What do we know about THE FUTURE OF ENERGY AND FOOD SYSTEMS?

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Key messages

- The global energy transition currently in process involves increases in variable renewable energy generation and ongoing electrification of transport and industrial processes, leading to the possibility of absolute declines in the use of coal and petroleum before 2030.
- This transition creates both opportunities and risks for agri-food systems.
- Trade will be an important impact channel for net exporters and net importers of fossil fuels, with impacts spilling into the agri-food sector.
- Improvements in energy technology, particularly solar generation, have broad applications with potentially large implications for agri-food systems.

RECENT TRENDS AND CHALLENGES

A large-scale global energy transition is underway. In 2023, global investment in solar power alone exceeded investment in all other forms of electricity generation combined (IEA 2024a). Currently, investment in renewable energy is approximately twice that of investment in fossil fuels (IEA 2024a). This transition is extending rapidly into transport. In 2023, 18 percent of all new light vehicles sold worldwide were electric (EVs), up from about 2 percent in 2018 and 4 percent in 2020 (IEA 2024b).

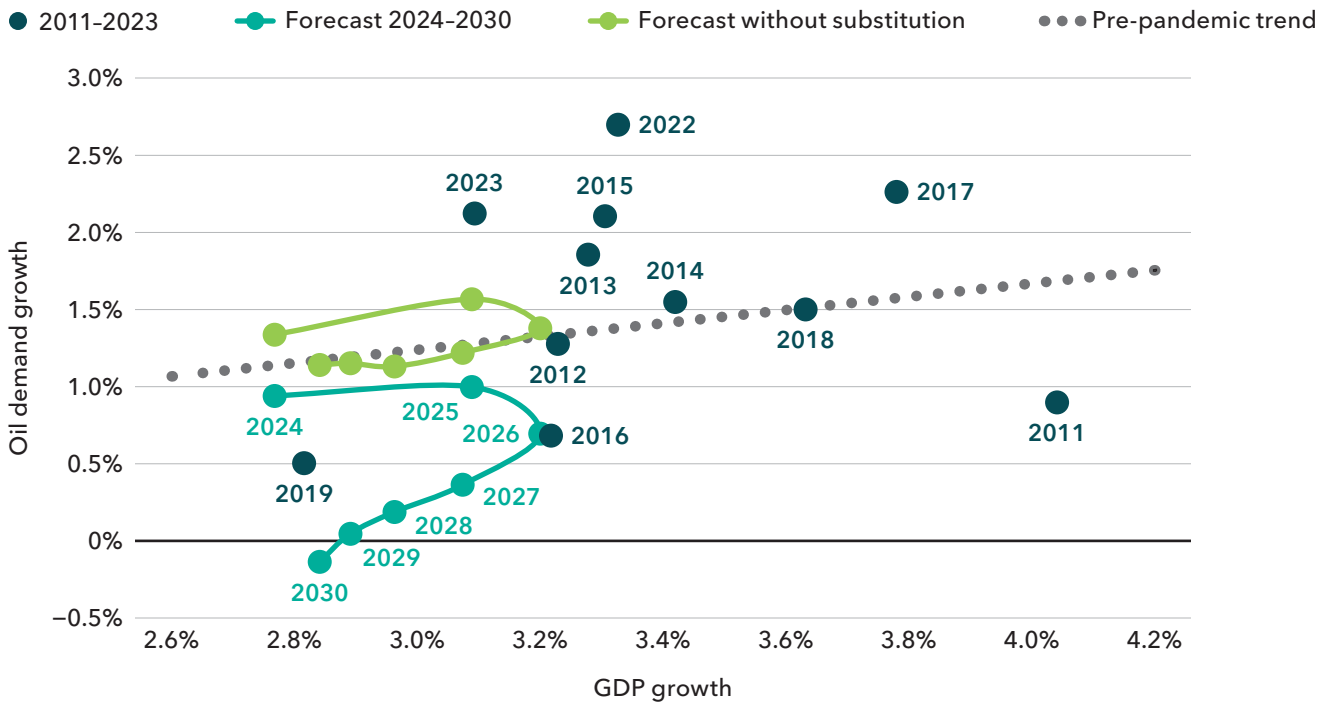
A key point is that the sectors leading this energy transition are no longer small. From 2017 to 2022, the share of power generated by solar and wind doubled, from about 6 percent to 12 percent. From these larger bases, the next doubling brings the share of solar and wind to about 24 percent of generation and the share of EVs in light vehicle sales to about 36 percent. These larger absolute values imply a greater and more noticeable force of change, with concomitantly larger direct and indirect implications, including for agrifood systems.

LATEST FORESIGHT RESEARCH

Let us begin with fuel. As a result of the abovementioned structural factors, the International Energy Agency's (IEA) most recent forecasts predict a decline in global oil demand in 2030 (IEA 2024c). Figure 1 shows the forecast for oil demand to 2030 and relates oil demand to gross domestic product (GDP) growth. Prior to the COVID-19 pandemic, simple regression analysis illustrates a standard trend (shown in the dashed line) whereby oil demand increases with GDP. However, this relationship has weakened over time, and the IEA now expects it to break down altogether in the latter half of this decade. This occurs because "substitution away from oil in transport and power generation pushes oil demand growth towards zero, and eventually into decline" (IEA 2024c, 13).

As these structural factors are expected to persist, an unprecedented long-run decline in oil demand is expected to commence from a peak in 2029. Even though other forecasters, such as the Organization of Petroleum Exporting Countries (OPEC 2024), expect peak oil demand to occur much farther into the future, the

FIGURE 1 Growth in global oil demand and GDP, 2011–2030



Source: IEA (2024c, 12).

IEA forecast merits attention for two principal reasons. First, oil has traditionally been viewed as a nonrenewable resource whose supply would eventually be exhausted. In this view, accessible oil in the ground is an asset whose value is likely to grow with time. However, a world with declining oil demand opens the possibility that much of the oil currently in the ground will stay there and may eventually become worthless. This creates incentives to extract sooner. Second, incentives to extract sooner notwithstanding, a long-run decline in oil demand must be accompanied by a long-run compression of supply.

Because a sustained decline in global oil demand has never occurred in the industrial era, how exactly the combination of increasing incentives to extract sooner and a necessary compression in supply will unfold is unknown. Nevertheless, it is clear that as demand declines, low-cost producers have incentives to force high-cost producers out of the market by allowing oil prices to drop low enough for long enough to induce a sufficient volume of permanent shutdown. This puts high-cost oil producers at risk. At the same time, these periods of low prices will generate significant terms-of-trade gains for net importers of fuels (Arndt et al. 2019).

Turning to electricity generation, for almost anywhere sunny, solar power is likely to be the least-cost generation option at the margin. This is most likely to hold for grids with relatively low penetration rates of variable renewable energy (because other generating units can accommodate the variability) and in (sunny) locations where service from the grid is poor or nonexistent. Nevertheless, to date, solar investment has been concentrated in the developed world plus China. However, given the cost advantages that solar generation now possesses, it is reasonable to expect rapidly growing investment in solar generation in the developing world, both at grid scale and for bespoke uses in locations that are off grid or have unreliable grid service.

KEY GAPS AND OPPORTUNITIES FOR FORESIGHT RESEARCH

The implications of these trends are vast. The potential implications of the predicted structural decline in demand for oil and of ongoing technical advance in generation technologies, notably solar, are described briefly below.

Oil and derived products represent a significant share of global trade, and the share of oil and derived products in total trade tends to be higher in lower-income settings. For example, for sub-Saharan Africa (SSA), oil and derived products represented about 25 percent of total exports and imports in 2022 (WITS 2024). While nearly all countries in SSA tend to import large volumes of fuel, exports of petroleum products tend to be concentrated among a few producers.

For major net exporters, particularly those with relatively high extraction costs, the implications of declining global oil demand are potentially profound. Consider Nigeria, which is both the largest economy in SSA and the most populous nation on the continent. Despite decades of rhetoric about diversification of the Nigerian economy, Nigeria still counts on oil and derived products for more than 80 percent of export revenue (Pauw, Randiamamonjy, and Thurlow 2024). And while exact figures are not known, Nigeria is widely viewed as a relatively high-cost oil producer and is not known as an easy place to do business (Economist 2024; ITA 2023). Hence, Nigeria could confront, in the not-too-distant future, a period of low oil prices that is designed specifically to force higher-cost producers permanently out of the market. If Nigerian petroleum-related export revenues decline due to a combination of lower prices and volumes, this would oblige Nigeria to enter an intense period of structural adjustment to raise nonoil export revenues. More generally, to meet foreign currency needs, higher-cost oil-exporting countries facing both lower prices and volumes must stage a nonoil export push.

Even for low-cost net exporters of fuels, the incentives to diversify exports have likely never been greater. Unfortunately, especially for low- and middle-income countries (LMICs), breaking into new export markets is distressingly difficult (Forge, Garred, and Kwon 2024). For countries with little experience exporting anything other than oil for a generation or more, the difficulties are likely to be pronounced. While it is not easy to break into global food markets, agrifood products seem very likely to figure prominently in an export diversification push in many country cases (Nigeria not least). Achieving much greater export diversification through very rapid expansion of exports in agrifood and other products, notably for high-cost oil producers, is a very important topic for research.

Net importers of fuels are in a much more favorable position. Periods of low prices represent a substantial terms-of-trade gain. For net fuel importers, lower fuel prices

combined with ongoing electrification of transport (resulting in lower fuel import volumes) typically drive a real exchange rate appreciation (an increase in the price of nontradable goods relative to tradable goods), signaling a reduced need to export and/or an expanded scope to import products other than fuel. Because agrifood products are often traded globally and because LMICs frequently export and import substantial volumes of agrifood commodities, declining oil demand will very likely influence agrifood production and trade patterns, perhaps significantly. An intriguing possibility is that lower fuel prices facilitate a shift toward healthier diets because the components of a healthy diet (fresh foods) are typically less tradable. More generally, for net importers of fossil fuels, tracking the likely benefits of reduced dependence on volatile fossil fuel markets should inform policies related to the pace of electrification of transport and industrial processes and the accompanying policies/investments that build upon this structural transformation.

Turning to electricity generation, the massive declines in the cost of solar generation combined with ongoing declines in battery prices create large opportunities for developing countries, many of which are well-endowed with sun, to generate electricity at scale, almost anywhere, and at low cost. Agrifood systems will be crucial to realizing the considerable upside that the ongoing energy transition offers to LMICs; however, realizing the gains and avoiding pitfalls will not be easy. Increased attention to energy in foresight research on agrifood systems is needed to ensure a reasonably smooth and fair transition that benefits marginalized populations, including those with limited access to modern energy. Research into the policies and institutions necessary to avoid pitfalls – such as excessive water withdrawals due to very low marginal costs of pumping from solar-powered systems – is also important.

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Related chapters on the future of food system drivers and impacts, regional and national perspectives, food commodities, and foresight tools are available in our Table of Contents.

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References

Arndt, C., D. Arent, F. Hartley, B. Merven, and A.H. Mondal. 2019. "Faster Than You Think: Renewable Energy and Developing Countries." *Annual Review of Resource Economics* 11 (1): 149–168. https://doi.org/10.1146/annurev-resource-100518-093759

Economist. 2024. "Nigeria's High-Cost Oil Industry Is in Decline." May 21. https://www.economist.com/middle-east-and-africa/2024/03/21/nigerias-high-cost-oil-industry-is-in-decline.

Forge, F., J. Garred, and K.L. Kwon. 2024. "When Are Tariff Cuts Not Enough? Heterogeneous Effects of Trade Preferences for the Least Developed Countries." *Journal of International Economics* 152 (November): 103971. https://doi.org/10.1016/j.jinteco.2024.103971

IEA (International Energy Agency). 2024a. *World Energy Investment 2024*. Paris. https://www.iea.org/reports/world-energy-investment-2024

IEA. 2024b. *Global EV Outlook 2024: Moving Towards Increased Affordability*. Paris. https://www.iea.org/reports/global-ev-outlook-2024

IEA. 2024c. *Oil 2024: Analysis and Forecast to 2030*. Paris. https://www.iea.org/reports/oil-2024

ITA (International Trade Administration). 2023. *Nigeria Investment Climate Statement*. https://www.trade.gov/country-commercial-guides/nigeria-investment-climate-statement

OPEC (Organization of Petroleum Exporting Countries). 2024. *World Oil Outlook*. Vienna. https://www.opec.org/opec_web/en/publications/340.htm

Pauw, K., J. Randriamamonjy, and J. Thurlow. 2024. "2021 Social Accounting Matrix for Nigeria: A Nexus Project SAM." Data Paper. Washington, DC: International Food Policy Research Institute. https://hdl.handle.net/10568/137911

World Integrated Trade Solutions (WITS). 2024. https://wits.worldbank.org/CountryProfile/en/Country/SSF/Year/2022/TradeFlow/Import/Partner/all/Product/27-27_Fuels.

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