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The Impact of Energy Transition to Net-Zero Emissions on The World Economy and Global Strategies

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ABSTRACT

The world is going towards a net-zero emissions future, and this transition is expected to have a significant impact on the global economy. The shift towards low-carbon sources and the reduction of greenhouse gas emissions will bring about changes in the way we produce, distribute, and consume energy, as well as in the way we conduct business and trade with other countries. One of the most significant impacts of the energy transition will be on the industries which work with fossil fuels. On the other hand, the renewable energy and nuclear sector is expected to grow rapidly, creating new jobs and opportunities for investment. transition to a net zero energy system by 2050 should be ensuring stable and affordable energy supplies, provide universal energy access, and enable robust economic growth. this transition should set out a cost-effective and economically productive pathway, resulting in a clean, dynamic, and resilient energy economy dominated by clean energy resources such as solar, wind, and nuclear instead of fossil fuels. To achieve net-zero emissions countries will require cooperation on issues such as technology transfer, financing, and policy development. The Paris Agreement, signed by 196 countries in 2015, provides a framework for this cooperation and sets a goal of limiting global warming to well below 2 degrees Celsius above pre-industrial levels. In this article, we will investigate which disruptive events and crises could endanger the security of supply and what long-term and cost-effective transformation strategies for transition to net-zero emissions can be imagined. and also, what are the key drivers in this transition.

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Introduction

With almost three-quarters of anthropogenic greenhouse gas emissions coming from the energy sector, a shift to clean, renewable energy sources is essential to solving the climate crisis. Increasing fossil fuel consumption has two potential effects. One of the effects is the increase in carbon dioxide gas and other greenhouse gases, which contributes to global warming. For example, 99% of the world's coral reefs are projected to disappear if temperatures rise by 2°C. Irreversible loss of the Greenland ice sheet could be caused by global warming of about 1.5°C to 2°C. This will ultimately lead to further sea-level rise, with direct impacts on coastal areas around the world, including low-lying areas. The rapid loss of summer Arctic sea ice is already happening, adversely affecting the biodiversity of the Nordic region and the livelihoods of local people [1]. Another effect is the increase in air pollution and its harmful effects on human health. Today, health costs have increased dramatically due to diseases caused by industrial pollutants. Globally, 7.4 million people die each year from the effects of air pollution, including carbon dioxide (CO2), nitrogen oxides (NOx), particulate matter (PM10), and heavy metals, of which 56.2. % is due to outdoor pollution [2]. Air pollution is the second leading cause of death after heart disease. 48% of deaths occur in China and India, home to 36% of the world's population [3].

Without stepped-up international action on climate change, the average global temperature increase could reach 2°C in the immediate aftermath of 2060 and continue to rise thereafter. Such unchecked climate change would turn the planet into a 'hothouse', increasing the likelihood of large-scale, irreversible climate impacts.

Because of these issues, energy is now a priority in many countries' climate change plans [4]. And then there is also the urge to do more. About 95% of the NDCs submitted by countries with climate change commitments include separate or detailed sections on energy goals and policies [5]. Furthermore, climate-committed countries will not only focus on the energy transition but also ensure the realization of the vision of a "net-zero global economy" with access to clean and flexible energy.

The benefits of moving away from fossil fuels go beyond fighting climate change. The energy transition is an economic opportunity that could create millions of jobs for women and men. At the same time, renewable energy has the potential to enable universal access to energy, from health and well-being to reducing inequalities, empowering women, decent work, and economic growth. Supports achievement of nearly all other Sustainable Development Goals. The speed and scale of the clean energy revolution promise not only reduced carbon emissions but also energy access for millions of people. The world is in the midst of an energy revolution and many governments are considering how to capitalize on this opportunity. Enabling the large-scale clean energy investments needed for a just transition is critical [5].

History of Transition

Several energy transitions have taken place in the last 200 years. Technological innovation is the biggest driver of these changes and plays a key role in the current move towards cleaner energy. Looking back over the centuries, we can see that we depended on only one or two major sources of energy. Figure 1 shows global primary energy consumption since 1820 [6].

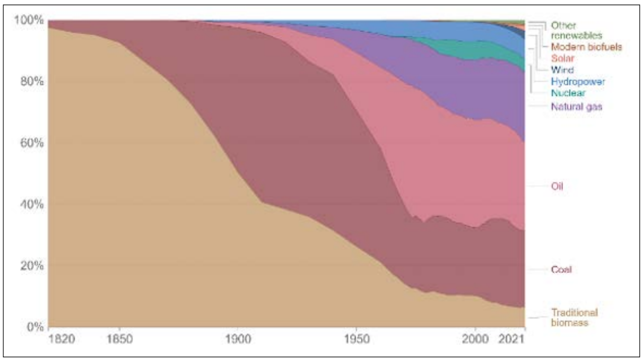

Figure 1: Global primary energy consumption by source, 1800-2020 [7].

Until the mid-19th century, traditional biomass, the burning of solid fuels such as wood, crop residues and charcoal, was the world's main source of energy. Coal rose rapidly with the industrial revolution. At the beginning of the 20th century, about half of the world's energy came from coal. And half are still from biomass.

As the 20th century progressed, the world adopted a wider range of sources of information. First oil, then gas, then hydropower. Nuclear energy was not added until the 1960s. Solar and wind, often referred to as "modern renewables", came much later in the 1980s. What is special about this 200-year history of global energy consumption is that the energy transition has been very slow in the past. It took decades, even a century, for any particular energy source to become mainstream. That used to be the case, but there are signs that this is changing. Some of the recent energy transitions have happened very rapidly [8].

One of the key technologies behind the industrial revolution was that the steam engine relied heavily on coal, and at the same time, homeowners used coal for heating and cooking in their homes. This is reflected in the growing share of coal in the global energy mix, which increased from 1.7% in 1800 to 47.2% in 1900.

After the introduction of the assembly line, the demand for oil from internal combustion engine vehicles began to increase, and 1960 demand surged with the surge in vehicle purchases. The invention of the Bunsen burner also opened up new possibilities for using natural gas in the home. With the advent of pipelines, gas has become an important source of energy used for heating, cooking, water heaters and other appliances.

Renewable energy sources are at the center of the ongoing energy transition. Solar and wind power capacity is expanding around the world as countries step up their efforts to curb emissions.

Here's (Table-1) how the share of renewables and Nuclear in the global primary energy mix changed over the last two decades [9].

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Table 1: share of renewables and nuclear in the global energy mix 2000-2020
(Source: Visual Capitalist)

Year	Traditional Biomass	Renewables	Fossil Fuels	Nuclear Power
2000	10.2%	6.6%	77.3%	5.9%
2005	8.7%	6.5%	79.4%	5.4%
2010	7.7%	7.7%	79.9%	4.7%
2015	6.9%	9.2%	79.9%	4.0%
2020	6.7%	11.2%	78.0%	4.0%

By 2019, 85% of the world's energy needs will be met by burning fossil fuels [10]. In 2018, energy production and consumption accounted for 76% of annual anthropogenic greenhouse gas emissions [11]. Achieving the goals of the 2015 Paris Climate Agreement requires reducing emissions as quickly as possible and reaching net zero by mid-century [12]. The rapid increase in competitiveness of solar and wind energy since the late 2010s has also facilitated the transition to renewable energy [13]. Another inspiration for the transition is to restrain other natural impacts of the vitality industry [14].

The IEA predicts that the global economy will evolve from a "fuel-intensive to a mineral-intensive energy system," leading to "increased demand for critical minerals".

As vehicles become more electrified and need for energy storage in both electrical and thermal form increases, so does the consumption of various materials such as copper, lithium, and steel.

Copper is an important mineral in the manufacture of electric vehicles and is used in electric motors, batteries and charging infrastructure. According to the International Energy Agency (IEA), an average electric vehicle can contain around 53kg of copper, compared to 22kg for an internal combustion engine vehicle. As a result, copper demand for electric vehicle batteries alone is expected to grow from 210,000 tons in 2020 to 1.8 million tons in 2030. Nickel is another important mineral for transition as it is used in the production of electric vehicle batteries. One advantage of using nickel in electric vehicle batteries is that it can improve the energy density of the battery [15].

As demand for lithium batteries increases, so will the price of this strategic metal. Countries with resources and technology will therefore play a major role in determining the cost of renewable electricity. Of course, we have to keep in mind that each country's share in energy market is proportional to the size of its share in the global economy.

Total Energy Supply in The Nze Pathway

following Figure-2, The total energy supply is expected to drop to 550 exajoules (EJ) in 2030, 7% less than in 2020. This is happening despite a significant increase in the world's population and economy due to declining energy intensity. Energy intensity will decrease by an average of 4% per year from 2020 to 2030. This will be achieved through a combination of electrification, promotion to take advantage of all energy and materials efficiency opportunities, behavioral changes that reduce demand for energy services, and a significant shift away from conventional bioenergy use. This energy intensity improvement is much greater than what has been achieved in recent years. Between 2010 and 2020, average annual energy intensity decreased by less than 2% per year.

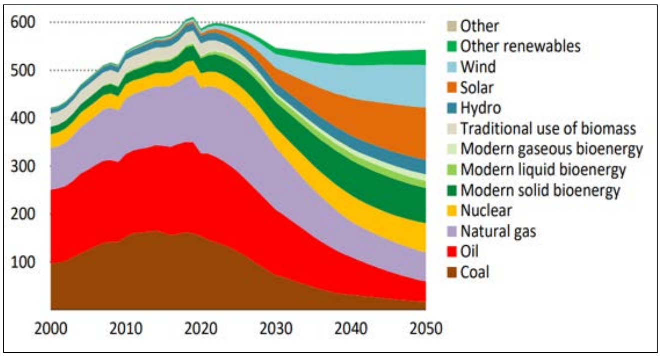

Figure 2: Total energy supply in the NZE [IEA]

Note that renewables and nuclear power have largely will be squeezed out fossil fuel use in the NZE, and the share of fossil fuels falls from 80% in 2020 to just over 20% in 2050. Also, it should be noted that the production of fossil fuels will not be completely eliminated by 2050. Some of the oil is used in the production of non-fuel materials such as polymers and chemicals. Also, amounts of natural gas are converted into hydrogen. However, some amounts include oil used as aviation fuel, as it is difficult to completely eliminate oil from this sector [16].

The transformation of the NZE's energy sector is taking place against the backdrop of a rapidly growing world population and economy (Figure 3). In 2020, there were about 7.8 billion people living in the world. This number is expected to increase by about 750 million by 2030, and by about 2 billion by 2050, according to the United Nations projections in moderate (UNDESA, 2019). Most of the population growth is occurring in emerging and developing countries. In Africa alone, the population is expected to grow by more than 1.1 billion between 2020 and 2050 [17].

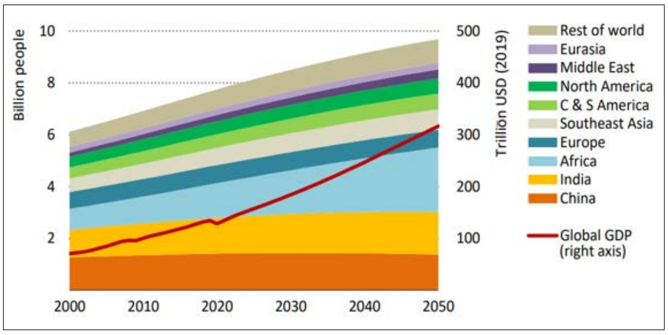

Figure 3: World population by region and global GDP in the NZE [17]

By 2050, the world population will grow to 9.7 billion and the global economy will more than double as large as in 2020.

Global Scenarios and Pathway to Net-Zero CO_2 Emissions in 2050

The Net Zero Emissions Scenario (NZE) by 2050 is the IEA's reference scenario that outlines a path for the global energy sector to reach net zero emissions by 2050, with advanced economies achieving net-zero emissions ahead of others. This scenario also meets key energy-related UN Sustainable Development Goals (SDGs), notably by achieving universal access to energy and significant improvements in air quality by 2030 [18].

The global economy has recovered from the COVID-19 pandemic, and the first global energy crisis has pushed global energy prices to record highs in many markets, raising concerns about energy security.

WEO-2022 and ETP (Energy Technology Perspectives)-2023 consider three scenarios based on the integrated GEC (Global Energy and Climate) modeling cycle. All of these scenarios have been completely updated to include the latest energy market and cost data [19]. Definitions and objectives of the Global Energy and Climate Model 2022 scenarios are notice in table-2.

Table 2: Definitions and objectives of the GEC Model 2022 scenarios [19].

Scenario	Definitions	Objectives
Net Zero Emissions by 2050 Scenario	A scenario outlining a path for the global energy sector to reach net-zero carbon emissions by 2050. We do not rely on emissions reductions outside the energy sector to meet our targets. By 2030, everyone should have access to electricity and clean cooking.	What are the needs of different stakeholders in key sectors and how the world can achieve energy and energy efficiency by 2050 while achieving other energy-related Sustainable Development Goals such as universal access to energy. To indicate when we need to reach net zero carbon emissions in industrial processes.
Announced Pledges Scenario	Assuming that governments around the world's climate change commitments, including government-mandated contributions (NDCs), long-term net-zero targets, access to electricity, and clean cooking targets, are met in full and on time by this scenario.	To show how close current pledges are to keeping the world from warming to 1.5°C, she highlights the ambition gap that must be closed to meet the targets agreed in Paris in 2015. bottom. it also points to the gap between current goals and achieving universal energy access.
Stated Policies Scenario	Scenarios that reflect current political attitudes and are based on sectoral and country-by-country assessments of specific policies currently in force and policies announced by governments around the world.	To provide a benchmark for assessing the potential outcomes (and limitations) of recent developments in energy and climate policy development.

There are many possible pathways to achieving net zero global carbon emissions by 2050, but there are many uncertainties that can affect each of those pathways. NZE is therefore just a path, not a path to net zero emissions. Much depends, for example, on the pace of innovation in new and emerging technologies, the extent to which citizens are able or willing to change behavior, the availability of sustainable bioenergy and the extent and effectiveness of international collaboration. The "net-zero emissions by 2050" scenario is based on the following principles [16].

- The use of all available emission reduction technologies and options will be driven by cost, technology maturity, policy preferences, market and country conditions.
- All countries cooperate towards achieving net-zero emissions worldwide. This involves all countries participating in efforts to meet the net zero goal, working together in an effective and mutually beneficial way, and recognizing the different stages of economic development of countries and regions, and the importance of ensuring a just transition.
- An orderly transition across the energy sector. This includes ensuring the security of fuel and power supplies at all times, minimizing asset losses as much as possible, and aiming to avoid energy market volatility.

Challenges and Obstacles to Accelerating the Transition To Nze
Russia's baseless war and the world's reaction to it reveal another, more fundamental problem: Analysis of economic policy and energy policy, in general, has implications for the inherently limited ability of policymakers to influence policies choice in managing crises such as the one we are facing today, especially overlapping crises (such as the pandemic and Russia's war on Ukraine). The economic model of the time was similarly limited. its main conclusions are: A 10% gas supply shock would reduce Eurozone GDP by 0.7% [20].

The impact of Russia's war against Ukraine will accelerate the transition to net-zero emissions. It should be noted that this transition must be carefully managed to avoid disorder. Unlike previous transitions that happened mostly due to technological and economic attractiveness, the current transition will be based on net zero emissions due to political factors and strategic decisions of governments on the global economy. For this reason, accelerating the movement to net zero emissions brings several challenges, the most important of which are:

- Supply Chain Constraints: As mentioned earlier, the current transition will put a lot of pressure on the production resources of metals and raw materials.
- Increase in costs due to high demand: As mentioned, the increase in demand for battery production, hydrogen storage tanks, etc. will lead to an increase in the price of metals such as copper, nickel, lithium, etc. On the other hand, reducing fossil fuel consumption in the medium term reduces the price of fossil fuel and increases the economic attractiveness of fossil fuel consumption.
- Failure of emerging economies to comply with net-zero emission climate policies: most of the world's population is located in Asia. The need for energy in these areas is increasing. Countries like India and Pakistan currently rely on cheap fossil fuels. Transitioning from oil and complying with the global climate program is much more difficult for these countries than European and North American countries.

Perhaps the biggest challenge will be managing the phase-out of high-emission forms of energy and the expansion of low-emission forms of energy to ensure reliable and affordable energy supplies. To adapt to the transition to net zero emissions, the world's largest fossil fuel producers may consider not only decarbonizing their operations but also realigning their business portfolios. More broadly, regions dependent on fossil fuel-based sectors will need to consider economic diversification policies [21].

Global Energy Transition Investment By 2050

According to the International Energy Agency (IEA), global energy investment is currently around $2 trillion annually, equivalent to 2.5% of global GDP. In an illustrative pathway they recently developed, this will have to rise to $5 trillion or 4.5 percent of GDP by 2030 and stay there until at least 2050 to reach net zero CO_2 emissions by 2050 (Figure-4). Much of that will be spent on power generation and infrastructure to power new sectors of the economy and make the power system better suited to the massive increases and fluctuations in renewable energy.

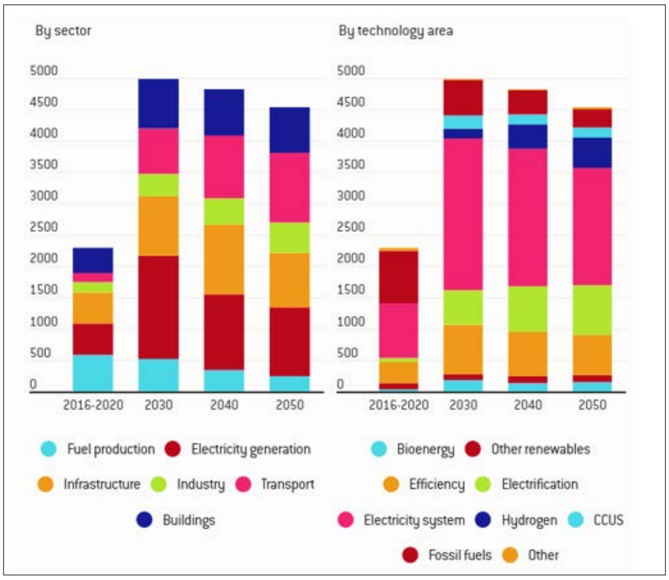

Figure 4: Annual average capital investments worldwide to reach net zero CO_2 emissions by 2050 (USD billion, 2019 prices) [16].

Other net zero paths suggest similar scales (Figure-5). The International Renewable Energy Agency (IRENA) has shifted the required investment to the current decade, with US$ 5.7 trillion invested annually until 2030, after which it will decline. Bloomberg New Energy Finance (BNEF) estimates the average investment needed to 2050 at $3.1-5.8 trillion annually [22].

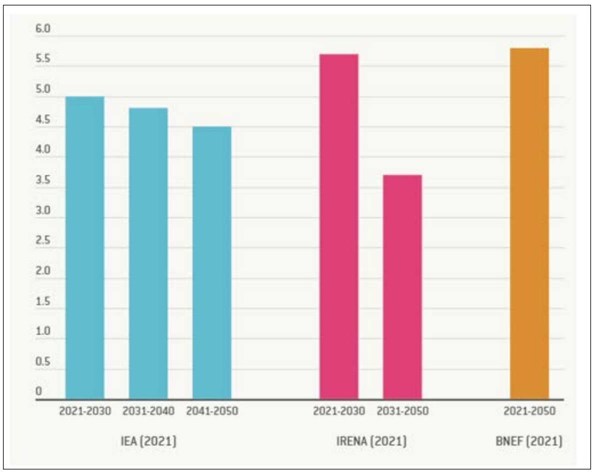

Figure 5: Average yearly global investment needs in order to reach net zero CO_2 emissions from energy by 2050, different estimates (USD trillion) [23].

The top 10 countries together invested $561 billion in the energy transition, nearly ¾ of the world total (see table-3). Also, in tabe-4 Investment in each Low-Carbon Technologies is shown.

Table 3: Energy Transition Investment by Country [24].

Country	2021 Energy Transition Investment (US$)	% of World Total
China	$266B	35.2%
U.S.	$114B	15.1%
Germany	$47B	6.2%
U.K.	$31B	4.1%
France	$27B	3.6%
Japan	$26B	3.4%
India	$14B	1.9%
South Korea	$13B	1.7%
Brazil	$12B	1.6%
Spain	$11B	1.5%
Total	$561B	74.3%

Table 4: energy transition investment by sector in 2021 [24]

Sustainable Materials	$19.3B	141.3%
Renewable energy	$365.9B	6.8%
Nuclear	$31.5B	6.1%
Hydrogen	$2.0B	33.3%
Energy Storage	$7.9B	-6.0%
Electrified transport	$273.2B	76.7%
Electrified heat	$52.7B	10.7%
Carbon capture & storage	$2.3B	-23.3%
Total	$754.8B	26.8%

Renewable energy accounted for almost 50% of total investment in 2021. However, electrified transport has been responsible for most of the growth as several countries have switched to electric vehicles. There is a growing belief that nuclear power can provide reliable, carbon-free electricity, and about $32 billion has been invested in nuclear power as well. The beginnings of clean energy are still in their early stages, and the technology in this area is constantly evolving [25].

The question of who should pay for these investments is going to give rise to some tough political battles. But even from a purely economic standpoint, there are certainly many winners from these additional investments. From a social perspective, these investments pay off many times over as fossil fuel use does more external damage than it adds value to GDP. Thus, Policy is key.

Global momentum to set net-zero targets is accelerating rapidly, with major economies such as China, the United States, India and the European Union making such commitments. Currently, more than 90 countries, accounting for almost 80% of global emissions, are covered by net-zero targets [26]. This transition comes with risks, such as energy supply instability. At the same time, it offers many possibilities. This transition will hamper the emergence of physical climate risks and reduce the likelihood of the most catastrophic impacts of climate change. It would too bring development openings, as decarbonization makes efficiencies and opens markets for low-emissions items and services. A growing number of countries are committing to net zero emissions in the coming decades. But the pledges by governments to date – even if fully achieved – fall well short of what is required to bring global energy-related carbon dioxide emissions to net zero by 2050 and give the world an even chance of limiting the global temperature rise to 1.5 °C [16].

Policymakers and global leaders need actionable roadmaps and long-term strategies on how to transition to a net zero energy system by 2050 and ensure sustainable and affordable energy sources, as well as universal energy access and robust economic growth.

Long-Term Climate Strategy To 2050

Article 4.19 of the Paris Agreement states: "All Parties, due to Article 2, taking into account their common but different responsibilities and their respective capacities from different national perspectives, should seek to develop and communicate long-term low greenhouse gas emission development strategies". Long-term strategies help countries align their short-term plans with their long-term perspective. This process establishes a clear way to plan for the long-term considering climate risks and informs planning and investments to mitigate and adapt to climate change. Central to the long-term strategy is the setting of targets to significantly reduce greenhouse gas emissions by 2050. In addition, long-term strategies help align national, regional and international goals and objectives such as national development plans, regional development plans and the Sustainable Development Goals (SDGs) [27].

The challenge is daunting, but time is short and we only have decades left. We need an ambitious effort and a solid roadmap to guide us [26].

Besides the net zero goal, we need a strategy to get there. UNFCCC policy instruments such as the Long-Term Strategy (LTS) can help provide these roadmaps.

The momentum is building as countries seek to combine nationally determined contributions with long-term visionary thinking. From helping countries explore and apply the tools available to them towards the goal of achieving net zero by 2050, UNDP will help policymakers in the initiation, design, and improvement of LTS to facilitate it. it is working multi-faceted to leverage the NDC process towards our long-term goals, from providing resources to South-South cooperation and knowledge sharing [5]. Here we have listed some key strategies that organizations and governments can follow. See Table-5.

Table 5: View of Main Characteristics of Global Energy Transition

Vision	✓ Global net-zero emission by 2050
Goals	• Net-zero emissions • Sustainability in energy sector
Main Strategies	• Realization of technological innovation • Build a large supply chain and support infrastructure • Management of necessary natural resources • Effective capital reallocation and funding structure • Manage changes in demand and short-term increases in unit costs • Establish mechanisms to address socio-economic impacts; • Build engagement and collaboration among public, private and social sector leaders around the world; • Public and consumer support
Key Drivers	1. Policy 2. Climate change 3. Fossil fuel price instability

Nuclear Energy Role in Transition to NZE

Nuclear power, as part of a sustainable energy system to decarbonize electric and non-electric power generation, will partner with renewable energy sources and other low-carbon options to achieve global net-zero targets. Nuclear energy is a major driver of economic growth, creating jobs in many economic sectors and enabling a just transition away from coal [28].

Table 6 summarizes the potential applications of various reactor designs in transitioning from coal. Most of the nuclear power plants in operation today rely on large water-cooled reactors. In comparison, coal-fired boiler plants tend to be smaller, so a single nuclear reactor can replace multiple coal-fired power plants. By comparison, different SMR and advanced reactor designs at different stages of development may be suitable to replace smaller coal-fired units in a wider range of applications.

Table 6: Categorizing selected nuclear technologies suitable for replacing coal [28].

		Plant output				
		Electricity	Low temperature heat (300°C) (district heat, industry, H_2)	High temperature heat (600-700°C) (industry, H_2)	Coal replacement applications	Technological and commercial maturity
Nuclear reactor design	Large water cooled	✓	✓		Multi-unit power plant	Mature; more than 300 units in operation
	SMR, water cooled	✓	✓		Single unit, power or CHP	Demonstration; pre-commercial; conventional nuclear licensing process widely applicable
	SMR, advanced (gas/sodium cooled)	✓	✓	✓	Single unit, power, CHP, industrial boiler, H_2	Design phase; demonstrated technology; pre-commercial
	SMR, advanced (salt or lead cooling; micro-reactors)	✓	✓	✓	Single unit, power, CHP, industrial boiler, H_2	Research, development and demonstration

It will reach 30 GW annually, five times more than in the last decade" [16]. These figures are in good agreement with the International Atomic Energy Agency's (IAEA) high forecast of about 550 GW of new capacity by 2050, based on a detailed bottom-up assessment of each country [29]. Maintaining low-carbon power generation capacity by safely extending the operating life of existing nuclear power plants is critical.

Nuclear power plays a more modest role, but ensuring the reliability and availability of energy supply will help complement and integrate the anticipated large portion of renewable energy generation. Synergy between nuclear and renewable energy sources can also ensure a faster transition: Due to the relatively low material intensity of nuclear power, it is unlikely that there will be a shortage of critical mineral supplies that may hinder the introduction of other low-carbon options [30]. This highlights the importance of keeping nuclear power as part of a portfolio of solutions for a successful transition to a net-zero future. Nuclear power also helps reduce overall system costs by providing distributable power and reducing the need for grid expansion and storage. Nuclear energy can provide low-carbon heat and can be used to produce hydrogen for hard-to-abate sectors through established new production processes [28].

Conclusion

In short, net-zero efforts must be effective and robust to drive climate change action. Concrete steps must be taken to ensure this if countries are to effectively meet the challenges ahead. A true net-zero transition requires both rapid deployment of new low-carbon technologies and major system changes.

the transition to net zero emissions in the energy sector is a complex process that requires the involvement of various key drivers. The most significant key drivers include policy and regulation, technological innovation, finance and investment, consumer behavior and societal acceptance, and international cooperation. These key drivers are interconnected and interdependent, and they play a critical role in accelerating the transition to a sustainable and low-carbon energy system. In this century's transition, politics has a key and strategic role, and due to important political decisions, we can transition to a net zero economy.

However, achieving net zero emissions in the energy sector requires a collective effort from all stakeholders, including governments, businesses, investors, and individuals. Therefore, it is crucial to continue investing in and promoting the development of these key drivers to ensure a successful transition to a net-zero carbon future.

Governments, policymakers, and regulators also play a significant role in setting targets and implementing policies and regulations that promote the transition to a low-carbon economy. These policies can include carbon pricing, renewable energy mandates, energy efficiency standards, and other measures that incentivize the adoption and deployment of low-carbon technologies.

Finally, international cooperation is essential in addressing the global challenge of climate change. Collaboration and coordination among nations can help accelerate the transition to a sustainable and low-carbon energy system, promote technology transfer, and mobilize financial resources. The Paris Agreement, for instance, is a significant international agreement that aims to limit global warming to below 2 °C above pre-industrial levels and to strive to limit temperature rise to 1.5 °C.

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