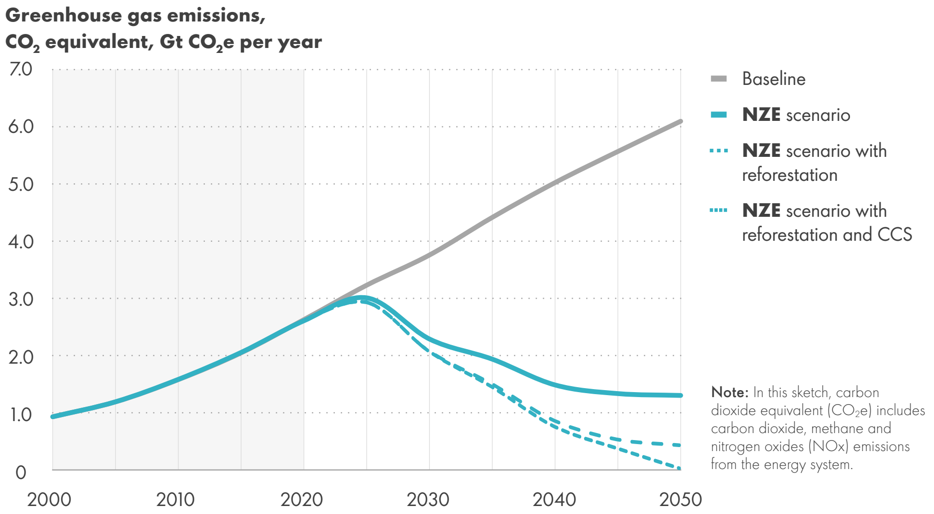
Figure 10: Technology and nature are required to remove remaining emissions



Note: In this sketch, carbon dioxide equivalent (CO_2e) includes carbon dioxide, methane and nitrogen oxides (NOx) emissions from the energy system.

Source: TERI analysis

The **NZE** scenario has residual emissions of 1.3 billion tonnes in 2050, primarily from industry. To achieve net-zero emissions, forestry can, at best, sequester 0.9 billion tonnes,[22] including a contribution from trees outside forests. The remaining 0.4 billion tonnes will still need sequestration through other options, such as carbon capture and storage (CCS), carbon capture and use (CCU), expanding wetland areas and CO_2 removed from the atmosphere by India's extensive coastal ocean ecosystems, such as mangroves. India is home to more than 7% of the world's mangrove forests, which cover 8% of the Indian coastline.

Carbon capture and storage

Carbon capture and storage (CCS) technologies have been deployed in many locations globally with individual projects storing as much as 4 million tonnes of CO_2 a year. CO_2 typically requires geological storage at depths of two or more kilometres. The cost of implementing CCS is dependent on specific local circumstances, but opportunities normally exist[23] around $50 per tonne of CO_2. CCS could be applied in three ways:

- in direct use at industrial facilities, such as a cement plant, to capture both combustion and process emissions;
- in combination with the combustion of biomass in power stations or the processing of biomass into biofuels (known as bioenergy with carbon capture and storage, BECCS), offering the opportunity for negative emissions (a net removal from the atmosphere because carbon absorbed during biomass growth is then stored geologically). This can balance emission sources from sectors such as aviation, where the direct application of CCS is not possible; and
- in combination with the emerging direct air capture technology which also offers the opportunity to generate negative emissions.

There is uncertainty about the overall geological storage potential in India. The Global Carbon Capture and Storage Institute estimates there is around 47 gigatonnes of storage potential,[24] but acknowledges that India requires a national study of deep saline formations and of a depleted oil and gas field to identify effective storage potential.

While biomass in power generation is limited in the **NZE** scenario, the significant biofuels industry that develops could offer the opportunity for negative emissions with BECCS. For example, a synthesis gas production route to aviation fuels from biomass also produces CO_2 within the process.

A further option is CCU. Instead of the CO_2 being geologically stored, it is used to make specific products. Where the products remain in society for an extended period of time, for example embedded in the built environment, the effect is similar to geological storage, albeit not as long lived.

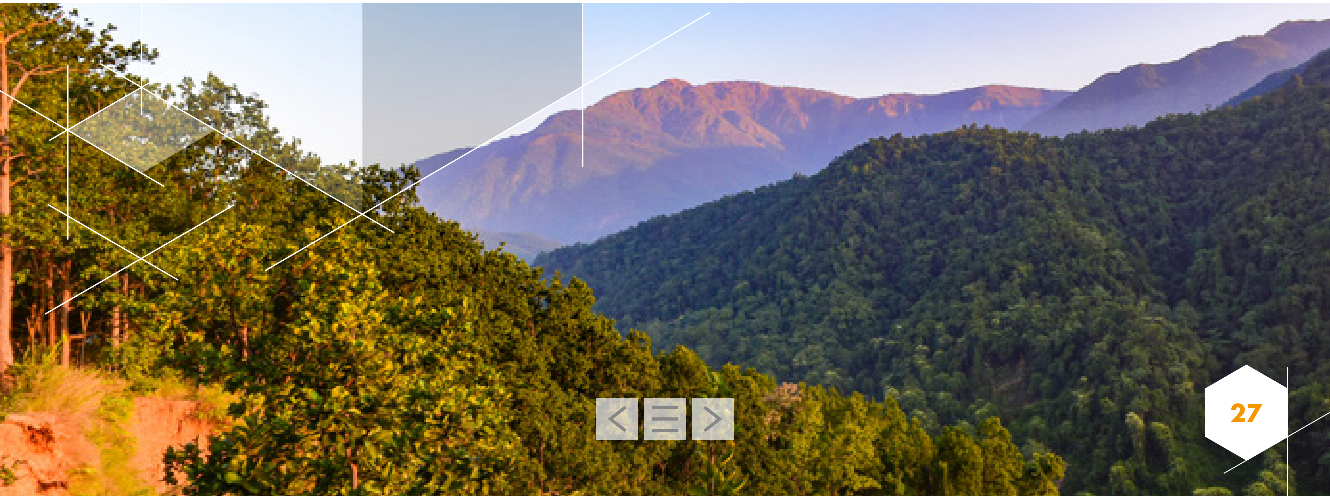
The deployment of CCS requires a focused policy approach with CCS being a very specific desired outcome. To date, only the USA has anything close to an established CCS sector, through a combination of commercial drivers for enhanced oil recovery and tax credits for CCS projects. Canada has two landmark projects but remains a distant second alongside Australia and Norway.

The challenge faced by industry in India requires the capture and geological storage of 400 Mt CO_2 per year by mid-century. This means construction needs to begin in the near-term. These projects could be linked to various industrial facilities, including cement plants, biofuel production plants and iron ore smelters.

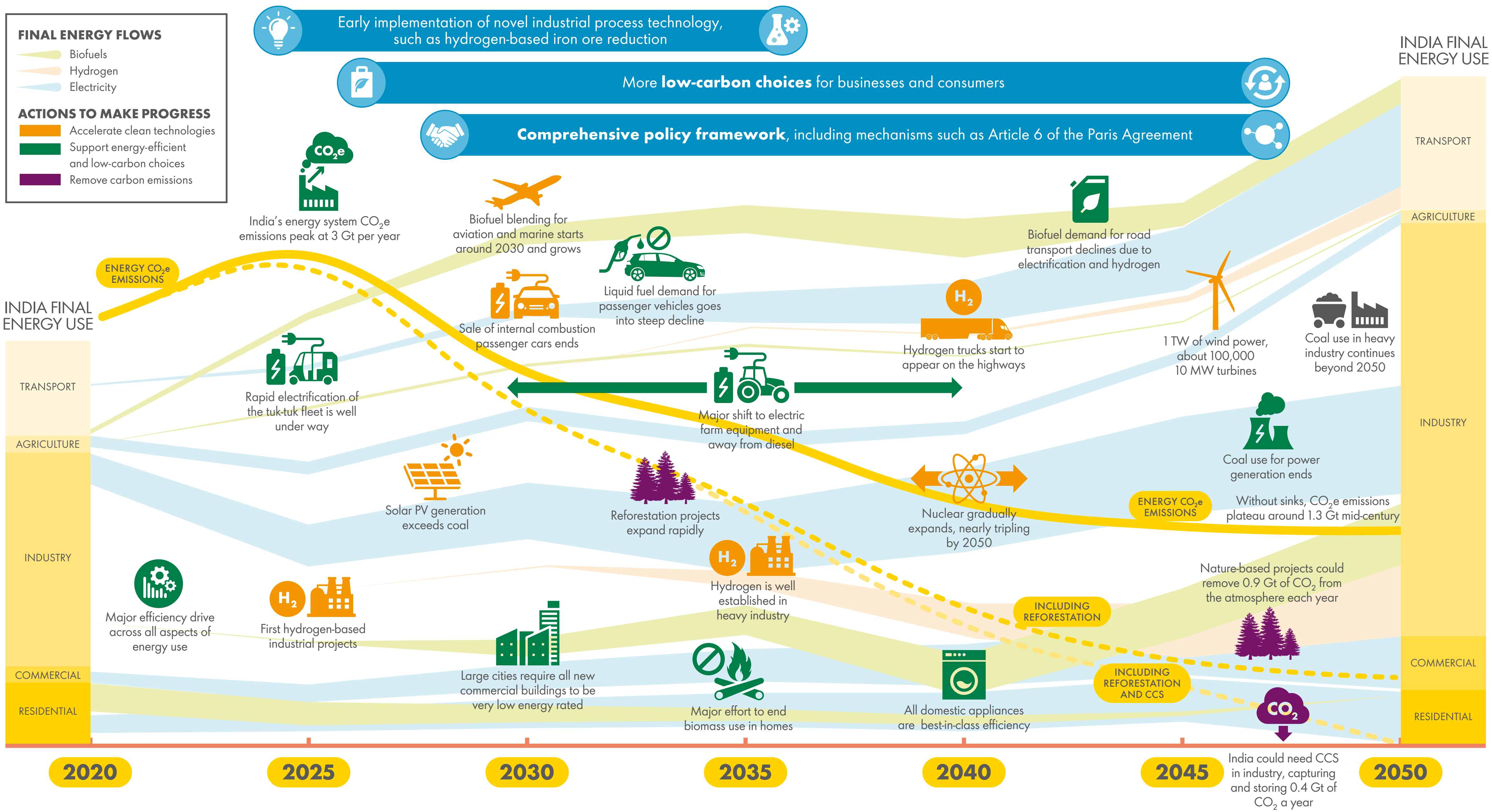
Nature-based carbon removal solutions

In tandem with the development of CCS and carbon capture, utilisation and storage, the expansion of forest cover in India through large-scale nature-based projects can act as a CO_2 sink. Nature-based solutions can potentially offer a rapid pathway to nearly 1 gigatonne of CO_2 removal per year once the necessary scale is reached. Removal at this scale may become essential if India is limited on geological storage capacity or if the direct carbon capture industry is slow to establish itself. Removing 0.9 gigatonnes of CO_2 a year by 2050 could require some 30-40 million hectares of additional forest cover – an area equivalent to Rajasthan – as well as a concerted effort to plant trees outside forests.

Reforestation projects could lead India to work in cooperation with other countries under Article 6 of the Paris Agreement to help balance remaining global emissions, potentially becoming a trader of forestry sinks as carbon removal units.



INDIA: TRANSFORMING TO A NET-ZERO EMISSIONS ENERGY SYSTEM



In the India scenario sketch carbon dioxide equivalent (CO_2e) includes carbon dioxide, methane and nitrogen oxides (NOx) emissions from the energy system.

SECTION TWO

A NET-ZERO EMISSIONS ENERGY SYSTEM

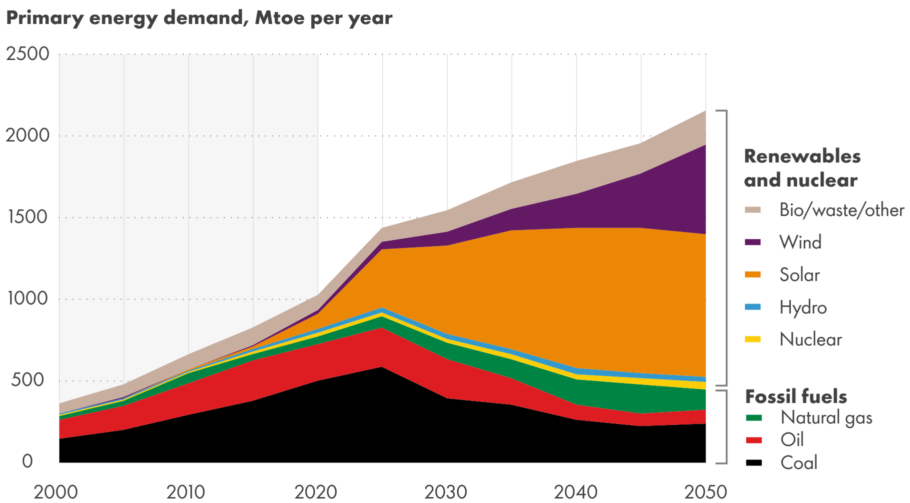
A ROADMAP TO NET-ZERO EMISSIONS

India's pathway to a net-zero emissions energy system will require unprecedented co-operation. Society must make cleaner energy choices and every sector will need to play a part. The transition to a final energy system based on electricity, hydrogen and biofuels must be matched by a primary energy transformation to solar, wind, nuclear and biomass. That transition is under way in India today and the country is making progress towards its 2030 Nationally Determined Contribution of 40% installed non-fossil (solar, wind, hydro, biomass and nuclear) generation capacity. But the pace of change will need to accelerate, both to keep up with increasing demand and to progressively reduce demand for coal, oil and gas.

TRANSFORMING THE ENERGY MIX

India is currently dependent on coal, oil and traditional biomass for its energy needs, but solar becomes the dominant energy source in the late 2030s in the **NZE** scenario. This builds on recent developments in India where solar generation has increased sharply, up by nearly 30% in 2018 alone.

Figure 11: Energy production transforms from fossil to primarily non-fossil fuels



Source: TERI analysis