Making it happen: national pathways to net zero

Long-term transformations in national pathways to net zero

USE OF FOSSIL FUELS

National pathways to net zero necessitate a relentless decrease in the direct use of fossil fuels by mid century, aligning with domestic socio-economic priorities. These trends particularly require country-driven shifts in infrastructure and organizations to reduce energy needs for development objectives.

Today, everyday activities, such as living and working in buildings, producing goods and services, transporting people and goods, are largely dependent on the use of energy, especially fossil fuels. In most countries, direct fossil fuel use accounts for approximately 70% of national final energy consumption. However, specific country circumstances can lead to different starting points, as demonstrated by Brazil, with its abundant natural resources, and Nigeria, due to the dominant role of traditional biomass (**Figure 4**).

National pathways to net zero focus on how countries can enhance the quality of life for their populations, particularly the most vulnerable, while achieving carbon neutrality. They highlight the need for a significant decline in the share of fossil fuels in energy consumption among the countries studied. (**Figure 4**).

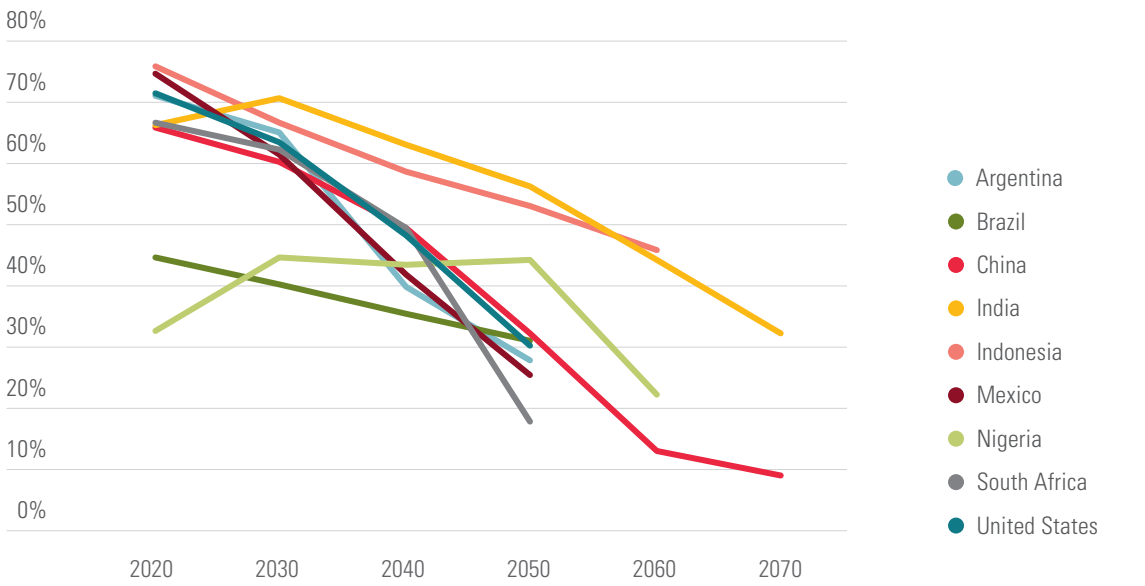
However, these national pathways are not uniform. They vary due to distinct patterns of energy use shaped by the specificities of each country's socio-economic context and energy landscape, as well as their target dates for national carbon neutrality. For instance, some countries are experiencing a steady decline in the share of fossil fuels in energy use, decreasing from around 70% to about 30% or lower. In contrast, India and Indonesia are two examples of countries where this decrease, although steady, is more gradual, largely due to rapid growth in total energy demand in response to significant development challenges and later target dates for carbon neutrality.

Nigeria demonstrates a different situation where the share of fossil fuels will initially increase as the country gains access to modern energy technologies and services, and experiences a surge in energy demand to support domestic development objectives. A reduction in fossil fuel dependence will occur later, after 2050, in a second phase of development when the country can shift towards less reliance on fossil fuels and step up efforts to reduce energy-related emissions to reach the 2060 carbon neutrality goal.

Despite these variations, all countries show a clear structural decreasing trend in the use of fossil fuels for final energy consumption. The limited role of CCS in national pathways to net zero significantly reinforces this need to reduce fossil fuel usage (cf. section - Carbon Capture and Storage).

As a result, there will be a notable decrease in the total volume of fossil fuels used in 2050 compared to 2020 – by around 30% in total across the nine

Figure 4. Share of fossil fuels in final energy consumption (%)



Fossil fuels are coal, natural gas and oil final derivatives. In India, fossil fuel shares have been extrapolated for the years 2060 and 2070 based on Garg et al., 2024. (https://psa.gov.in/CMS/web/sites/default/files/publication/ESN%20Report-2024_New-21032024.pdf)

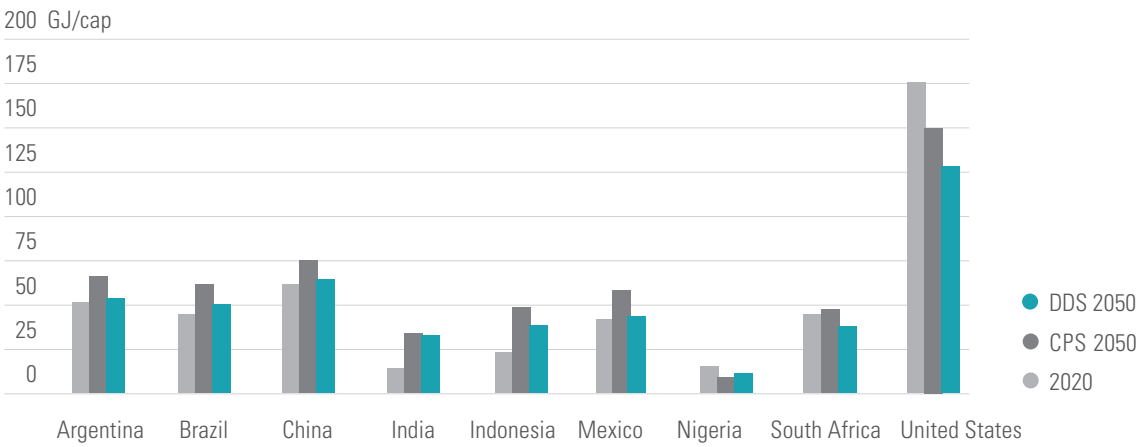
analyzed countries. The shift away from fossil fuels will be only partial in 2050, demonstrating the need for a progressive reduction of fossil fuels to meet development needs. Importantly, the analysis in countries looking beyond 2050 shows that fossil fuel use will continue to decline after that point, and do so even more rapidly, paving the way for progressive but sustained reductions in fossil fuel volumes in the decades ahead.

These national trends, which align the reduction of fossil fuels with domestic socio-economic priorities, particularly energy access, are driven by two main factors.

On one hand, national pathways to net zero, which integrate climate and development objectives within a specific country context, emphasize the need to create development patterns that are less dependent on energy. This decoupling can be seen in the lower energy consumption per capita in DDS as compared to the CPS, across all countries studied , which shows that, all else being equal, decarbonization strategies can help to achieve development objectives with a lower energy input (**Figure 5**). However, these national pathways are not uniform; they vary significantly based on country-specific energy consumption patterns. Most of the countries studied project an increase in energy consumption per capita in the DDS, consistent with socio-economic needs by 2050, although this increase is lower compared to the continuation of current trends of the CPS. In industrialized countries such as the US, energy consumption per capita is expected to decrease due to the saturation of energy access and the dissemination of energy-efficient technologies, with a more rapid decrease occurring under carbon neutrality than if current trends are continued. South Africa serves as an example of a country where systemic shifts in infrastructure and organization, combined with technological progress, can significantly influence energy demand. Indeed, these shifts can outweigh the increased energy needs for development, therefore leading to an absolute decrease in energy use per capita (**Figure 5**).

Systemic shifts in infrastructure and organization are crucial for supporting these trends by enabling development patterns that require less energy to meet domestic socio-economic objectives. In other words, these structural changes will ensure that the future provision of key socio-economic functions, such as mobility, work, consumption, production, and nutrition, can be carried out with lower energy consumption. This shift goes beyond simply replacing energy-consuming systems with more efficient options. For mobility, transformations include integrating the planning of land use and transport infrastructure to improve access to daily activities using low-carbon modes (walking, biking and public transport) and therefore support the shift away from the current dependence on cars and energy-intensive mobility systems (Case study - Structural changes in urban and transport infrastructure and organization).

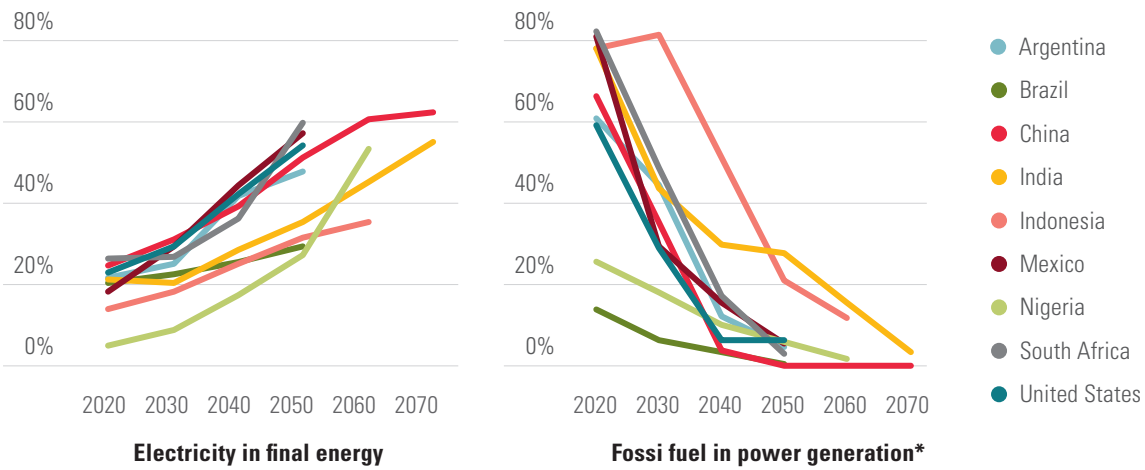
Figure 5. Final energy consumption per capita (GJ/cap)



For residential buildings, the shift requires an emphasis on bioclimatic design to minimize heating and cooling needs or encouraging behavioral changes in energy use at home. In the production and consumption patterns of industry, key changes include the rethinking of product design and industrial processes, as well as changes in consumption behaviors to promote the reduction, repair, reuse and recycling of goods and raw materials.

On the other hand, national pathways to net zero emphasize significant electrification across most end uses in buildings, the mobility of people and goods, and goods production, driven by the adoption of electricity-based equipment (Case study - Examples of end-use electrification). As a result, electricity is projected to become the dominant end-use energy by 2050 in Argentina, China, Mexico, South Africa and the United States and by their national target dates for carbon neutrality in the case of Nigeria and India (**Figure 6**, left). In contrast Brazil and Indonesia are two examples of countries where the electrification of end-uses is more gradual, largely due to the prefered use and availability of biomass and the rapid growth in total energy demand related to significant development challenges. (**Figure 6**, left). This electrification is consistent with carbon neutrality, because national pathways also entail a substantial reduction in fossil fuels for power generation, which is expected to be largely fossil-free by the target date for a country's carbon neutrality (**Figure 6**, right). The limited role of CCS in national pathways to net zero (Section - Carbon Capture and Storage) emphasizes the need to decouple electricity generation from fossil fuels. However, this decoupling will vary according to country-specific trends. For instance, in India, the projected small increase in fossil fuel use in the power sector from 2040 to 2050 (prior to a reduction to almost zero by 2070) results from investments in gas power plants, which are required to rapidly increase renewable capacities and facilitate grid stability.

Figure 6. Share of electricity in final energy consumption and share of power generation from fossil fuels (%)



** this share includes abated and unabated fossil fuel power generation.*

CASE STUDY

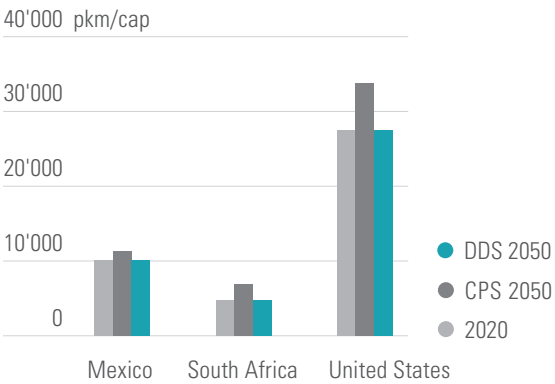
Structural changes in urban and transport infrastructure and organization

In Mexico, South Africa and the US, the analysis shows that structural changes in urban and transport organization could help moderate the increase in per capita mobility, and related energy and emissions, compared to the CPS, while continuing to meet the needs of the population (**Figure 7**).

This is the result of changes in urban planning to better integrate land-use policies, investments in public transport infrastructure and services, as well as economic and regulatory incentives to create more mixed-use neighbourhoods. In these areas, daily necessities such as homes, work, shops, and public services are within short walking distances or bike rides, i.e. accessible by non-motorized transport (NMT), or are easily reachable by public transport (PT). However, optimizing the spatial distribution of human activities must be complemented with revised investment in NMT and PT infrastructure, as well as regulations and incentives that promote these modes of transport and develop services while limiting car use.

Ultimately, such changes to the infrastructure and organization of daily mobility are viewed as key to aligning climate and other sustainable development goals. As travel distances decrease and people make increasing use of NMT and PT instead of cars, citizens will benefit from less congested cities, reduced travel times, the lower costs of NMT and PT, improved road safety, and more open spaces in urban areas, which could be repurposed into green areas to help adapt to climate change...

Figure 7. Passenger mobility per capita (pkm/cap)



CASE STUDY

Examples of end-use electrification

To meet net zero targets, households, companies and public authorities must electrify their remaining energy devices and uses:

- In Argentina, space heating, water heating and cooking in residential buildings represented respectively 43%, 23% and 11% of national household energy consumption in 2018 and were mostly using natural gas. Achieving net zero in the DDS would necessitate a significant shift from natural gas systems to heat pumps, electric or solar water heaters, or electric cooking devices. However, according to Fundación Bariloche, the successful penetration of these technologies will require major economic and financial barriers to be surmounted (Bouille et al., 2021).[19] In the United States, federal tax credits and rebates for appliance efficiency and electrification, enhanced state-level energy efficiency standards, and the implementation of zero-emission appliance standards and zero-emission construction standards can increase building electrification while decreasing overall energy demand.
- For industrial energy uses, in South Africa for example, many processes would need to transition to electricity to meet net zero. Electricity, either directly or indirectly through heat pumps, will be utilized more in industry for processes requiring heat production. In addition, for specific niche applications, hydrogen produced via electrolysis could be used in processes requiring high temperatures, or as a chemical feedstock for some industries like iron and steel, as well as chemicals. Shifting industrial energy uses is a key challenge primarily from a financial perspective rather than a technical one.
- In the transportation sector, in the United States for example, there is a potential to substantially increase electric car and truck sales through a combination of extended federal tax credits for EVs, enhanced state-level EV sales targets and incentives, and corresponding investments in EV infrastructures.

19 https://eficienciaenergetica.net.ar/img_publicaciones/09011503_PropuestaPlaNEEAr.pdf