Policymakers' corner: Presenting recent trends in different energy transition pathways to enable net-zero emissions by 2050

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EcoDataTrend is an independent and non-profit policy research organization that utilizes its expertise in comprehensive data collection, analysis and reporting, clean energy technologies and sustainability, coupled with its research-driven advocacy for innovative solutions to actively support production and utilization of energy in a responsible and sustainable manner. Specially, EcoDataTrend specializes in data collection and reporting of energy transition trends (with particular interest in clean energy technologies) and environmental pollution trends, particularly emission trends in greenhouse gases. Key areas of focus are (i) Energy Transition and Clean Energy Technologies, (ii) Data Collection and analysis and (iii) Climate Action and Sustainability. Learn more at www.ecodatatrend.com

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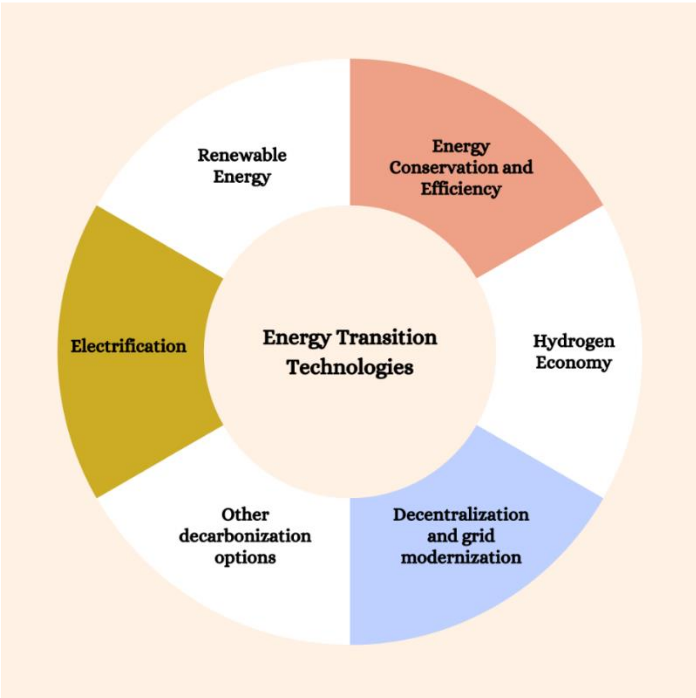
Introduction

In line with Paris Agreement of 2015, there is need to limit temperature rise to 1.5°C to prevent global warming. This requires reconfiguration of existing energy systems, that are the main emitters of greenhouse gases. Projections show that emission of greenhouse gases need to be reduced by 60 – 79% globally, if the goal of the Paris Agreement by 2050 with little or no overshoot. From the different scenarios modelled to achieve this, there is need to transition existing energy systems to energy sources that are clean so as to ensure significant reduction in the emissions from the existing energy systems.

Achieving this energy transition requires the deployment of technologies that would limit emissions from the chain of energy production and utilization. These technologies offer mitigation options to these existing systems, enabling transition to a future energy system. Also, these technologies are critical to achieving net-zero energy systems globally, that is vital to sustainability. An overview of these mitigation options (technologies) is presented in this article to bring into perspective, the different options are that currently commercialized globally. It is believed that policymakers and other critical stakeholders would be provided with vital information on the current state of these technologies, to enable their adoption, especially in emerging economies and developing countries.



An overview of Energy transition pathways

Renewable Energy Adoption

At the forefront driving energy transition are renewable energy sources, which play a critical role in limiting emissions from the electricity sector. Renewables refer to energy from solar, wind, hydropower, geothermal and nuclear sources, which are infinite and sustainable, unlike fossil fuels that are finite. Due to the criticality of renewables to the achievement Paris Agreement target based on their market readiness and significantly dropping cost, it is reported that global renewable capacity needs to be tripled by 2030 to ensure that net-zero emissions is achieved by 2050, as indicated at COP28. Specifically, renewables are able to enable the strategic from shift from fossil fuel use by significantly decarbonizing the electricity sector, by fostering the use of solar, wind, hydropower and nuclear for electricity production.

Putting this in perspective, the share of renewables for electricity has grown from 18.71% as at 2000 to 30.24% as at 2023, leading to significant drop in energy-related CO_2 emissions.

Set of Solar PVs being installed for renewable power generation

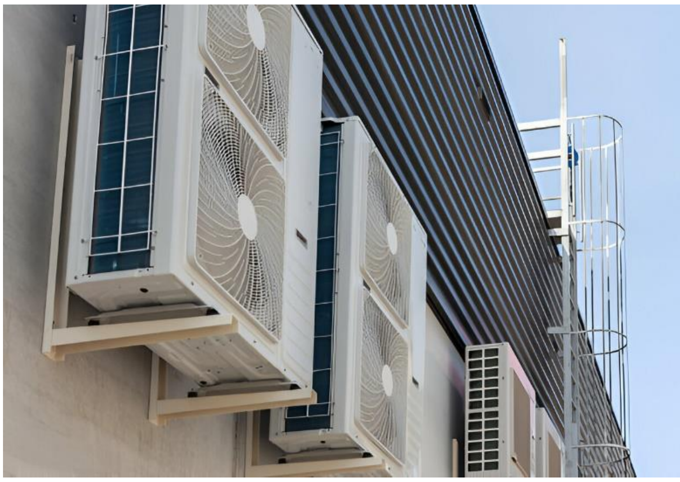
Recent trends in the renewable energy sector show that renewable energy technologies have witnessed significantly drop in prices. Report from IEA indicates that spot prices of solar PVs dropped by 50% in 2023 based on year-on-year basis while the manufacturing capacity has tripled compared to 2021 levels of manufacturing. Also, ~96% of onshore wind capacity and utility solar PV installed in 2023 have lower generation costs than natural gas and coal plants constructed in 2023. This goes to show that renewable energy technologies are gaining economically against fossil fuels, showing capacity to drive energy transition within the electricity sector. In fact, an estimated 507 gigawatts of renewable energy electricity were added to global renewable energy capacity, which is 50% higher than additions made in 2022.

It is important to note that the adoption of renewables is strongly tied to the large-scale development of power grids. Recent report from Bloomberg shows that the cost of investment of power grids (estimated at USD 24.1 trillion) by 2050, needed to transmit renewable-powered generated electricity, is higher than the investment in renewables, estimated at USD 22.7 trillion by 2050. Further, a vital element in renewable energy adoption is battery technology, which solves the intrinsic problem of intermittency facing renewables. Currently, lithium-ion batteries are the go-to option due to ~90% cost reduction, higher energy density and longer lifetime, enabling their use in mini-grids, solar home systems, behind-the-meter batteries and utility-scale battery projects.

Energy Conservation and Efficiency

Regarded as the "first fuel" in the energy transition discourse, energy conservation and efficiency offers the most cost effective and quickest method to achieve clean energy transition. This mitigation pathway offers the opportunity to reduce global energy demand, minimize energy wastage and optimization of energy resources, which ultimately limits the use of fossil fuels, and reduce global emissions. In this case, energy conservation and efficiency has gained recognition in reducing energy costs, whole also ensuring energy security for countries; consequently, this has resulted in reduction in energy intensity.

Report from IEA shows that in 2022, global energy intensity slowed by 2%, while in the EU (which has experienced disruptions to its energy systems), a higher drop of 8% was recorded. The highest progress in energy intensity reduction of 14% was recorded in Netherlands in 2022. While most developed economies are making progress in reducing energy intensity, significant energy demand in Asian economies (especially in China) continues to limit global progress in energy intensity and increase energy demand. A lot of the energy demand is in specific sectors such as building, transport, electricity and buildings. However, it is reported that the building and transport sector recorded the highest reduction in energy intensity amongst these sectors.



Heat pump for space heating

A reduction of about 25% in energy intensity was recorded in energy consumed per unit of floor area and energy used per passenger kilometre. Interestingly, there are technologies on track that are able to drive reduce energy intensity in specific sectors while others require more attention to ensure that they are able to ensure energy conservation and efficiency. An overview of these technologies in the different sectors and their level of contribution to energy efficiency is presented below.

S/N	Sectors	Technologies	
		On track	**Requires more effort**
1	Building	Lighting	Heating, space cooling, heat pumps and appliance & equipment
2	Transport	Electric vehicles	Cars, vans and rail
3	Electricity	-	Grid scale storage, demand storage and smart grids
4	Industry	-	Light industry (cement, chemical products manufacturing, textiles, ferrous metals, pulp and paper etc.)

Electrification

The concept of electrification focuses on replacing processes and technologies utilizing fossil fuels such as gas boilers and internal combustion engines with alternatives that are electrically powered. Often times, these electrically-powdered equivalents have reduced energy demand and more process efficiency, leading to lower emission footprint. Electrification is regarded as one of the most important pathways for global CO_2 reduction and reach net-zero, hence it is well integrated into different energy transition scenarios.

Specifically, a significant amount of CO_2 emission reduction recorded via electrification is through the use of electric vehicles. In recent times, this trend has even become more significant as the number of registered electric vehicles on the road, hitting 40 million globally, according to the Global Electric Vehicle Outlook 2024. In fact, in 2023, a total of 14 million sales was made with 95% of these sales taking place in China, US and Europe. It is important to note that these sales are 600% higher than total sales of electric vehicles recorded in 2018, showing the growth in global EV adoption.

An electric vehicle getting charged at an EV charging station

Currently, the price parity between electric vehicles and internal combustion engine vehicles present barrier to the adoption of electric vehicles in countries with low customer purchasing power. In this regard, electric two- and three-wheelers are becoming popular as a pathway of electrification in the transport sector; in 2023, it constituted 13% of electric vehicle sales. This specifically applies to Latin America and Africa where there is already a market for two- and three-wheeler, hence its adoption is promising for decarbonising mobility. Meanwhile, it is vital to highlight that infrastructure (as applies to charging infrastructure) remains a significant challenge to the widespread adoption of electric vehicles.

Further, global heating in building emits about 10% of global emissions (which amounts to 4 gigatonnes of CO_2 annual emissions) as outlined the report on heat pumps by the IEA. Hence, electrification of space heating using electric heat pumps (which is found to consume 300 – 500% less energy than a typical gas boiler) offers a reliable element of electrification pathway to global net-zero. This is in addition to the fact that space heating consumes about one-sixth of global natural gas demand, hence use of heat pumps would reduce emissions via reduced natural gas production and utilization, limiting carbon footprint.

Decentralization and grid modernization

In the bid to increase renewable energy adoption especially within the electricity sector (whose emission increased by more than 200 million tonnes of CO_2 in 2022) as a means to drop emission from the sector, it is vital to resort to decentralized electricity systems. In this case, the model of energy production and consumption shifts from a centralized system where large power plants dominate to a distributed model where smaller scale energy production systems where energy generation points are located to the consumers. In this case, a key element of decentralization is embedded generation

Decentralization enables the incorporation of diverse renewable energy sources in a manner that affords resilience, effective management, amidst variability. Therefore, without the concept of decentralization, the significant progress recorded in global renewable capacity would face hindrance in its incorporation it into the centralized energy system. Another critical aspect of this pathway is the grid modernization. Due to its importance, it is estimated that the total investment required for power grids, which encompasses grid modernization (which is valued at USD 24.1 trillion) exceeds investments in renewables estimated by USD 22.7 trillion, if net-zero is to be achieved by 2050, according to a report by Bloomberg.

Extensive power grids used for renewable incorporation

Specifically, it is reported that there is need to add, refurbish and modernize over 80 million kilometres of grids (which an equivalent of the world's existing electricity grid) by 2040, if climate goals are to be achieved. The need for grid modernization is also vital as there is over 3000 gigawatts of renewable energy capacity, waiting to in grid connected queues waiting to be connected into the power grid. Also imperative is the fact the concept of grid modernization encompasses smart and digital grids, with capacity to react intelligently to the variabilities and intermittency inherent in the massive increase witnessed in renewable energy capacity.

Hydrogen economy

Hydrogen is an efficient, versatile and clean energy carrier that finds strong applicability in the decarbonization of hard-to-abate sectors. Hence, it is regarded as a vital energy option that can drive energy transition in these sectors, while also offering at-scale energy transport option to resource-constrained regions. It is important to note that the bulk of hydrogen demand is in industrial application (chemical sector) and refining, with limited demand found in power, transportation and synfuel production.

It is worthy of note that the production, storage, distribution and utilization of hydrogen form an evolving economy known as hydrogen economy, which is gaining prominence globally. Currently, the production aspect of the economy (which is receiving significant attention in terms of research and development) is dominated by grey hydrogen, accounting for ~62% of global production in 2021, while brown hydrogen accounted for 21%. Interestingly, low-emission hydrogen such as blue hydrogen and green hydrogen accounts for about 0.7% of global production in 2021.

Green hydrogen has increasingly become popular in recent times due to its environmentally friendly nature, with low kg of CO_2 produced per kg of H_2. For instance, scientific evidence shows that green hydrogen from wind energy has carbon footprint of 0.6 kg CO_2 per kg H_2 while grey hydrogen has footprint of 13.9 kgCO_2 per kg H_2. Further comparison of the different types of hydrogen (especially those that influence energy transition) is presented in the table below. Meanwhile, one significant challenge that faces green hydrogen production is high cost, currently standing at USD 4.5 – 6.5 per kg as outlined by a report from Hydrogen Council, which is driven by high cost of capital, high cost of building electrolyzer plants amongst other process factors. However, it is projected that the cost would drop to 2.5 – 4.0 USD per kg towards 2030.

Green hydrogen production outlay

As regards the transportation, pipelines remain the go-to option with over 1400 pipeline projects announced in 2023, equalling investment cost of ~USD 570 billion. Amongst these announced projects, Europe leads with 540 projects followed by North America at 248 projects. In summary, the hydrogen economy is vital evolving significantly, with the Global North leading the development, especially as regards green production, even though the Global South has the resources to drive this growth.

Comparison of grey, blue and green hydrogen considering cost of production, carbon footprint and cost of transportation

S/N	Type of Hydrogen	Production mechanism	Cost of production (USD per gH_2)	Carbon footprint (kgCO_2 per kgH_2)	Cost of transportation mode (USD per kgH_2)	
1	Grey	Steam reforming of natural gas (methane)	0.98 – 2.93	12.3 - 13.9	Pipeline	-
					Road	-
					Rail	-
2	Blue	Steam reforming of natural gas (methane) using carbon capture and storage for emission reduction	1.80 – 4.70	7.6 – 9.3	Pipeline	-
					Road	-
					Rail	-
3	Green	Produced through electrolysis of water using renewable energy	4.50 – 6.50	0.6 – 2.5	Pipeline	1.50 – 2.50
					Road	3.50 – 5.00
					Rail	4.00 – 6.00

Other Decarbonization options

Scientific evidence has shown that carbon capture and storage (CCS) and other carbon removal technologies are required to capture gigatonnes of CO_2 per annum if net-zero target of 2050 must be achieved. CCS is particularly important to address emissions from industries and the power sector that are dominated by carbon-intensive energy sources and feedstock, with no quick-fix solution considering current business trends and trajectory of government policies. It is on this note that CCS technologies has witnessed significant growth in this decade, resulting a total carbon capture capacity of 361 million tonnes of CO_2 per annum (as at July 31st, 2023), an increase of 50% compared to that reported in 2022.

Well, it must be noted that this growth in CCS deployment is due to significant shift in government policies that make the business case of the technology attractive. For instance, policies such as the EU Net-zero Industry Act, UK's CCUS Net-zero Investment Roadmap, US Inflation Reduction Act, Japan's CCS Long-term Roadmap and recent announcement by Saudi Arabia to specific amounts of CO_2 by 2035 all give strong inclinations of government support to drive up CCS deployment in their respective countries. This government policies are in line with the global target of increasing annual CO_2 storage capacity to 1 gigatonnes per annum (Gtpa) by 2030, while gradually increasing it to 10 Gtpa by 2050.

A critical trend noticed from the growing CCS industry is that its viability is strongly dependent on government policies, which makes its economies attractive for investment. In this case, it becomes vital for governments all over the world to carefully develop policies and programmes that would incentivize CCS deployment in their countries, as a means to meet their nationally determined contributions.