Energy Transitions Commission

AN ELECTRIFIED AND RESILIENT FUTURE BEYOND FOSSIL FUELS

Electrification can double the size of the global economy while cutting energy demand

Discussions about moving away from fossil fuels often start with one headline number: fossil fuels still supply about 80% of global primary energy[1]. But that figure can make our dependence on fossil fuels look bigger than it really is, because it mixes together energy use and energy efficiency. To see why, it helps to separate the three stages of the energy supply chain. Primary energy enters the energy supply chain in its raw, original form, before any conversion takes place (for example, crude oil, coal, or sunlight). It is then transformed and delivered as final energy—the forms that consumers can buy and use directly (such as petrol at the pump or electricity from a plug). Finally, only part of that final energy becomes useful energy: the portion that actually provides the service people want (for example, the motion that turns a car's wheels). In the end, people do not need a specific type of energy; they need the services energy provides—such as heating a home in Oslo, cooling an office in Lagos, or travelling to and from work in Delhi.

The amount of energy needed to deliver useful services varies greatly depending on the energy inputs. In today's fossil fuel-dominated landscape, approximately 171,000 TWh of primary energy is consumed, which is then converted into around 122,000 TWh of final energy. Ultimately, only about 64,000 TWh reaches us as useful energy[2]. [Exhibit 1] This means that nearly 60% of primary energy—roughly 107,000 TWh—is lost, mainly as waste heat. These losses are inherent to the structure of the fossil fuel system and stem from the fundamental limits of thermodynamics[3]. The process of burning fossil fuels first transforms chemical energy into heat, and then heat into work. This two-step conversion is intrinsically inefficient, meaning a significant proportion of the original energy is lost before it can be used.

Electric systems are not bound by the same constraints, which is why the same services can be delivered with far less energy input. Fossil fuel combustion accounts for around 80% of global greenhouse gas emissions[4]. Reducing fossil fuel demand through electrification therefore addresses both the efficiency and the emissions challenge simultaneously.

The Energy Transitions Commission identifies clean electrification as key to moving away from fossil fuels. By mid-century, electricity's share of energy demand is projected to rise from 20% to over 60%, mainly from wind and solar. Fossil fuels are expected to drop from about 70% to below 20%, with the rest supplied by hydrogen, bioenergy, and carbon capture. [5]

This brief note explains:

- How the efficiency of electrification delivers more useful energy whilst growing GDP

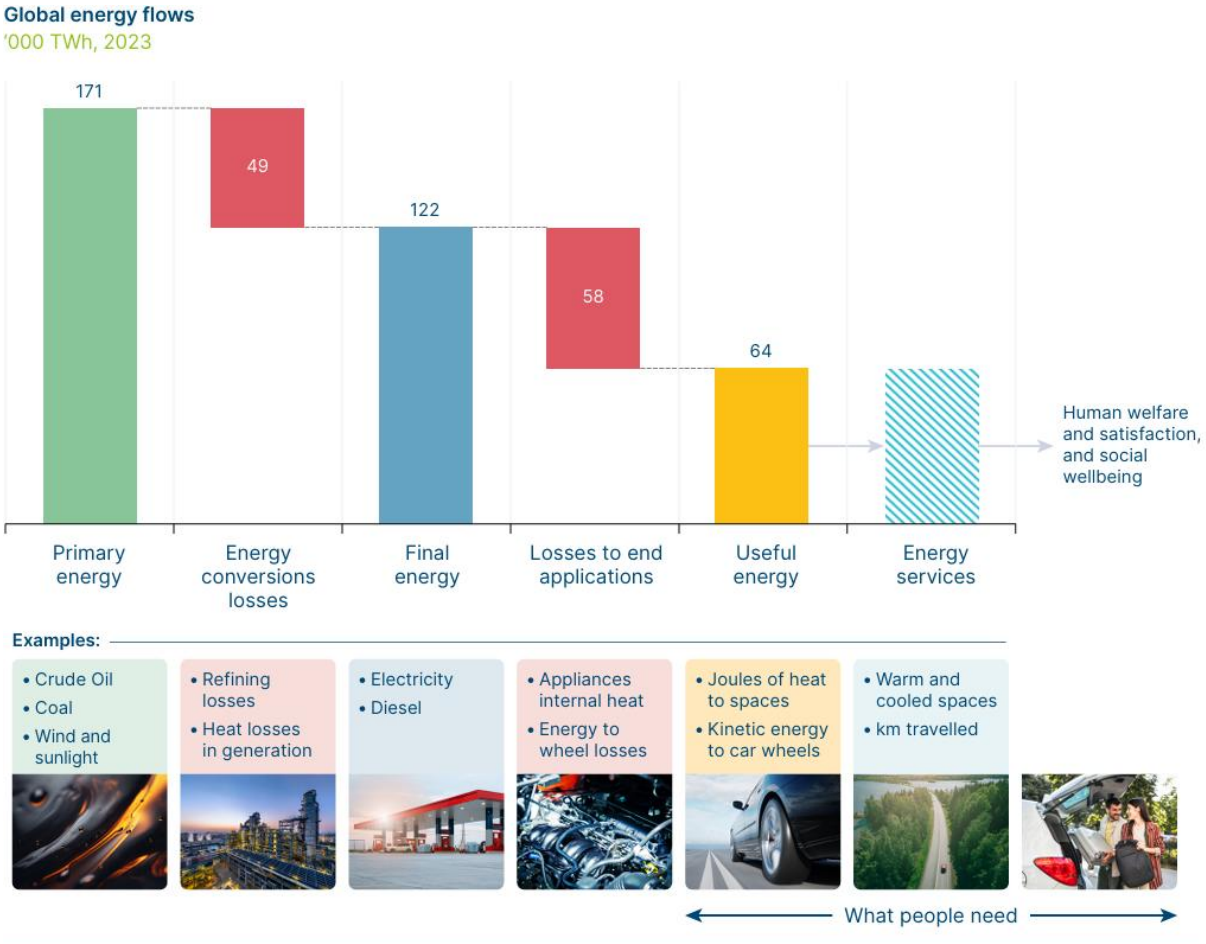
[1] ETC (2025), *Energy productivity: Increasing efficiency in an expanded, electrified energy system*.
[2] Ibid.
[3] The second law of thermodynamics dictates that no cyclic engine can convert heat, i.e. combustion, entirely into work, moving a turbine to generate electricity or a pistol in a car engine. The absolute maximum efficiency is the Carnot efficiency ($1-T_{cold}/T_{hot}$), determined solely by the temperatures of the hot and cold reservoirs, the only way to reach close to 100% efficiency would be to the cold reservoir to be close to the absolute zero (0K), which is impossible to reach, practical limits point to a third to half of a heat fuel converted into work. See RMI (2024), *Energy after Fire*.
[4] ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels.*
[5] ETC (2025), *Carbon in an electrified future*.

- The key sectoral opportunities for electrification decreasing fossil fuel reliance
- The resulting impacts: reduced exposure to fossil fuels associated volatility
- Actions to accelerate deployment of key solutions and technologies

The efficiency opportunity

At the power station, fossil thermal power plants convert only 30–45% of fuel into electricity. Gas combined-cycle plants achieve 50–65%. Renewable electricity generation eliminates these conversion losses entirely, making it 2–3 times more efficient than fossil thermal generation[6]. At the point of use, energy losses persist. Conventional internal combustion engine vehicles typically convert only 25–30% of the fuel in their tanks into motion at the wheels, whereas electric vehicles are capable of converting 80–90% of the electricity stored in their batteries into wheels movement.[7] [Exhibit 2] In practical terms, an electric vehicle can travel approximately three times farther than a petrol-powered car given the same energy input. Consequently, within fossil fuel systems, the majority of energy extracted from the ground fails to reach consumers as useful work.

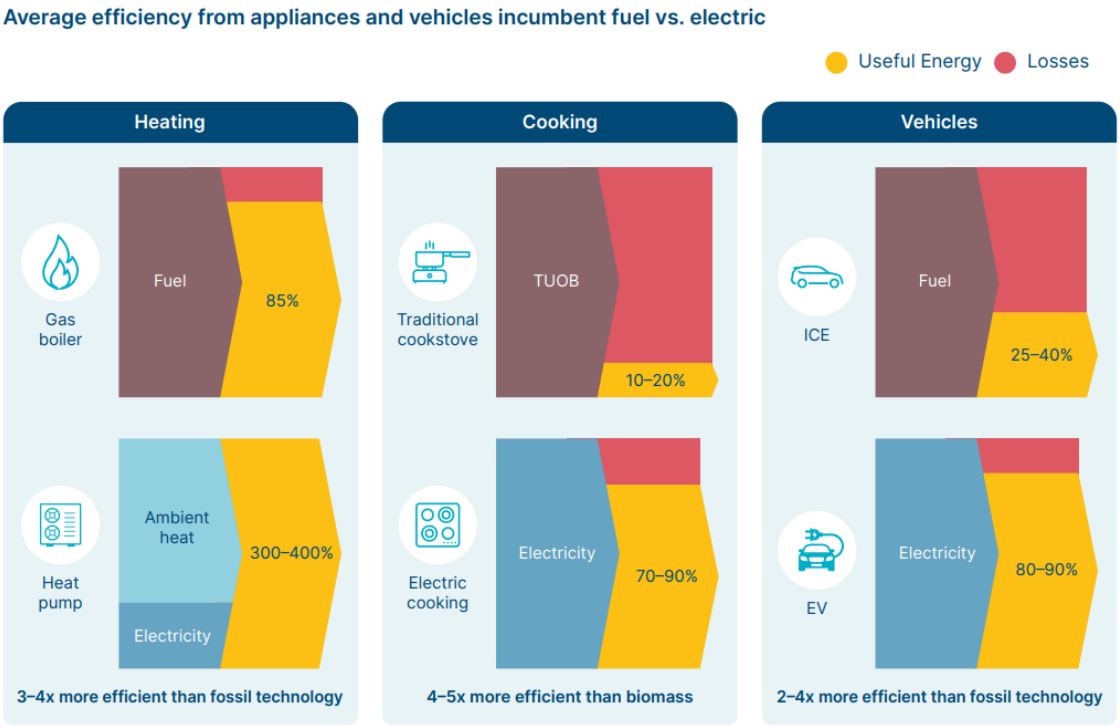
Exhibit 1: Global energy flows measured in primary, final and useful energy



SOURCE: Systemiq analysis for the ETC; IEA, (2025) *World Energy Review*; IEA (2024), World Energy Outlook; International Institute for Applied Systems Analysis, *IIASA PFU Dataset*. Available at https://tntcat.iiasa.ac.at/PFUDB/dsd?Action=htmlpage&page=about. [Accessed May 2025].

[6] ETC (2025), *Energy productivity: Increasing efficiency in an expanded, electrified energy system*.
[7] Ibid.

Exhibit 2: Heat pumps, electric cooking and EVs use 2-5 times less energy than alternative technologies



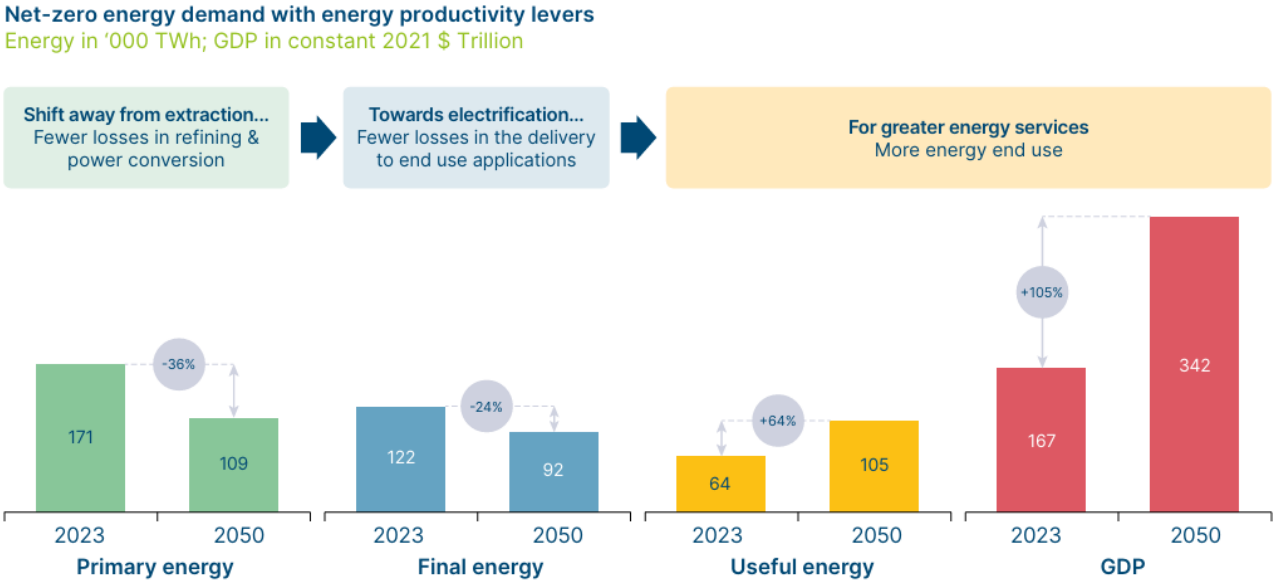
NOTE: Biomass here refers to Traditional Use of biomass (TUOB), predominantly wood; ICE = Internal combustion engine.

SOURCE: RMI (2024), *Clean Tech Revolution;* ETC (2025), *Achieving Zero-Carbon Buildings.*

The transition away from fossil fuels does not require constraining economic growth or energy services. The opposite is true. The world could double GDP by 2050 while reducing final energy use by 24% and primary energy use by 36% below today's levels, even as useful energy rises 64%[8]. [Exhibit 3] Passenger road transport km could grow 70%, cooling demand could rise 150%, and aviation demand could increase 150%. The reduction in energy inputs comes overwhelmingly from electrification and efficiency, not from constraining consumer demand.

[8] Ibid.

Exhibit 3: Clean electrification and efficiency lead to 25-35% reduction in primary and final energy, 65% increase in useful energy and doubling of GDP



NOTE: Useful energy in 2050 was estimated by applying specific efficiency assumptions to each category of final energy demand. For electrified end uses, such as heating and cooling, assumed efficiencies reflect average performance of available technologies - e.g., 350% for heat pumps, 600% for air conditioners, and 80% for electric cooking. In road transport, EVs were modelled with 85% efficiency. Lighting efficiency was also assumed at 85% based on widespread LED adoption. For shipping and aviation, tank-to-wheel efficiencies remained unchanged at today's levels (30% and 40%). In industry, a decreasing final-to-useful energy ratio (starting from 1.4 in 2023 and falling 1% annually) reflects continued process improvements.

SOURCE: Systemiq analysis for the ETC; IEA (2025), *World Energy Outlook*; MPP (2023), *Hard-to-Abate Sector Transition Strategies*; ETC (2025), *Achieving Zero-Carbon Buildings*; ETC (2023), *Fossil Fuels in Transition*; BNEF (2023), *Electric Vehicle Outlook*; Systemiq (2022), *Planet Positive Chemicals*.

The sectoral opportunity: clean electrification in road transport, buildings heating and light industry can decrease fossil fuel reliance

Road transport: Electric vehicles are already reshaping road transport. Global EV sales exceeded 17 million in 2024 and are expected to exceed 20 million in 2025[9]. For passenger vehicles, EVs are already cheaper on a total cost of ownership basis in most markets, and upfront price parity is approaching rapidly[10]. In heavier vehicles, improvements in battery energy density are progressively extending the range and payload capacity of electric truck as proof point in 2025, electric trucks outsold diesel in China[11]. By 2050, demand for passenger road transport could rise 70% and 90% for freight traffic, but final energy demand could fall by 80% through electrification of 90% of the vehicle fleet, combined with a potential 50% improvement in EV technical efficiency, this is equivalent to approximately 50 mb/d[12].

Buildings: Buildings account for around 30% of global final energy demand, but the opportunities to shift away from fossil fuels differ sharply by region.

- **Heating.** In high-latitude countries such as those in northern Europe, Canada, and northern China, space heating dominates building energy use and deepens

[9] IEA (2025), *Global EV Outlook*.

[10] Ibid.

[11] Electrive (2026) *Year-end surge: electric trucks outsell diesel for the first time in China*

[12] ETC (2025), *Energy productivity: Increasing efficiency in an expanded, electrified energy system*.

dependence on imported gas. Global heated floor area is projected to grow 25% globally by 2050[10], and heat electrification is the largest single opportunity to decrease dependency on gas: heating accounts for 45% of total building energy use, and heat pumps are three to four times more efficient than gas boilers[10]. By 2050, with 95% of heating demand electrified and 75% of that being met by heat pumps, final energy demand for heating could fall dramatically even as floor area rises.[10]

- **Cooling.** In tropical and subtropical regions, including South and Southeast Asia and sub-Saharan Africa, around 3.5 billion people live with high temperatures but only 15% own an air conditioner[13]. As incomes and temperatures raise, this will rapidly change. In Southeast Asia, the stock of air conditioners is set to increase ninefold between 2020 and 2040[10]. Cooled floor area globally is projected to increase by 150% by 2050[14]. The average air conditioner sold globally today is only about half as efficient as the best available models, and often for a similar upfront cost[15]. In developing and tropical countries, high-efficiency air conditioning must become the norm, accelerating stock turnover and higher minimal efficiency standards[16].

- **Efficiency.** Beyond heating and cooling, better building design and construction standards can compound these gains. This is particularly important in emerging markets, where over 60% of the global floor area by 2050 is yet to be built[10]. Smart energy management systems can further reduce both total and peak energy demand, with well-insulated buildings able to shift energy use away from peak hours, reducing strain on electricity grids[10].

Industry. Around a third of industrial energy use is in light industry e.g. food and beverage or textiles, where much of the heat demand is at low or medium temperatures. Heat pumps can now serve industrial applications up to 200-400°C, directly displacing gas-fired boilers and furnaces. Final energy demand in light industry could be reduced by 38% versus business as usual through a combination of electrified heat, improved motor efficiency, and process improvements[10].

Where electrification is not yet possible, other technologies can still cut fossil fuel demand, although it will be more costly to do so in some cases

But there are sectors where direct electrification is unlikely at scale: heavy industry (steel, cement, chemicals) and long-distance transport (aviation, shipping). The reason why electrification is not the answer is a combination of fossil fuels either being used as reductact agents in chemical reactions, high temperatures requirements that are not yet enabled by electricity technologies or lack of enough energy density in batteries to support long flights and marine routes. These sectors account for around 20% of global greenhouse gas emissions, and fossil fuels remain deeply embedded in their production processes and fuel supply[10].

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[13] IEA (2025), *Staying cool without overheating the energy system*.

[14] ETC (2025), *Energy productivity: Increasing efficiency in an expanded, electrified energy system*.

[15] IEA (2025), *Staying cool without overheating the energy system*.

[16] ETC (2025), *Energy productivity: Increasing efficiency in an expanded, electrified energy system*.

Technologies to reduce fossil fuel dependence in these sectors already exist, from hydrogen-based steelmaking to sustainable aviation fuels to green ammonia for shipping. The challenge is not technology but policy, these technologies are more expensive and will incur a green premia. At the consumer level these green premia is mostly diluted, adding 75% to the cost of iron adds only around 7% to the cost of automotive or construction components, and roughly 1% to the price of a finished car[17]. However, at the intermediate product level the green premia effect can be quite significant for business, and the right combination of carbon pricing, fuel mandates, and regulation is needed to drive their adoption[18][19].

To decrease fossil fuel reliance the direction is clear: turbocharge clean electrification in the sectors where it works, while simultaneously using carbon pricing and regulation to drive decarbonisation where it does not.

Beyond efficiency and reducing reliance on fossil fuels, electrification also reduces exposure to the fossil fuel price shocks that keep recurring

The shift away from fossil fuel is not only about efficiency and climate. It is also the most effective strategy for reducing the economic vulnerability that fossil fuel dependence creates. Renewable electricity systems are more resilient because solar panels, wind turbines, and batteries are manufactured goods, not extracted commodities. Once installed, they generate energy with no ongoing fuel imports and no exposure to chokepoint disruption[20]. Importing solar panels from a country that subsequently refuses to supply more is fundamentally different from depending on pipeline gas: the panels already installed continue producing electricity for decades at near-zero marginal cost, while a gas supply cut leaves consumers exposed immediately[21].

Since 2021 governments worldwide spent roughly $900 billion on short-term measures to shield consumers from fossil fuel price spikes.[22] The EU's fossil import bill rose from EUR 313 billion in 2021 to EUR 693 billion in 2022, adding almost EUR 1 trillion in inflated costs over the crisis period[23]. [Exhibit 4]

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[17] Turner, A. (2026), *LSE Lecture I: Abundant clean energy for all*. Available at: youtube.com/watch?v=ohAvw0XKtmE&list=PLK4elntcUEy3kR3B4Ws8PcKndb1g5a68Y&index=56.

[18] Turner, A. (2026), *LSE Lecture III: Keeping global warming well below 2C: six priorities*. Available at: https://www.youtube.com/watch?v=ZFTFBrvAMX8.

[19] ITA (2025) Building the EU's Clean Industrial Future: Unlocking Investment through Lead Markets

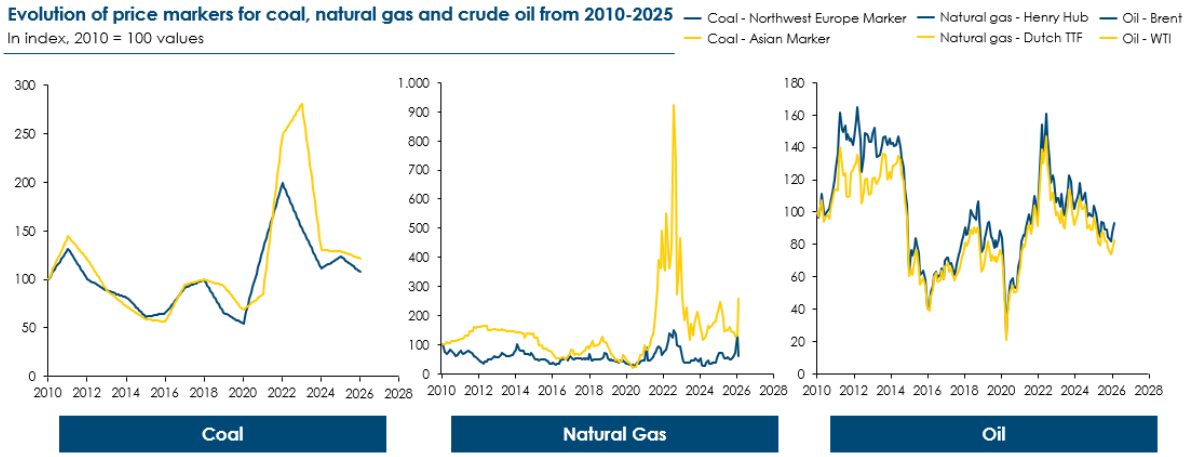
[20] We Mean Business Coalition, ETC, Ember, E3G (2025), *Power Up: How Clean Energy Is Putting Fossil Fuel Demand in Doubt*.

[21] Turner, A. (2026). *LSE Lecture III: Keeping global warming well below 2C: six priorities*. Available at: https://www.youtube.com/watch?v=ZFTFBrvAMX8.

[22] IEA (2024), *Strategies for Affordable and Fair Clean Energy Transitions.*

[23] Ember (2026), *Latest energy shock reminds Europe of its risky gas reliance*.

Exhibit 4: Global fossil fuel prices experience significant price shocks due to geopolitical events



Notes: Electric vehicle include both battery electric and fuel-cell vehicles for heavy commercial vehicles. S-curve methodology is based on Rogers' innovation diffusion theory (1962). Dotted lines represent the maximum growth and inflection points, respectively equivalent to 16 and 84% of sales. These points are defined as points on the curve in which the concavity changes. Growth and inflection point are calculated based on BNEF 2023 Electric Vehicle Outlook. For HCV, Europe and US curves are identical and thus Europe's curve is hidden.
Source: Chart from ETC (2023) Fossil Fuels in Transition, underlying from Systemiq analysis of EIA (2023), Henry Hub Natural Gas Spot Price; EIA (2023), Europe Brent Spot Price FOB; Nasdaq (2023), Dutch TTF Natural Gas Forward Day Ahead; Nasdaq (2023), Coal Marker Prices; EIA (2023), Cushing, OK WTI Spot Price FOB.

With the current Middle East conflict, Brent crude has surged ~40% to over $100 per barrel[24], and flows through the Strait of Hormuz have collapsed to an estimated 600,000 barrels per day from normal levels above 19 million[25]. The IEA said that the conflict is "creating the largest supply disruption in the history of the global oil market"[26] which led to member countries agreeing on the release of 400 million barrels from oil reserves, the largest coordinated release in the agency's history[27]. Beyond fuel, around one third of global seaborne fertilizer trade passes through the Strait of Hormuz[28], and its current closure increased urea import prices to the US by up to 30% in a week[29]. For developing countries dependent on imported fertilizer, the situation translates into higher food prices.

Within the realms of energy security what is possible is to accelerate support for renewables and electrification. During the industrial revolution coal displaced animal power, water and wind. Later, oil and gas displaced coal. Now electricity displaces coal, oil and gas.

Countries that have moved furthest on electrification are already better insulated from these shocks. In Spain, where wind and solar capacity doubled between 2019 and 2025, gas set the power price in only 15% of hours in early 2026, compared to 89% in Italy[30]. The result is a structural decoupling of electricity from fossil fuels prices.

Today the majority of countries worldwide remain net importers of fossil fuels, accounting for almost 75% of the global population[31]. For each of these countries every unit of demand displaced by domestic clean electricity reduces both the fiscal burden of energy imports and the macroeconomic exposure to supply disruptions beyond their control.

[24] Ember (2026), *Latest energy shock reminds Europe of its risky gas reliance*.
[25] FT (2026), *Wall Street warns Iran war will trigger prolonged energy crisis*.
[26] IEA (2026), *Oil Market Report - March 2026*.
[27] IEA (2026), *Emergency collective action press release, 11 March 2026*.
[28] UNCTAD (2026), *Strait of Hormuz disruptions: Implications for global trade and development*.
[29] CNBC (2026), *Food prices could rise as Iran conflict disrupts fertilizer supply chain*.
[30] Ember (2026), *Latest energy shock reminds Europe of its risky gas reliance*.
[31] Ember (2024), *Global Electricity Review*.

Clean electrification paired with renewable power can displace fossil fuel use across sectors that account for roughly 60% of global greenhouse gas emissions, including buildings, road transport, and light industry. In most of these sectors, the clean electric alternative is already at or approaching cost parity with fossil incumbents, meaning fossil fuel demand can fall at nil or negative cost to consumers while also reducing their exposure to fuel price volatility[32].

[32] Turner, A. (2026), *LSE Lecture I: Abundant clean energy for all*. Available at: youtube.com/watch?v=ohAvw0XKtmE&list=PLK4eIntcUEy3kR3B4Ws8PcKndb1g5a68Y&index=56.

Accelerating the electrified, resilient future requires action across four areas

Achieving an electrified, resilient energy system could reduce fossil fuel demand by over two thirds by mid-century, while enabling a doubling of global GDP, cleaner air and reduced climate damage[33].

Electrify demand across sectors. Road transport electrification should be a priority in all countries, with EV sales targets, ICE phase-out dates, and charging infrastructure investment. In high-latitude countries, electrification of building heating through heat pump deployment is critical, as well as adjusting power to gas price ratio in order to create the right incentives[34].

Improve efficiency of the electrified system. Appliance and vehicle efficiency standards, accelerated stock turnover through scrappage schemes and labelling programmes, and improved building insulation standards can compound the gains from electrification[35].

Decarbonise power supply. The shift from thermal power generation to renewables is the largest single driver of improved primary energy productivity. Countries should set ambitious targets for power decarbonisation and support the required investment in storage, flexibility, and grids[33].

Use carbon pricing to drive decarbonisation in hard-to-electrify sectors. Adequately high carbon prices, supported by carbon border adjustment mechanisms, should be extended to heavy industry, aviation, and shipping globally.

[33] ETC (2023), *Fossil Fuels in Transition: Committing to the phase-down of all fossil fuels.*

[34] ETC (2025), *Energy productivity: Increasing efficiency in an expanded, electrified energy system.*

[35] Ibid.