In India today, there is a successful programme of solar PV installation under way, but by 2030 as solar starts to dominate the generation mix in the **NZE** scenario, it will need to be matched by large-scale energy storage to manage intermittency. More than 1,000 gigawatts of solar PV, 700 GW of which with matching storage, needs to be installed through the 2020s, far exceeding the amount of solar PV installed over the last decade. This level of deployment is challenging, even in global terms. In 2019 global solar module production[26] was about 140 GW, but growing at some 20% per year. Even if growth continues at this rate through the 2020s, the demand in India for modules under **NZE** would still equate to 20% of global supply.

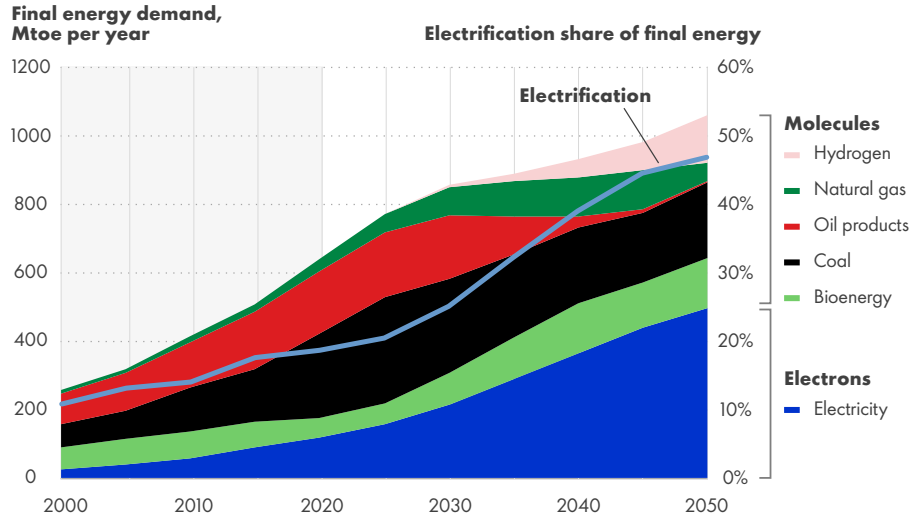
The 2020s will need to see the emergence of offshore wind, as well as a tripling of onshore wind capacity and a 50% increase in nuclear.

In the **NZE** scenario crude oil peaks around 2030 but declines after that as electric vehicles permeate transport. By the 2040s, oil products hardly feature in the final energy mix, as both transport and domestic users have switched to electricity.

Natural gas demand continues to increase in India through to the 2040s, but by 2050 demand is falling. While there is some initial growth of compressed natural gas use in transport, this declines in the 2040s as electrification and hydrogen take hold. The largest growth in natural gas demand comes from industry, as new facilities shift away from coal, which quadruples natural gas demand from 2020 to 2040.

The transformation of the final energy mix is a story of rapid electrification, although fossil fuels continue to make up a third of India's energy mix in 2050, albeit they are in decline over the longer term. Coal continues to meet an important part of energy demand for industry, but no additional coal-based power generation capacity is installed after 2030.

Figure 12: Deep electrification of the economy, predominantly from renewables; molecules are still required



Source: TERI analysis

> The largest growth in natural gas demand comes from industry, as new facilities shift away from coal, which quadruples natural gas demand from 2020 to 2040.

Sector emission outcomes

The **NZE** scenario outlines a turning point for the major emitting sectors in the economy by 2030 at the latest.

In the power sector, nearly two-thirds of existing coal generation is retired in the second half of the 2020s, with solar backed up by storage rising rapidly to be the major source of electricity. Over the following two decades both wind and solar grow rapidly, such that by 2050 they make up nearly 90% of the generation mix. The electricity system grows by a factor of more than four by 2050, yet emissions fall from current levels. By mid-century, around 100 million tonnes of emissions a year remain due to natural gas use, which helps balance the intermittency of solar.

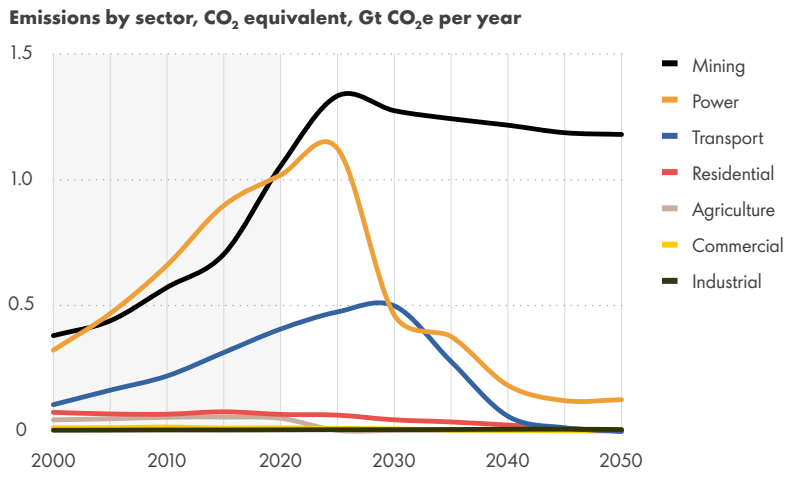
The future pathway for transport assumes rapidly growing availability of electric vehicles throughout the 2020s, with only electric vehicles being sold by 2030. Buses, vans and trucks follow, either as electric or fuel cell vehicles, the latter powered by green hydrogen produced by electrolysis. As the vehicle fleet turns over through new sales, emissions from transport fall rapidly. The growth in low-carbon biofuels reduces remaining emissions from sectors such as aviation.

Emissions from energy use in the industrial sector reaches a plateau, not a peak, largely due to the lack of readily available alternative technologies in India. While industry begins the transition to hydrogen, it is insufficient to counter the continued rapid growth of traditional industries. The ongoing emissions in this sector in 2050 highlights the need to deploy carbon capture and storage technologies during the 2020s and to make use of natural carbon sinks.

In both the commercial and residential sectors, the transition to electricity is virtually complete by 2050, with a small demand for biogas for residential cooking remaining in some places.

By 2050, the agricultural sector makes a rapid transition to net-zero emissions, depending largely on local solar power for farm equipment, but larger tractors and mobile machinery continue to use biodiesel.

Figure 13: Decline in energy emissions for most sectors; remaining emissions are removed using nature and technology



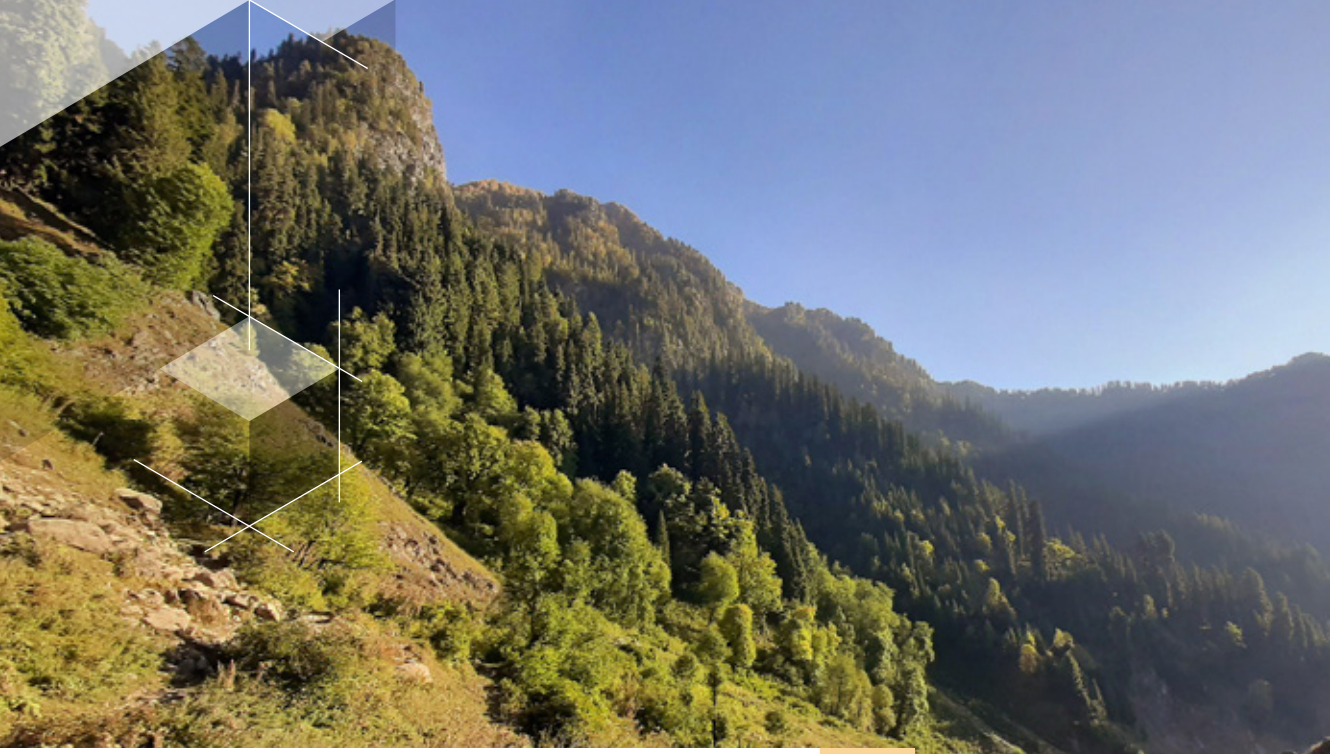
Source: TERI analysis

Box 1

BARRIERS TO TRANSITION

During development of the **NZE** scenario, we identified the many barriers that could slow progress of an energy system transition of this scale. We captured these insights in a second scenario called **Towards Net-Zero (TNZ)**. In the **TNZ** scenario, the transition proceeds, but at a slower pace; key energy trends lag by about a decade, sometimes longer.

- **Electrification:** While the **NZE** scenario assumes rapid electrification in all sectors, **TNZ** identifies several technological and behavioural constraints. In agriculture, smaller farm vehicles can quickly electrify, but the replacement of large, powerful diesel tractors is more limited, due to cost constraints and battery weight. A preference for flame cooking lingers in homes and technological hurdles emerge in industry, limiting electrification. While electric passenger vehicles are now available, mass production, cost reductions and better financing mechanisms all need to be in place to increase the market share of electric cars. The **NZE** scenario places a heavy reliance on storage technology to support solar PV, but battery storage has yet to fully develop as a long duration backup for intermittency.
- **Hydrogen:** The adoption of hydrogen for heavy transport, shipping, aviation and industry is highly anticipated but technology development to use hydrogen at scale is only just emerging. A pilot plant is being built in Europe to demonstrate iron ore smelting, but there is no visible progress of hydrogen in aviation, although the sector has made some announcements. Large-scale green hydrogen production is still a nascent industrial process and while costs are coming down, more progress is required.
- **Bioenergy:** The use of biomass and biofuels will require considerable transition in existing supply chains. In some cases, this will involve moving to more centralised collection for large-scale industrial use, switching the type of biomass collected for alternative biofuel production and adapting existing processes to meet new demand, such as for the very stringent aviation market. While biomass availability is not an issue, getting the right biomass in the right place may well take some time to implement.



SECTION THREE

HOW TO MAKE PROGRESS