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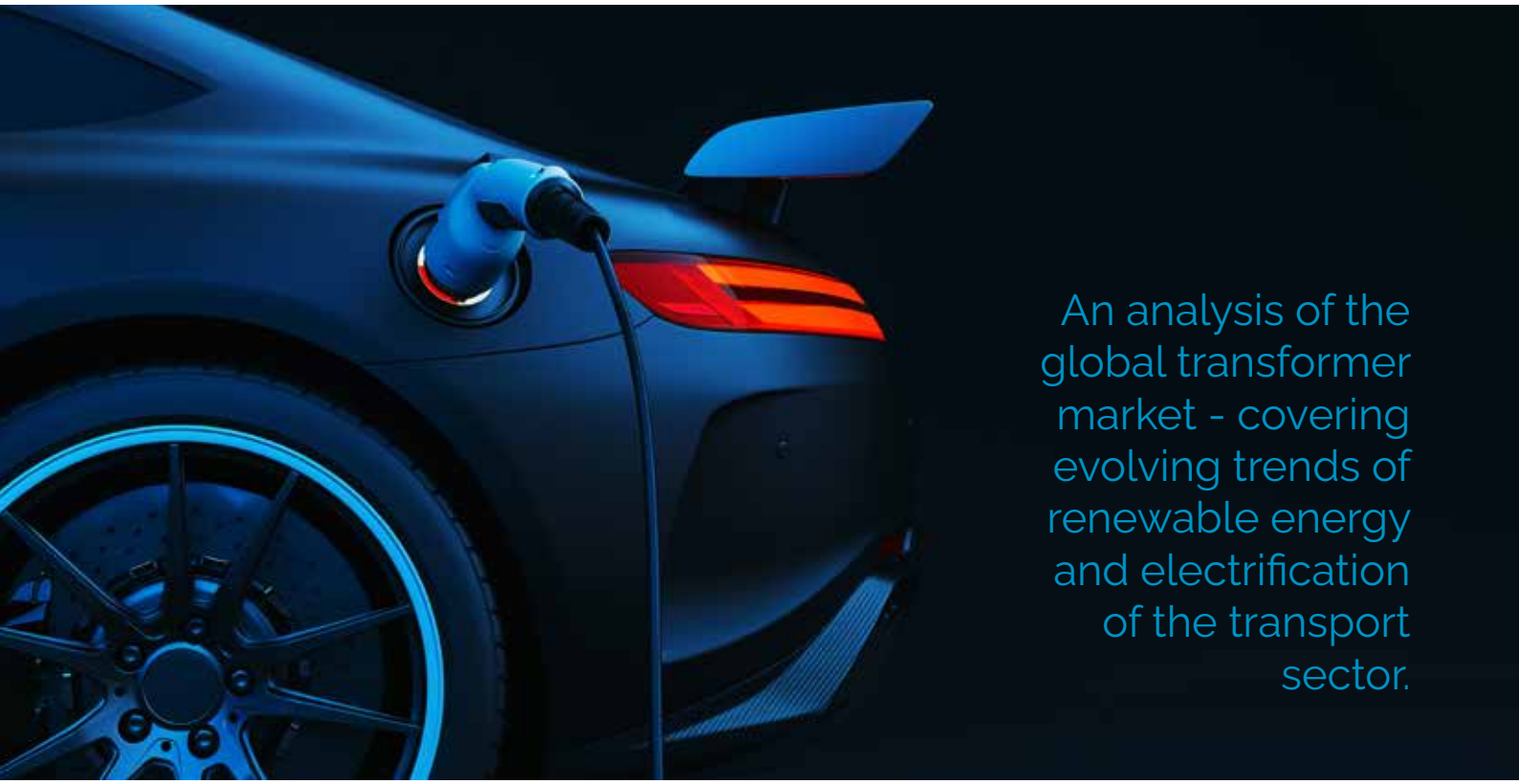
MARKET REPORT:
CLEAN ENERGY TRANSITION: THE IMPACT OF EVS AND RENEWABLES ON TRANSFORMER MARKET



An analysis of the global transformer market - covering evolving trends of renewable energy and electrification of the transport sector.

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DEFINITIONS AND **ACRONYMS**

APAC	Asia-Pacific
DISCOM	Distribution Company
EV	Electric Vehicle
EMEA	Europe, the Middle East & Africa
IEA	International Energy Agency
MEA	Middle East Africa
O&G	Oil and Gas
T&D	Transmission and Distribution
YoY	Year on Year
EGD	European Green Deal
GHG	Greenhouse Gas

EXECUTIVE **SUMMARY**

In 2021, the global transformer market was able to recover from the dip experienced in 2020. The spread of Covid-19 has been contained and the economic slowdown has reversed. Asia Pacific recorded the largest total transformer market at USD 18.61 billion, followed by North America at USD 7.94 billion, Europe at USD 4.89 billion, the Middle East and Africa at USD 3.59 billion, and South America at USD 2.21 billion.

Service sectors like travel, leisure and transport that especially suffered during the pandemic have been able to bounce back but are still not at the pre pandemic levels.

Broadly speaking, investments in transmission and distribution network to meet demand from growing industries and residential sector, to integrate power from renewable sources and to complement the growing charging infrastructure have driven the transformer market in 2021.

In the Asia Pacific region, demand can be attributed to the growing industrial base and increased investment in transmission and distribution, especially in countries like India.

In Europe, aggressive renewable energy targets to be met under the Fit for 55 package are driving the demand. Additionally, the electric vehicle installed base in Europe, accounting for a large proportion of the global installed base, demands transformers to manage additional loads introduced to the grid from charging.

In Middle East Africa, many development projects are underway as the region attempts to reduce reliance on oil resources and diversify the economy. Several power projects are also being developed to add additional capacity into the system.

In South America, most of the demand is driven by the development of renewable energy. There is a lot of potential for development of wind and solar energy which has not yet been tapped into fully. The adoption of electric vehicles is much slower in this region compared to others and the region has a long way to go when it comes to electrification of the transport sector.

In North America, an aging grid means that the market is primarily driven by replacements while new additions are supporting charging infrastructure for the growing electric vehicle market and integration of power from renewable sources.

MARKET **SNAPSHOT**

The global transformer market crossed USD 37 billion in revenue in 2021. Asia Pacific accounted for 50% of the global market while the other 50% was split among the remaining regions. Within Asia Pacific, the market was dominated by China and India. North America was the second largest market with a global share of 21% followed by Europe at 13%, Middle East Africa at 10%, and South America was the smallest market with a share of only 6%.

The global demand for transformers experienced a dip in 2020 due to the slowdown caused by Covid-19. The transformer market is driven by utility, generation, and industry and all these sectors were hit by the pandemic causing a retraction in the demand.

In 2021, the market was able to recover from the dip due to increased investment in the T&D sector to integrate current and future renewable generation. Furthermore, increasing penetration of electric vehicles and their charging infrastructure has led to increased investment in the power grid specifically expansion projects driving the demand for transformers. This trend is expected to continue in the future and become more pronounced as the electric vehicle market grows. The impact of growing share of renewable in the energy mix is also expected to increase as countries set aggressive policies to meet their climate goals. PTR expects the global transformer market to grow positively.

INTRODUCTION

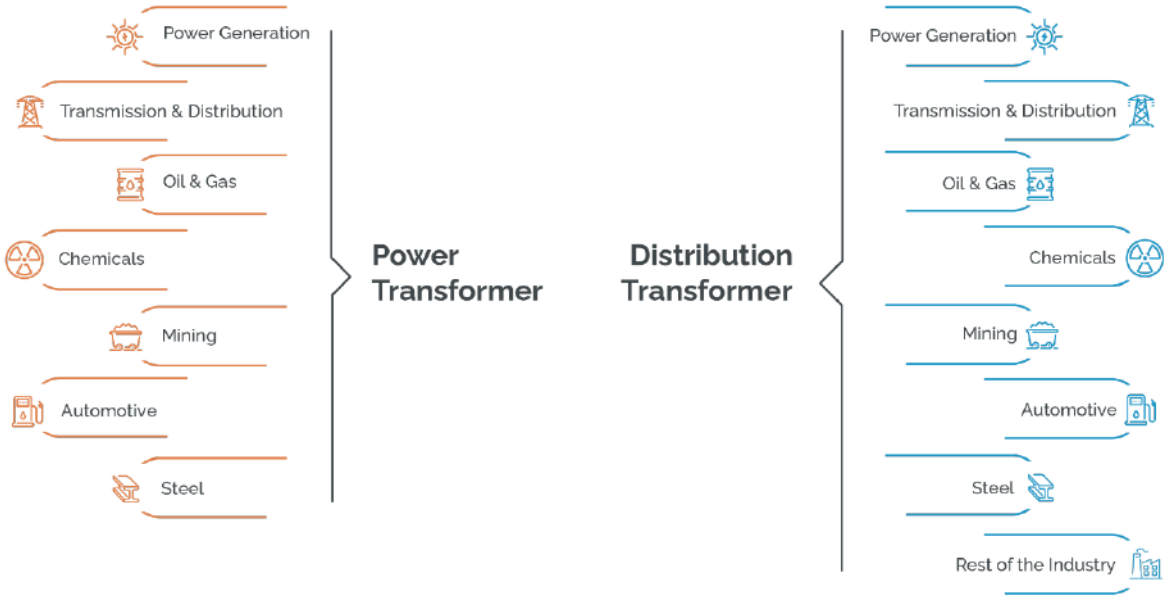
DEFINITION OF TRANSFORMER MARKET SEGMENT

A transformer is defined as a passive electrical device that transfers electrical energy from one circuit to another through the phenomenon of electromagnetic induction. Transformers can either be used to increase ("step up") or decrease ("step down") the voltage between different circuits.

Voltages are stepped up, at power generation facilities, using transformers to minimize heat losses while transmitting electricity over long distances. This high voltage is then stepped down via T&D infrastructure to different low voltage levels depending on end user applications. The industrial segment also needs transformers to step down the voltage from input feed to bring it to the level where it can be used on plant secondary distribution. However, energy intensive industries, like O&G, and the steel and mining sector, use power transformers while less energy intensive industries use distribution transformers.

We will cover both power and distribution transformers irrespective of distinctions based upon types, such as oil-immersed, dry-type, single-phase, three-phase, pole-mounted, or pad-mounted. Power transformers are defined as transformers operating at a voltage level greater than 42kV while distribution transformers are defined as transformers operating at a voltage level 42 kV or below.

Figure 1: Covered Applications of Transformers



TRANSFORMER MARKET

GLOBAL LANDSCAPE

The global transformer market in 2021 crossed USD 37 billion with power transformers accounting for USD 23.6 billion and distribution transformers at USD 13.7 billion. The market slowed down in 2020, however as predicted by PTR, it has bounced back to 2019 levels in 2021 and in some cases has even exceeded it.

The driving factors of the market recovery were:

Investments in the transmission and distribution infrastructure

Investments in generation especially renewable energy in line with the ambitious wind and solar targets for 2030

Revival of the industrial sector which was severely impacted by Covid-19

Growing EV penetration due to the shift towards electrification in the transport sector as part of the efforts to reduce carbon emissions.

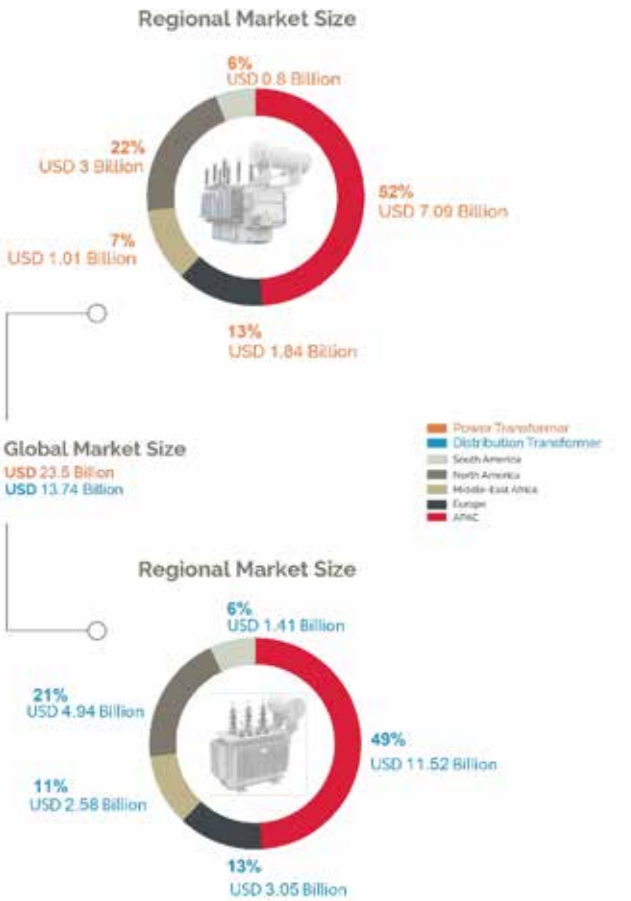
According to IEA data published in June 2021, the expected global investment in grids in 2021 stood at USD 286 billion. This was a 10% increase from the level of investment in 2020. Out of this, USD 187 billion would be invested in the distribution grid and USD 98 billion in the transmission grid. The investment in distribution grid is at a higher than the investment in transmission because the impact of renewables and EVS is more pronounced at distribution level.

IEA has also reported the investment in energy as USD 530 billion in 2021, which is a 3% rise from the investment in 2020. Investment in renewable power was reported as USD 336 billion in 2019, USD 359 billion in 2020 and was expected to cross USD 367 billion in 2021 at the time of publishing, clearly illustrating an upward trend.

This year-on-year increase in investment in transmission, distribution and generation sector will be reflected in an increased demand for transformers, both distribution and power.

Figure 2: Global Transformers Market

Source: PTR



ASIA PACIFIC

At 50%, Asia Pacific has the largest share of the global transformer market. The power transformer market crossed USD 11.5 billion in revenue, equivalent to 49% of the global power transformer market, while the distribution transformer market amounted to USD 7.09 billion, or 52% of the global distribution transformer market.

The two main factors driving the transformer market in the region are T&D projects and industrial growth.

Power grid expansion is taking place rapidly in India.

10,392 MVA was added by June 2021 against annual target of 81,545 MVA for FY2021-2022 (13% of total target achieved).

1,550 circuit km in transmission network expansion was completed by June 2021 against annual FY2021-2022 target of 19,255 circuit km (8% of total target achieved).

The manufacturing sector in the region is growing for instance Vietnam has emerged as a manufacturing hub due to:

Trade wars between United States and China have resulted in Vietnam becoming a more attractive manufacturing site

Furthermore, during Covid-19, China was locked down and disconnected from the world

Vietnam was already starting to develop as an alternative manufacturing site because of higher labor costs in China.

According to IEA, in 2021 the investment in transmission and distribution amounted to USD 16 billion in India and USD 82 billion in China. Compared to 2020, investment has increased 11% in India and 17% in China. This is expected to increase further in the coming years as the region moves towards expanding and upgrading the power grid especially to integrate the additional capacity from renewable energy. Recently, the Power Grid Corporation of India approved an investment of USD 88 million for transmission projects.

Key Markets

India has a market share of 17% in the Asia Pacific transformer market with the power transformer market crossing USD 2 billion and the distribution transformer market crossing USD 1 billion in 2021.

China is the biggest market in Asia Pacific region owing to both to its economic size its population and accounted for 39% of the total transformer market in the region. The power transformer market was USD 4.14 billion, and the distribution transformer market was USD 3.05 billion in 2021.

NORTH AMERICA

North America accounted for 21% of the global transformer market. The power transformer market crossed USD 4.9 billion in revenue, equivalent to 21% of the global power transformer market, while the distribution transformer market was USD 3 billion, or 22% of the global distribution transformer market.

The main factors driving the transformer market are the penetration of renewables in the energy mix and replacements of the aging power grid.

For the US, President Biden is calling for 80% renewable clean power by 2030.

Canada has set a goal of increasing the share of zero emitting sources for power generation to 90% by 2030.

The transformer fleet in the US is aging with more than 70% of transformers older than 25 years and approximately 15% already having exceeded the average life expectancy of 40 years. Most of the investment in grid infrastructure took place in the period between the 1950s and the 1980s and hence there is a need for a complete overhaul.

According to IEA, the transmission and distribution investment in the USA amounted to USD 76 billion in 2021. A huge share of the future investment in the power grid will come from Biden's infrastructure bill that has allocated USD 65 billion to clean energy transmission and grid infrastructure.

Key Markets

USA accounted for 79% of the total transformer market in North America with a power transformer market of USD 3.85 billion in revenue and a distribution transformer market of USD 2.4 billion. The EIA reported that 85 GW of new generating capacity will come online from 2022 to 2023 and that solar power and batteries will account for 60% of it.

EUROPE

Europe accounted for 13% of the global transformer market. The European power transformer market amounted to USD 3.05 Billion, while the distribution transformer market was USD 1.84 billion in revenue.

The two main factors driving the transformer market in the region are increasing share of renewables in the energy mix and the penetration of electric vehicles.

As per the Fit for 55 package, the EU commission has raised the target for renewables from 32% to 40% by 2030. Renewables accounted for approximately 20% in 2019.

Europe accounted for 30% of the electric vehicle market in 2021. The annual market is expected to increase in the future as the region moves towards complete electrification in the transport sector and elimination of internal combustion engine (ICE) vehicles.

According to IEA, transmission and distribution investment in the region amounted to USD 56 billion in 2021. This has followed a steady trend over the years, and we can expect a similar or higher level of investment in the coming years which will be directed towards modernization and digitalization of the power grid to facilitate the integration of renewable energy and EV charging infrastructure.

Key Markets

Germany accounted for 14% of the total transformer market in Europe with a power transformer market of USD 279 million in revenue and a distribution transformer market of USD 361 million.

UK accounted for 10% of the total transformer market in Europe with a power transformer market of USD 275 million in revenue and a distribution transformer market of USD 205 million.

MIDDLE EAST & AFRICA

Middle East and Africa accounted for 10% of the global transformer market. The power transformer market amounted to USD 2.58 Billion in revenue, equivalent to 11% of the global power transformer market while the distribution transformer market crossed USD 1 billion, or 7% of the global distribution transformer market.

The two main factors driving the transformer market in the region are power generation and development projects.

KA-CARE Nuclear Power Reactor in KSA with an investment of USD 33,550 million and KAPP - Al Khiran IWPP: Phase I: Power Plant in Kuwait with an investment of USD 488 million are examples of high investment power projects underway in the region.

664,000 MVAs in transmission capacity are planned in the region over the next 10 years which will translate into demand for both power and distribution transformers.

Eskom which is the largest South African Utility is planning an investment of USD 7.2 billion in wind and solar energy by 2030 in the bid to increase its renewable energy contribution to power generation

Transformer demand is directly tied with infrastructure projects like Neom City development project in KSA with an investment of USD 500,000 million, Al-Khiran Residential City Development Project in Kuwait with an investment of USD 13,900 million and Lusail City Development Project in Qatar with an investment of USD 8,268 million

Key Markets

Saudi Arabia accounted for 42% of the total transformer market in MEA with a power transformer market of USD 1.29 billion in revenue and a distribution transformer market of USD 0.23 billion.

SOUTH AMERICA

South America's share of the global transformer market was 6%. The power transformer market crossed USD 1.4 Billion in revenue, equivalent to 6% of the global power transformer market, while the distribution transformer market amounted to USD 0.8 billion, or 6% of the global distribution transformer market.

The main driving factor in the region is the penetration of renewables. Although the region is working on the electrification of the transport sector, the adoption rate is still quite low with little impact on the power grid.

Brazil increased its renewable energy investment by 74% to USD 6.5 billion. This will help the country achieve its goal of 45% renewable energy in the energy mix by 2030. At the same time, we can expect investment for the expansion and modernization of the power grid to transmit and distribute the electricity from renewable sources. This will in turn give rise to demand for legacy grid equipment including transformers.

Key Markets

Brazil accounted for 18% of the South American transformer market with a power transformer market of USD 705 million in revenue and a distribution transformer market of USD 260 million.

Figure 3: Key Transformers Market

Source: PTR

FUTURE OUTLOOK

Investment in the grid in 2021 was higher than the previous year and this trend is expected to continue in the future as the renewable capacity and electric vehicle market grows.

China, with the largest share in the transmission and distribution grid investment globally, will lead the growth of the transformer market. Accounting for 39% of the transformer market in Asia Pacific and 19% of the transformer market globally, movements in this market will have a huge impact than other regions or countries. The country with the second largest share is United States which has also invested large amounts in T&D in 2021 and is expected to continue the trend under President Biden's bipartisan infrastructure bill.

This investment will drive the demand for legacy grid equipment including transformers and switchgear. T&D will be the biggest driver of transformer market followed closely by generation and industry.

Within the distribution transformer, dry type transformers are expected to grow at a faster rate than oil type transformers. This is because their growth is directly tied to the growth of renewables, being preferred for wind turbines and solar installations.

When it comes to technology, PTR expects growth in the digital transformer market. This growth will come from the increased focus on digitalization of the grid to enable the integration of charging infrastructure load and electricity from renewable energy source which is dynamic in nature.

KEY MARKET **TRENDS**

Figure 4:
Key Market Trends (2021)

EVOLVING TARGETS OF CLEAN ENERGY AND EFFICIENCY

Governments around the world have set ambitious renewable energy targets that have evolved over time to ensure that the goals of the Paris Agreement are met. Several initiatives have been introduced in the effort to drive the transition towards solar and wind energy and to achieve carbon neutrality.

EUROPEAN GREEN DEAL - FIT FOR 55

The European Commission established the European Green Deal (EGD) to set out policy initiatives aimed at helping the EU to achieve its 2050 climate neutrality goal. The Fit for 55 package, released by the EGD, is a set of proposals whose aim is to align with the EU's 2030 and 2050 climate goals. Under this package.

The following two points of the EGD proposal have the most direct and significant impact on the power grid:

1. Amendment of the Renewable Energy Directive

This sets a new 2030 target of 40% (up from 32%) energy use from renewables by 2030. This translates to a commitment, by the EU, to add 500 GW by 2030 and will be a key instigator for the legacy grid to become greener moving forward. Since the end-goal of the EGD is for Europe to become the first climate neutral continent by 2050, it makes sense for the T&D equipment being used to support this massive integration of renewables into the grid to utilize environmentally friendly technologies in the coming years.

To comply with this deal, new green raw material like Thyssenkrupp Green steel is expected to enter the market. We can also expect an increased use of biodegradable transformer oils. As an example, in early Jan. 2021, manufacturer Itaipu Transformadores partnered with Cargill BioIndustrial to use FR3® natural ester fluid for their new line of ecological transformers.

2. Amendment of Energy Efficiency Directive

This calls for the EU to increase the grid's efficiency, setting a more ambitious binding annual target, raised from 32.5% to 36%.

The EU Ecodesign Directive establishes a framework under which manufacturers of energy-using products are obliged to reduce energy consumption and other negative environmental impacts occurring throughout the product life cycle.

Tier 2 is in effect from July 1st, 2021. (Tier 2 and Tier 3 are revisions of Tier 1, the original directive)

The European Commission estimates that 2.9% of all energy generated across EU27 and the UK is wasted through transformer losses. This amounts to 93 TWh which is equivalent to the electricity consumed in Denmark over three years.

Tier 1 transformers can be purchased from existing stock, but no further work can be done on them. Manufacturers and importers can't deliver Tier 1 transformers but distributor to distributor and distributor to user selling can take place if the order was placed before 1st July 2021.

As a result of this regulation, the cost of manufacturing is expected to go up resulting on a price increase of the final product.

The commission will review this regulation in the light of technological progress and will present the results of the assessment, including, if appropriate, a draft revision proposal, to the consultation forum no later than 1 July 2023. The review will address the following issues: the extent to which requirements set out for Tier 2 have been cost-effective and the appropriateness to introduce stricter Tier 3 requirements.

US CLEAN ENERGY PLAN

According to President Biden's executive order, the federal government will use its scale and procurement power to achieve five ambitious goals:

100% Carbon pollution-Free Electricity (CFE) by 2030, at least half of which will be locally supplied clean energy to meet 24/7 demand.

Purchase 100% Zero Emission Vehicle (ZEV) by 2035, including 100% zero-emission light-duty vehicle acquisitions by 2027.

Net-zero emissions from federal procurement no later than 2050, including a Buy Clean policy to promote use of construction materials with lower embodied emissions.

A net-zero emissions building portfolio by 2045, including a 50% emissions reduction by 2032.

Net-zero emissions from overall federal operations by 2050, including a 65% emissions reduction by 2030.

President Biden's Bipartisan Infrastructure Law has allocated a USD 65 Billion investment for clean energy transmission and grid infrastructure. Out of this, USD 21 billion is for clean energy demonstrations and research hubs (USD 8 billion for clean hydrogen), USD 3 billion for smart grid infrastructure, USD 2.5 billion for transmission facilitation program to develop critical transmission lines and USD 11 billion to states, tribes and utilities to build a resilient power grid against weather and cyber-attacks. Biden's infrastructure bill will be a huge driver of the transformer demand in the country in the coming years.

CHINA'S 3060 TARGET

China aims to achieve carbon emission peaks in 2030 and carbon neutrality in 2060 and this is collectively referred to as "3060 Target". The country is making efforts to achieve this target in advance of the set timeline.

The government has released a national decarbonization roadmap also referred to as 1+N where 1 means the overall guideline for carbon neutrality and carbon peaking and N refers to the policies addressing sectors and regions. According to this plan:

40 GW of hydropower will be added by 2030.

New-energy storage capacity will reach 30 GW by 2025, while pumped hydro capacity will reach 120 GW by 2030.

All new long distance power lines that cross provinces should transmit at least 50% renewable power.

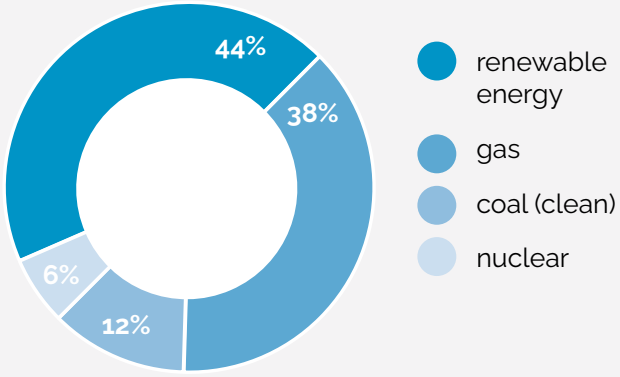
40% of all new vehicles each year will be powered by new energy by 2030 and green travel will account for at least 70% of trips in all cities with more than 1 million people, and oil demand from land transportation will have peaked.

Green building standards will be fully implemented in towns and cities by 2025, solar roofs will cover half of new factories and public buildings, and urban buildings will get 8% of their energy from renewable-integrated construction materials.

UAE ENERGY STRATEGY 2050

Launched in 2017, the strategy aims to increase the contribution of clean energy in the total energy mix from 25% to 50% by 2050 and to reduce the carbon emissions from generation sector by 70%. In addition to this, there is a focus on increasing consumption efficiency to reduce energy losses with a target of 40% for households and companies.

The energy mix being targeted for 2050 is as follows:



Under this strategy, an investment of AED 600 billion (USD 163 billion) has been allocated which will be used to meet energy demand while ensuring that it is met through sustainable means.

SAUDI VISION 2030

This is a strategic framework to reduce Saudi Arabia's dependence on oil and diversify its economy through the development of tourism, infrastructure, education, health and more.

Under this framework, Saudi Arabia has also made a commitment to develop its renewable energy sector. For instance, the country has been operating the 300MW Sakak plant, their first utility-scale solar power project since April 2021 and the 400MW Dumat AL Jandal wind farm, their first utility-scale wind farm within the Kingdom, came online in August 2021. The Saudi government also announced an investment plan of USD 30 billion in the renewable energy sector by 2025 which will help the country reduce its dependence on fossil fuels. Increasing the share of renewables in the energy mix is crucial for the country to reduce its domestic emissions and by extension contribute to reduction of global emissions.

As part of the Saudi Green Initiative:

Cut global methane emissions by 30% by 2030 through the six-sector solution proposed by UNEP.

Reduce carbon emissions by more than 278 million tons per annum by 2030.

Aim to achieve net zero by 2060.

INDIA

In the COP26 summit, India has pledged to achieve net zero carbon emissions by 2070. To achieve this, PM Modi has made a promise to ensure 50% of the energy demand is met through renewables by 2030, developing 500 GW of non-fossil fuel electricity and to reduce carbon emissions by one billion tons.

Several initiatives and projects have been launched to ensure that these goals can be met:

The Ministry of New and Renewable Energy (MNRE) has set an ambitious target of 227 GW of renewable energy by 2022. Out of this, about 114 GW is planned for solar energy, 67 GW for wind and the remaining for hydro and bio.

In July 2021, the MNRE undertook Rooftop Solar Programme Phase II, which aimed to install residential rooftop solar capacity of 4,000 MW in the by 2022 with a provision of subsidy.

Green Energy Corridor Projects aims to facilitate the integration of renewable energy into the existing grid. This will involve modernization of the grid infrastructure to account for the variable nature of solar and wind energy.

In July 2021, NTPC Renewable Energy received the go ahead from MNRE for a 4750 MW renewable energy park at Rann of Kutch in Gujarat. This will be the largest solar park in the country. NTPC targets having over 60GW of renewable energy capacity by 2032 through solar and wind projects.

As illustrated above, countries are investing in wind and solar energy projects to achieve their respective renewable targets. This increase in the generation capacity will call for expansion of transmission and distribution infrastructure. Since a huge percentage of the added generation capacity is coming from renewables, this will require a complete overhaul of the existing infrastructure through modernization and digitalization to facilitate the integration of renewable energy which is dynamic in nature. This in turn will translate into an increase in investment in legacy grid equipment including transformer, switchgear, transmission, and distribution lines etc.

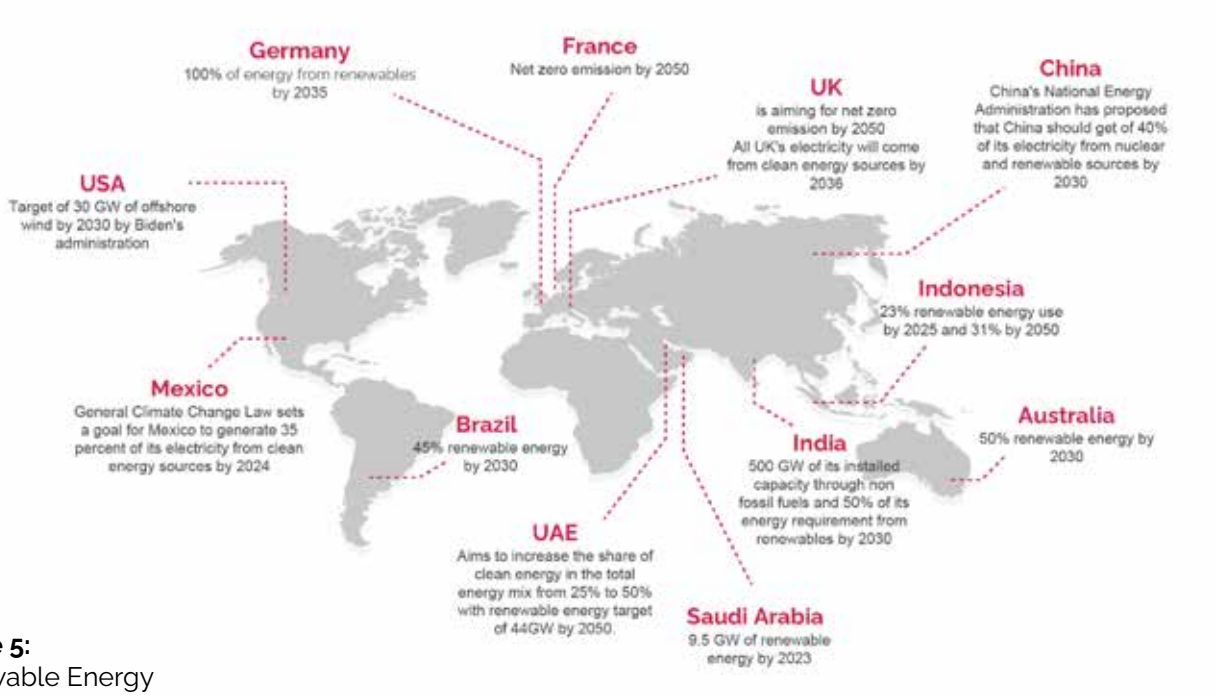


Figure 5:
Renewable Energy Targets

ELECTRIFICATION **IN TRANSPORT SECTOR**

Passenger vehicles are the most talked about when it comes to electrification in the transport sector. However, electric buses and trucks are also gaining popularity and demonstrating significant growth especially in the Americas and EMEA regions. Figure 6 illustrates the growth rates for electric vehicles by region and by type over a 9-year period from 2021 to 2030.

Globally, the electric vehicle market is expected to grow with a CAGR of 22%. This growth is coming from electric buses, electric light commercial vehicles, electric trucks, and passenger vehicles. It is interesting to note that the electric trucks are showing the fastest growth at 43% followed by electric light commercial vehicles at 33%, passenger vehicles at 21% and electric buses have the slowest rate at 9%.

The fastest growing region is the Americas where electric trucks are dominating the growth followed by electric buses. Electric vehicle sales are growing in Europe and Americas especially due to government initiatives supporting the adoption in these regions, however, the market is also growing steadily in the Asia Pacific region. For instance, the government of India has been supporting the EV industry through schemes such as FAME1 and FAME2 which are two phases of the National Electric Mobility Plan (NEMMP) aimed at stimulating the production of electric and hybrid vehicles, China has developed a New Energy Automobile Industry Development Plan, and Australia has allocated USD 132 billion for EV and hydrogen charging under the Future Fuels Fund.

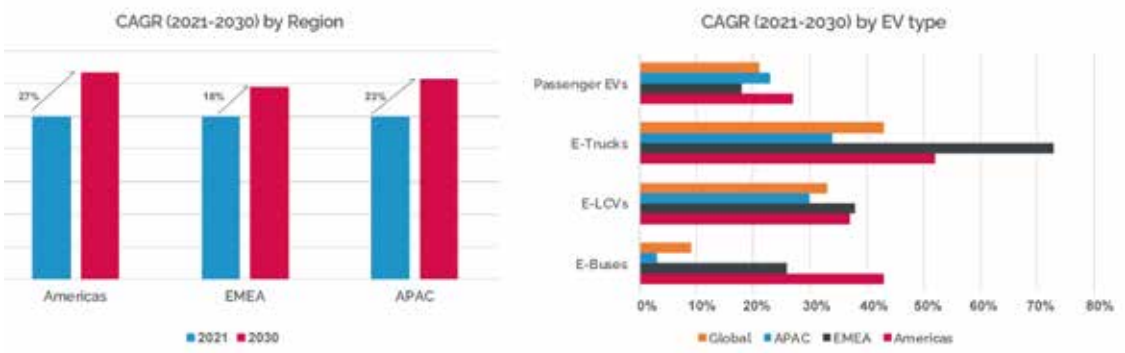


Figure 6: Electric vehicle growth rates

Source: PTR

ELECTRIFICATION TARGETS

Just like renewable energy, countries have set ambitious targets for electrification in the transport sector.

Norway is aiming to achieve 100% electrification target in annual sales by 2025. Netherlands, Denmark, and Sweden are aiming to achieve this by 2030, UK and Germany by 2035. Portugal, Canada, France, and Spain have set this target for 2040. Other countries are not as aggressive and have set targets for around 20% to be achieved by China in 2025, Japan, Finland, and Belgium by 2030 and Australia by 2035. However, a gap has been observed between these targets and the announcements from automotive companies in terms of timeline.

ELECTRIC VEHICLE CHARGING

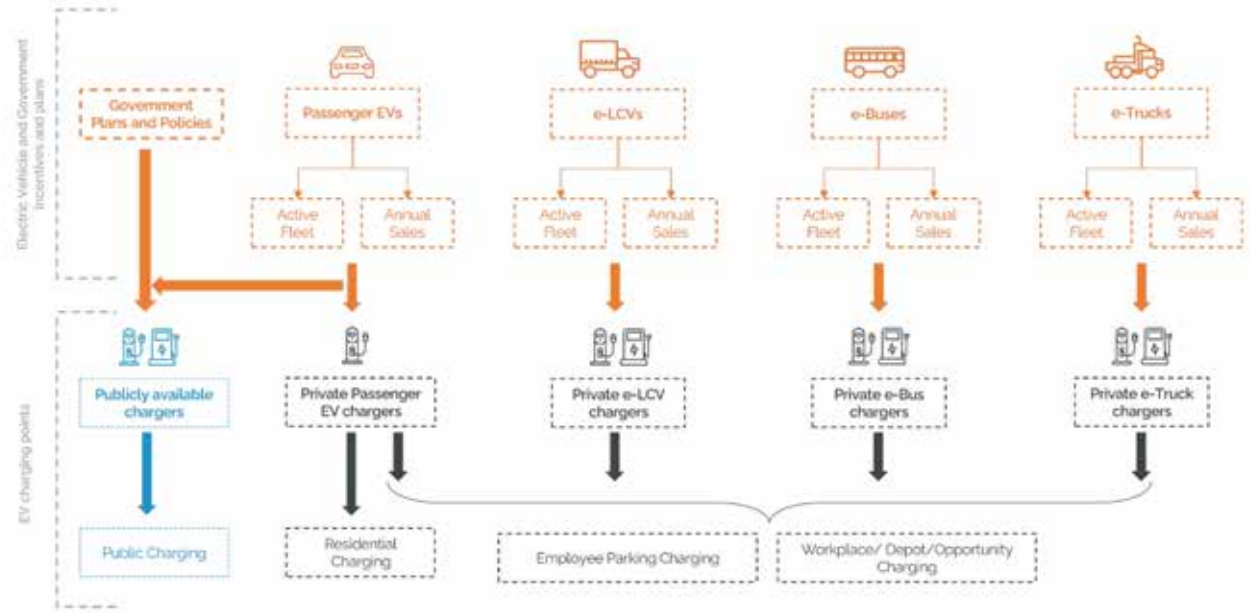


Figure 7:
Charging infrastructure for different EV types

A growing electric vehicle fleet must be accompanied with growth in the charging infrastructure. Figure 7 illustrates the different types of charges for each type of vehicle. The type of vehicle will determine whether the charging infrastructure will be public or private, with passenger vehicles falling in the public charging category and the rest falling in the private charging category. This in turn will determine whether the investment in the grid will come from public or private sector.

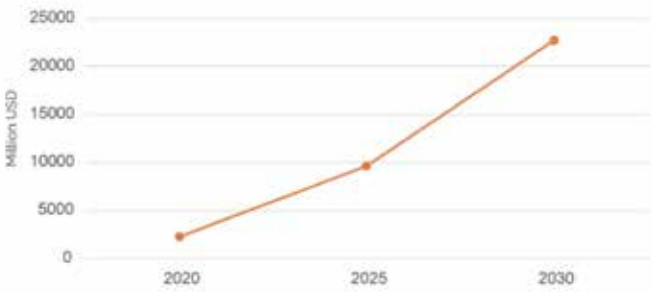


Figure 8: Electric vehicles chargers CAGR (2020-2030)
Source: PTR

Globally, electric vehicle charging market is expected to grow with a CAGR of 23% between 2021 to 2030. This growth is going to be driven by the increased rate of penetration of electric vehicles, implementation of government plans and incentives for charging infrastructure, and decline in the price of chargers as the technology matures. In the case of public EV charging market DC high power charging is expected to grow rapidly. In the private EV charging market, AC chargers will remain the dominant type based on volume comparison, but DC charging is expected to grow exponentially.

There are several types of chargers: AC, DC low power, DC high power and pantographs. The charging capacities for AC is 0-22kW and for DC 31-350 kW. However, charging capacities are now going beyond 350 kW. DC chargers have a direct impact on the distribution grid. As the capacities of these chargers increases through technological development so will the load on the power grid calling for upgrades to the equipment.

Several chargers are being developed that will revolutionize the world of fast charging by reducing wait times for drivers during travel. While government incentives and policies are encouraging the adoption of EVs, these technology developments in the future will further support the transition away from fossil fuels-based cars by addressing driver's concern about slow charging, wait times, charger availability and its impact on travel.

There are two types of charging methods: managed and unmanaged. While both have an impact on the power grid, the nature and extent of that impact varies.

In the case of unmanaged charging, EVs are plugged in when, for instance, people return home from work. This usually coincides with peak times, causing the peak load to increase, and puts strain on the power grid and electrical equipment such as transformers and feeders. This calls for upgrades and additional maintenance costs.

Managed charging can be done in several ways:

EV Time Of Use (TOU) pricing incentivizes charging at off peak hours. This helps in flattening the load curves and reducing the strain on the power grid. However, this could also result in too many EVs being charged during off-peak hours thereby causing another peak load.

Utility controlled charging can ensure that this problem doesn't occur by having sophisticated algorithms to prevent overlapping of charge times. However, this will limit the freedom the user has to charge as they will have to specify the time when they need to use the vehicle next.

Bi-directional charging involves coordination at the end of the utility and the use of battery storage technology. The electric vehicle battery discharges power back into the grid as required helping reduce peak load and absorbs excess generation from renewables when generation exceed demand. In addition, it also helps in regulating voltage. Apart from these advantages to the grid, it allows the owner to earn revenue and reap benefits from the vehicle even when it is not in use making electric vehicles an attractive investment.

CHARGING APPLICATION

The impact of charging on power grid will vary with the applications. There are four types of charging applications:

Residential and workplace chargers are usually private and are integrated into the local energy infrastructure. This means that they have a direct relationship with the load on the grid and are typically installed in residential areas where overnight charging takes place.

Enroute chargers are usually fast chargers to reduce wait time when traveling from one place to another. Higher capacity chargers draw more power from the grid than their lower capacity counterparts.

Destination charging speed will be determined by the duration of the stay at that place which is dependent on the nature of the destination.

IMPACT OF GROWING CHARGING INFRASTRUCTURE

The demand for energy will increase but in short to medium term, it will remain a very small percentage of global electricity consumption. Within that same period however, EV charging infrastructure will present a new challenge to the existing transmission and distribution grid that was not designed for this. To make the grid suitable for this new load will include upgrades and expansions which will in turn drive the demand for legacy grid equipment like transformers and switchgear. It is also important that the grid is powered by renewable energy to ensure that the entire chain from charger to grid is climate friendly and meets country targets for carbon neutrality.

In the efforts to reduce carbon emissions, governments are incentivizing electric vehicles purchase and investing in charging infrastructure to reduce range anxiety and improve refueling experience which are currently the two roadblocks to widescale EV adoption. However, it is important to note that charging infrastructure will draw electricity from the power grid hence increasing the peak load and impacting the grid equipment thus it is important to spend a share of the investment on the power grid.

Without managed charging, required grid upgrades can be as high as $2,500 per EV in a utility's network.

"Make-ready" is the additional infrastructure between the utility-side infrastructure and the actual chargers. Make-ready broadly refers to all necessary electrical infrastructure between the utility grid interconnection and the chargers. This includes stepdown transformers, electric service panels, conduit, conductors (wire), switchgear and power conditioning units (for DCFC), mounting pads or brackets, and other such elements. The cost of the make-ready infrastructure must be factored in when drawing up investment plans for EV adoption.

In Poland, for instance, in addition to the investment allocated to developing charging infrastructure, PLN 1 billion under the program "Development of electricity infrastructure for the development of electric vehicle charging stations" has been allocated for the construction, expansion and modernization of about 4000 km of power lines (overhead and underground) and the creation of about 800 transformer and distribution stations.

DIGITALIZATION OF GRID

Digitalization is fundamental for the integration of charging infrastructure in the power grid. Currently, data is not being monitored at enough points in the grid but by doing so and using sophisticated algorithms, communication between charger, vehicle and grid can be set up. The information gathered can be used to control charging in a specific way. The utility or third part can control the level of charging as per the needs of the grid. This is also known as active managed charging. Smart chargers are becoming increasingly popular. They allow users to intelligently manage the process of vehicle charging.

Furthermore, by employing the phenomena of bi-directional charging, power can flow from vehicle to grid and grid to vehicle thereby taking power from the grid when they are charging and giving it back when the demand for electricity is high, Furthermore, this can help regulate peak load and provide battery backup especially for excess generation from renewables.

SHORE ELECTRIFICATION

Although the primary focus is on renewable energy and electrification in the transport sector, another segment that is gaining traction is shore to ship power. This technology enables vessels to shut down their onboard diesel generators during the berthing periods at docking points and provides electric power for services from the shore with the help of the local grid. This technology will help reduce carbon emissions. According to EU's directives for Alternative Fuel Technologies:

Member States shall ensure that:	(a) At least one installation providing shoreside electricity supply to inland waterway vessels is deployed at all Trans-European Transport Network (TEN-T) primary or core inland waterway ports by January 1, 2025.	(b) At least one installation providing shoreside electricity supply to inland waterway vessels is deployed at all TEN-T comprehensive inland waterway ports by January 1, 2030.

Furthermore, they have set a target of 13% reduction in maritime GHG emissions by 2035, 26% reduction in maritime GHG emissions by 2040 and 75% reduction in maritime GHG emissions by 2050.

HYDROGEN

Hydrogen is being developed as a fuel for the energy transition. Although it is in the early stages of development and adoption, this is something to keep an eye on. It is naturally occurring and the most abundant element in the universe. Hydrogen contains three times more energy than oil and natural gas of a similar volume and hence, is significantly more efficient than fossil fuels.

Hydrogen only occurs on Earth combined with other elements and although hydrogen itself produces no GHGs, the electricity used in the production of hydrogen can. As of now, 95% of hydrogen production is fossil fuel based, according to IEA, and globally is responsible for 830 million tons of CO_2 emissions per year. So, for hydrogen to play a vital role in the energy transition around the world, its production needs to shift to renewable based.

Currently most of hydrogen demand comes from industrial applications such as refining and petrochemical, but in the future, hydrogen might play a pivotal role in the electricity and transportation sectors.

CONCLUSION

There is an energy transition underway with countries working on increasing the share of renewables in the energy mix and reducing carbon emissions to achieve the ambitious Paris Agreement targets set for 2030. This energy transition begins with the generation sector however, it has direct impact on the transformer market. Electric vehicles are the future as countries move away from fossil fuel-based vehicles to achieve their carbon neutrality targets. As more electric vehicles enter the market, the charging infrastructure will impact the grid and the demand for transformers. The extent of the impact however will vary region to region as do the renewable targets, level of EV penetration and the level of investment in the grid.

Power grids will need to be expanded and upgraded to prepare them for the energy transition underway. This will drive the demand for transformers in the coming years. Apart from the quantitative impact, we can expect to see technological advancements like digitalization of transformers. This is fundamental to developing a digital power grid which is able to handle the introduction of decentralized energy sources and the dynamic charging load.

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