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Vision Net Zero: A review of decarbonisation strategies to minimise climate risks of developing countries

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Abstract
The IPCC's6th Assessment Report of Working Group I projects the view that world will exceed the Paris Goal to limit global warming to 1.5 °C over the pre-industrial levels by as early as 2035 due to the "widespread, rapid and growing" nature of climate change. To stop climate change, there is an urgent need to redefine our industrial and agricultural practices. Decarbonisation and circular material management of resources require global implementation to resolve climate change challenges. More importantly, developing nations need proper framework and strategies to enable a decarbonisation pathway. In the present study, we discuss performance of developing countries (taking the case of India and its environmental, social, economic backgrounds) in achieving 'net zero vision' as discussed in the Conference of Parties (COP) under UNFCCC. In this research, we have emphasised on: (a) sustainable practices countries need to follow, (b) key elements of the net-zero framework, and (c) key institutional strategies to support key elements of sustainability practices. The study includes 15 relevant scopes to work upon (called the pillars of Green India). These pillars encompass the institutional areas of policy regulations, awareness, technology and finance. Some major areas of focus in this domain include: switch to renewables (policy and politics in its adaptation), electricity usage and its transformation (policy and politics in the adaptation of the same), and market value design for carbon pricing (making strategies for its adaptation). This study helps in developing a proper framework that is essential to achieve the vision of COP 26 and COP 27 on "net zero" and the way forward for COP 28. Bibliometric mapping of countries shows that developed nations such as the USA and UK are way ahead in "decarbonisation" research as compared to developing nations like India and other South Asian countries.

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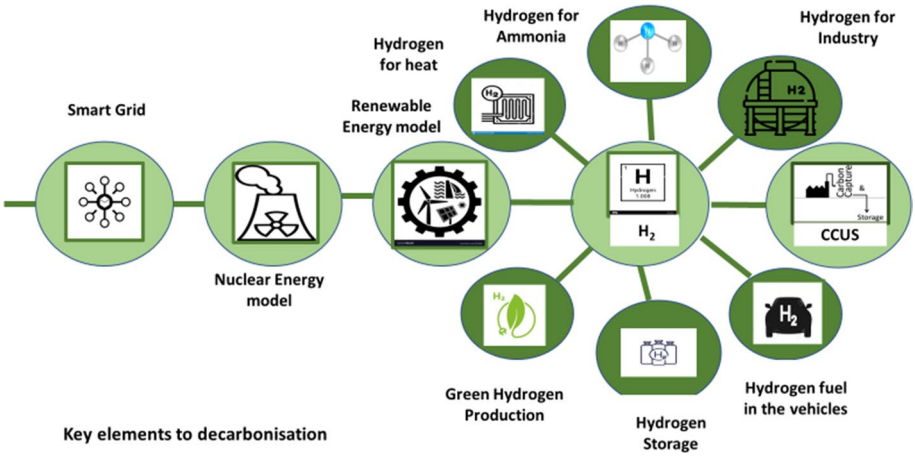
Graphical abstract



Keywords Net-zero · Decarbonisation · Carbon pathway · Carbon taxation · Business-sustainability · Circular material management

Abbreviations

COP	Conference of Parties
CNG	Compressed natural gas
SDG	Sustainable development goals
IPCC	Intergovernmental Panel on Climate Change
G20	The group of twenty
GHG	Greenhouse gases
UN	United Nations
USA	United States of America
PLI	Production-linked incentive
KPI	Key Performance Index
MRV	Monitoring, reporting and verification
NbS	Nature-based solutions
TCFD	Task Force on Climate-Related Financial Disclosures
EPSF	Expert Panel on Sustainable Finance

1 Introduction

The world will surpass the Paris Goal of keeping global warming to 1.5 °C above pre-industrial levels by as early as 2035 because climate change is "widespread, quick and growing", according to the IPCC's Working Group I Sixth Assessment Report. Global warming may reach + 3 °C by the end of the century resulting in significantly more frequent catastrophic events such as heat waves, droughts, changes in monsoon patterns, rising sea levels and flooding (Balbus et al., 2022; DeWit, 2022; Hanna & Victor, 2021; Smil, 2022). Climate change is set to receive due consideration by the G20 Summit in October 2023 and CoP-26 in November, 2021. These Conferences will take place at a time when

dangers of climate change are being recognised on a large scale by the public, as evidenced by the perspectives of major business leaders, NGOs and other thought leaders. Revolutionary changes in current business and agriculture practices are needed to mitigate climate change. Decision-makers setting the stage for these major summits should shift attention from gauging progress made on reducing carbon emissions to implementing emerging technologies in cutting-edge markets (Rode et al., 2022; Chase, 2022). All eyes will be on India to see if we are on track to meet the goals of the Paris Agreement. Diplomats and negotiators from countries all over the world will gather to convene a series of climate-related events in 2023 including the Group of 7 sessions in May in Hiroshima and the 28th Conference of Parties (COP 28) in Dubai, of the United Nations Framework Convention on Climate Change. Nearly every government will make fresh pledges before COP27 to reduce emissions; many have already made audacious plans to completely eliminate emissions over the following 3 decades, considering short-term, mid long-term and long-term targets as 2030, 2050 and 2070. A worldwide inventory was conducted after COP26 to identify potential trends for global emissions in the light of all the commitments. India's transition to a net-zero economy can save lives, catalyse new industries, create over 50 million jobs and contribute more than $15 trillion in economic impact (Başar et al., 2021).

The world is witnessing constant conflicts between nations striving to expand their boundaries or gain power (Saint et al., 2020; Adams & Acheampong, 2019; Zafar et al., 2020; Vo, 2020). These conflicts hinder the success of all the SDG's and particularly SDG 13 (Climate Action), SDG 15 (Life on Land), SDG 16 (Peace, justice, and strong institutions), and SDG 17 (Partnership for Goals).

The insistence by some countries on Common but Differentiated Responsibility (CBDR) has undermined the importance of a united stand by all the nations in achieving these broad and long-term goals. The concept of universality has been lost and national aim has suddenly gained ground with nations vying with each other to present their nationally determined goals and success reports. This has become a major hindrance to the achievement of sustainable development.

The decarbonisation vision envisages action towards low-carbon transition. It envisages that countries take leadership position in climate action with specific focus on awareness, certifications and protocols observed, infrastructural compatibility with sustainable practices, funding mechanisms, prioritisation of goals, cooperation of government agencies, real-time convictions, waste disposal and recycling mechanisms, water and electricity usage, venting, drainage, and chimney release. However, these factors together have added to the pressure on developing countries, forcing them to cut down on carbon emissions, thereby slowing their journey to development. The Sustainable Development Goals (SDGs) are focused on the implementation of efficient frameworks and rules (Elder & Olsen, 2019; Sætra, 2021). Lack of united stand and demand for common but differentiated responsibility are proofs in themselves that no matter how ambitious the goals, they can be undermined by ineffective implementation. Cat-race as witnessed in the corporate world can now be seen between nations, with each nation trying to undermine the achievements of others in order to highlight their own. Thus, rather than working together as a team moving collectively towards the achievement of common goals, countries are now competing with each other (Sætra, 2021). Figure 1 shows the sustainability crisis and challenges.

Policies and governance models of many countries are also questionable. It is seen that developed countries with higher carbon footprints are pressurising the developing and least developed countries to cut down their emissions. Some countries like Finland have imposed pollution tax on their population whereas some developed countries are actually buying carbon credits from the developing and least developing countries and forcing them

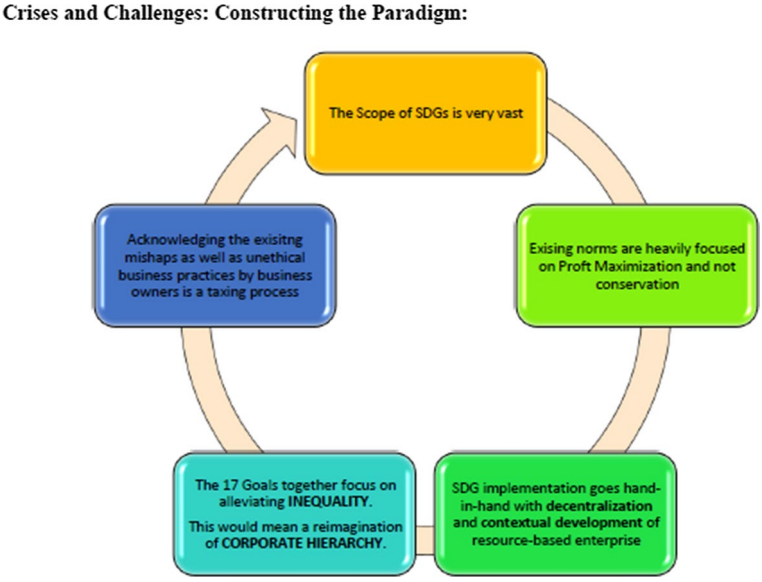


Fig. 1 Sustainability crisis and challenges: constructing the paradigm

to further reduce carbon emissions (Allam et al., 2022; Åberg et al., 2021; Gingerich, 2022; Van Den Berg et al., 2022; Calliari et al., 2020). To promote energy adjustment and reduce carbon footprint, industries should increase environmental consciousness and incentives for technological innovation relating to renewable energy consumption (Su et al., 2022). Inequalities in the policies and mindset of countries are a major challenge. Existing SDG norms are heavily focused on profit maximisation and not on natural resources conservation. SDG implementation goes hand in hand with decentralisation and contextual development of resource-based enterprises. The 17 SDGs focus on alleviating pollution.

This would mean re-imagining of corporate hierarchy. However, acknowledging existing mishaps as well as unethical business practices by business owners is a taxing process.

1.1 'India should be the largest contributor to sustainability goals': "a perspective"

India has the resources to be the largest contributor to the success of SDG goals because of the huge variety in its demographics and geographies. It also has a huge population that can spearhead changes. The country has adopted a holistic strategy to achieve its 2030 Sustainable Development Goals (SDGs) by executing several programs. The SDG Index Score ranges from 42 to 69 for States and 57 to 68 for UTs. According to a report by Niti Aayog, 'State ranking on SDG's 2020', Kerala and Himachal Pradesh lead all other States with 69 points while Chandigarh and Puducherry lead the UTs with 68 and 65 points, respectively. The National Clean Air Programme was launched by the Indian government in 2019 as a PAN-India, time-bound national policy for air pollution prevention, control, and abatement as well as to enhance the country's air quality (Khalid et al., 2021; Vij & Singh, 2022). The Namami Gange Mission was launched as a priority project with a budget of Rs.20,000 crores for 2015–2020 (The Hindu, 2015). Amongst the primary components of the project are sewerage project management, urban and rural sanitation, industrial

pollution reduction, improved water usage efficiency and quality, ecosystem conservation, and the Clean Ganga Fund. The National Policy on Resource Efficiency (RE) builds on existing policies to target a wide range of industries to integrate resource efficiency strategy into the development path for achieving the SDGs. Resource efficiency has the potential to be a powerful instrument for addressing the country's resource requirements. According to Climate Finance and the Nationally Determined Contribution of India, India is the world's 11th largest economy in emerging countries, accounting for 33% of Certified Climate Bonds. The country's vigorous engagement in the COP 24 discussions in Katowice, Poland in 2018 helped it to protect its vital interests, while also bringing the spotlight on the differential treatment between developed and developing countries (Kuchler et al., 2018; Asadnabizadeh, 2019). India's Nationally Determined Contributions (NDCs) call for unprecedented scale and size expenditures. This implies that a variety of resources, including those from the international public finance system and the private sector, must be used in addition to domestic government expenditures. To ensure long-term sustainability of the measures planned for cities, new strategic interventions such as (a) strengthening the clean air ecosystem/institutions, (b) air quality monitoring and health effect evaluation and, (c) talent development, are needed (Das & Ghosh, 2023).

Hunger is again an issue that needs to be addressed. In India, there are a huge number of people below the poverty line, accounting to some extent for the huge number of deaths during the pandemic and also lack of food. Except in premier cities, gender equality is yet to be achieved. India with its huge population can create wonderful results if the youth are educated. Industry and innovation should not only be profit-driven but have other motivations as well, for example, sustainability. India needs more companies like TATA and Infosys to promote Corporate Social Responsibilities and associated activities. Also, the country can greatly benefit from its traditional wisdom and practices for instance, implementing Indian architectural methods that can help to completely eliminate the use of ACs in homes and offices.

The key elements for any developing country to achieve net zero would encompass five major areas as depicted in Fig. 2. The key elements are again broken down into pillars and strategies to achieve Green India (Fig. 3). These five areas are:

(a) Energy and its effective usage,
(b) Mobility and its shift to green,
(c) Industry and green manufacturing,
(d) Green infrastructure/green urbanisation, and
(e) Sustainable agriculture.

This study also identifies increasing environmental awareness and providing incentives for technological innovation related to the use of renewable energy sources as two things that industries should do to encourage structural energy adjustment to lower carbon footprint. It also provides credible net zero plans which include: (a)setting short-term and long-term goals, (b) being thorough in accounting for all greenhouse gas emissions, (c) continuing commitment to lowering greenhouse gas emissions, (d) planning to permanently remove carbon dioxide from the atmosphere in order to set off remaining emissions, (e) publishing a detailed plan with immediate activities to reach net zero by the middle of the century, (f) increasing climate finance, creating new financial instruments and markets, (g) building awareness and transparency

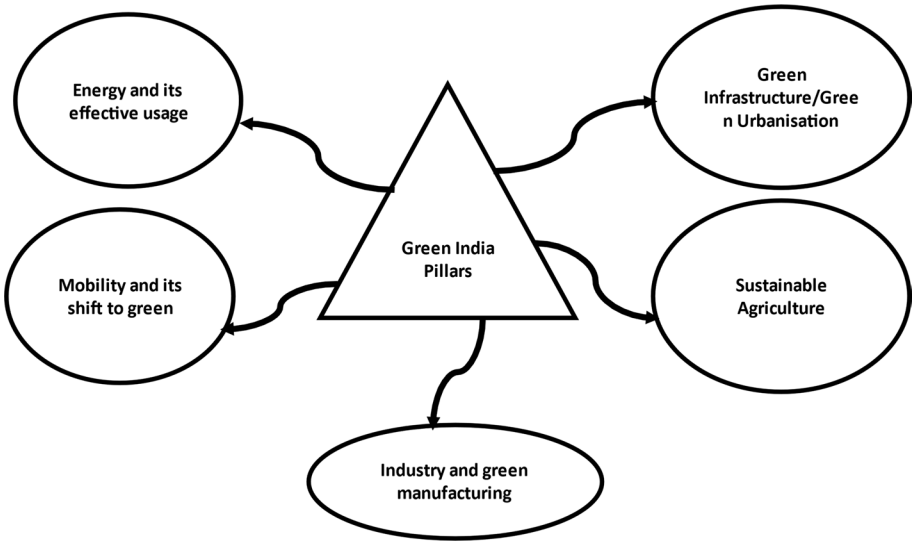


Fig. 2 Pillars of sustainability goals

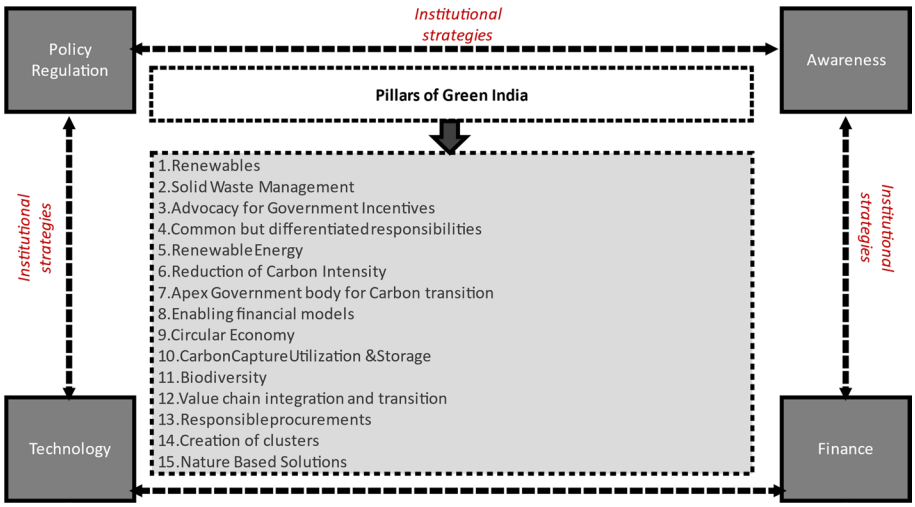


Fig. 3 Pillars of Green India demystified using 15 key institutional goals

about climate risks and opportunities, (h) putting in place compensatory mechanisms to address socioeconomic effects including social assistance programs, reskilling and redeployment initiatives for impacted workers and economic diversification initiatives.

This study also gives the status of scientific research as a part of the climate science initiatives taken by scientific communities worldwide to help government bodies take steps/strategise and develop framework, to work upon "decarbonisation pathways".

2 Methodology

2.1 Literature review

The methodology followed in the current study started with collection of the most recent research studies globally (from developed and developing nations) and focussing on the best current practices to achieve net-zero. Bottle-necks that need to be looked into to make the pathway easier were identified. We discuss the performance of developing nations in realising the "net zero vision" as outlined in COP 26. Essential elements of the net-zero framework, important institutional methods supporting key elements of sustainability practices, and discussions on sustainable factors are all highlighted in this research. This study also includes 15 relevant scopes to work upon (called the pillars of Green India). These pillars encompass the institutional areas of policy regulations, awareness, technology and finance. (Please see Fig. 3 for better understanding.)

2.2 Bibliometric analysis

Bibliometric analysis is quantitative analysis of literature in a specific area. It enables us to explore the subtleties of the evolutionary history of a particular field while also illuminating its frontiers (De Bellis, 2009; Donthu et al., 2021; Kumar et al., 2021). Scopus, the world's largest database of abstracts and citations, was used to search for relevant documents using a variety of keywords in order to grasp the current state of global research and by extension, the concern of scientists related to decarbonisation and net zero. In the present study, the Scopus database was simulated with different sets of keywords to download files for bibliometric analysis. We searched the database with different combination of keywords such as 'COP', 'NetZero', 'Decarbonisation', 'Emission' on 30 March, 2023, encompassing research data till December, 2022. There were very few documents found with combinational keywords. This implied lack of publications on topics such as COP, NetZero, with two keywords such as 'NetZero' and 'Decarbonisation'. The search found 17 articles with all fields criteria. A separate search with a single keyword like 'NetZero' or 'Decarbonisation' found 261 and 19,237 documents, respectively, with all fields criteria. The final search was made with the filtering criteria 'Article title' with keyword 'Decarbonisation' on Scopus database in order to keep maximum amount of relevant articles. In all, 1249 documents were found. Further, only articles excluding reviews, conference, book chapters and such others were kept in the final search. Also, a few articles of 2023 (10)were excluded from the list. The list of 850 articles was downloaded as.csv file and was further used for bibliometric analysis. Analysis was performed to explore publication trend in this domain, influential authors and influential articles, and the most cited countries. The bibliometric analysis was performed using the data set of 850 articles with the help of R-Studio Biblioshiny. Bibliometric analysis was performed to understand "Climate Science—Decarbonisation status of countries on a global scale".

3 Recent literature

The research question for article search was 'What are the decarbonisation strategies to achieve net zero?'. According to Fankhauser et al., (2022), there are five attributes to achieve NetZero: (a) front-loaded emission reductions, (b) a comprehensive approach to reduce emission, (c) cautious use of carbon dioxide removal, (d) effective regulation of carbon offsets, (e) equitable transition to net zero. Net zero must be aligned with the broader sustainable development goals, which entails equitable transition to net zero, socio-ecological sustainability and pursuit of expansive economic opportunities. Table 1 includes information about the recent articles including country name, published in 2022. The articles showed that change to a net-zero carbon economy will be largely driven by industry and policy, which will need expertise in strategies of both emissions and renewable energy. It proves that researchers are recently focusing mainly on strategies to achieve Net Zero target in order to achieve the goals of Paris Conference.

3.1 Bibliometric analysis

Details about the Scopus downloaded file are shown in Fig. 4. The articles in this area by 2666 authors were published from 1895 till 2022, with annual growth rate 4.52%. Figure 5 shows the publication trend in this domain, which was found to have increased in the recent 1–2 years after the COP 26 agenda to achieve NetZero emission across the globe. Figure 6 shows that the *Energies* is the major publisher (45 articles) in the 'Decarbonisation' research domain. Author 'Wang Y' is the most publishing author (13 articles) in this research domain and shares collaboration network with other influential authors such as Chen J, Liu L and others (Figs. 7, 8). The influential article published by Bumpus and Liverman (2008) from Oxford University, UK was found to be the most cited by researchers on decarbonisation and carbon offsets. Citations of the article are: in Scopus, 438 and 813 in Google Scholar. Affiliation with North China Electric Power University is the major publisher in the domain (Fig. 9). The maximum cited countries are USA (citations 2057) and China (citations 1166) in the research domain as per Scopus database. Developing countries are lagging far behind in this research domain and need to focus more in this area to achieve NetZero successfully in the near future. Figure 10 shows that the developed nations are far aggressive when it comes to the research related to the net zero strategies and can be seen to have more research citations on the same. Figure 11 shows majorly co-occurred words such as decarbonisation, carbon dioxide, emission control, carbon emission, greenhouse gas etc.) in the research domain, their counts and percentage.

4 Elements and sub-elements of achieving net-zero

4.1 Renewables

4.1.1 Switch to renewables

Solving today's environmental concerns necessitates long-term prospective measures for long-term sustainable growth. Renewable energy resources appear to be one of the most efficient and effective alternatives in this regard. Our society relies on energy to maintain standard of living and it also supports all other aspects of the economy (Golubchikov &

Table 1 Summary of recent year (2022) journal articles published in net zero and decarbonisation area from different countries

S. no.	Country	Description	References
1	India	The likelihood of full decarbonisation by 2050 is decreasing because there are inadequate technology solutions in the heavy freight and industrial sectors, which make it difficult to achieve full decarbonisation	Vats and Mathur (2022)
2	United Kingdom	The findings demonstrate that widespread adoption of air source or ground source heat pumps can dependably achieve combined embodied and operating emissions below national carbon budgets by 2050. In order to reduce the embodied emissions and specially to adhere to tougher carbon budgets, proper insulating material selection is essential	Li et al. (2022)
3	Morocco	Fossil fuels are used in the manufacturing of fertiliser as both a fuel source and a feedstock, and each tonne of fertiliser produces at least 3 tonnes of CO2	Ouikhalfan et al. (2022)
4	United Kingdom	The goals of the European Green Deal are The Green Deal targets have been set by Member States with greater clarity than the activities necessary to achieve those targets. Actions are still in their infancy and only partially addressed in terms of national policies and financial administration	Perissi and Jones (2022)
5	Netherlands; Indonesia	While also being particularly vulnerable to climate change, the electricity industry is one of the main sources of global greenhouse gas emissions. According to the low emission analysis platform (LEAP) simulation, GHG emissions increase until a peak is reached in 2029, after 66which they begin to fall progressively until they are completely eliminated by 2050. Under the meantime, the cost of reducing emissions in the scenarios of renewable policies and net-zero emissions is 16 USD/ton CO2e and 12 USD/ton CO2e, respectively	Handayani et al. (2022)
6	United States	Three integrated water and municipal solid waste (MSW) management systems were compared in terms of energy consumption, CO2 equivalent emissions, and production. The CO2eq emissions of biogas and hydrogen-based systems differ significantly	Novotny (2022)
7	United States; China	The Emissions-Sustainability-Governance-Operation (ESGO) framework was suggested in the study for a structured evaluation and open communication of national capabilities and realisations for achieving net zero emissions	Zhang et al. (2022)
8	Romania	The level of economic development, the degree of globalisation, trade openness, and the intensity of the energy transition as measured by the share of renewable energy in total energy consumption were all factors that the study identified as statistically significant in determining the carbon dioxide emissions per capita in the European countries	Apostu et al. (2022)

Table 1 (continued)

S. no.	Country	Description	References
9	United Kingdom; Sri Lanka	The integrated models were used to evaluate a variety of heating and transportation technologies and policies where the UK's 2050 net zero carbon emissions target is achieved. By 2050, compared to 2015, it is anticipated that yearly primary energy use would have decreased by 25 to 50 percent overall, largely because of aggressive efficiency improvements in homes and cars. However, compared to 2015, the annual and peak electricity demands in 2050 are more than twice as high	Chaudry et al. (2022)

Fig. 4 Main information about the Scopus imported file for bibliometric analysis

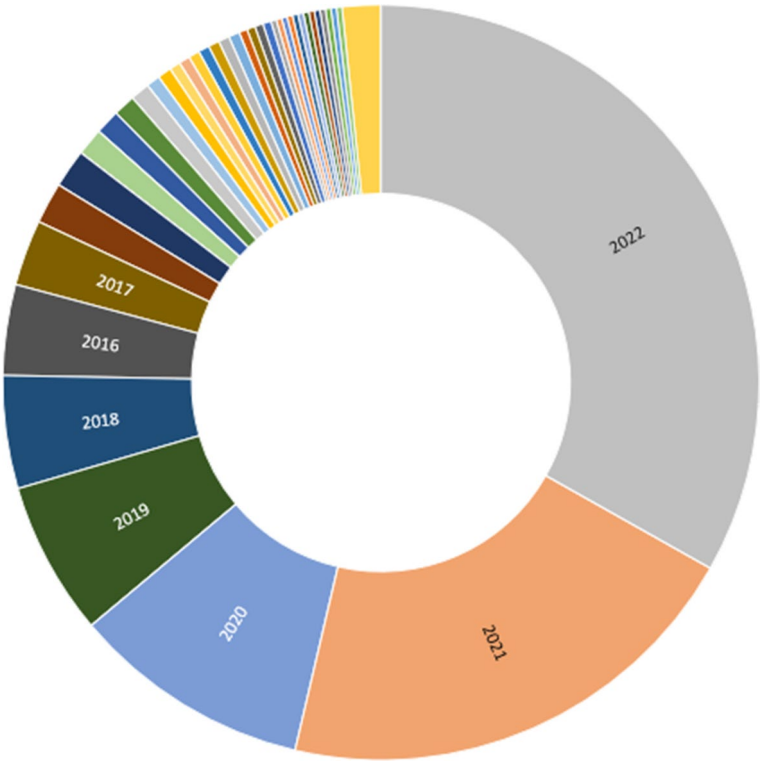


Fig. 5 Publication trend in 'Decarbonisation' domain from 1895 to 2022

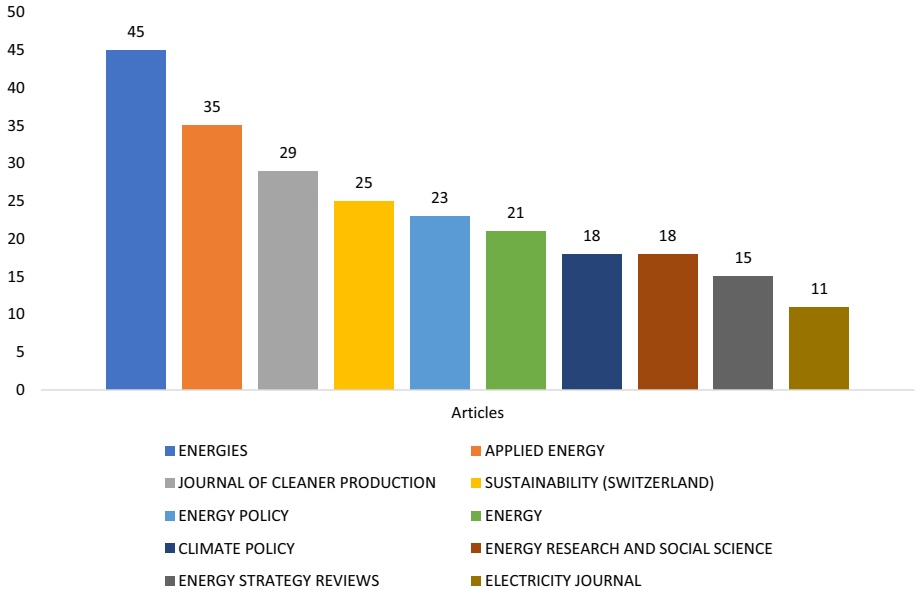


Fig. 6 Major publishing journals in 'Decarbonisation' domain from 1895 to 2022

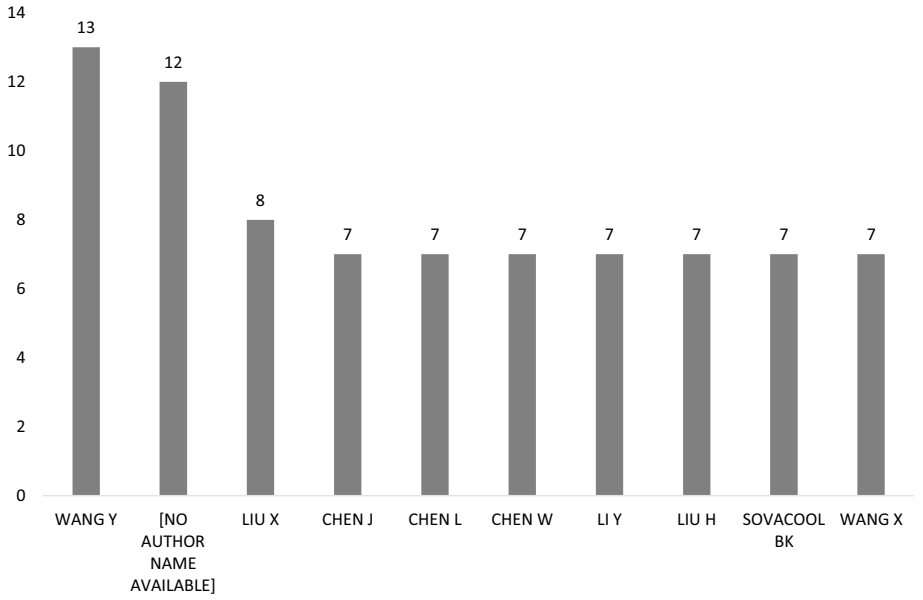


Fig. 7 Major publishing authors in 'Decarbonisation' domain from 1895 to 2022

O'Sullivan, 2020; Clausen and Rudolph, 2020). Renewable energy technologies promise abundant, clean energy derived from self-renewing resources such as the sun, wind, earth, and plants. Renewable energy is gaining importance in combating air pollution and climate

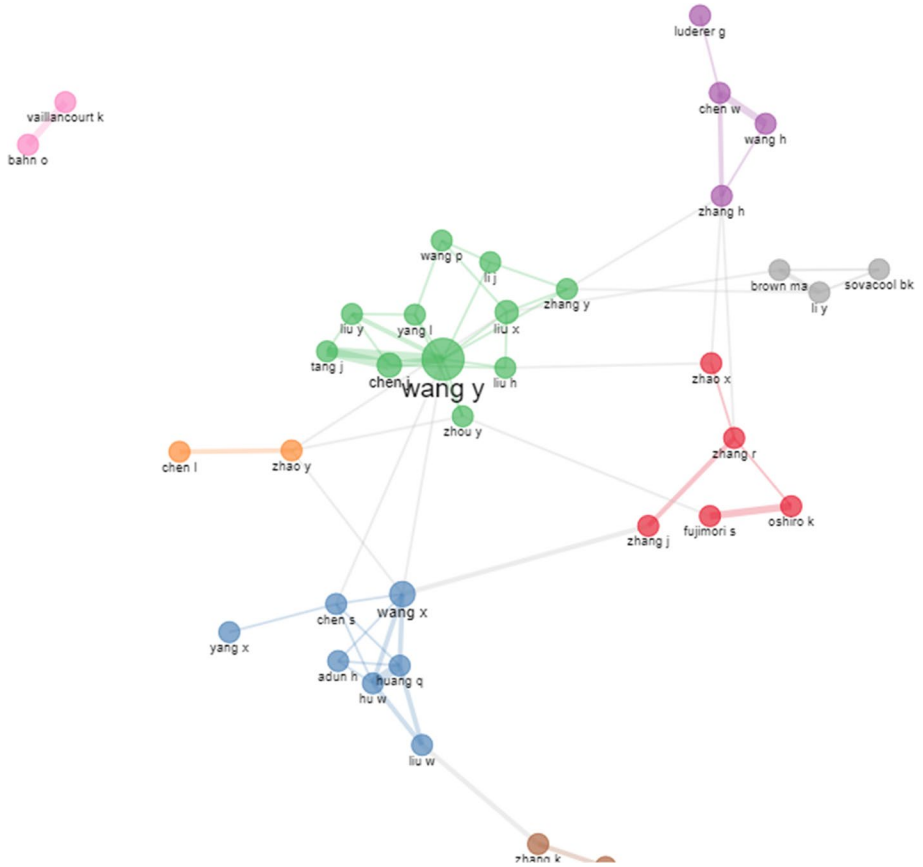


Fig. 8 The influential authors network in 'Decarbonisation' domain from 1895 to 2022

change crises. There is huge generation of greenhouse gases and criteria pollutants due to burning of fossil fuels and important natural resources. Shift from non-renewable to renewable comes with the possibility of producing biogas from organic solid waste through the bio-gasification process, fermentation process and others. This is possible to a huge extent in India as the country boasts of a huge number of cattle as well as production and feeds, and so there is possibility for large-scale production of biogas. Solar power is also witnessing impressive growth in the country. Wind energy and solar energy do not cause any harmful emissions (Desing et al., 2020; Khan et al., 2020).

4.1.2 Clean energy and hydrogen fuel

Transition to renewable energy from traditional non-renewable ones as well as pricing and trading of carbon, a key element of the economy's low-carbon transition will only come from technology adaptation and advances in technology. Green hydrogen is generated from a clean source; however, the most prevalent type of hydrogen is grey, which is produced from methane or natural gas. Blue hydrogen is occasionally referred to as carbon neutral.

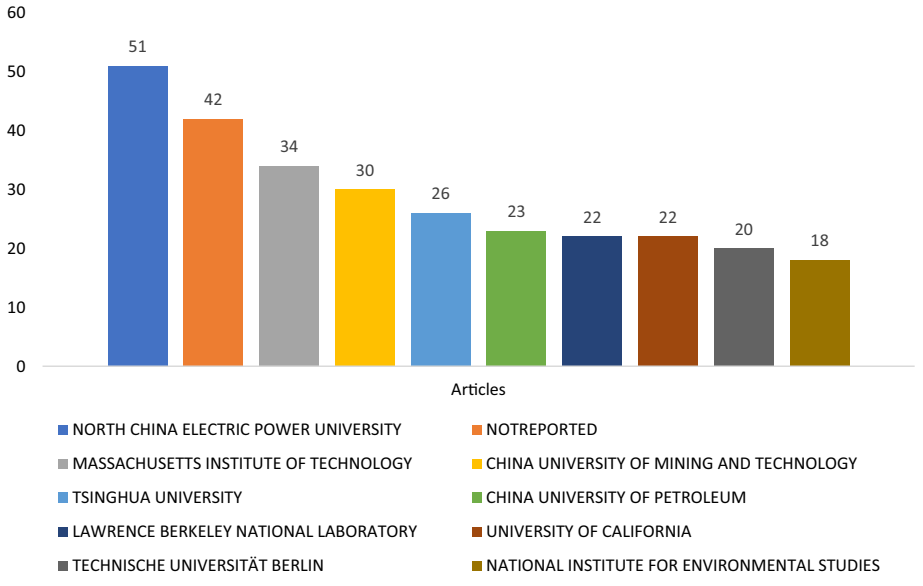


Fig. 9 The influential affiliation in 'Decarbonisation' domain

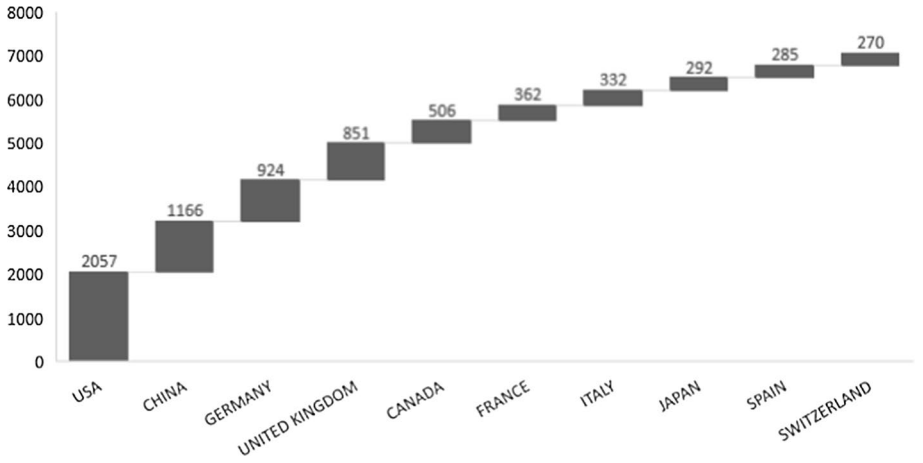


Fig. 10 The most cited countries in 'Decarbonisation' domain

There have been massive technological advances in hydrogen technology which is fast emerging as an important alternative form of green energy. Several organisations, both government and non-government, are attempting to create mandates for green hydrogen mixing in refineries, fertilisers and municipal gas networks. For important technologies like electrolysers, this would help to fulfil required demand and enable economies of scale. The Indian Government is also creating a Production-Linked Incentive (PLI) scheme to encourage indigenisation of electrolysers. The new green hydrogen initiative is targeted to generate around approximately 10 GW of domestic manufacturing capacity. Private sector

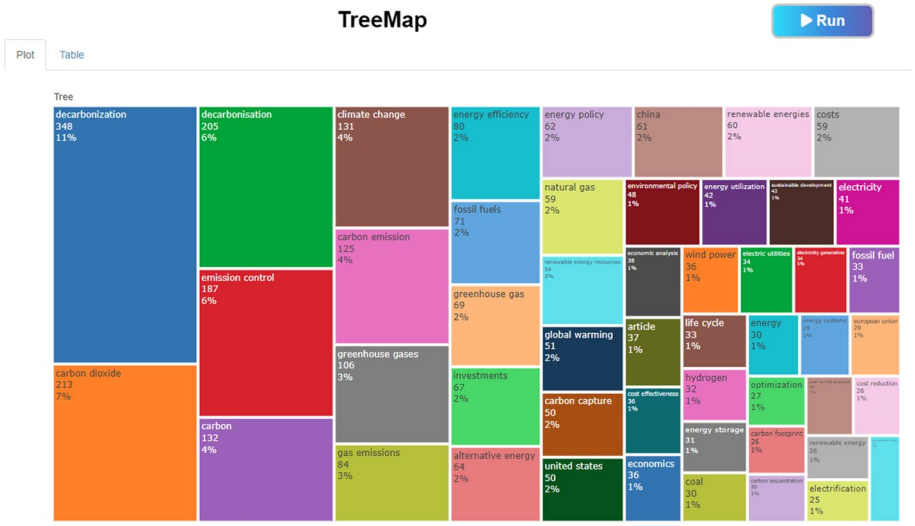


Fig. 11 The treemap of words in 'Decarbonisation' research domain

participation in advancing the Government's push for hydrogen could potentially provide a significant incentive for faster innovation (Esily et al., 2022; Lebrouhi et al., 2022; Taibi et al., 2020).

Research advances claim that improved technologies such as use of green hydrogen (or even blue hydrogen), in the hard-to-abate sectors such as steel, can lessen non-renewable, carbon-rich energy consumption and add substantially to the decarbonisation pathway. According to research, producing steel with 9% combination of green hydrogen will have 68% lower environmental impact than using a traditional blast furnace. While these are longer-term investments and will require government incentivisation, the current decade would be instrumental in setting the tone for mainstreaming hydrogen (with more technology involvement and converting blue to green hydrogen), and moving away from coal-based processes (Fan and Friedmann, 2021; Cavaliere, 2019). The green/blue/grey hydrogen should be focused for short/medium/long-term goals to produce clean energy.

4.1.3 Economic strategy development of fossil fuel-dependent States

State-level decision-makers are crucial to India's development story. Some States have built their development narratives for manufacturing, while others have done so with an emphasis on the service sector for example, tourism and information technology services. Given the substantial resources that are accessible inside their borders, growth trajectory of certain Indian States continues to be dependent on fossil fuels, particularly coal. Thousands of people work in coal mines in the coal-dependent States, mainly in India's eastern region, and a sizable portion of their income comes from this industry. In extensive decarbonisation scenarios, coal must be phased out as soon as possible (Chaturvedi, 2021). Without coal mining profits in a net-zero India, budgets of these states will suffer greatly. A diversified economic development plan of such fossil-dependent states would be a fundamental component of such a future. These States would have to approach economic planning and strategy using a radically different

framework based on the revised assumption which discounts the existence of fossil resources from where they have historically derived economic rents. If the economy were to diversify away from fossil fuels, these States would see a radically different type of employment (Chandra, 2018; Toumbourou et al., 2020). While the amount of local coal jobs lost and the potential for solar and wind opportunities in India's coal-dependent states are proportional, it may be difficult to teach unskilled labourers who have spent their whole lives performing manual labour, in complex systems like solar. As already mentioned, account of these States' economic transformation must be included in the pathways for transition.

4.1.4 Engaging with energy sector workforce

The energy sector workforce (mainly labour unions) needs to actively work with the Government to ensure better energy distribution reforms and enable privatisation of the discoms. Decarbonisation cannot be achieved without the direct and indirect participation of citizens. Behavioural change is required to implement change successfully. Therefore, citizens should be equal stakeholders in any decision process, implying that the Government and policy-makers must engage with citizens and ensure their active participation in the change (Gillings & Harris, 2022; Heinz et al., 2021; Rej et al., 2022). Apart from energy and electricity reforms, it is also important for the Government to engage with the citizens on Scope 1 and Scopes 2 & 3 emission reductions.

4.2 Solid waste management

The principal method for removal of both organic and inorganic solid waste is landfills. However, landfills require huge area of land, and landfill leachate can contaminate clean groundwater (Ghosh et al., 2023; Mishra et al., 2022). Landfill heap is a worrisome point in today's world (Javadinejad et al., 2019; Ostad-Ali-Askari, 2022a). Primarily, waste should be segregated at source into two different categories (dry waste and wet waste) (Fiksel et al. 2021; Wainaina et al. 2020). Dry waste can further go for reuse and recycle. Wet waste (generally biodegradable waste, vegetable and fruit peels, and food waste) can be used for bio-composting, vermicomposting and bio-gasification. Bio-compost and biogas are both value-added products from waste and are environmentally friendly. Bio-compost is useful in organic farming and production of biogas is economically beneficial in cooking (Ghosh et al., 2023). Incineration is also a method of reducing garbage by burning but it has some issues too.

The 5R principles (Reuse, Recycle, Reduce, Repurpose, Regenerate) also stress on optimum use of resources and their conservation. Proper solid waste management and organic fertilisers help in land conservation, resource recovery and implementing a circular economy (Bora et al., 2020; Fiksel et al., 2021; Roy et al., 2023; Sharma et al., 2021; Turan et al., 2019, 2022; Wainaina et al., 2020). This will help to achieve SDG goals for clean water, life below water, life on earth, responsible consumption and production and a circular value chain of sloid waste, along with several benefits by adopting organic farming such as improved soil enzymatic activity, soil-health and human-health (Turan, 2019, 2020, 2021, 2022). According to Ostad-Ali-Askari (2022b), poor management in dealing with hazardous products and trash cause risks in financial progress and human rights.

4.2.1 Creating responsible citizens

Crop rotation and companion planting are important aspects of organic farming, as are organic fertilisers including compost manure, green manure and bone meal. Crop rotation began in the early twentieth century as a reaction to rapidly changing agricultural techniques. The use of bio-compost and vermicompost in agricultural fields ensures sustainability of organic waste utilisation. Also, chemical fertilisers have adverse effect on health, further building the case for sustainable practices (Ashokkumar et al., 2022; Sinha et al., 2021). According to Talebmorad and et al. (2021), there is significant increase in crop-evapotranspitation during summer.

4.3 Advocacy for government incentives

Incentivising green finance for the industrial sector is very important to enable organisations to adopt new technologies.

Mandatory advocacy and guidelines must be in place before rolling out incentives (green funds) for industries. The key performance index (KPI) standardisation and score calculation of different sectors must be done before handing out incentives or funds to organisations (Voland et al., 2022). These in return would create a process that is easier for industries to follow and update their sustainable actions according to the Key Performance Indices's, and then the industries can be in the race and compete for incentives provided by the Government. On the other end, this will also help the Government to have a baseline KPI to provide financial aids/ loans to the organisations.

4.4 Common but differentiated responsibilities

Undoubtedly there is need for collaborative actions across value chains and industrial sectors, including stakeholders' groups of policy advisors, regulations, finance and technology. However, providing sectoral guidance on differentiated responsibilities is also a prime factor for consideration while making framework and strategies for net-zero commitments (Miemczyk et al., 2022; Pereno and Eriksson, 2020).

4.5 Electricity usage and transformation

Electricity usage and transformation remain a very important factor in the energy transition pathway (Bogdanov et al., 2019; Markard, 2018); however, there are several associated factors which are key challenges in the transformation roadmaps. Some of them are: (i) behavioural change and its requirement, (ii) less government enterprises interference/ dominance in the sector, (iii) redesigning the power sector, (iv) electricity pricing structure—market structure and household availability.

4.5.1 Behavioural changes

Transformation in electricity usage can be achieved only by behavioural changes along with implementation of an institutional framework encompassing policy changes and discom reforms (Rishi, 2022; van Doren et al., 2020). Some aspirations or behavioural changes include switching to star-rated appliances wherever possible, hundred percent switching to

renewables, optimised energy planning based on quantitative energy forecasting models, and adopting the use of green hydrogen and other advanced technologies.

4.5.2 Less government enterprises interference/dominance in the sector

In developing countries, and also in some developed ones, power sector is dominated by the government in the form of PSUs or public sector undertakings. This sector includes coal and coal-based energy (Montrone et al., 2021; Nandi et al., 2022). Public sector is better positioned to play a leadership role in energy transition from the coal-based traditional system to renewable energy. Similarly, natural gas PSUs are better positioned to transition from carbon-rich gases to green hydrogen. Further, monopoly of the traditional sectors (coal and power, energy, steel and cement) can be broken by making way for new players in the road to decarbonisation. Over a long tenure, this strategy will help achieve net zero in the future.

4.5.3 Power sector re-design

In the net zero scenario, power sector needs to be re-designed entirely with minimum use of coal. Renewable energy sources should be blended with non-renewable ones (for example, green hydrogen and CNG) to meet power demand (Kouchachvili and Entchev, 2018). The promise of nuclear-based electricity will only be partially fulfilled in the present scenario, given the hazards in the production process. However, steps are being taken to eliminate hazards in the process, and in the near future, nuclear-based energy can be a powerful player in the net zero journey. In the Indian context, solar energy could be a powerful energy source. However, its use would require the redesigning of key features of the Indian electricity system, as the use of solar to support the market for base load, mid-peak and super peak loads would be risky. There should be a mix model of all other forms of energies (variable renewable energy for specific times) and coal-generated energy to support all business loads over the period. Variability and mix model approaches for power dissemination are required because of the different sectorial load on the grid, and the pattern of the multi-sectorial (hard to abate, light manufacturing and service sectors etc.) usage. This mix of energies would ensure greater utilisation, thus creating a road map for net zero (Iannuzzi et al., 2021).

4.5.4 Electricity pricing structure–market structure and household availability

Lower cost of electricity is one of the key reasons for its adoption. State governments in India are responsible for pricing for both industrial and household consumptions. Household electricity is over-subsidised while that for commercial use is over-priced, to balance the loss arising due to over-subsidisation of domestic/residential sector consumers. Retail pricing of electricity in Indian States is one of the important parameters to consider in decarbonisation of the industrial sector. Research points to the need to increase the share of electricity in the net zero scenario. This increased use would require a change in pricing policy of electricity (Dell'Anna et al., 2022; Liu et al., 2021). Industrial electrification is essential to replace fossil fuels in the hard to abate sectors for a carbon-free country. So, deep electrification/ industrial energy use must be supported with accurate pricing to increase its adoption by the industrial sector. One of the key aspects of India's net-zero future would be a retail price system based on the market.

4.6 Reduction of carbon intensity

To reduce climate change and limit the associated risks, it is important to reduce addition of greenhouse gases (GHG) in the atmosphere. Several malpractices such as wrong land use patterns and use of energy, increase carbon dioxide emissions and consequently, the carbon burden (Guo & Fang, 2021; Zhu et al., 2021). Good practices such as afforestation, wet-land conservations and land-use pattern, can be used as a sink to store carbon dioxide and increase the rate of absorption of carbon dioxide gas. This can help in reducing greenhouse gases in the atmosphere and add other co-benefits also. These are some of the easily available techniques to reduce carbon intensity with existing technology, implying that no further investments in new technology are required. There can be several other pathways to reduce carbon intensity. A thorough research on climate science to derive climate technologies for carbon intensity reduction must be undertaken to develop a framework for net zero in the context of developing countries.

4.6.1 Pricing carbon and policy incorporation for internal usages

Another pathway to net zero can be redefining carbon pricing policy. Pricing of carbon should be incorporated under policy initiatives by government bodies. Without a proper pricing structure in place, it becomes difficult for the stakeholders such as citizens and investors, to adopt and implement changes. It is important to develop a credible framework to price carbon so that investors can make judicious decisions (Gautam et al., 2022; Johansson et al., 2021). Moreover, implementation of early carbon pricing in the system, along with the necessary policies, regulations and incentives, would greatly help industry players to adopt sustainable practices.

4.6.2 Structuring of functional trading markets for green-house gas emissions

Carbon is a negative commodity in realising the net zero vision for all relevant stakeholders for example, policy makers, investors and even common citizens. So, there is a need of fully functional carbon pricing mechanisms or an emission trading scheme (ETS) supported by the government and backed by strong policy guidelines (Chaturvedi, 2021). There are certain governmental schemes at the State level, which run ETS schemes to price carbon. However, a national ETS scheme is required to limit the price of the carbon and making the process of pricing it easier and in a more proficient way. To achieve net zero for the future, there should be vision and sectoral road maps with decarbonisation strategies starting, from the year 2025 till 2030 (that is, much ahead of 2050 and 2070, the benchmark year for most developing nations to go net zero) in place. There should be specific monitoring schemes and maintenance of emission inventories of industries modulated by government sectors and agencies such as BEE (Bureau of Energy Efficiency). There should be technical organisations for achieving and measuring the performance achieved by businesses per year (Rissman et al., 2020). This, along with special sector specific policies from the Government, would help countries achieve net zero.

4.7 Enabling financial models

To achieve net zero, decarbonisation pathways must be supported by development or adaptation of new financial mechanisms or models revolving around funds (Hampton et al., 2022; Kourgiozou et al., 2021; Miller et al., 2021). Savings from investments in energy efficiency and other low-carbon development pathways can be captured and reinvested to either reduce the need for finance or increase financial support. These approaches are already being implemented in industrialised nations (with necessary financing) (; Ford & Hardy, 2020). The tactics that have been used in various contexts to achieve a variety of ideals and purposes include improving energy efficiency, promoting renewable energy, ensuring the best and most efficient use of land and decontaminating toxic locations.

4.7.1 Low-cost finance for the transition of energy into renewable energy (RE)

The entire structure of financing for the transition to renewable energy (RE) needs to be lowered down for Indian scenarios and for other developing countries sharing similar landscape. Several studies have pointed out that large investments are required for meeting the ambitious goal of greening all the energy sectors, and achieving the net-zero target on time (Wei et al., 2021). The grey area where practical implementation is needed is aligning private–public sector policies. With the right amount of incentivisation, policies and low-cost financing, the pathway towards achieving net zero would become simpler (Kourgiozou et al., 2021).

4.7.2 Market values designing for carbon taxation (CT) and pricing

Indian business sectors would need a robust and regulatory framework to incorporate carbon pricing. There are existing challenges in pricing carbon in the Indian market. These include lack of robust strategy for communication, public dialogue, social deliberation, challenges in regenerating revenue, and how economically feasible and competent the process is for the market, its long-run and competitiveness (Zhang et al., 2020). In the process of creating a framework for carbon-taxation and pricing, which would be a part of—revenue recycling system (that is, in turn inclusion of strategies for carbon taxation), phase-wise implementation of a taxation scheme, clarity in the identification process of fund flow channels involving carbon taxation scheme, durations and the frequency needed for polies in place for CT, identification of projects which are directly depended on carbon finance and the way to leverage them.

4.8 Circular economy (circularity in business model: *linear take-make-waste mindset, multi-lifecycle circular mindset*)

The year 2015 was a landmark year in terms of adoption of inclusive global policy for sustainable, multi-dimensional development. All United Nations member states came together to implement and adopt the 2030 Agenda for Sustainable Development that proposed an egalitarian and much-needed precedent and modus operandi to achieve global peace, progress, and equality. The 17 sustainable development goals link all the developed and developing nations of the Global South with a common vision, that is,

a global partnership for pragmatic, conservatory development practices. The SDGs impressed upon the need to eradicate global poverty and ideate innovative strategies to improve healthcare infrastructure and accessibility, ensure responsible consumption and production, all the while keeping in mind environmental conservation, climate change, and diminishing inequality in society (Al-Chaer, 2020).

Linear material management (take-make-waste practice), therefore, leads to increase in waste in landfills and oceans, catalyses climate change, affects implementation of sustainable development goals and leads to irresponsible consumption and production. It does not support optimum resource utilisation and is not conducive for economic growth and development, society and environment. Value is created by producing materials in mass, and using them and throwing them away. Linear economy exhausts raw materials and depletes energy. The main emphasis is on production with little or no emphasis on sustainability (Kickbusch et al., 2021).

Circular material management or circular economy is a more modern concept in which a product of consumption is not disposed of; rather its constituents are recycled, reused, or repaired, to create new products for further cycles of consumption. As a result, less waste is generated, which bodes well for the environment and economy. Another example is to treat waste water for reuse—this would help in addressing the problem of water scarcity. A case in point is Singapore which treats waste water for consumption. To a lower level, after primary treatment, such water can be used for non-drinking purposes like gardening. Another example is composting bio-waste and using it as organic fertiliser for use in farming. The circular material management process starts with collection of raw materials, then converting them into products for use, and post-consumption recycling and repairing the left overs for further use. In other words, left-overs of the first cycle would be the raw material for further cycles of manufacturing, distribution and consumption. As a result, there will be minimum waste left to process or find its way to landfills and water. Circular economies are therefore more attuned to fulfil environmental and health goals, while also leading to sustainable development. As a case point, the production process of one pair of jeans involves approx. 10,000 L of water, so the environmental cost or impact of one pair of jeans is equivalent to 10,000 L water.

So, circular material management would lead to the practice where raw materials and final consumer products are recycled and reused after their primary usage (Romero-Hernández and Romero, 2018; Mayer et al., 2019). Circular economy revolves mostly around 3R, that is, Reduce, Reuse & Recycle. This economy lays emphasis on using renewables (Fig. 12) and reducing waste. Therefore, it helps to prevent environmental degradation, promote sustainable development and address other social issues such as poverty and hunger. For instance, leftover food after weddings and other events is distributed amongst hungry people—this helps to ensure they have food in their stomach, which in turn, promotes good health and wellbeing (SDG 3).

Multiple Material Model Management will increase resource recovery and strengthen the value chain and economic profit (Ilame and Ghosh, 2022; Ding et al., 2022). As per Ehrlich's (IPAT) equation, degradation of the environment increases with increase in population, affluence and technological drawbacks. India is the second most populated country in the world and its maximum resources exceed carrying capacity. It therefore becomes all the more important to implement circular economy to conserve resources and follow sustainable practices. For instance, garbage burning is still followed in several urban areas, along with crop residue, which causes major environmental and health hazards.

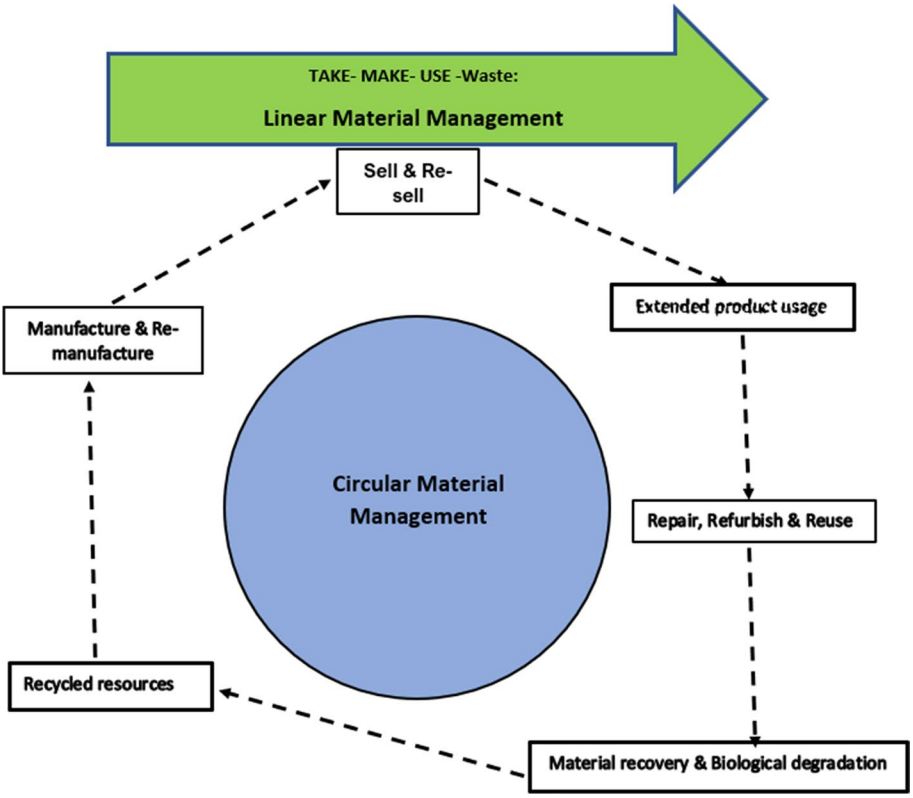


Fig. 12 Linear versus circular material management

4.9 Carbon capture utilisation & storage

Net-zero has re-emphasised focus on carbon sinks—natural or artificial. Carbon capture, utilisation and storage (CCUS) has gained significance across several industries such as oil and gas, steel, cement, and transport, as a means to reduce carbon intensity across sectors and create a potential business segment based on numerous potential uses of CO2 (Hong, 2022; Bistline, 2021). Reforestation, afforestation, and agroforestry techniques can be implemented to construct natural reservoirs that absorb CO2, supported by geological and mineral sequestration (Benhelal et al., 2021).

4.9.1 Carbon utilisation techniques usages

Adopting CCUS technologies for industrial plants can aid in minimising industrial emissions at source (Chen et al., 2022).

- Direct air carbon capture and storage (DACCS): scaling newly developed technology to recover CO2 from the air can unleash virtually endless decarbonisation potential.

- CO2 utilisation: the captured CO2 can be effectively employed in a variety of applications including production of synthetic fuels, curing of concrete, and increasing crop productivity.

Following global momentum, India needs to focus on the following: (1) create more awareness and understanding of green practices (creating zero carbon zones in industrial zones, recycling of carbon); (2) assess geological storage potential; and, (3) create supportive policy mechanisms to implement CCUS domestically (Jiang & Ashworth, 2021; Yan et al., 2021). Some activities in the present scenario could include: (i) Conduct studies on geological storage capacity in India. (ii) Draft and implement policies and carbon financing mechanisms. (iii) Identify suitable technology options and ascertain their potential. (iv) Provide policy/regulatory options at the national and state-levels to enable industries make an informed decision on implementing CCUS technologies. (v) Frame policies for finance/funding options (since the upfront CAPEX cost of implementation of CCUS technology is very high). (vi) Create road-map for development of sector-specific technologies and define the role of the taskforce in laying this roadmap. (vii) Create CO2 grid to enable CO2 supply to players in hub areas. (viii) Draft charter/document on the financial incentives to be achieved, for setting up commercial-scale CCUS initiatives. (ix) Ensure availability and quality of adequate data. (x) Facilitate utilisation and conversion of the CO2 to ethanol/methanol/adipic acid on a larger scale. (xi) Conduct more research studies on the feasibility/costs of implementing, and the priorities. (xii) Demarcate important routes of the CCUS technology for achieving net zero in the commercial sector.

4.10 Biodiversity

The quote "Human beings have a relationship with Nature for its co-existence" signifies the interdependence between the two. Humans are dependent on nature and natural resources for survival. Nature existed way before humans evolved has been changing constantly. Even as humans strive to gain command over nature, it continues to evolve. In the current scenario, there is greater need to balance the relationship and rather than command, humans have to live in harmony with nature for peaceful coexistence. The fact that we cannot conquer nature is now more evident than ever before, and at this crucial juncture, the need to implement sustainable practices is all the more crucial (Carr et al., 2021).

India is one of the world's 17 megadiverse countries identified by Conservation International, with a wealth of biodiversity and traditional wisdom. It is home to 7.6% of all mammal species, 12.66% of all bird species, 6.26% of all reptiles, 4.46% of all amphibians, 11.76% of all fish and 6.06% of all flowering plant species. Forests and trees cover 23.39 percent of its land area. Despite having only 2.4 percent of the land area, India is home to about 7% of the world's recorded species and nearly 18% of the human population. In terms of species richness, the country ranks seventh in mammals, tenth in birds, and sixth in reptiles. In terms of vertebrate endemism, it ranks tenth with 69 species of birds, fifth with 156 species of reptiles, and seventh with 110 species of amphibians. The crop share is 44 percent, far higher than the global average of 11 percent (Joshi et al., 2020; Sharma & Kumar, 2021). Also, India is the second most populated country in the world housing one-sixth of the world's population. In this context, it is a major stakeholder in achieving sustainability targets by 2030.

4.11 Value chain integration and transition

Industry can form geography-specific alliances to localise supply chains and make them sustainable. Several industries have to source raw materials from places far from their working units. One way to achieve sustainability in supply chains is to source raw material locally. Therefore, we need to make the supply chain local or push for "Vocal for Local" (Pandey, 2021). Industry can come together and work with local governments to create Management Information Systems with user-friendly interface to track output and waste generation from companies and ancillaries in specific geographies. Additionally, there is need to measure and monitor emissions (Scope 1, 2 & 3), and also hand-hold industry players in adopting green and sustainable practices. This would help the industry realign supply chains to use locally available material, thereby reducing their carbon footprint and going green, a step towards the decarbonisation path.

4.12 Responsible procurements

Focus should also be on removing unavoidable substances and processes in the supply chain, logistics and manufacturing, notwithstanding efforts to replace materials to reduce GHG emissions. Therefore, it is imperative that technology be upgraded for coal power plants for carbon capture, storage and utilisation techniques. Additionally, encouraging production of green hydrogen at industrial scales, internal carbon pricing for corporations, and responsible product procurement across the value chain, are also essential. The transition journey to sustainability should include the 3Rs of technology, that is, Replace, Reduce and Remove. In other words, there is need to reduce and remove all raw materials and products with high carbon footprint, and replace them with more sustainable ones (Asante-Sackey et al., 2021; Tahir et al., 2020). Companies would require cross-regional coordination in order to refocus current investment, secure more funding, restructure energy distribution and align the value chain (e.g. local and also States).

4.12.1 Going beyond co-benefits

There is also need to change the mind-set from personal profits to co-benefits for making net zero mission a reality. For example, there are several trade-offs that come with decarbonisation of bigger industries or from hard to abate sectors such as coal, energy, steel and cement etc. (for example, loss of coal jobs, loss of fiscal resources of coal dependent States, electricity price drop, energy security issues etc.). These need to be addressed in government policies. All the co-benefits related to the transition are presented in silos and not together in a single narrative; for example, "air pollution reduction" transition (Sharifi, 2021; Ürge-Vorsatz et al., 2014). The government, policy-makers and non-government organisations must come together to build a strong case for the co-benefit narrative including the associated health benefits, to enable this shift.

4.13 Work in clusters

Working with industrial clusters (mix industrial clusters, single industry-based industrial clusters etc.) to create the framework to reduce GHG gas emissions is always effective.

Analysis of energy use pattern of a cluster can be done smoothly with a proper research and development approach. This would lay the foundation for setting policies for technology use and upgradation (Bechara & Alnouri, 2022; Upham et al., 2022).

4.14 Nature-based solutions

Nature-based Solutions (NbS) are techniques of sustainably managing nature in tackling socio-environmental challenges and using naturally existing techniques. Moreover, NbS also helps in dealing with societal challenges. They encompass a wide range of actions. Some of them are:

(a) Protecting the ecosystem and semi-natural biomes/ecosystems;
(b) Incorporating sustainable (blue and green) infrastructure in the urban areas;
(c) Incorporating and applying of NbS in agricultural systems.

A properly managed natural ecosystem can increase the wellbeing of the entire population, and help to fix carbon utilisation issues (such as flood controlling, stabilising shorelines and slopes to provide clean air and water, food, fuel and other genetic resources). NbS is an umbrella concept that uses nature-based approaches and creates an ecosystem-based adaptation and solves sustainability issues (Hirons, 2021; Kaarakka et al., 2021). A very recent approach called "natural climate solutions (NCS) on mitigating more carbon-related or carbon emission-related problems has been adopted by climate change mitigation bodies. NCS also falls under the broad head of NbS, but with more specificity to reduce greenhouse gas emissions (GHG) from ecosystems and to harness their potential to store carbon (Seddon et al., 2021).

5 Stakeholders: policy actions

5.1 Redesigning the curriculum of engineering schools

The curriculum of engineering courses in technological universities should be modified and amended according to the need of the hour. The courses should be designed with classes imparting knowledge on information technology and artificial intelligence. Besides, it should also include management courses to build skills for the energy and power management sectors. The curriculum should be designed to meet current and anticipated industry needs with specific focus on emerging technologies and how they can be leveraged to implement the net zero vision (Huseien & Shah, 2022; Sharifi et al., 2021).

5.2 Engaging with the citizens

There is need to create awareness amongst the general public on the 3R principles of reuse, reduce and recycle on the one hand, and implement stringent fines for those who break the rules. Awareness campaigns can be launched on all media channels including radio, TV, print and social media. TERI recently launched a scheme to sell things in exchange for plastic PET bottles (Knickmeyer, 2020; Moh and Abd Manaf 2014).

5.3 Engaging with finance sector workforce

De-risking green investments is the need of the hour. Many studies have highlighted that easy availability of low-cost finance can support the transition towards renewable energy (Egli, 2020; Hall et al., 2018). So, it is necessary to work and engage with the finance sector to ease the transition to renewable energy across all sectors (Olleik et al., 2022; Steckel & Jakob, 2021).

5.4 Infrastructural development

5.4.1 Generation of MRV (monitoring, reporting and verification) system

There is need to implement an MRV system to automatically collect data on emissions across all sectors on an annual basis (domestic and international stakeholders). The better the monitoring and measurement of emissions, the better the understanding about emitters and sources of emissions. This information would be important in drafting and enforcing policy and compliances. The system of MRV (for developing countries, specifically India) would act efficiently and regularly to report with high efficiency and ensure effective verification of the reduction of emission mitigation claims by various emitters/ stakeholders across sectors (Fox et al., 2019). Therefore, an MRV system will help in putting in place the net-zero target for a developing nation like India (Marin et al., 2022).

5.4.2 EV charging infrastructure development

Electric vehicles are a much better solution than replacing old traditional fuel with new carbon–neutral options such as blended synthetic fuels. The percentage estimates of the share of EV cars in the market will be based on the efforts of the Original Equipment Manufacturers (OEMs) and charging infrastructure across the country over the coming decades. There should be enough infrastructure to support EV including the setting up of charging stations across cities, semi-urban areas and even rural areas. This will disrupt the market with EV integration in the automobile sector. So, there should be a mix of financial, behavioural and infrastructure-related incentives from the government and private sector players, to ensure mass-scale electrification and adoption of the EVs (Singh et al., 2021; Conway et al., 2021).

5.4.3 Demand-side management infrastructure development

Green labels and green products are still not in high demand. Hence, manufacturing sector is not growing in this context. For enterprises working with green labelling, green products, to get incorporated into a sustainable system, there must be proper demand to need ratio mapping in place (demand to need mapping would include mapping the social factors, geographic influences, economic factors that directly and indirectly influence communities' need for a shift to green products, and the status of green products manufacturing for that place). Investment from banking, financial and insurance sectors (BFSI) is required for the construction of infrastructure, to provide loans to support sustainable growth, and to mobilise funds for green adaptation. Therefore, to develop the infrastructure for usage of green products, all factors should work and operate in sync in an ecosystem. Such factors in the ecosystem would include building policies, development of management and

leadership infrastructure, and enough interest and engagement from producers, users and financial sectors, including banking and insurance (Bhasin & Gulati, 2021). Ahmed et al., (2022a, 2022b) investigated contributions of renewable energy generation (hydropower, wind energy, solar, heat exchangers and bioenergy) to the development of zero-energy buildings and its role in tackling the decarbonisation challenge. For criterion evaluation, acost-benefit analysis and life cycle assessment of net-zero energy buildings are required.

5.4.4 Grid development for electricity generation and distribution: reforms and requirements

Distribution of energy in India is carried out in the States by their respective governments. This restricts the choice of energy for a consumer. The state discoms in India are financially distressed and the imposition of wheeling charges, traditional power purchase agreements and licensing systems make it difficult to pass on the benefit of tariff reduction to consumers.

Several amendments over the years have been proposed by the Government, including reforming the licensing system, revamping the regulatory system, and improving financial health of power distribution companies. The tariff policy also requires significant amendments to ensure payment security for power suppliers, and reduce losses and cross-subsidies. Energy projects in India are deemed financially risky because of the precedents of discoms having refused to purchase power after contracts were awarded. Energy reforms must be made equivalent to financial gains in the coming years for the industry to realise gains from green energy transition (Maulidia et al., 2019; Verma et al., 2020).

5.5 Ecosystem creation between the government, corporates, and investors

It is important to create an ecosystem (collaboration between the government, corporates, and investors) that can support decarbonisation. All the three stakeholders that is, the Government, corporates and investors face heightened expectations to take on responsibilities of the social, environmental and economic impacts. It is nearly impossible for any single sector to work in isolation. So, there is a need for deeper collaborations to drive progress towards the common decarbonisation or net zero directives. Some of the common collaborative areas where stakeholders can work together are: value chain integration and handholding across small and medium enterprises (MSMES); building appropriate markets for fixing the price of green products to ensure uniform procurement (also, giving a green taxonomy or code for everyone's use); and working on policy and regulations, i.e. offering the right incentives for markets and going in for feasible technology transfer (Masum et al., 2020; Naciti et al., 2022).

6 Conclusion and policy implications

Technological developments, financial innovation and strong political leadership can help to build the five pillars of sustainability goals (Ahluwalia & Patel, 2021; Balbus et al., 2022; Chase2022; Clausen & Rudolph, 2020). All these drivers can collectively help developing countries like India to meet the sustainability goals. The SDGs offer every nation the opportunities to meet challenges based on its unique assets and regional issues.

Technological advances have helped to bring down physical labour and associated costs of producing energy, and also has co-benefits like reducing air pollution (in terms of fine and ultrafine) (Das et al., 2020a, 2020b).

India will be able to deploy renewable energy at the lowest cost per unit if technology, leadership and financing are used in the right proportions. India is on the route to restructuring its economy with new green developments (its paradigm), optimal land use, expanding e-mobility sectors and services, and with different techniques of afforestation, etc. India as a country can therefore provide and come up with a template norm for all other developing countries and emerging economies to follow if all the plans and structures are in place for a sustainable future with low carbon pathways to achieve net zero target (DeWit, 2022; NITI Aayog report, 2020). The multifaceted repercussions of India's green growth will pave the way for decarbonisation and inclusive prosperity.

The Fourth Industrial Revolution, also known as "Industry 4.0," conceptualises rapid change to technology, industries and societal patterns and processes in the twenty-first century due to increasing interconnectivity and intelligent automation (Mayer et al., 2019). The revolution is also expected to play a significant role in the country's decarbonisation process. Circular economy is aided by Industry 4.0 technologies (Romero-Hernández and Romero, 2018). Circular business strategies for recycling garbage and delivering new products can be accelerated by automation and connection, thereby dramatically lowering resource use and maximising natural resources. Conversely, by integrating web technologies, reverse logistics and additive manufacturing (AM) as a technology platform to support the model, circular business models can be utilised to recycle electronic waste. The paradigms of Industry 4.0 effect societies in a number of ways including the economical, socio-technical and environmental aspects. By creating collection and processing methods for urban waste using three-dimensional (3D) printing technology and artificial intelligence, Industry 4.0 may also support circular business models. In addition, automated processes will free up resources—time and money—from associated stakeholders, which can then be allocated to fulfilling the technical aspects of recycling or be dedicated to research, development and innovation. The focus of policymakers should be to strengthen net zero emission targets by establishing robust standards for net zero emission targets and bolstering the capacity of entities, particularly in the global South to meet technical and resource challenges, necessary for the effective operationalisation of net zero emission targets (Hale et al., 2022). The work also entails focusing sustainability, helps to improve the economic value chain of materials and hence the economic growth. The developing nations need to follow the same lessons for long term business sustainability.

Also, integration of the Task Force Related Financial Disclosures (TCFD) and the Expert Panel on the Sustainable Finances (EPSF) advisory on climate change and extreme weather risk factor should be taken into account for institutional portfolio management of businesses and most important, "Factoring Climate Risk into Financial Valuation"; forming the risk matrix is very important for businesses. The net zero transition is becoming financially and practically achievable in India due to ongoing improvements at both business and policy levels. At COP27, India unveiled its long-term low carbon emission development strategy. India's climate action plan will be focussed on the following seven areas:

(a) Low-carbon electrical systems that are development-compatible;
(b) Comprehensive, effective and low-carbon transportation systems;

(c) Material and energy efficiency in buildings;
(d) Disentangling emissions from growth and creating an effective, low-emission industrial system;
(e) Engineering solutions involving CO2 removal;
(f) Increasing forest cover while taking socioeconomic and ecological factors into account;
(g) Increasing climate resilience in the fight against poverty and creation of jobs.

6.1 Credible net zero plans at the national level should, at the very least

1. Set short-term and long-term goals.
2. Be thorough when accounting for all greenhouse gas emissions.
3. Show continuing commitment to lowering greenhouse gas emissions.
4. Plan to permanently remove carbon dioxide from the atmosphere in order to balance off any remaining emissions.
5. Publish a detailed plan with immediate activities to reach net zero by the middle of the century.
6. Increasing climate finance, creating new financial instruments and markets such as voluntary carbon markets, implementing public–private sector partnerships, and controlling risk to stranded assets, are all ways to catalyse effective capital reallocation and new financing arrangements.
7. Building awareness and transparency about climate risks and opportunities, reducing technology costs through R&D, fostering industrial ecosystems, collaborating across value chains to reduce or pass through cost increases from the transition, sending the right demand signals, and creating incentives for the transition, are all ways to manage demand shifts and near-term unit cost increases for sectors.
8. Putting in place compensatory mechanisms to address socioeconomic effects including social assistance programs, reskilling and redeployment initiatives for impacted workers, and economic diversification initiatives.

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Data availability There are no datasets used and/or analysed during the current study. The current study is an extensive review paper.

Declarations

Conflict of interest The authors declare that no conflict of interest exists for this manuscript.

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