2040. It is fair to say that renewable energy is no longer "alternative" energy but in fact has entered the energy "mainstream." This trend can be attributed to the rapid decline in renewable energy technology costs. The levelized cost of energy (LCOE)[4] of solar photovoltaic (PV) exceeded USD 100/kWh in 1980, but plunged to less than 3 cents/kWh in 2016 (Fotowatio Renewable Ventures, Mexico). In addition, the LCOE of onshore wind also reached three US cents per kilowatt hour in 2016 (Enel Green Power, Morocco) and that of offshore wind recorded 5.3 cents/kWh in 2015 (Vattenfall,

4
The levelized cost of energy (LCOE) refers to a measure for calculating the lifetime total cost of an energy source. It includes initial capital and the discount rate, as well as the costs of continuous operation, fuel, maintenance and scrap (Source: Wikipedia)

**Figure 4. Electricity Generation by Fuel Type**



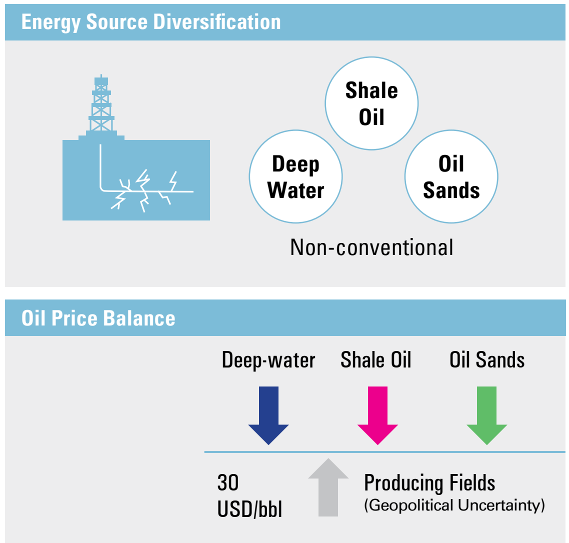

Source: World Energy Outlook 2016, IEA

Denmark). This means that renewable energy has achieved grid parity, the point at which the cost of alternative energy becomes equal to or less than electricity from conventional energy without subsidies.[5]

## Oil market reaching a new balance

Influenced by the shale oil revolution, oil prices have spiraled down due to energy hegemony competition, unstable political conditions in the Middle East, and economic slowdowns, but they seemed to pick up recently thanks to last year's OPEC agreement to cut oil production. However, the boom soon returned to bust as U.S. shale-oil enterprises rapidly increased production following the rise of oil to above USD 50/barrel. Currently, OPEC members, including Iran, are poised to extend production cuts in order to support a market recovery. The IEA has predicted that global oil supply could lag demand after 2020 due to stalled investment in oil production over the last few years. On the other hand, some view this era of low oil prices as the new balance in the midst of a slow global economic recovery and slack demand stemming from increased energy efficiency, enhanced fuel economy, and the widespread use of EVs. In the past, oil prices were determined by shifting political circumstances in oil-producing countries, but today shale oil production buffers prices as U.S. companies are able to rapidly increase production in response to any oil price increase. Although many uncertainties have disappeared, the oil market can still swing at any time given its com-

**Figure 5. Non-conventional Energy Resources and Oil Price Balance**

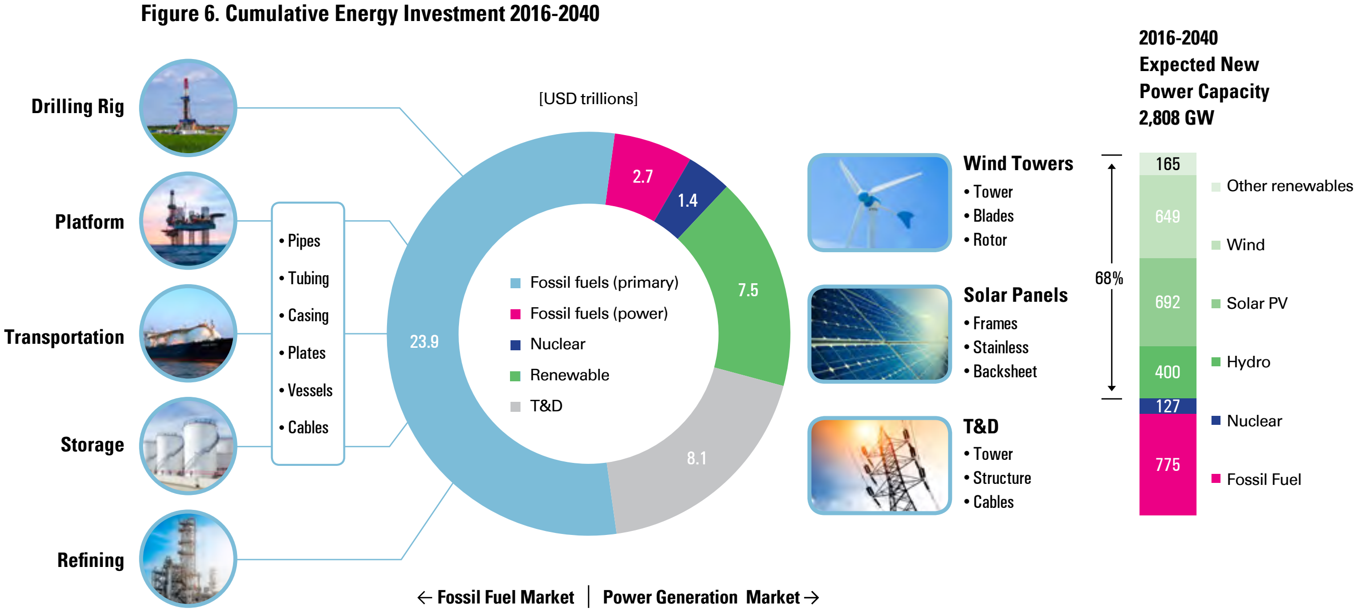



Source: Rystad Energy Cost Curve, April 2016

**Steel companies must target new markets by developing innovative steel products for the micro-grids and energy storage systems which will grow alongside renewable energy.**

5 "Bloomberg New Energy Finance Summit", M. Liebreich, BNEF, April 25, 2017

**Figure 6. Cumulative Energy Investment 2016-2040**




Source: World Energy Outlook 2016

plex nature. Furthermore, oil prices are a key factor for determining the scale of investment in fossil fuels and have a profound impact on the automotive market, such as the distribution of renewable energy and the popularity of SUVs. Therefore, a careful watch must be kept on fluctuations in oil prices.

## Energy investment and steel products

As seen in Figure 6, energy investment is mainly made in two sectors: the fossil fuel sector, including exploration and production (E&P), transportation, storage, refining, and petrochemical production; and the power sector that generates electricity based on coal, gas, nuclear, and renewable sources.

According to the IEA, cumulative global energy investment is expected to reach USD 43.6 trillion during the 2016-2040 period, USD 23.9 trillion of which will be dedicated to the fossil fuel sector, and the remaining USD 19.7 trillion to the power sector. In detail, electricity transmission and distribution (T&D) takes up the lion's share (USD 8.1 trillion) of energy investment in the power sector, half of which is occurring in China due to its vast land area and continuous demand for development. As T&D includes renewable energy grids and energy storage systems, investment in this category is expected to make up an even more meaningful share in the future. Renewables investment in the power sector is projected to reach USD 7.5 trillion, twice the USD 2.7 trillion investment in fossil fuel.[6]

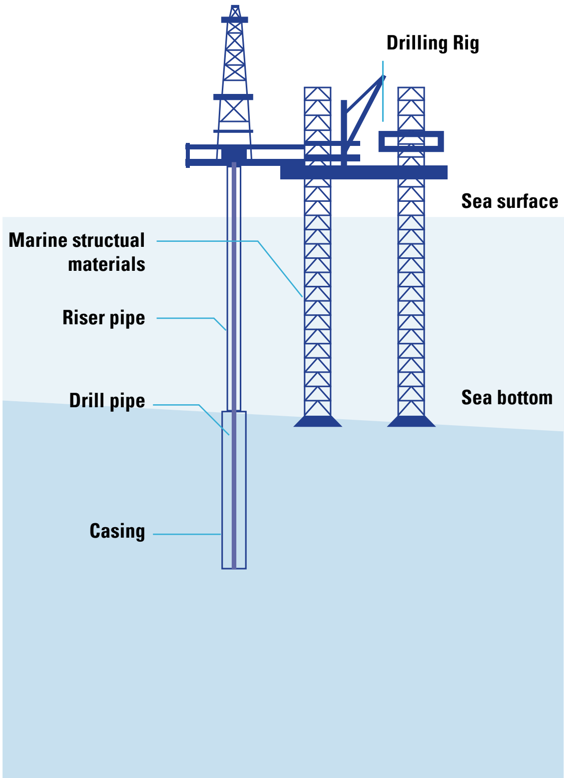
6 "World Energy Outlook 2016", IEA

**Table 1. Application of Steel Products for the Development and Production System of Sub-sea Wells for Oil and Gas**

| Process | Equipment/Plant | Steel product used |
|---|---|---|
| Development | Drilling rig | Drill pipe<br>Casing, Riser pipe<br>High tensile strength steel plates(Marine structures) |
| Extraction/ Production | Platform | Tubing, Casing, Linepipe(Flow lines, Gathering lines) |
| | | High tensile strength steel plates(Marine structures) |
| Transportation | Marine transportation<br>Oil tanker<br>Liquefied natural gas (LNG) carrier | Steel products for shipbuilding, Corrosion resistant materials for shipbuilding |
| | Pipeline | Linepipe<br>Plates for linepipe |
| Storage | Oil tank<br>Gas holder | High tensile strength steel plates |
| Refining Plant | Plant piping<br>Heating furnace piping | Special tubes(Cr-Mo Steel) |
| | Pressure vessel | High tensile strength steel plates<br>Clad steel plates |
| Power generation | Superheater piping | Special tubes(Cr-Mo Steel) |

Source: Steel Products for Energy Industries, JFE Technical Report, Mar. 2013

**Figure 7. Schematic Drawing of Jack-up Rig and Steel Products**




Source: Steel Products for Energy Industries, JFE Technical Report, Mar. 2013

In the fossil fuel sector, a wide range of steel products such as pipes, tubes, plates and cables are used for transportation, including for drilling rigs, offshore platforms, and LNG ships, as well as for storage and refining facilities. An offshore platform has a topside weight of over 20,000 tons and deep-sea platforms reach a depth greater than 2,000 meters. To meet the harsh conditions they must withstand, steel materials for offshore platforms have developed in terms of both quality and quantity. The renewable energy sector is also adopting various types of steel products. The tube tower, which accounts for 65% of the weight of a wind turbine, is made mainly of steel, while thin stainless steel sheets and frames are required for solar panels. This wide application of steel products offers additional business opportunities to steel companies. The T&D sector, including high-voltage transmission towers, is also traditionally steel intensive. Steel companies must target new markets by developing innovative steel products for the micro-grids and energy storage systems which will grow alongside renewable energy.

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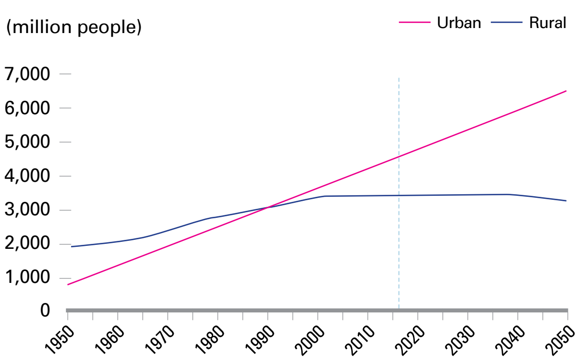
# Future Cities and Changes in Steel Materials

## Urbanization, the key driver for the construction industry

The megatrend of urbanization is a key driver in the development of the global construction industry. The global proportion of the urban population increased from a mere 29% in 1950 to surpass that of the rural population in 2007. By 2050, about 9.5 billion people, or 66% of the global population, is expected to reside in urban areas. This means that the number of urban dwellers will increase by an annual average of 100 million people. Urbanization will further accelerate in the future with rapid industrialization in developing countries and the shift to a knowledge economy in advanced countries.

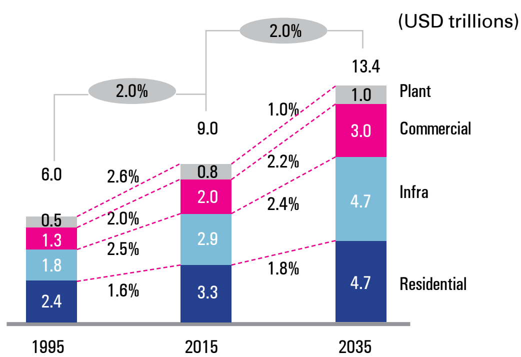
Urbanization aggravates existing urban concerns such as housing, transportation, water supply and sewage, and electricity provision, which in turn stimulates investment in construction. Global construction investment stood at roughly USD 9 trillion in 2015, but is expected to increase by a CAGR of 2% to USD 13.4 trillion by 2035. Notably, growth in global construc-

**Figure 1. Global Urban and Rural Population**



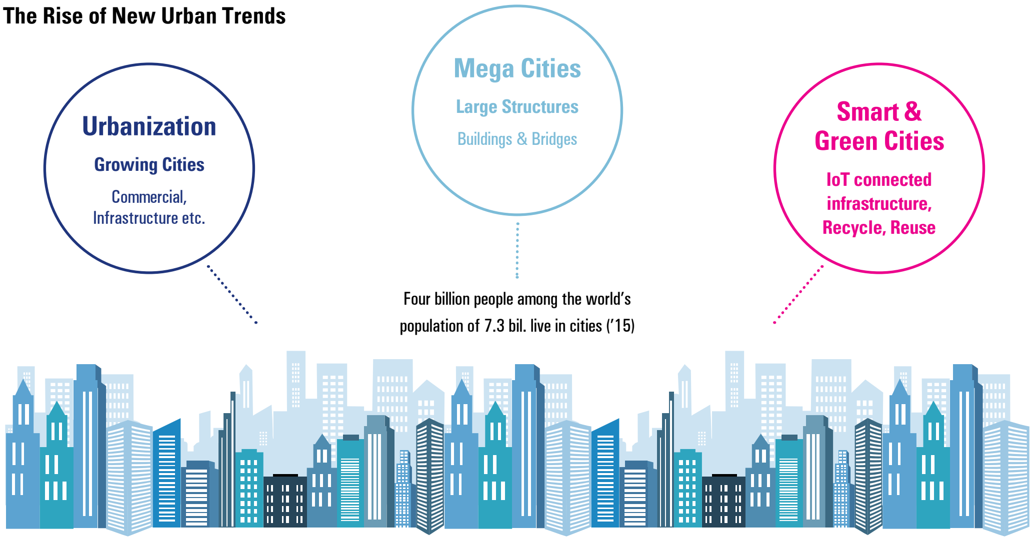

Source: World Urbanization Prospects, United Nations, 2014

**Figure 2. Global Construction Investment**




Source: POSCO Research Institute based on IHS Markit

**Figure 3. The Rise of New Urban Trends**




tion investment will vary by sector: investment in residential, commercial, and infrastructure construction will soar, while plant construction investment will lag historical performance, following a shift of focus to new and renewable energy in response to global warming and environmental pollution.

## Emerging urban trends—megacities, green cities, and smart cities

Within the overall shift toward urbanization, megacities, green cities, and smart cities are emerging as new trends. In the future, there will be an increasing number of megacities with 10 million or more inhabitants, smart cities drawing on the Fourth Industrial Revolution, and green cities that consume fewer resources and recycle more.

### ❶ Megacities—Rising higher and further

The number of megacities with populations of more than 10 million is expected to increase by 32.3% from 31 in 2016 to 41 by 2030. Likewise, the number of cities with more than 500,000 poeple will increase by 31% from 1,063 in 2016 to 1,393 by 2030, according to the World's Cities in 2016, United Nations.

As the competition paradigm shifts from competition among countries to competition among cities, many countries are actively crafting policies to develop their cities as globally competitive megacities. In April 2016, Saudi Arabia formulated its Long-term Strategy 2030 (Vision 2030) and released related five-year action plans. Under this Vision 2030, Saudi Arabia plans to have three of its cities recognized among the top-ranked 100 cities in the world.[1]

The rise of megacities through competition among cities is well reflected in the construction of landmark skyscrapers. The number of supertall buildings over 300 meters tall[2] doubled between 2012 and 2016. Currently, 100 supertall buildings are under construction around the world. This figure is expected to double to 200

1 http://www.vision2030.gov.sa/en

2 According to the Council on Tall Buildings and Urban Habitat, supertall buildings are defined as buildings of 300 meters or higher.

**Figure 4. The Sky Mile Tower in Tokyo**

Source: en.wikipedia.org

by 2020.

As of 2017, the world's tallest building is the Burj Khalifa in the UAE at 828 meters height and 163 stories. This structure was designed to be the centerpiece of a large-scale, mixed-used development that includes apartments, hotels, offices, department stores, and shopping centers.

In addition to land use efficiency, global warming is accelerating the demand for skyscraper construction. Experts warn that if sea levels rise by just one meter, many major low-lying coastal cities including Shanghai and Tokyo could be submerged, suggesting supertalls as a potential response. The Sky Mile Tower, which has been proposed for the Tokyo of the future, could reach as high as 1,700 meters, or twice the height of the Burj Khalifa. This mega-tall building scheduled to be constructed by 2045 is viewed as a response to rising sea levels. It could hold roughly 500,000 people, including 55,000 residential units, shopping malls, restaurants, hotels, gyms, and medical centers.

3 plug.hani.co.kr/futures

Japan has even gone as far as envisioning a self-contained high-rise city that could house over one million people—the X-Seed 4000. Currently there are technical obstacles to constructing such a mega-tall building reaching a whopping 4,000 meters and 800 stories. If construction technologies and advanced construction materials are developed, this structure could become a reality. This mountain-like building towering thousands of meters high is imagined as a space isolated from the ground. Future forecasts predict that cities in the air, secluded from the land, will loom large in a mega-tall building boom. Population increases, urban expansion, rising land prices, and resource shortages will last until the end of 21st century, eventually driving up the height of buildings.[3]

### ❷ Green cities—Go greener

Ozone depletion, climate change, and energy and resource exhaustion can undermine the sustainable development of humanity and degrade the quality of life of urban dwellers. With a growing sense of obligation to improve the environment, the paradigm is shifting to eco-friendly cities.

Construction materials will be recycled or used in smaller quantities, and buildings will be restored or rebuilt rather than being constructed from scratch. Leadership in Energy and Environmental Design (LEED), a rating system that is recognized as an international mark of excellence for green buildings by the U.S. Green Building Council, is now being applied to only some new buildings, but it will soon become more widespread and provide mandatory standards for all building designs.

A transition to green cities will provide a wealth of business opportunities to private enterprises. Companies will be able to diversify their businesses to the development of eco-friendly technologies and construction materials for reducing environmental impact, new and renewable energy development, and zero-energy houses, contributing to the development of greener and safer cities. Public investment in traditional construction efforts such as roads and bridges will be reduced, but will increase for green sectors such as railways, green energy, and green public construction.

The green city concept is reflected in solarCity in Linz, Austria. This is an eco-friendly and energy-efficient residential district designed for sustainable development under Linz City's Lokale Agenda 21. Linz City provides subsidies for solar installations for heating and power generation and rainwater harvesting systems. Already, one-third of heating within solarCity is provided using solar energy, and the rest comes from renewable energy generated by waste incineration.[4]

In addition to eco-friendly residential districts like solarCity, vertical urban farms are another interesting example of green city techniques. Vertical farming is the practice of producing food in vertically stacked layers. As nature has been devastated by the ever-expanding agricultural production required by increasing populations and food shortages, vertical farming is emerging as an alternative response. Using eco-friendly energy, vertical farming can achieve high productivity throughout the year without suffering damage from climate abnormalities or blights and harmful insects.

**Figure 5. An Example of Vertical Urban Farm**

Source: shutterstock.com

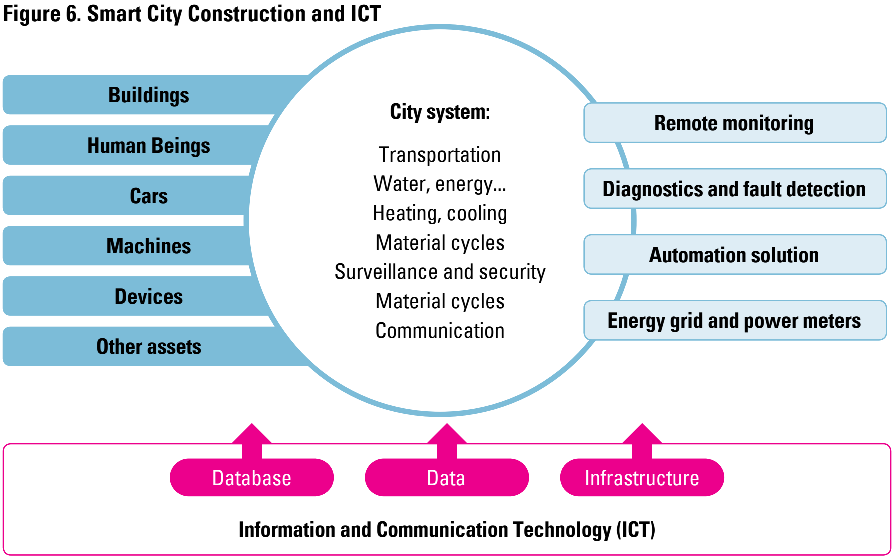
### ❸ Smart cities—Cities becoming smarter

The construction industry is a product of integration and convergence. This field requires the involvement of a great number of backward-linked industries such as design, engineering, technology, and equipment to build structures on demand, and also has high forward-backward linkage effects. Information Technology (IT) represents the type of industry from which the construction industry can seek convergence to create added value and stake an early claim to new markets. One case in point is smart cities.

A smart city is defined as a city that integrates IT technology within the operations of the city to maximize efficiency in urban functions such as energy use, transportation, and risk reduction. In the past,

4
Urban Renewal Projects in Linz, Australia, Kim Sang-won, August 2015; Linz Life (www.linz.at/english/life/3199.asp)

**Figure 6. Smart City Construction and ICT**




Source: Smart City Concept, Applications and Services, Telecommunications Systems & Management, March 2014

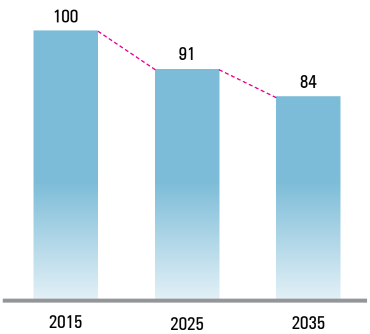
the problems of cities were solved by hardware techniques such as new construction, but smart cities provide software solutions for urban problems by collecting big data via sensors on smart platforms, analyzing big data using AI, and realizing an optimal distribution of resources.

This integration and convergence taking place between construction and IT will continue to progress from the adaptation of new technology to the transformation of production structures and systems in construction. For example, 5D Building Information Modeling (BIM) and 3D printing will be applied on a commercial scale to construction. Steel materials will become stronger and lighter, and even intelligent steel materials equipped with RFID tag technology will be broadly adopted in the construction industry.

A smart city has two main characteristics: digital transformation and energy revolution. From the digital transformation perspective, conventional cities can evolve into IoT-based, hyper-connected localities, bringing massive transformations to people's lifestyles. Intelligent infrastructure and automation design and engineering will be significantly advanced using AI. In terms of energy revolution, environmentally-friendly carbon-free ecological cities will emerge. Carbon-free, zero marginal cost cities with a high utilization of new and renewable energy will be further expanded. In addition, cities will be able to maximize energy efficiency by using energy storage systems (ESS) and energy circulation systems.

The concept of a smart city has been evolving out of the notion of a digital city in the 1990s and ubiquitous city in the 2000s. With the rising awareness of IT innovation, energy, and the environment, the smart city has become a subject of tremendous attention. It is clear that smart cities will be rapidly expanding in the future, fueled by technological development in platform and data analysis and rising demand for urban development in emerging countries. China has recently declared the official launch of smart city projects and is advancing the sophistication of its smart cities using cutting-edge AI technology based in Google's deep learning. India has also announced

**Figure 7. Steel Intensity of Construction Investment**




Source: POSCO Research Institute,
Note: Steel intensity = Steel demand for construction ÷ Construction investment

The emerging trends of megacities, green cities, and smart cities closely interwoven with the ongoing trend of urbanization will spark innovation in construction products and technologies.

a plan to construct smart cities to get its "Smart Cities Mission" on track.

## Qualitative and quantitative changes in construction steel materials

In the future, the emerging trends of megacities, green cities, and smart cities closely interwoven with the ongoing trend of urbanization will spark innovation in construction products and technologies. This will require new steel products for construction as well as new materials.

As societies increasingly require advanced construction products to suit emerging trends, construction steel demand will change as follows. First, conventional steel materials for construction, such as steel bar and section, will have their functionality improved to include increased strength, higher thermal conductivity, and better sound isolation. To enhance performance, they will also be developed as composite materials (i.e. composite materials made of steel bars and concrete). Second, new materials such as carbon nanotubes and shape memory alloys will be widely deployed in construction processes. The utilization of high-functional new materials in construction will allow and accelerate megatall, eco-friendly, and smart construction products.

Under ongoing and emerging trends, construction investment has resulted in a qualitative diversification of steel construction materials. However, quantitative demand, or so-called steel intensity, which refers to steel demand divided by construction investment, is expected to decline. Despite urbanization, construction costs excluding steel, such as labor costs, are rising compared to the past. High-strength steel materials will be increasingly used for supertall buildings and super-long-span bridges in megacities; therefore, steel content per the unit of construction investment is expected to decline. Moreover, construction costs will be redirected to intelligent devices such as IoT and sensors in smart cities and away from steel. As a result, steel intensity (Base 2015 = 100) will gradually decline to 91 by 2025 and 84 by 2035.

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# The Steel Industry over the Next Two Decades

This article comprehensively reviews how megatrends in the major steel-consuming industries as explained in the preceding articles will impact the global steel industry. Fundamentally, the global steel industry will face the following four challenges over the next twenty years, driven by a continuous rise in global steel demand; slowing steel demand growth due to decreasing steel intensity; a need for more advanced steel products; upgrading to eco-friendly and smart steelmaking processes; and changes in manufacturing based on the Fourth Industrial Revolution.

## Slowing steel demand growth with decreasing steel intensity

An industry-wise approach is used to forecast global steel demand: steel demand in each steel-consuming industry is projected and then combined in order to estimate total steel demand. To this end, production and steel intensity[1] in each of the four major steel-consuming industries are projected through 2035 as shown in Table 1. By multiplying production amount (or investment amount) by steel intensity, the steel demand for each industry can be calculated.

In the automobile industry, global production is expected to grow at a compound annual growth rate (CAGR) of 1.6% through 2035, but steel intensity per vehicle is projected to fall by about 20% by 2035 compared to 2015. This means that it will be difficult for steel demand in the automobile industry to increase. The same is true for the shipbuilding industry, but steel demand in this sector is indeed expected to grow slowly since shipbuilding demand is estimated to recover starting around 2025 and the decline in steel intensity will remain around only 10%. In the case of the construction industry, a steady increase in global construction investment will offset the decline of its steel intensity, leading to a stable overall increase in steel demand. In the energy sector, there will be only slight changes in steel intensity and energy investment, so steel demand will follow suit.

1 Steel intensity is defined as the amount of steel used per unit of production or investment.

Combining all accounts, the global steel demand forecast is shown in Figure 1. With the emerging trends of global climate action and the Fourth Industrial Revolution as already described in other articles, global steel demand will continue on a path of expansion, although the growth rate will moderate. From 2016 to 2025, steel demand will grow at a CAGR of 1.2%, while for the succeeding decade it is expected to remain at 0.9%. By industry, the construction industry will be a main driver for lifting steel demand. Steel demand in the construction industry will increase rapidly to reach 920 million tonnes (Mt) in 2035, accounting for almost 50% of total steel demand. However, steel demand in the automotive and energy industries will just be maintained, while steel demand in shipbuilding will expand moderately after 2025. Steel demand in other sectors such as machinary and domestic appliances is not analyzed in detail. However, as a result of regression analysis using industrial production index forecast, it should rise by around 1%. All in all, global steel demand will reach 1.69 billion tonnes by 2025 and 1.86 billion tonnes by 2035. Therefore, it can be concluded that global steel demand has not yet peaked and will not do so within the next two decades.

The steel industry will inevitably progress from the quantitative growth of the past twenty years to a future of qualitative growth.
The global steel industry must astutely overcome the challenges.

### A need for more advanced steel products

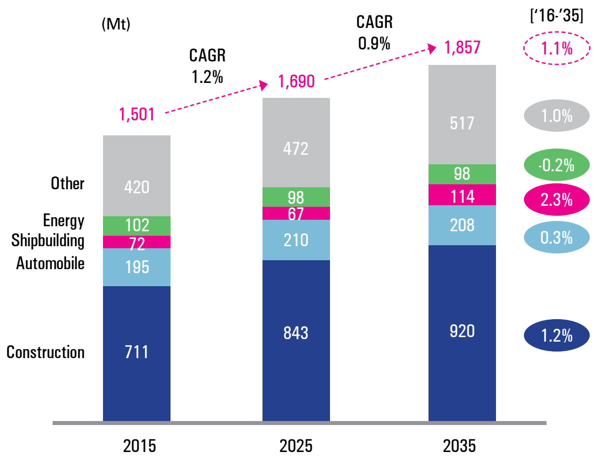
The second challenge facing the global steel industry is how it will properly respond to steel-consuming industries' stricter and more diverse requirements for steel products under the influence of evolving megatrends. Their needs will become more sophisticated mainly in three areas: high strength and high toughness, high corrosion resistance, and high performance. These were of course requirements in the past, but today steel-consuming industries need even higher-strength and more corrosion resistant steel with better performance than ever before.

**Table 1. Forecast of Production and Steel Intensity of Steel-Consuming Industries**

| | Automobile | | Shipbuilding | | Construction | | Energy | |
|---|---|---|---|---|---|---|---|---|
| | Production (mil. unit) | Steel Intensity | New Orders (mil. GT) | Steel Intensity | Investment (USD Tril.) | Steel Intensity | Investment (USD Tril.) | Steel Intensity |
| **2015** | 92 | 100 | 79 | 100 | 9.0 | 100 | 1.8 | 100 |
| **2025** | 114 | 89 | 61 | 97 | 11.5 | 91 | 1.7 | 98 |
| **2035** | 127 | 80 | 109 | 90 | 13.4 | 84 | 1.7 | 99 |

Note: Steel intensities are normalized (2015 = 100)

**Figure 1. Global Steel Demand Forecast**




Source: POSCO Research Institute
Note: 1) Shipbuilding sector includes other transportation,
2) Demand for other sectors is forecast using industrial production index

In the automobile industry, weight reduction has become a central issue due to demanding environmental and fuel economy regulations. High-strength steels are increasingly being adopted in response to stricter collision regulations. To meet such requirements, steel companies have developed and expanded the application of high-strength steels through joint research on minimizing the weight of a vehicle's body, including the Ultra Light Steel Auto Body (ULSAB) Program in 1994, the Ultra Light Steel Auto Body-Advanced Vehicle Concepts (ULSAB-AVC) Program in 1999, and the Future Steel Vehicle (FSV) in 2008.

Auto steel has continuously improved in strength, reaching 450MPa in ULSAB, 1GPa in ULSAB-AVC, and 1.5 GPa in FSV. GigaPascal steels have already been adopted in Dual Phase (DP),[2] Complex Phase (CP),[3] and Hot Press Forming (HPF)[4] steels for the FSV projects currently underway. Moreover, most flat products used for automobiles are high-strength flat products. However, the stronger the steel becomes, the more its formability is reduced. POSCO has recently mass produced twinning-induced plasticity steel TWIP[5] to provide both strength and ductility.

Ensuring corrosion resistance is one of the ultimate goals of the steel industry. High-resistance stainless steel 409L is used for automotive exhaust systems, including mufflers, in order to withstand thermal oxidation. Its application has recently expanded to exhaust manifolds since the manifold is close to the engine and thus exposed to high temperatures. Heat-resistant products such as 429EM, High Cr, and 310S are being used for manifolds. In addition, demand is rising for steel products with more diverse functions, such as hyper non-oriented (NO) electrical steel for the motors of electric vehicles and bio-shield and vibration damping steel for sensors.

In the energy and shipbuilding industries, the development, production, and transmission of oil and gas are increasingly being conducted under extreme conditions such as deep underwater and in the Arctic. High-strength and high-toughness steels are required for standing up to such harsh environments. As offshore structures become larger, they require ultra-thick steels and high-strength steels with yield strengths of over 500 MPa. High fracture toughness steel must withstand extreme cold weather with temperatures below -60°C to be used in the polar regions. In particular, brittle crack-arrest steel is being developed and used to provide facture toughness in

2 DP steels consist of a ferritic matrix containing a hard martensitic second phase in the form of islands. Increasing the volume fraction of hard second phases generally increases strength.

3 CP steels contains small amounts of martensite, retained austenite and pearlite within the ferrite/bainite matrix. In comparison to DP steels, CP steels show significantly higher yield strengths at tensile strengths of 800MPa and greater.

4 HPF is the combination of press-hardening applications and hardenable steels. In this process, conventional boron steel is heated to about 880 to 950° C, formed hot and then cooled, i.e. hardened, in the die.

**Table 2. Requirements for Steel Products by Steel-consuming Industry**

| | Automobile | Energy/ Shipbuilding | Construction |
|---|---|---|---|
| **High strength & high toughness** | Expanded application of giga-pascal AHSS for lighter cars<br>• DP, CP, HPF, TWIP, etc. | High strength & low-temperature toughness steel for deep-sea & polar exploration<br>• BCA, TMCP, etc. | High strength steel for skyscrapers/ super-long span bridges<br>• High strength reinforced bar, section, cable |
| **High corrosion resistance** | Heat resistant Stainless steels for exhaust systems<br>• 429EM, high Cr, 310S | Sour(H2S) resistant steel for extream conditions<br>• API steel for linepipe | High corrosion resistant steel for high temperature, high humidity environ.<br>• PosMAC, ZAM, Super Dyma, etc |
| **High performance** | Highly efficient hyper NO for EV motors, bio-shield steel for sensors, vibration damping steels | Thick plate for offshore wind towers, radiation shield plate for nuclear power plants | High performance steel for interior/ exterior building applications<br>• Thermal insulation, self-cleaning, anti-bacterial, sound-proof |

the welded joints of shipbuilding steel.

Line pipe steel also needs to become stronger to withstand increasing pressures and reduce the use of steel; API (American Petroleum Institute) X80 grade steel is consequently being increasingly adopted for line pipes. Furthermore, demand is also rising for ultra-thick and high-deformability steel to improve low-temperature toughness (to -20°C) for the deep-water environment or for resistance to seismic ground movement. For the shipbuilding industry, vessels are increasing in scale and ships such as container ships, tankers, and bulk carriers require high-strength and ultra-thick steel to hone shipping efficiency and high-toughness steel to enhance the safety of structures.

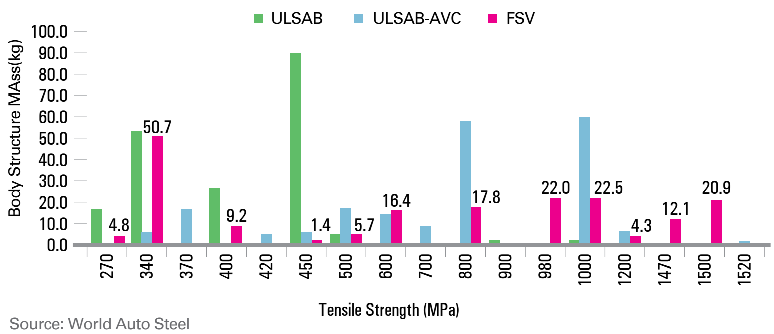
In the meantime, line pipe steel is exposed to different forms of corrosion as oil or natural gas is transmitted from production bases to customers. Particularly in a sour environment in which hydrogen sulfide (H2S) is present as an impurity in oil or gas with water, steel materials become prone to cracking and must be resistant to Hydrogen-induced Cracking (HIC) and Sulfide Stress Corrosion Cracking (SSCC). Radiation shield plates are used in nuclear power plants, and ultra-thick plates are applied in the wind turbine towers that account for more

5 TWIP (Twinning-Induced Plasticity) steel is a class of austenitic steels which can be deformed by both glide of individual dislocations and mechanical twinning.

**Figure 2. Lightweight Autobody Projects**

| ULSAB ('94~'98) | ULSAB-AVC ('99~'02) | FSV ('08~'20) |
|---|---|---|
| **UltraLight Steel Autobody**<br>• Developed by 35 steel companies around the world<br>• 25% weight reduction using the TWB technique, HSS, and UHSS | **UltraLight Steel Autobody-Advanced Vehicle Concepts**<br>• Developed by 33 steel companies around the world<br>• $CO_2$ 140g/km, 20-30% weight reduction through concept design of entire vehicle | **Future Steel Vehicle**<br>• Developed by 16 steel companies around the world<br>• Aims for 35% weight reduction with an optimal structure for application to future vehicles (PHEV, EV, and FCEV) |

**Figure 3. Adoption of High Strength Steel in ULSAB, ULSAB-AVC, and FSV**




Source: World Auto Steel

**Table 3. Steel Use Proportion in FSV**

| Steel type | Share |
|---|---|
| Mild Steel | 2.6% |
| HSLA 450/BH 340 | 32.7% |
| Mart 1200 | 1.3% |
| DP 500&600 | 11.8% |
| DP 800 | 9.5% |
| DP 1000 | 10% |
| TRIP 980 | 9.5% |
| TWIP 980 | 2.3% |
| CP 1000-1470 | 9.3% |
| HF 1500 | 11.1% |

than 80% of the components for erecting a wind turbine. As wind power becomes widespread, more high-strength and high-toughness steel will be adopted.

In the construction sector, steel materials must become stronger and more corrosion-resistant to meet safety concerns and for the reduction of life-cycle costs. As buildings become higher and larger and bridge spans grow longer under the trend toward megacities, high-strength steel materials are gaining ground. In the case of South Korea, 800 MPa high-strength steel was used for trusses and columns in the 120-story (555-meter) Lotte World Tower, and 2.1 GPa steel cables were applied in the Yi Sun-sin Bridge with its main span length of 1,545 meters.

Cost-saving efforts are being expanded across the construction industry by developing engineering technologies that simplify construction design and execution and by selecting optimized materials able to extend the lifespan of buildings and structures.

A representative steel material is weathering steel developed by US Steel, often referred to by the generalized trademark COR-TEN. This material is allowed to rust in order to form a protective coating and improve corrosion resistance. With no need for painting, it is cost-effective and provides a pleasing rustic antique appearance. Recently, titanium is also being used for a coating.

With the rise in the cost of zinc, highly corrosion-resistant but affordable steel materials are gaining prominence. One case in point is hot-dip Zn-Mg-Al alloy-coated steels, such as Nisshin ZAM, NSSMC Superdyma, JFE Ecogal, and POSCO PosMAC. By adding aluminum and magnesium to the coating, hot-dip Zn-Mg-Al alloy-coated steel achieves the same performance while using 50-70% less zinc than conventional hot-dip galvanized steel. It can be widely utilized in housing components, podiums, cattle sheds, shutters, and electronics and automobile components. In addition, steel products with various functions, such as thermal insulating, self-cleaning, anti-bacterial, and sound-proofing qualities,

**Figure 4. The Lotte World Tower and the Yi Sun-sin Bridge in Korea**

Source: shutterstock

Source: tour.yeosu.go.kr

are being developed as internal and external construction materials.

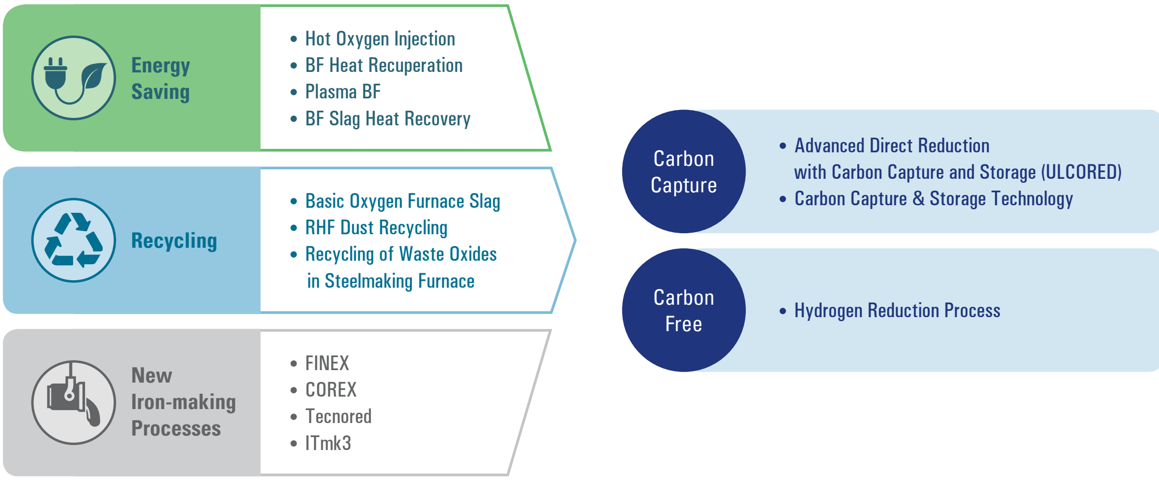
## Upgrading to eco-friendly and smart steelmaking processes

The rising megatrend of global climate action will compel steelmaking processes to become more eco-friendly. In the face of environmental concerns, the steel industry has been attempting to advance energy-saving and recycling technologies and develop new steelmaking processes to replace the conventional blast furnace (BF) operations. Such efforts will continue in the future.

Various types of energy-saving technologies are being developed for BF, which consume the largest share of energy in the steel-making process. Hot oxygen injection is a technology in which oxygen is directly injected into the BF to improve productivity by 15% compared to a conventional BF. Developed by the U.S. Department of Energy (DOE), the technology is currently in the pilot stages. Blast furnace heat recuperation recycles the BF exit gas at a temperature of 250°C into a burner to preheat stove combustion air. This technology reduces fuel costs and heightens fuel efficiency, although the effects differ with the scale of the BF. Research into this technology began in the 1980s and a demonstration plant has been developed. In addition, plasma blast furnaces apply plasma, which is widely used in the chemical and metal industries, to the BF process to minimize metal losses. The technology was primarily developed by the European Steel Association and has already completed validity testing.

One of the major themes of research into the steelmaking process is recycling slag, dust, and other surplus oxides generated as waste materials during steelmaking. The U.S. Department of Energy (DOE) and the Massachusetts Institute of Technology (MIT) have conducted joint research on methods for increasing the iron recovery rate from slag. Japan's JFE Steel has performed research on technologies for recycling steelmaking slag into "marine blocks." These two

**Figure 5. Development of the Future Steelmaking Process**




Source: POSCO Research Institute

research on technologies to separate iron and zinc from the dust generated in a rotary heat furnace. The DOE and Advanced Industrial Science and Technology (AIST) are developing technologies to reduce waste oxides in the steelmaking process and improve the iron recovery rate.

Furthermore, new iron-making technologies are being developed to replace the conventional BF, including POSCO's FINEX, Siemens VAI's COREX, the Tecnored process, and Kobelco's ITmk3. These processes use fine iron ore or pulverized coal to reduce energy use and minimize hazardous substances such as SOx and NOx.

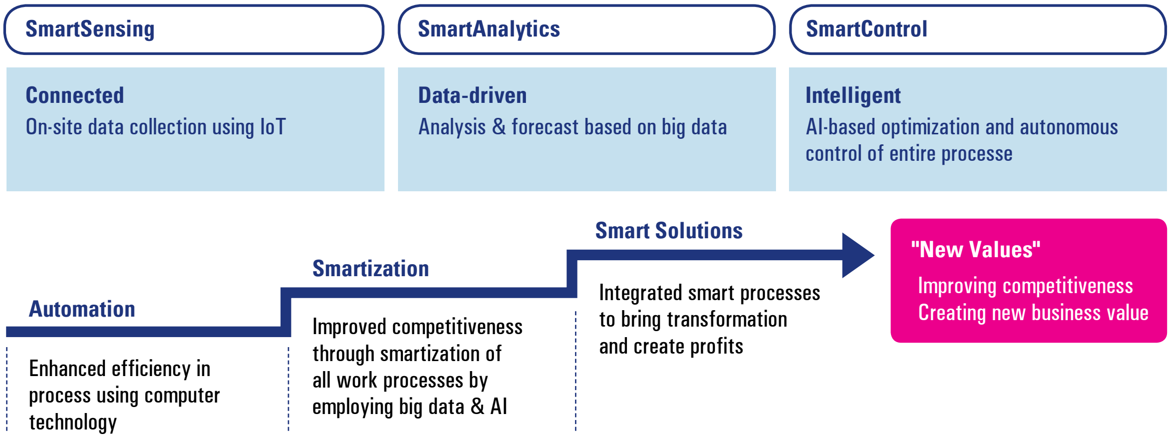
To address environmental concerns, the steelmaking process must not only adopt energy-saving and recycling technologies and new alternative technologies, but also focus on reducing carbon dioxide emissions. In the short term, carbon dioxide capture technologies can be applied to each process to reduce $CO_2$ emissions, but for the long term the steel industry is gearing up to develop carbon-free technologies such as the hydrogen reduction process.

## Creating value through a smart transformation using IoT, Big Data and AI

Another emerging megatrend is Industry 4.0. This refers to the Fourth Industrial Revolution, which succeeds the First Industrial Revolution triggered by the advent of steam engines in the 18th century, the Second Industrial Revolution characterized by mass production in the early 1900s, and the Third Industrial Revolution brought about by plant automation in the 1970s.

The key characteristic of the Fourth Industrial Revolution is the digitalization of manufacturing using advanced ICT technologies, including big data and AI. It involves a more gradual evolution compared to the past industrial revolutions that brought about more sudden and radical shifts. The advancement of ICT technologies will in the future convert steel plants into smart factories. Smart steel plants collect data on-site using IoT (smart sensing), analyze and predict the status of production processes based on big data (smart analytics), and optimize production while using AI

**Figure 6. Smart Transformation in the Steel Industry**




Source: POSCO Research Institute

to automatically control the overall process.

The smartening of the steel industry will be most effective in three areas: advanced factory automation, smart manufacturing system, and internalization of know-how.

• Advanced Factory Automation: Wireless measurement and monitoring, including temperature measurement using sensors, robot scarfing, and autonomous cranes using location recognition sensors and software

• Smart Manufacturing Systems: Prediction of potential production defects and facility malfunctions using big data, effective production scheduling using AI, and integration of facilities and systems at steel plants via IoT (current manufacturing execution systems are separately operated by plants)

• Internalization of Know-How: Converting implicit knowledge into explicit knowledge in the form of manuals, and improving work styles through the realization of smart workplaces.

Smart Factories are anticipated to bring about a great number of benefits: reduction of product error rates and decision-making time, inventory minimization, enhancing facility maintenance, reduced number of accidents, and quicker response to errors. Such positive effects will immediately result in cost reductions.

The concept of smart factories in the steel industry will develop from automation to smartening. Smart factories will have to integrate each smart process at the enterprise level in order to maximize efficiency and develop new profit-making models using smart solutions to create value for customers. The steel industry will inevitably progress from the quantitative growth of the past twenty years to a future of qualitative growth. To this end, the steel industry needs to boost capabilities for smart transformations and continuous product and process innovation; and build a sound steel ecosystem by strengthening partnerships with steel-consuming industries and seeking open innovation in the development of steel products and solutions. The global steel industry must astutely overcome the challenges of the future in order to remain a key industry.