Megatrends and their influence on the global steel industry

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Introduction

Megatrends are powerful, sustained forces. While their impact might not be felt in the short-term, over decades they transform the global social, economic and geopolitical landscape in a major way. Urbanisation, technological progress, and climate change are typical examples of megatrends that are also expected to shape the future of the global steel industry.

We have experienced unusually uncertain and volatile conditions since late the 2000s, as environmental, technological, socioeconomical and geopolitical megatrends have put growing pressures on the established global order. Moreover, we have observed that the COVID-19 pandemic reinforced some of these long-term trends and accelerated the systemic changes that are driven by them. Before COVID-19 we had been considering a timeline over the next 10-20 years. It is now clear that things will move more rapidly.

As the world moves towards a new global (economic, geopolitical, industrial) order at an accelerating pace, identifying the right vision and strategies that ensure the long-term sustainability of our businesses gains the utmost importance. This requires the development of a clear understanding of megatrends, and the new global order that they are likely to bring about.

worldsteel launched a megatrends evaluation study[1] in February 2021 to develop a deeper understanding of megatrends and how they are expected to shape the future of the global steel value chain. The main findings of this study were presented at the Annual General Meeting (AGM) of the Board of Members in October 2022. With this paper we would like to share these main findings with the public, and also aim to initiate a discussion on the future of our industry with all our stakeholders.

In Chapter 1 we begin with an overview of megatrends and then present our view on how megatrends are likely to influence the future global socioeconomic and geopolitical landscape. Chapter 2 presents our findings on the future of urban areas, mobility and the future of two main steel-using sectors, construction and automotive. Chapter 3 concludes with a discussion of what could be the right vision and strategies that ensure the long-term sustainability of the global steel industry in light of our findings.

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[1] We'd like to thank our member companies that participated in this study - Çolakoğlu, Erdemir, Gerdau, POSCO and Tata Steel - for their invaluable support.

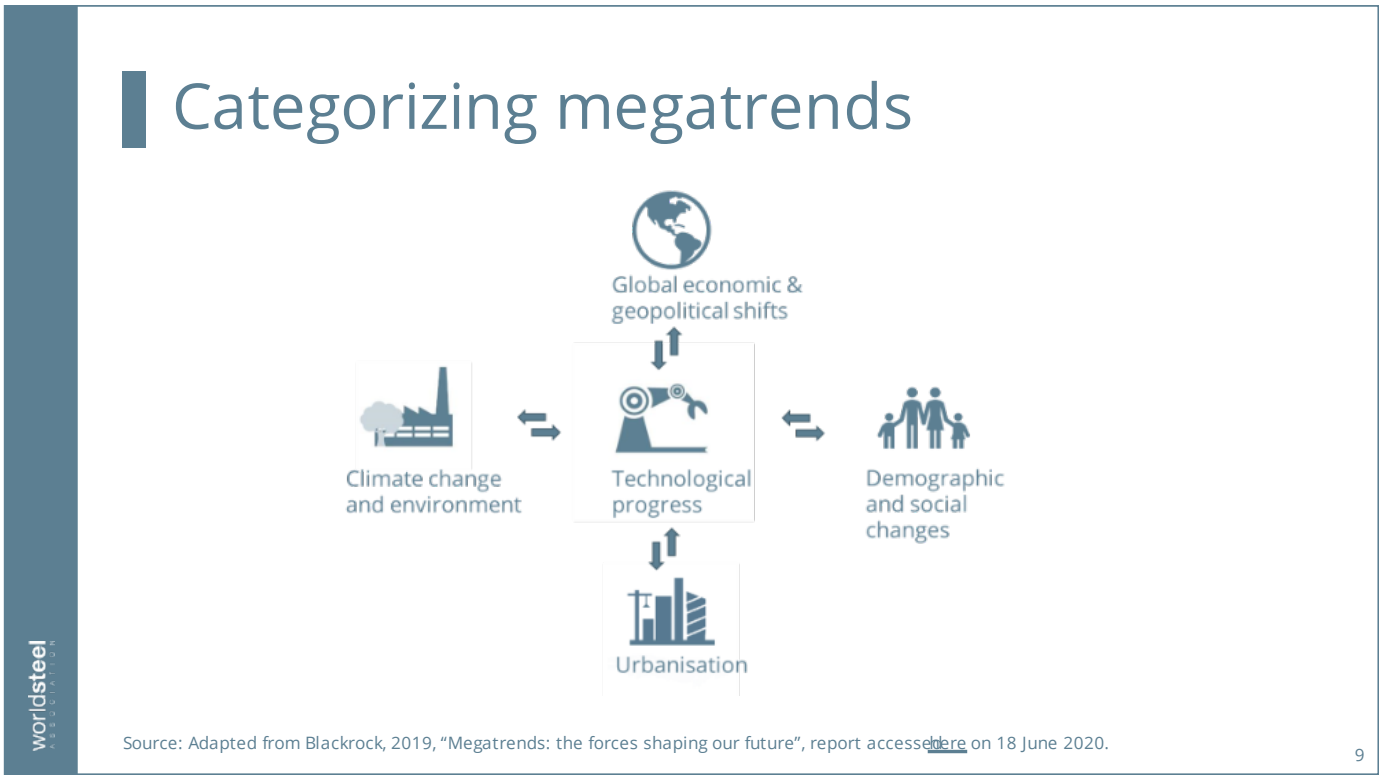
1. Overview of megatrends and their influence on the global socioeconomic and geopolitical landscape

1.1 Overview of megatrends

It is generally argued that a megatrend should satisfy 3 criteria: being long-term, having a broad scope and having a major impact.

That is, megatrends should be sustained over at least several decades, and they should result in fundamental changes worldwide: in the way we work and live, our priorities and preferences, the industrial order, the political order and hence governmental priorities too.

Which megatrends can we identify by using these criteria and how to categorise them? The picture below presents the 5 megatrends categories we've considered in our megatrends evaluation study.



Starting from the right-hand side of the picture, the first megatrends category is demographic and social change megatrends. Here, we consider some well-known demographic megatrends such as continued population growth, population ageing and the expansion of the global middle class.

The second category is the well-known urbanisation megatrend, which is the movement of people from rural to urban areas for the promise of a better life. It is a process that has been transforming the world for centuries now. As the share of the global urban population reached above 50% for the first time in world history in the mid-2010s, urban areas, simply cities, have become the dominating force in global economics.

The third megatrends category is climate change and environment-related megatrends. Here, we consider the trends driven by increasing "environmental consciousness and increasing environmental pressures" at the individual level, corporate level and governmental level. We observe that increasing environmental consciousness and pressures are driving a reformation of the global socioeconomic order. This process is also known as the *green transition*.

The fourth megatrends category is the global economic and geopolitical shifts category. Here, we consider several megatrends that we have observed for the last three / four decades such as globalisation, the shift of economic, military, technological innovation power from developed to developing countries, the shrinking role of the state in the economy and the growing role of the finance sector in the global economy.

The last megatrends category we consider is the well-known technological progress category.

Technological progress has always been the main transformative force in history. In different periods in history, we see different megatrends standing out as major transformative forces. For example, urbanisation was one of the main transformative forces of the 20th century. For the 21st century, it seems the green transition and technological progress are the two main transformative forces driving the world towards a smart and green future.

1.2 Broad outlines of a possible new vision emerging: sustainable & resilient

As these two great forces, the green transition and the technological progress, transform the global socioeconomic landscape, we see major countries around the world recognising this transformation and devising new development visions and economic, environmental and geopolitical strategies to govern this transformation.

We observed that some key policy documents such as the European Green Deal, Infrastructure Plan in the US, and the harmonious coexistence between mankind and nature policies in China share a broad base. They all lay out a set of environmental, economic and social goals to build a *sustainable & resilient* new life. That is, they point to achieving long-term sustainability as the new

vision and aim at building resilience to the growing impact of climate change and changing socioeconomic and geopolitical conditions.

Decarbonisation lies at the heart of the environmental vision, as all these policy documents lay out detailed action plans with ambitious targets. We also saw increasingly more detailed roadmaps to address climate change adaptation needs (preparedness), boost the efficient use of resources, restore biodiversity and cut pollution.

Socially, we see a major focus on addressing income inequality, especially in the developed part of the world, and in China too. With policies aiming to address income inequality, policy makers also aim at enhancing political stability, as increasing income inequality and a perception of decreasing quality of life in developed countries have had a severe political impact, strengthening populistic forces in several countries.

Economically, we see a major focus on infrastructure (both hard and social service infrastructure), investments in clean energy and in building other parts of enabling infrastructure[2] for the green transition.

We see action plans to incentivise the development of those sectors that are considered strategic, sectors that are key to the economic and technological leadership in the future such as electric vehicles and semiconductors. Major countries around the world are also devising policies aiming to secure the supply of those materials and components that are assessed as strategic/critical.

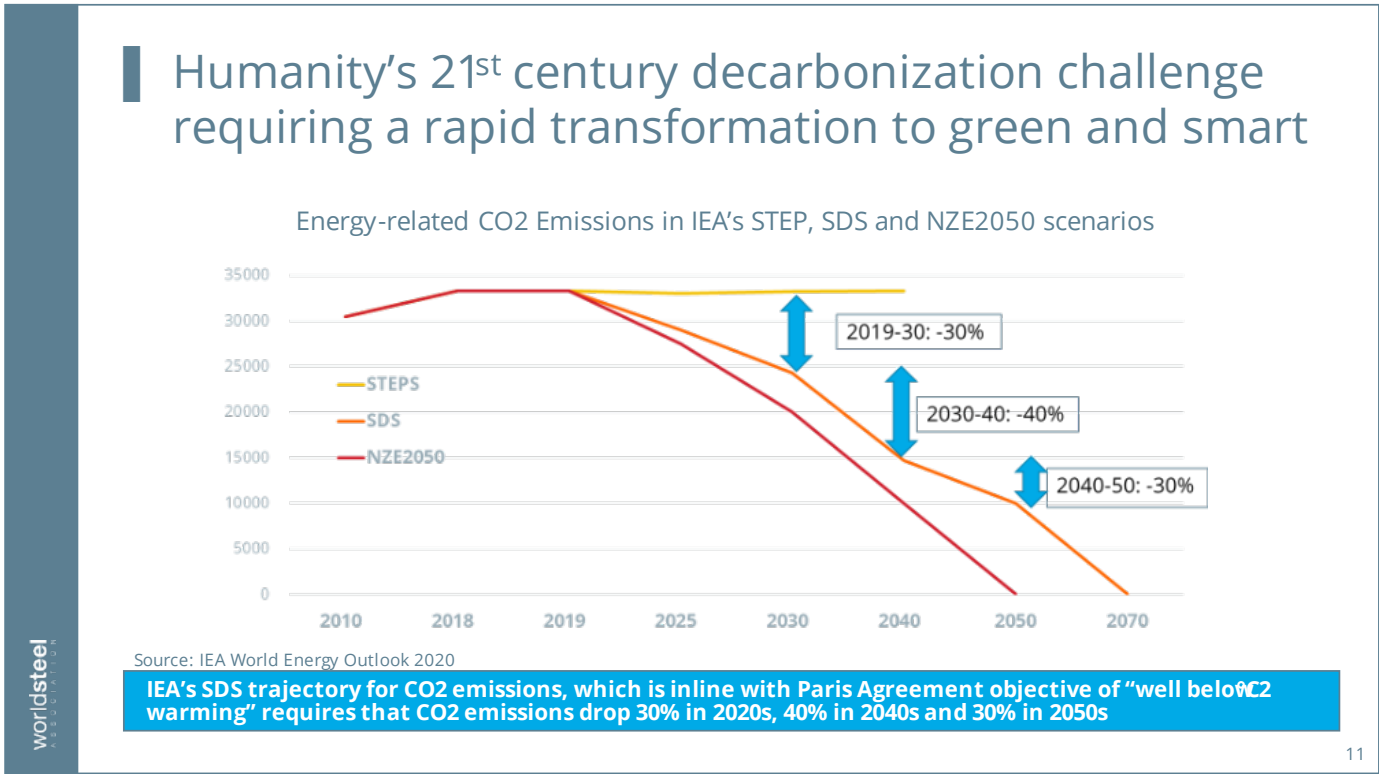
Governments aim at boosting productivity and job creation, and making rapid progress in climate change mitigation and in the race for leadership of the future through infrastructure investments and development of strategic sectors.

1.3 The green transition requires a complete transformation of the world's basic economic systems in a few decades

The picture below shows the International Energy Agency's (IEA) Sustainable Development Scenario (SDS) projection for global energy-related CO_2 emissions. This projection is in line with

[2] Infrastructure investments necessary to enable the green transition such as development of renewable energy generation capacity, modernisation of electricity grids, development of hydrogen production capacity, storage and transportation systems, carbon capture and storage infrastructure and systems.

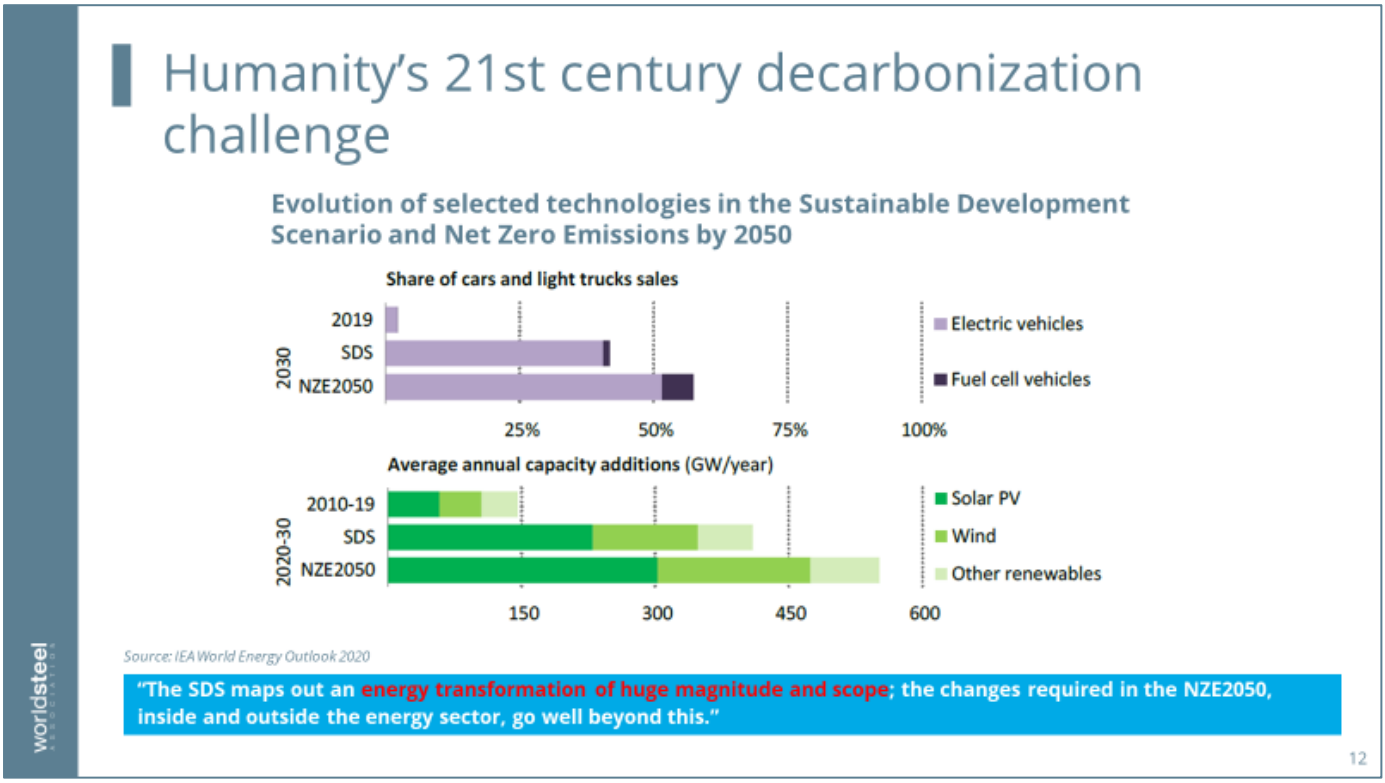
the Paris Agreement objective of holding the increase in the global average temperature to well below 2°C above pre-industrial levels.



According to the IEA's SDS projection, meeting the Paris Agreement objective requires bringing down the global energy-related CO_2 emissions to less than 10 billion tonnes by 2050 from around 36 billion tonnes in 2019, while the global population & the global economy continue to grow.

Such a big challenge cannot be met without a complete green transformation of the world's basic economic systems, such as energy infrastructure, mobility and buildings.

The picture below provides two examples that demonstrate the magnitude and scope of the transformation necessary to meet the Paris Agreement's objective.



Average annual renewable energy generation capacity additions in the 2010s were a bit less than 150 gigawatts (GW) per year and the IEA's SDS projection requires that they should reach about 400 GW/year by 2030. According to the IEA, almost 295 GW of new renewable power generation capacity[3] was commissioned in 2021, setting a new annual record. That is, the world has already made considerable progress towards meeting the SDS projection objective in renewable energy capacity development. Nevertheless, the IEA SDS projection requires further rapid growth in renewables expansion pace in the rest of 2020s with continued policy support, expansion of supply chains, and manufacturing and deployment capabilities.

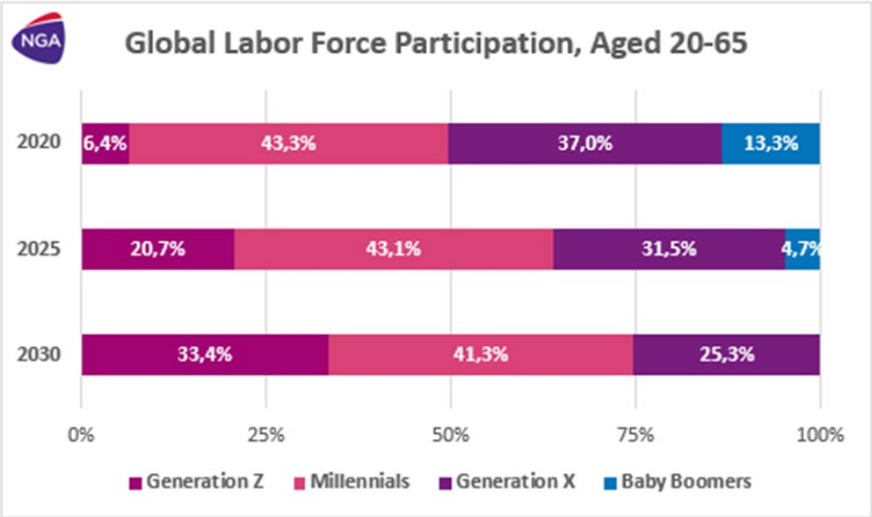
Last year electric vehicles represented about 8-9% of global car sales in 2021 with about 8 million vehicles. The IEA's SDS projection assumes that the share of electric vehicles will reach 40% by 2030 or about 40 million vehicles. In other words, IEA's SDS projection requires that electric vehicle sales grow by 32 million vehicles in just 9 years, which in turn requires the development of supply chains, manufacturing capacities, and the introduction of many more models across segments and price levels at lightning speed.

[3] Please see link for further details.

We do not know if these targets/assumptions will be realised. However, we know that humanity's efforts towards these objectives are going to intensify and accelerate. We have already heated the planet by roughly 1.1°C, and started suffering from the consequences of climate change. Moreover, a hotter future with more frequent and severe disasters is essentially locked in. As the impact of climate change grows, we should expect to see decarbonisation pressures grow too. We should also expect to see a much wider recognition that climate change is only one of the many environmental crises we are faced with. Biodiversity loss, for example, could become the next frontier in sustainability, as continued loss of diversity poses a serious risk to global food security by undermining the resilience of many agricultural systems.

1.4 Changes in individual preferences and social norms towards "responsibility" should be expected to accelerate

Another factor that will accelerate the global transformation towards green and smart behaviour will be a change in individual preferences and social norms. The chart below shows that Generation Z[4], entering their 20s in the 2020s, represented only about 6% of the global labour force in 2020, but their share is expected to grow to more than 30% by 2030.



In the year 2030, Generation Z together with millennials are expected to represent about 75% of the global labour force. That is to say that this new generation's role in society will be growing rapidly throughout the 2020s, probably leading to an acceleration of change in individual

[4] According to Pew Research Center, Generation Z is defined as those who were born after 1996, and millennials are those who were born between 1981 and 1996.

preferences and social norms towards “responsibility”. Acceleration of generational change in preferences might be expected to give a boost to fundamental changes in both production and consumption of goods and services such as the ongoing shift from private ownership to the sharing economy (car/bicycle/ride/flat sharing) and the transition away from linear production models to more circular production models.

1.5 A new geopolitical order emerging

During the last 3-4 decades we have witnessed the rise of globalism, with increasing international trade and integration of markets. Lately, we have started observing a retreat from globalist policies both in major developed economies and major developing economies. We believe that the weakening of the globalisation process reflects the growing rivalry between major developed and developing economies. With higher rates of economic growth, larger populations, and increasing technological and military capabilities, major developing economies have started challenging the established global economic and geopolitical order. Finally, with the invasion of Ukraine by Russia in 2022, it seems the world transited from a uni-polar geopolitical order to a multi-polar geopolitical order. Here, we would like to summarise our expectations for global supply chains and international cooperation structure in the future in a multi-polar geopolitical world order.

We expect to see a continued gradual retreat from (hyper-)globalisation as nationalistic forces, protectionist policies and the pressures for back/nearshoring intensify. In addition to these geopolitical trends, there are also some economic forces working against the globalisation process and making global supply chains less attractive for countries and businesses. Gains from labour arbitrage are losing importance with digitalisation and automation. Increased risk of environmental disasters makes global supply chains more fragile, requiring redundancy buffers and in turn increased costs. Lastly, supply chains are subject to increasing scrutiny for responsible practices and ESG[5] risks. From this perspective, operating in one continent or in one region or in a bloc of countries with the same or similar regulations is likely to become more attractive for supply chains.

Moreover, for those sectors that are assessed as strategic, we can expect the emergence of a “one world multiple systems paradigm” with the adoption of different technological standards and decoupled value chains in different regions/blocs of the world. Major economies see strategic

[5] The abbreviation ESG stands for environmental, social, and governance.

technologies as the key to leadership in the future and would like to secure the supply of materials and components that are critical for such technologies.

As a corollary to the discussion above, we can expect regions or blocs to play an increasingly bigger role in supply chains and international cooperation due to the ease of aligning interests and establishing standards with key allies or regional partners, and due to growing supply security concerns in a multi-polar world order. We can also expect trade barriers to remain relatively high between different blocs, but relatively low between the countries in the same bloc.

1.6 Conclusions on the influence of megatrends on the socioeconomic and geopolitical world order

To sum up, we have argued that the green transition and technological progress are the main transformative forces of the 21st century. We have also argued that decarbonisation cannot be achieved without a complete green transformation of the world's basic economic systems, such as energy, mobility and buildings, and these systems should be completely decarbonised within a few decades to meet the Paris Agreement's objectives. We do not know if such objectives will be achieved, however, we know that the transformation towards green and smart should accelerate and intensify going forward with regulatory support from major economies, generational change in preferences and norms towards responsible and increasing impact from climate change. We believe that the acceleration of the green transition and technological progress, and the increasing impact of climate change are likely to result in rising volatility, uncertainty, and complexity in the rest of the 2020s.

We argued that major economies of the world have recognised the accelerating transformation towards green and smart, and are devising a new development vision and strategies to govern this transformation. We argued in particular that some key policy documents released by several major economies of the world point to achieving long-term sustainability as the new vision, and also aim at building resilience to the growing impact of climate change and to changing socioeconomic and geopolitical conditions. Businesses should expect the transition towards this vision to accelerate and to see similar policies and strategies being adopted in all major economies of the world going forward.

We noted that after a period of about 40 years, where the role of governments in economies gradually shrank, we have entered a new era where governments are likely to play a growing role again with big infrastructure projects, setting targets and standards for the transformation to a smart and green era, social transfer programs to ensure a just transition and new economic development visions and agendas, and international trade policies for a new world order.

And lastly, we argued that we should expect to see a continued gradual retreat from globalisation and the rising importance of regions (blocs) in global supply chains and international cooperation.

2. Future of urban areas, mobility and the construction and automotive sectors

In this section, we present our view on the influence of megatrends on urban areas and the two main steel-using sectors, construction and automotive.

2.1 Future of urban areas

Urban areas, or simply cities are at the heart of global transformation. Cities represent about 55% of the global population, 80% of global GDP, and 75% of GHG emissions & energy consumption. These statistics show very clearly that the green transition and technological progress will drive an accelerating transformation of cities and our urban lives around the world during the next few decades.

As urban areas account for most of the world's energy consumption and CO_2 emissions, the transformation of urban energy systems will be the key to the decarbonisation of the world economy. During this transition, cities themselves will become significant renewable energy generators with installation of rooftop solar systems, wind turbines and bioenergy systems. Moreover, cities will become much more efficient energy consumers through renovation of building stock, introducing strict energy requirements for new buildings, encouraging active, shared, and public mobility, replacing gas fuelled vehicles with more efficient electric vehicles and making use of a plethora of new smart city initiatives aiming to increase energy and resource efficiency of urban life. Many major cities have already announced ambitious climate action targets and shown significant progress. Paris[6], for example, targeted halving energy consumption and achieving 100% renewables by 2050.

Mobility systems in urban areas are going through a rapid transformation. We see many cities taking actions to discourage private car use by limiting road space for driving and parking, increasing car ownership costs, establishing low speed/emissions zones and car bans. Meanwhile, public, shared, multi-modal and active mobility is being encouraged. We should expect to see such actions being adopted in many major cities around the world in the rest of the 2020s, as decarbonisation pressures grow. The development and wider adoption of autonomous vehicles in the 2030s is likely to give a further boost to the adoption of shared and multi-modal mobility in urban areas. Interestingly, adoption of automated vehicles and shared mobility concepts bring

[6] Please see Climate Action Plan for Paris for further details.

new opportunities for efficiency gains and densification in cities, such as the repurposing of parking lots.

We expect to see cities becoming denser around major transportation hubs so that there will be less need for private vehicles. Some major cities have invested heavily in this strategy. For example, Paris is building a new extensive public transportation network that allows for higher buildings around transportation hubs.

In the search for efficiency, some cities are likely to explore mixed-use, multi-function neighbourhoods instead of only residential, only commercial, or only office space neighbourhoods to increase the occupation efficiency of buildings and reduce the need for transportation.

Densification through transitoriented development

Build extensive public transportation networks & densify around transit hubs

Paris' Grand Paris Express project aiming to transform the city's mobility infrastructure through establishing new neighborhoods within 800m radius of each new station

Higher Buildings: Paris' Clichy-Batignolles development allowed 50 m height for buildings (37 m height limit for Paris)

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With continued urbanisation and industrialisation, demand for resources and waste generation in urban areas can only grow further, putting further pressure on already strained global resources and wildlife. Therefore, governments around the world are exploring different circularity strategies to achieve a sustainable urban growth model. Materials flows for cities are being mapped out, and innovative business models based on services rather than possession of goods are being experimented with. Some cities have already announced ambitious materials use reduction targets (e.g., Amsterdam to halve the use of new raw materials by 2030).

We believe that these developments point to rapid advances in the adoption of a circular economy in the near future. Circularity will be growing from a very low base. Nevertheless, we expect the

impact of circularity to become more visible by the late 2020s, especially in shared economy practices, and to continue growing at a rapid pace thereafter.

Changes in cities and urban life, particularly the growing focus on energy, materials, occupancy and transportation efficiency will drive certain building design trends going forward. As mentioned above, buildings are likely to get higher on average. They will be much more energy efficient, and some will even be net-positive energy buildings, producing more energy from renewable energy sources than what they consume over a year.

Mixed-use, multi-function projects (such as mixed residential-office, or residential-commercial-office) projects can be expected to continue gaining market share, as they bring increased occupation efficiency and reduce the need for transportation.

Buildings of future – Higher and high performance

70m-high social housing with vertical forest (125 trees and 5200 plants grown by sensors)

Futuristic skyscrapper design with solar walls, bladeless wind turbines and sky gardens

Bioclimatic design based on local climate and environmental conditions to minimize energy demand

Source: Left DeTrudo Toren, which has 125 social housing rental apartments in-Strip in Eindhoven, NL. Middle https://www.nationalgeographic.com/magazine/graphics/sea-sustainable-future-city-designed-for-people-and-nature. Right An example of bioclimactic design from https://aasarchitecture.com/2018/01/le-17-office-building-batignolles-chartier-dalix-brenac-gonzalez.html/

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We expect to see an increasing focus on new requirements for buildings such as flexibility, scalability, and modularity to meet the demand for increased occupancy efficiency and longer lifetime from the buildings. The focus on the durability of materials is also likely to grow, as building designs will aim at achieving the longest possible lifetime with the lowest lifecycle impact. Redevelopment / repurposing projects preserving the original structure of the building should continue to gain importance, particularly in developed countries.

With a growing focus on circularity, (circular) designs that use recycled and used products and allow for the reuse of components will gain importance. Future building designs will incorporate

new systems that are necessary for circularity such as waste collection, water collection and recycling systems.

2.2 Future of the construction sector

The construction sector is relatively slow to adopt changes. It has a quite fragmented structure, and local conditions play an important role in the selection of materials and construction technologies. Such factors complicate the adoption of new materials or new technologies by the sector.

However, the construction sector is likely to come under growing sustainability pressures going forward. The sector is the biggest materials user, demolitions are the biggest source of solid waste in many major economies, and buildings are one of the biggest CO_2-emitting sectors.

With growing sustainability pressures, we believe that digitalisation, integration and automation of construction processes are likely to gain pace. Digitalisation and integration of different stages of construction will enable full life cycle and collaboration at an early stage. Consequently, we expect to see growing adoption of comparison of designs with respect to their materials use, waste generation, CO_2 emissions performance and choosing the designs that optimise such criteria. That is, we expect to see the importance of “lowest lifetime environmental impact” to grow progressively in awarding of contracts, and an accelerating change in the “lowest upfront cost wins the contract” mindset prevailing in the sector.

Sustainability pressures and digitalisation of construction processes are also likely to lead to the growing adoption of computer-aided structural design and other materials efficiency strategies to reduce materials requirements while enhancing performance. Research shows that optimisation of the cross-section or height of structures, avoiding over-specification and using materials where they are strictly required can bring quite considerable reductions in the overall weight of a structure, and hence in cost, waste and carbon emissions..

With digitalisation and process integration we also expect to see a growing use of prefabricated components and modular construction. Nevertheless, we expect that prefabrication and modular construction will continue to represent a small share of the overall market. That is, we do not expect the mainstream construction methods, for example, reinforced concrete construction for multistorey residential buildings, to lose their dominant position.

Steel and cement will remain as the main construction materials. Timber and some new products, such as bricks made from waste, might be expected to gain some market share. Nevertheless, the sector requires high-volume, low-cost, high-performance materials, and steel and cement are the two materials that meet these requirements. All other construction materials including timber are subject to severe volume, cost or performance limitations.

The main change we expect to see in materials demand from the sector is a rapid growth in its demand for low-carbon materials, recycled and used materials. And we believe that low-carbon steel can be one of the biggest levers for the construction sector in its challenge of decreasing embedded carbon in buildings and other constructed structures.

When we turn to the construction sector's steel demand in the medium term, we see two quite supportive developments.

Firstly, we expect to see strong infrastructure construction activity over the next several decades. The last 3-4 decades saw persistent underinvestment in infrastructure in some major economies, and as we mentioned before, all major economies of the world will focus on infrastructure investments as a new development strategy aiming to reach environmental, economic and social sustainability. As infrastructure investments are some of the most steel-intensive economic activities, we expect strong infrastructure building activity to support steel demand over the next several decades.

Secondly, we believe that most of the trends we expect to see in construction and building design in the future are positive for steel. The increasing focus on higher, flexible, scalable buildings, for example, should support steel framework designs. The Installation of energy generation, recycling and storage systems, the growing use of prefabricated components and modular construction, the increasing importance of circularity and durability, and reuse and recycling characteristics should all be supporting more steel-intensive designs going forward.

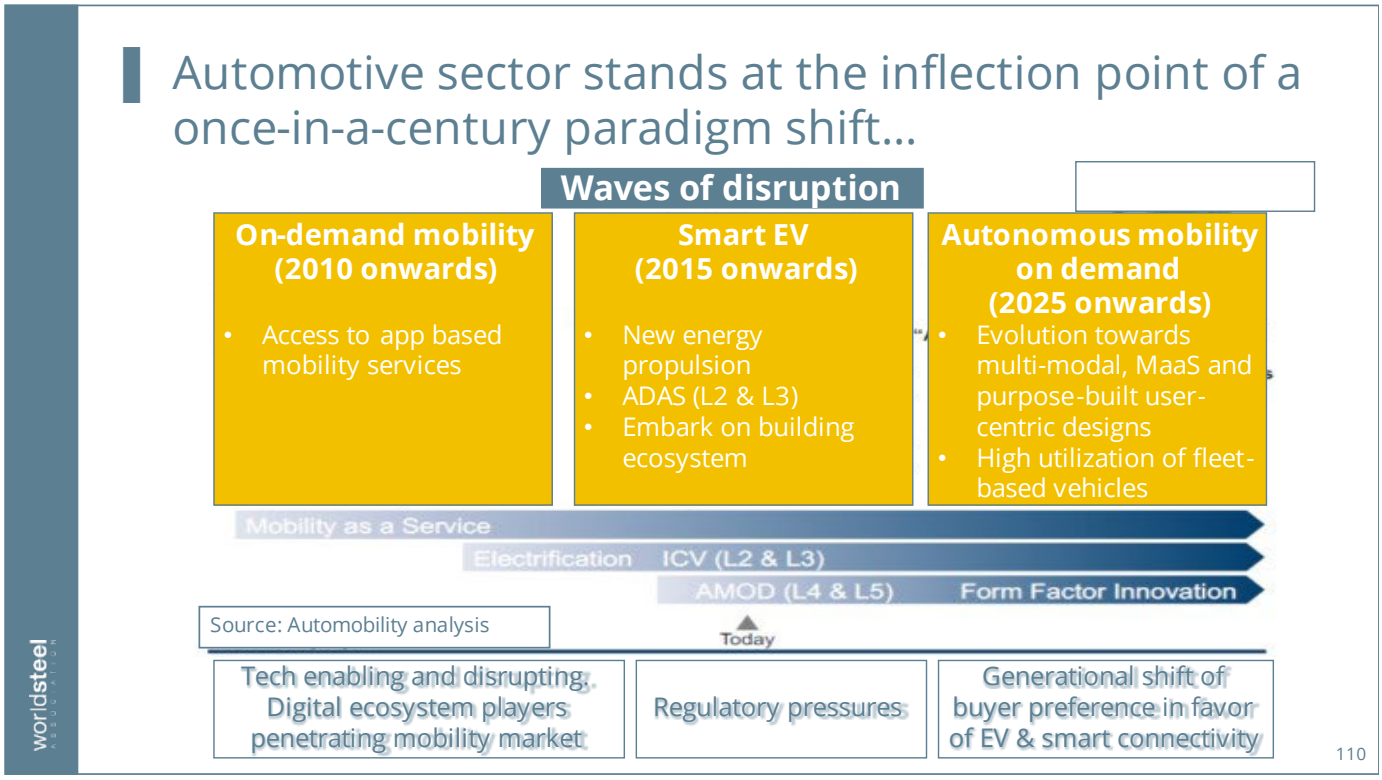
Thanks to these steel-positive developments, we expect that the construction sector will be showing relatively stronger growth in steel demand and grow its share of global total steel demand further in the future.

We expect the construction sector also to play an increasingly bigger role for the global steel industry in the decarbonisation of steelmaking, new product development and process improvements. As the largest and growing user of steel products, the construction sector's growing demand for low-carbon products will certainly be an important pull factor for the steel industry's decarbonisation process. Digitalisation and integration of construction processes will boost the digitalisation of the steel industry and its products, in fact, the whole steel value chain. The rising importance of circular and flexible building designs and the increasing importance of certain characteristics such as durability and recyclability will boost the steel industry's efforts to innovate to make products and solutions that meet these requirements.

2.3 Future of the automotive sector

The automotive sector is standing at the inflection point of a once-in-a-century paradigm shift. This paradigm shift is being driven by three main waves of change.

The first of these disruption waves is the ongoing transition to shared mobility (mobility as a service) from private vehicle-based mobility (mobility as a product) systems[7]. In the early 2010s digital ecosystem players have begun penetrating the mobility market introducing mobile phone applications for ride-hailing and carpooling services. These app-based mobility services showed explosive growth and quickly reached significant shares in the mobility markets of many cities around the world. The very fast adoption of shared mobility services (car/ride/micro-mobility) reflected the combined impact of several megatrends. The increasing population density in urban areas, traffic congestion, regulations and increasing environmental consciousness have reduced the willingness for car use and ownership, which used to be a dream of urban families.



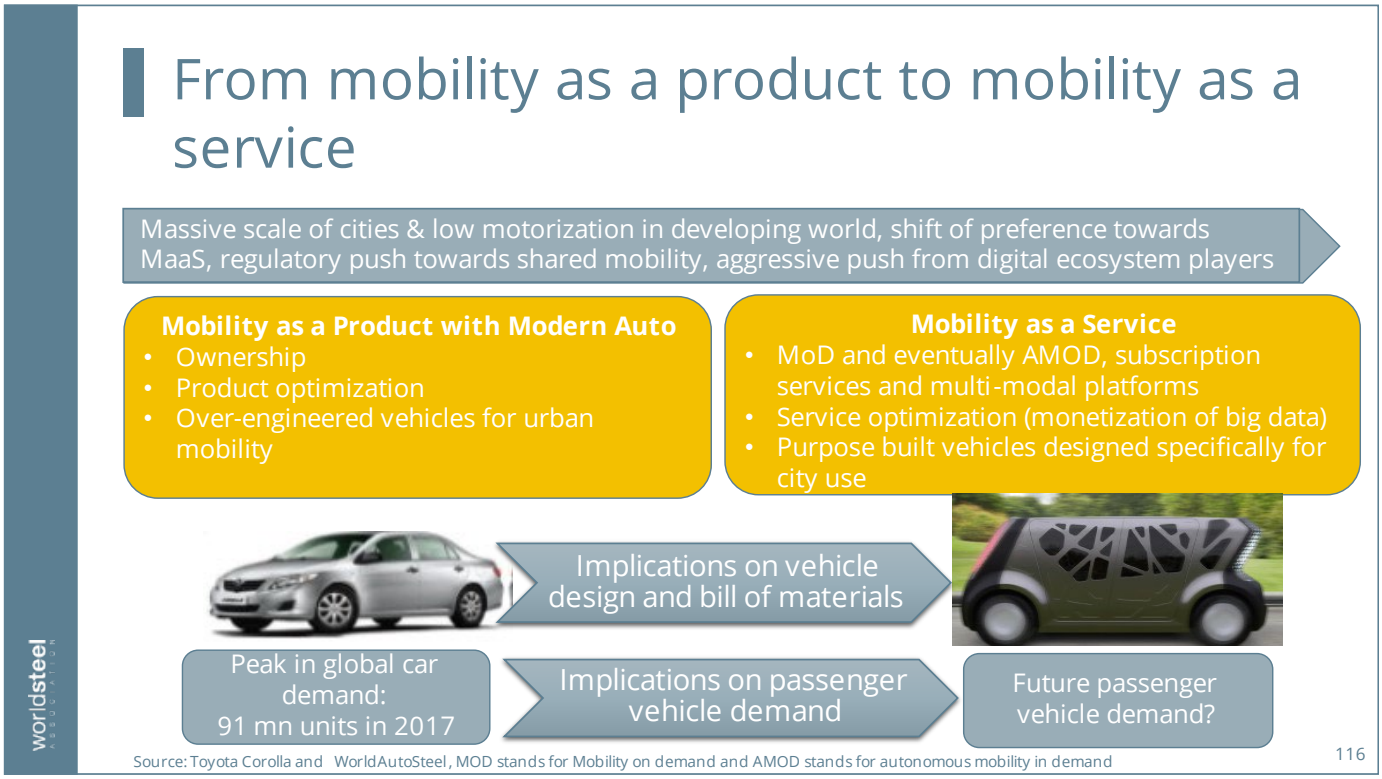
The second disruption wave for the automotive sector is electrification and the replacement of internal combustion engine (ICE) technology with electric vehicle technology. This trend has been accelerating since the mid-2010s, and the share of electric vehicles in global light vehicle sales reached 8-9% in 2021, as we mentioned before. Regulatory pressures and the generational shift of

[7] In 2021 private cars represented 97% of passenger kms driven in the US, 92% in the EU and 89% in China according to PWC's Autofacts, Digital Auto Report 2021.

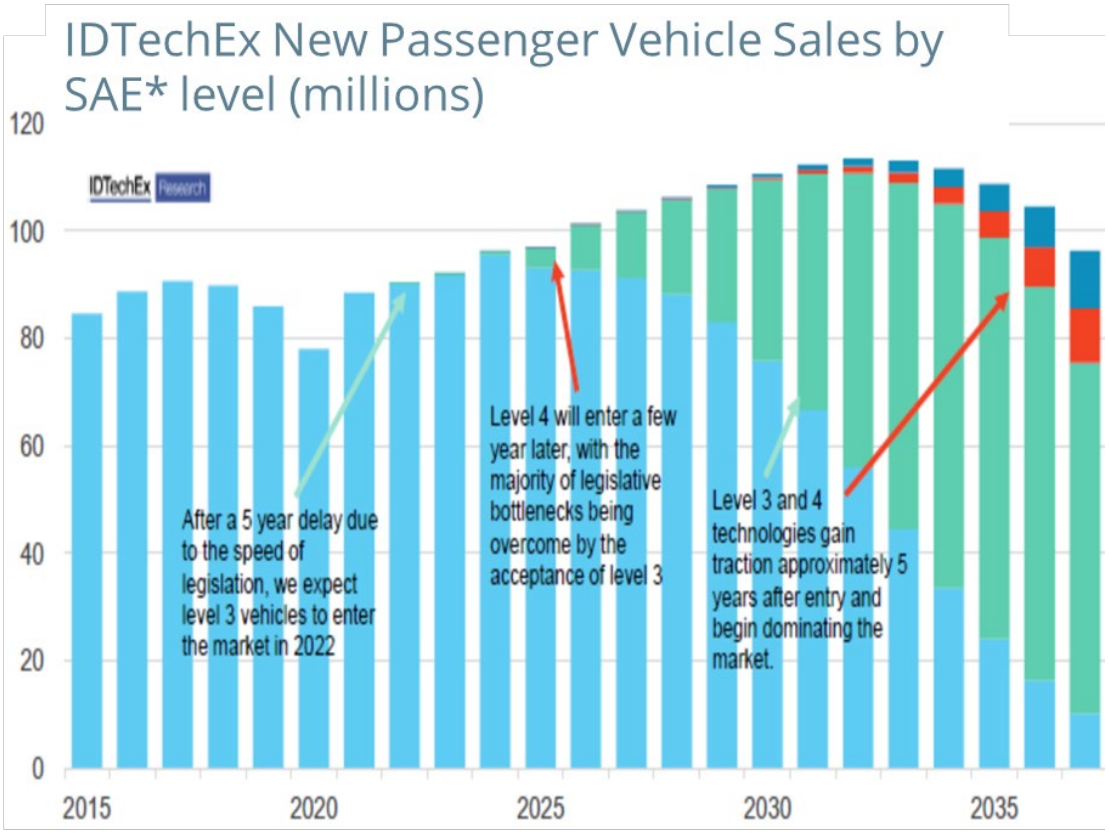
buyer preference towards electric vehicles are expected to accelerate this transition further in the rest of the 2020s.

The third wave is the development of autonomous vehicle technology. This wave is expected to gain momentum from the mid-2020s and drive a rapid transformation of the automotive sector and mobility systems around the world.

The ongoing shift from "mobility as a product" to "mobility as a service" is a real game changer. Especially with the advent of autonomous vehicles, this shift is likely to result in fundamental changes in vehicle design, vehicle demand, and material requirements. For example, we are likely to see major changes in vehicle design from conventional designs that prioritise the driver's comfort to new designs such as shuttles and pods that prioritise purpose of use and efficiency.



What will be the impact of the great transformation of the global automotive sector on steel demand? We will make use of IDTechEx's global light vehicle sales projections by the level of autonomy below to present our view on the future of steel demand from the automotive sector[8].



Source: IDTechEx Autonomous Cars, Robotaxis & Sensors 2022-2042 Report

First, we see that global light vehicle sales are forecast to grow from around 80 million units today to more than 100 million units by 2030. The growth in demand is expected to come mainly from developing countries with vast populations and low motorisation rates such as India. We believe that this is a reasonable expectation and bodes well for steel demand.

The IDTechEx projection does not show the share of electric vehicles in total sales. Many industry experts assume electric vehicle sales can reach about 30% of global sales by 2030. So, let's assume 30 million electric vehicle sales and 70 million ICE vehicle sales globally in 2030. We know that

[8] IDTechEx is a global consultancy company providing market research and business intelligence on emerging technologies.

electrification goes faster in premium segments. That is, most of these 70 million ICE vehicles to be sold in 2030 are likely to be in more economical segments, which have higher steel intensity than premium models. And for electric vehicles, we have observed that top-selling electric vehicles with conventional designs such as Tesla 3 have been steel-intensive vehicles and we do not expect to see a major change here.

The real game changer for steel demand will be autonomous vehicles with unconventional designs. And here IDTechEx has a particularly bullish projection. They expect to see about 30 million Level 3[9] autonomous vehicle sales, and some Level 4 vehicle sales by 2030. Here, we should note that many other industry experts have a more pessimistic outlook for autonomous vehicle sales. That is, the level that autonomous vehicle sales are likely to reach by 2030 is debatable. Still, most experts agree that mobility as a service and autonomous vehicles will take over a majority of the automotive market at some point. The IDTechEx projection suggests that global vehicle sales should start declining from the mid-2030s, as the adoption of autonomous vehicles ramps up and the need for privately owned vehicles drop rapidly.

From the mid-2030s, we will probably be facing a growing challenge: autonomous vehicles with unconventional designs. Steel is likely to face fierce competition in large surface closures for these vehicles from glass and plastics. However, steel is expected to remain the material of choice for chassis and body-in-white components for these vehicles.

The electrification of vehicles and the ongoing shift to shared mobility services are bringing big changes in the automotive sector's materials requirements. With the move to shared mobility, longevity will be measured by miles rather than years. That is, automotive materials will probably need to endure considerably higher mileage during a vehicle's lifetime. Moreover, electric vehicles have higher torque and speed, and require better NVH[10] characteristics than their ICE counterparts. Lastly, electric vehicles with conventional designs are heavier than their ICE counterparts. All these changes result in more demanding requirements for all moving and structural parts in electric vehicles. And we believe that more demanding durability and strength requirements are positive for steel.

Lightweighting pressures have worked against steel and we expect these pressures to remain for some time because of growing additional weight from battery and on-board technology in electric vehicles. However, we believe that the shift in regulations towards full lifecycle vehicle emissions

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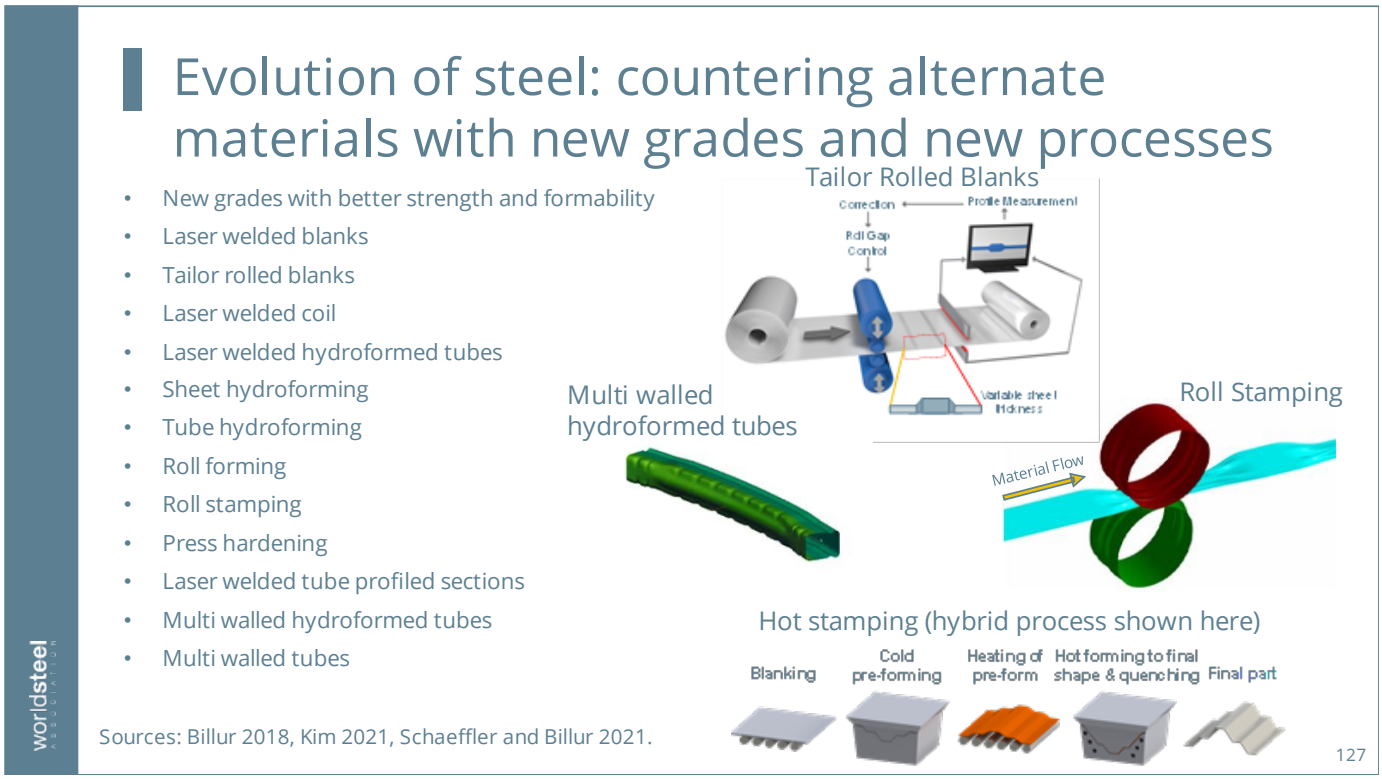
[9] Level 3 autonomous vehicles can perform most driving tasks, but driver must remain alert and ready to take control if the system is unable to execute a task. Level 4 autonomous vehicles, also known as robo-taxis, do not require human interaction in most circumstances.

[10] Noise, Vibration and Harshness

and improvements in battery energy density and cost are tilting the balance in favour of steel. Moreover, additional costs for batteries and new technology are also leading to increased cost pressure on other components, underpinning steel's competitiveness against alternative materials.

We are aware that alternate materials are investing heavily to penetrate the automotive market. Nevertheless, these materials are mostly subject to severe cost, volume, safety or environmental impact limitations at the moment. Increasing volumes and scrap availability, and renewable energy adoption might help narrow down the competitiveness gap between these materials and steel. However, the global steel industry is countering alternate materials with new grades and new processes (please see the visual below). Hence, we believe that steel will keep its position as the material of choice for the automotive sector, and maintain its absolute leadership in cost, volume, range of products, familiarity of use, extent of supply chain, efficiency, safety, environmental performance, carbon footprint and recyclability.



The automotive sector is likely to play a leading role in low-carbon materials demand, as there is a greater policy focus on mobility as an easier to decarbonise sector. We expect to see the use

phase emissions[11] of the sector to decrease rapidly during the 2020s and the early 2030s with the accelerating shift to electric vehicles and renewables-based energy systems. As the use phase is decarbonised, the focus on embodied carbon in vehicles is likely to grow considerably by the late 2020s. Some major OEMs have already announced ambitious targets for low-carbon materials content[12] in 2030 and aim to achieve value chain carbon neutrality in the 2050s.

To sum up, we believe that we are faced with a positive steel demand outlook for the automotive sector until the mid-2030s, but we are faced with a growing challenge from the mid-2030s, as autonomous vehicles with unconventional designs start penetrating the market rapidly. Another challenge for the steel industry will be to meet the automotive sector's growing demand for low-carbon materials from the late 2020s.

[11] Use phase emissions are estimated to account for about 75% of the total Scope 3 emissions of a vehicle.

[12] For example, BMW aims to use low-carbon steel to meet over 40% of demand at its European plants by 2030.

3. Vision and agenda for a sustainable and resilient global steel industry

This section presents our view on what the vision and strategies for the global steel industry should be under the light of our findings on megatrends, how they are likely to shape the future socioeconomic and geopolitical landscape and the future of steel-using sectors.

We have argued that steel-using sectors are going through an accelerating transformation phase, and we should expect to see fundamental changes in product designs and materials requirements going forward. Steel producers will need to develop a clear understanding of the ongoing and potential future changes in their markets, establish the right R&D, investment and marketing strategies, and act proactively to appeal the market with steel's superior performance.

Prepare for medium-term growth opportunities: our findings suggest a positive medium-term steel demand outlook. Continued urbanisation, industrialisation and motorisation in developing economies and strong infrastructure construction activity globally should support global steel demand in the medium term. Some segments such as electrical steels and steel products used in wind and solar energy generation projects might be expected to see particularly strong growth. Steel producers should assess such long-term growth opportunities, identify growth regions and segments, and establish the right investment strategies that would ensure sustainable growth.

Prepare for fundamental changes in product design and materials requirements: we have argued that megatrends are driving certain changes in product design and material requirements of steel-using sectors**.** We believe that most of these changes such as increasing focus on durability and lifecycle impact or increasing importance of flexibility and scalability in building design are likely to be positive for steel. Nevertheless, some of these changes such as the advent of autonomous vehicles with unconventional designs are likely to result in fiercer competition with alternate materials.

The global steel industry **should invest in the development of necessary data and tools to promote the sustainable potential of steel products**, and to demonstrate the superior performance of steel-intensive designs in meeting the strategic criteria for steel users and their changing requirements. WorldAutoSteel's Steel E-Motive programme provides a solid example of a joint industry effort to demonstrate steel's performance in meeting the requirements of future mobility. The programme is developing advanced steel architectures for autonomous vehicles and specifically demonstrating strength, durability, environmental impact and affordability.

We believe that increasing the adoption of lifecycle impact assessment should encourage the use of more steel-intensive designs in most use cases. Hence, the global steel industry should **focus on the use of lifecycle assessment as a strategic tool** to demonstrate steel's best-in-class environmental performance. The data and tools necessary for lifecycle assessment are still being

developed, and it is possible to see various databases, and models and software with varying assumptions in the market. Therefore, the global steel industry should invest in the development of the data and tools necessary for Life Cycle Assessment of steel products and steel-containing goods, and ensure that steel's performance is represented correctly in various lifecycle impact assessment tools.

Facing changing product designs and materials requirements and increasingly more digitalised steel users with a growing focus on lifetime environmental impact, steel producers are likely to feel increasing pressure to become **"solutions providers"**. Some steel producers have already partnered up with major construction, automotive and energy vendors to develop digitally driven, customised materials solutions. We expect such partnerships to play a bigger role in product and solutions development in the future, extending also to smaller steel users.

The global steel industry should also **explore partnerships with competing materials** supplying industries to innovate higher performance, multi-material solutions, that meet steel users' changing requirements. constructsteel[13] provides an interesting example with its steel-timber designs study aiming to explore and demonstrate the full potential of steel-timber composite structures in high-rise buildings. Multi-material solutions present challenges in terms of manufacturing and cost, as well as potential issues with compatibility and corrosion between different materials. Still, advances in materials science and joining and process technologies will be creating new collaboration potential for development of multi-material solutions. Recently developed steel-polymer composite solutions for automotive applications provide interesting examples, showing superior performance in lightweighting, acoustic properties and cost-competitiveness.

Steel producers will need to **connect with new players** penetrating automotive, construction or other steel-using sector markets. In automotive, for example, there is an urgent need to engage with new smart electric vehicle producers, and digital ecosystem players and fleet owners that show a growing interest in purpose-built designs. Interestingly, these new players do not have the steel use legacy and are keen on exploring new designs, technologies, and materials. So, the global steel industry should engage directly with these new players and their equipment suppliers to **demonstrate the material advantages of steel in addressing the key challenges** they are faced with such as safety, comfort, cost and sustainability.

Prepare for rapid growth in low-carbon steel demand. We expect steel-using sectors to show rapid progress in decarbonising their operations and the use phase of their products (vehicles,

[13] World Steel Association's global marketing and research-focused programme aiming to increase steel's share in the construction sector.

buildings, machinery etc) in the rest of 2020s. With that, as from late 2020s, steel-using sectors will increasingly focus on decreasing the embedded carbon in their products. Therefore, steel producers should expect the demand for low-carbon steel to surge from the late 2020s, initially from a low base, but reaching significant volumes quickly. **The global steel industry should focus on establishing steel as the most important material decarbonisation lever for all steel-using sectors.** For this purpose, we will need to combine steel's inherent superior qualities, such as durability, flexibility, recyclability, reusability, cost and volume with **a sensible decarbonisation pathway**.

Decarbonisation can only be achieved together with our partners in the steel value chain. From raw materials and energy supply to the usage and recycling of steel-containing goods, steel value chain should become progressively greener. So, we should **promote dialogue** over decarbonisation with our suppliers, consumers and with the public sector and **focus on establishing green partnerships** across our value chains and with other industries such as the chemical industry.

We have argued that the world will be making strides towards circularity as from the late 2020s, as the data for and understanding of materials flows come together and social and regulatory pressures for circularity intensify. The **global steel industry should monitor emerging circularity initiatives carefully and should try to establish steel also at the heart of emerging circular ecosystems.** We should ensure that steel and its impact is represented correctly in developing databases and materials flows models. We should study and promote steel's circularity characteristics such as recyclability and reuse and material advantages of steel in shared economy practices and in circular designs that allow for the reuse of components.

Alternate materials have invested heavily to penetrate steel markets. As the global steel industry, we have successfully countered alternate materials with new products, processes and applications, and defended steel's position as the material of choice in most use cases. Alternate materials will keep on investing in capacity and range of products, while long-term forces such as increasing use of renewables and increasing scrap availability might lead to a narrowing down of the competitiveness gap between alternate products and steel. The global steel industry **should carefully study the potential impact of megatrends on competitive position of steel,** and should continue to invest in the development of new products, processes and solutions that meet the key challenges steel users are facing.

The COVID-19 pandemic gave a big boost to technological progress megatrend, and we expect the digital transformation of steel value chains to continue accelerating going forward. As digital twins of business and manufacturing processes are established, the integration of the real and virtual worlds will accelerate and bring new big data analysis, simulation, robotisation and automation opportunities. Therefore, **steel producers will need to devise and implement the right digital transformation strategies and progressively expand smart manufacturing capabilities.**

Digitalisation of the steel value chain will bring **new collaboration opportunities with business partners through data sharing and process integration**. Steel producers will need to carefully study such digital ecosystem building opportunities and emerging issues such as data ownership, liability and benefit sharing in such more integrated approaches, and devise the right investment and collaboration strategies.

We believe that steel producers should focus on **building systemic resilience** to prepare for a future of more frequent and stronger disruptions brought about by the growing impact of climate change and ongoing systemic shifts in global geopolitical and socioeconomic order. Steel producers should develop a good understanding of the environmental, geopolitical and technological disruption risks material to their organisations and then **build long-term strategies to navigate market volatility and emerge from disruptions better positioned for growth.** For this purpose, steel producers will need to devise and implement risk mitigation and adaptation plans, and build capacity for a timely response.

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