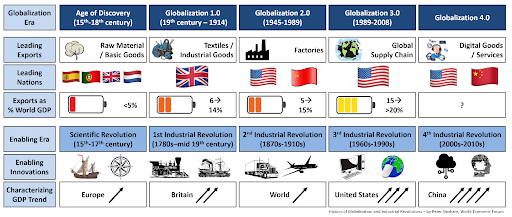
# ENERGY GLOBALIZATION – TRENDS AND DEVELOPMENTS

**Introduction.** Globalization has been defined in various forms as the widening, deepening and speeding up of worldwide interconnectedness in all aspects of economic, political, social and cultural relations across borders and the growing economic interdependence of countries through the increasing volume and variety of cross-border transactions in goods and services and of international capital flows.[[1]](#footnote-1)

The linkages created result in local happenings being shaped by distant events. Globalization covers a large number of sub-topics, including economics, politics, culture, social relations, technology and migration but energy is a missing link. During the last century, the transformation of energy sourcing, in particular oil, natural gas and nuclear fuel enhanced the scope of global interactions. The Middle-East oil crises of 1973 and 1979 and the Russian–Ukrainian gas crises of 2006, 2009, and 2014 illustrate dependency in energy globalization. Pursuit of energy has been a fundamental driver and underpins the economic and military potential of nations and has been a substantial cause of international conflict. Competition for political influence in major oil-producing regions, control of transport choke points and rights over continental shelves have been at the heart of confrontation and conflict. Energy is, therefore, central to globalization, and not merely a simple commodity. Energy globalization is the growing interconnectedness of world’s energy supplies through movement of growing volumes of energy across international borders.

**Aim.** The aim of this paper is to study the globalisation of energy in a bi-directional manner – both as a commodity shaped by the forces of globalisation and simultaneously as a driver for globalization.

**Preview.** The paper will first delve into the historical context of globalisation, tracing the advent of energy becoming a driving force. It will, thereafter, detail the manifestations of energy globalisation, tensions arising from interdependence and energy security. The role of energy as an engine for growth and the threat emanating for globalisation will bring forth the necessity and urgency of alternatives to fossil fuel. It will then identify the various developments occurring in the sphere of energy and alternatives, both shaping and shaped by the forces of globalisation.

**Globalisation – A Historical Context.** Trade has been a core human activity which was largely localised. However, around the 1st century BC, Chinese luxury products found their way over the Silk Route to Rome at the other edge of the Eurasian continent, heralding the era of global trade between two great empires dominating the route. A common thread of trade thriving under great power patronage, which itself becomes a source of power and strength, is evidenced in the Spice routes (7th-15th centuries) flourishing with Islamic merchants spreading the new religion from its Arabian heartland upto Marco Polo’s late medieval time.[[2]](#footnote-2) The Age of Discovery (15th-18th centuries) witnessed European explorers exploiting scientific revolution in establishing empires by subjugating and exploitation of colonies, creating an imperialistic mercantile economy. The first wave of globalisation, corresponding to the British Empire, rose on the foundations of the First Industrial Revolution, steamships and trains. These advancements allowed global exploitation of raw materials, production of finished goods on an industrialised scale and traded across continents at an unprecedented scale. Interconnectedness allowed participation and trading in the stock markets, the Suez created a key artery of shipping, railways allowed inland transportation to diverse markets in India and China, all providing an exponential impetus to global trade. The second and third waves riding on advancements in industrial manufacturing, transportation and the internet, raised global trade as a percentage of world GDP in a substantial manner. Global integration of value chains allowed R&D in one country, sourcing in others, production in yet another, and distribution all over the world, dominated by two global powers, the US and China. The next wave is the cyber domain through e-commerce, digital services, 3D printing, further enabled by artificial intelligence, but threatened by cross-border hacking and cyberattacks.

**Energy – An Engine of Growth.** For millennia, human populations led a nomadic hunter existence. The ‘agriculture revolution’ evolved with reliance on energy derived from domesticated plants and animals leading people to settling down in villages, which further evolved to cities and state formations with centralized governments. The renewable and benign agricultural ecosystem, upto the 15th century, evolved to the industrial revolution by the 18th century, driven by energy harnessed from fossil fuels. Energy was at it’s heart, which allowed the engines of globalisation (factories, industries, transportation, global communication networks and cyber systems) to integrate and maximise global interconnectedness and trade. Energy, the means to maximise production and transport, is the principle driver and glue of globalisation. Low energy based small economies are transformed to higher productive, job creating, tax and resource extracting prosperous economies with high goods and services output. The industrial revolution would not have occurred without them and globalization can potentially be reversed in the absence of adequate sources.

**Watershed Events – Energy in Globalisation**

**Oil – A Strategic Shift.** The discovery of oil in Persia in 1909 and Britain securing that flow of oil by taking a controlling interest in the Anglo-Persian Oil Company in July 1914 was a watershed event. Winston Churchill, as the pre-WWI First Lord of the Admiralty for the British Navy, converted the British Navy from coal-power to fuel oil, to make the fleet faster than the German Navy. In doing so a new vulnerability had been created since coal was a domestic source of fuel but oil had to be imported, creating a dependency on foreign sources. Ever since, it has been a strategic factor in shaping the interests of global powers, a fact well documented and manifested in the events that shaped the Mandate era and omnipresent turmoil in the region.

**The Petrodollar.** In July 1944, the United Nations Monetary and Financial Conference (commonly known as the Bretton Woods conference) was held in Bretton Woods, New Hampshire hosting delegates from 44 Allied nations with an aim to regulate the war-torn international economic system.[[3]](#footnote-3) The International Bank of Reconstruction and Development (IBRD, later known as the World Bank) and The International Monetary Fund (IMF) were established along with introducing the General Agreement on Tariffs and Trade (GATT, later known as the World Trade Organization, or WTO). It also created a new fixed exchange rate regime with all global currencies pegged to US Dollar playing a central role as an international gold-backed monetary standard completely convertible into gold at a fixed rate of $35 per ounce. It thus created a system of global demand for the US Dollar, allowing the Federal Reserve to print currency, despite a mismatch of proportionate gold holdings, due to the faith reposed in the US economy. The resultant American spending and debt, along with the financial burden of the Vietnam War, led to erosion of the American economy and a crisis was brewing by 1970 when nations sought to invoke convertibility of gold for the dollar reserves held. On August 15, 1971, President Richard Nixon decoupled dollar convertibility into gold, ending the Bretton Woods arrangement but maintained global demand for US dollars by way of a deal with Saudi Arabia who agreed to denominate their oil sales exclusively in US dollars, in return for American weapons and protection of their oil fields from neighboring nations.[[4]](#footnote-4) By 1975, all Organization of Petroleum Exporting Countries (OPEC) nations agreed to exclusive dollar pricing of oil in exchange for weapons and military protection, creating the petrodollar system and generating an artificial global demand for US dollars. Thus, the convergence of energy and reserves linked to the US dollar allowed the US economy to dominate the globalized environment. **On one hand energy was the engine of globalization which powered the instruments of global trade (industry, transportation and communication) and on the other hand, it became the means of globalization by linking to the US dollar, making it the defacto reserve currency of necessity which has shaped geo-politics.**

**Manifestations of Energy Globalisation.** Growing energy consumption in emerging economies and emerging/expanding petroleum-producing regions makes the global production picture more complex and multipolar (e.g., the Arctic, East Africa). New natural gas pipelines and interconnectors expands and connects the regions within which natural gas is traded. Unconventional oil and gas technology increase the number of locations where oil and gas are extracted. Increased LNG capacity makes it possible to trade gas around the world rather than only within national and regional markets connected by pipelines. Liberalization of trade in energy-intensive commodities such as steel, aluminium and cement lead to greater indirect competition between coal, hydropower and natural gas markets around the world. Regional energy markets have expanded geographically, promoted by free-trade agreements, especially in the EU. Global climate impact and globalization of news flows and public opinion affects patterns of energy use across national borders through attitudes toward nuclear power, renewable energy, diesel, sports utility vehicles, electric cars etc. Nations legislating a majority ownership interest and mounting pressure for greater percentages of 'national content' manifest are all manifestations of energy globalization.[[5]](#footnote-5) The China–Turkmenistan gas pipeline transporting gas from Turkmenistan to Shanghai in the east and westwards via Russia and Ukraine to the European pipeline grid, which in turn extends from Finland in the north to central Algeria in the south symbolizes such integration.

**Tensions Arising from Globalisation of Energy**

Structure of international trade and global interdependencies has downsides, as witnessed during the global financial crisis. A single state cannot regulate events and is almost always dependent on the world market. Speculation on raw materials and energy lead to higher prices and bottlenecks resulting in substantial tensions.

**Economic Growth – A Necessity for Stability.** Economies are analogues to a two-wheeled bicycle which needs to roll quickly enough, or will fall over. An economy must grow quickly enough, or debt cannot be repaid with interest and will impact growth and usher inequities. Dissatisfied populations tend to lean towards electing leaders who favor limits to globalization. Shortfall of cheap-to-produce energy results in a backlash against globalization and immigration.

**Pricing Paradox.** Producers around the world need higher oil prices, to be compensated for cost of extraction, developing new fields, and the tax levels governments of exporting countries need. Affordability beyond a $70 per barrel oil results in economic stress, reduced demands and slowdown of growth. The Soviet Union was an oil exporter and collapsed in 1991, indirectly because with low oil prices they could not support adequate new investment in oil and gas extraction resulting in business closure and job losses. Similarly, Venezuela despite having the largest oil reserves, cannot afford to develop those reserves with dropping oil prices corresponding to the period of civil unrest and protests. The need for energy alternatives that can be quickly scaled up to replace oil and coal in the very near term need to be cheap-to-produce, non-polluting, and available in huge quantities.

**Energy Security - Impact on National Security.** Incremental US demand of imported petroleum rose sharply from 19% in 1967 to 36% by 1973. Till this point major oil companies dictated terms, resulting in low oil prices and oil producing countries remained the poorest despite creating the product most responsible for prosperity of the West. Non-US petroleum producers, under OPEC, unleashed the power of oil exports and the oil-shock of 1973 was a watershed event, shifting the balance in favour of the oil cartel. Security of supply impacts basic human energy needs for heating, cooking food etc. Loss of access to imported gas, for example to Ukraine or Europe, during winter creates both an economic problem and also a direct physical threat to the population’s survival. Energy is the lifeblood of economy and disruptions to flow of energy strangulate the economy, making energy a matter of national security. 2003 - 2008 witnessed oil prices rising approximately of 500 percent (from $26 to $147) due to market fears of oil supply disruption from war in the Middle East and intensified threat of a nuclear armed Iran, adding a “fear premium”. Increased costs for oil products and fuels means diverting precious resources away from other products and services impacting global business, job creation and consumers spending.

**Regional Energy Mix.** Energy sources vary greatly from region to region. The entire primary energy supply in the Middle East is based on gas and oil accounting 50.8 and 48.1 percent, respectively. Africa has a very high share of renewable energies, at 49.6 percent, almost half of the primary energy supply since the International Energy Agency (IEA) also considers the traditional use of biomass to be a renewable energy source. In 2013, China covered more than two thirds of its primary energy supply with coal (67.6 percent) and accounted for 52.3 percent of the global primary energy, with USA (11.0 percent) and India (8.7 percent) following far behind. OECD countries are more diversified with the shares of oil, gas and nuclear energy higher than the global average, with lower share of coal and renewable energies.[[6]](#footnote-6) If energy based on hydropower, biomass, biogas and biodegradable waste is added without restriction to the renewable energies, it’s share in the primary energy supply in 2016 was 13.7 percent. As per IEA, 69.5 percent of this was accounted for by biomass, biogas and waste (including biofuels / excluding industrial waste), 18.6 percent by hydropower and 12.0 percent by new renewable energies.[[7]](#footnote-7)

**Depleting Resources and Adverse Impact of Fossil Fuels.** Exploitation has consequences for the existing reserves with estimates of their complete depletion in approximately 40 years and natural gas reserves lasting 60 years while coal reserves could last 120 years. Reliance on fossil fuel, resultant deforestation, climate change and pollution adversely impacts the environment. The struggle for scarce resources of oil or gas in the future and acute shortage of drinking water caused by climate change setting mass migrations in motion could lead to violence and conflict. The interaction of environmental concerns with energy have set in motion a transition to decarbonize. The development of renewable energies is progressing extremely slowly with wind, hydropower and solar growing rapidly, but still a small part of the overall energy mix. Nuclear is growing in China but faces shutdown in Germany by 2022. The energy system, requiring enormous embedded capital, does not change rapidly but evolves with a long lead time. Power plants with a 60-year life span and oil fields requiring over a decade of exploration before first production cannot be replaced overnight.

**Fossil Fuels – Need for Alternatives.**  Earth's seven billion population is expected to touch 9-12 billion by 2050 (UN World Population Prospects 2012).[[8]](#footnote-8) A surge in population, coinciding with the ‘industrial revolution’ energised by fossil fuels, has led to accumulated fossil fuels being depleted and descending towards exhaustion. If not interdicted and replaced with alternative sources that are environmentally benign and in sufficient quantity would threaten evolution of globalization. Existing technology relying on oil becoming redundant and reverting to reliance on coal would hasten climate change, in the absence of adequate alternatives. Additional sources such as gas, may extend the duration of the availability of oil but merely delays it’s inevitable depletion and exacerbates ecological damage. Non-renewable sources which are too costly to extract, beyond the reach of extraction technologies, or when the technologies, such as fracking, incur so much ecological damage that they are no longer viable will recommence the descent along the energy boundary. However, changes in consumer behaviour, increased energy efficiency and use of renewable energies can reduce fossil fuels and associated negative environmental impacts.

**Technological and Conceptual Advancements**

A Nov 2017 article by Bonnie Christian, ‘Meet the Startups Changing the Future of Energy’ identifies early-stage companies and highlighted disruptions in energy distribution, storage and generation pitched at the WIRED Energy conference:

(a) **BuffaloGrid**. It aims to bringing mobile and power to people who are off the grid, seeking to bridge next digital divide. A large powerpack attached to a solar panel, acting as a hub, allows people to plug in their phones and recharge them in 20 villages in India where shops use the hub to provide their customers with power with an aim to cover more than half a million people in India in 2018.

(b) **SEaB Energy**. It turns a neighbourhood or business into its own power plant with closed-loop systems known as the Flexibuster (for food waste) and the Muckbuster (for agricultural waste). The systems, fitting into a shipping container, generate electricity and heat that are sent to a microgrid to be shared between neighbours, with the NHS as one of their biggest clients. Waste turned into energy rather than transported to a dump allows tons of carbon offset.

(c) **Origami Energy**. It utilises machine learning and big data to forecast demand and supply behaviour creating an online marketplace where a distributed network of energy generating, energy using and energy storing assets are connected to the electricity grid and monitored allowing supply and demand of electricity is matched more evenly in real time.

(d) **H2GO Power**. The future energy crisis is more about energy storage than generation. On-site electricity storage to reduce outages is a costly undertaking. The solution is to store hydrogen gas that can be burned in fuel cells by using nanomaterials to create a flexible sponge that traps hydrogen atoms in its pores. When the structure is heated, gas is released.

(e) **Kite Power Systems**. A commercial kite-driven power stations, where the kites fly in a figure-of-eight pattern, 450 metres in the air, pulling a tether that turns a turbine and produces electricity. Two kites working in tandem create a continuous energy source tapping higher than wind turbine.

(f) **Oxford PV**. It seeks to boost efficiency of commercial silicon solar panels by applying a thin film of a crystalline structure called perovskite, which increases the standalone efficiency of perovskite from 4 to 20 percent.

Slow pace of efficiency improvements and incremental advances in contemporary necessitate revolutionary new carbon-free energy sources which can supply 10 to 30 carbon emission free terawatts. Technically feasible and plausible options are[[9]](#footnote-9):

(a) **Nuclear Fusion**. It promises unlimited fuel and minimal waste by harnessing thermonuclear force akin to those that fire the sun, extracting a gigawatt of electricity from a few kgs of fuel a day. Its hydrogen-isotope fuel would come from seawater and lithium, a common metal, and the reactor would produce no greenhouse gases and relatively small amounts of low-level radioactive waste. The International Thermonuclear Experimental Reactor (ITER) aims to control the fusion of the hydrogen isotopes deuterium and tritium into helium long enough to generate 10 times the energy it consumes. The prohibitive cost could be more cost-competitive, if the fast neutrons produced transmute thorium (which is relatively abundant) into uranium to use as fuel in nuclear fission plants with fusion-fission hybrids the way forward.

(b) **High-Altitude Wind**. Wind is solar energy in motion and only 0.5 percent of the sunlight is transmuted into the kinetic energy of air. That energy is not distributed evenly but concentrated into strong currents with the most powerful consistent currents in the upper troposphere. The mother lode is the jet stream, about 10,000 meters between 20 - 40 degrees latitude in the Northern Hemisphere where wind power surges to 5,000 - 10,000 watts a square meter. Affordable ways to mine the mother lode are experimenting on rotating, helium-filled generator exploiting the Magnus effect (giving loft to spinning golf balls) to float on a tether producing energy at its ground station. The “laddermill,” envisions a series of computer-controlled kites connected by a long tether, and the yo-yo of their rise and descent turning a generator. Effects of turbulence, lightning strikes, steep maintenance costs and regulatory hurdles to restrict aircraft traffic in the vicinity will need solutions.

(c) **Cold Fusion and Bubble Fusion.** Theoretically, beaming high-intensity ultrasound and neutrons into a vat of acetone cause microscopic bubbles to form and then implode at hypersonic speeds. The acetone is made using deuterium, a neutron-bearing form of hydrogen, and Taleyarkhan’s group claimed that the extraordinary temperatures and pressures created inside the imploding bubbles forced a few deuterium atoms to fuse with incoming neutrons to form tritium (hydrogen with two neutrons per atom).

(d) **Matter-Antimatter Reactors**. Mutual annihilation would release energy but there are no known natural sources of antimatter and would need to be synthesized. It is estimated that the particle accelerator at CERN near Geneva, would have to run nonstop for 100 trillion years to make a kilogram of antiprotons, making antimatter plants a distant dream.

(e) **Space-Based Solar**. City-size satellites could harvest solar power from deep space and beam it back to the earth as invisible microwaves. Clear of the earth’s shadow and atmosphere, the intensity of sunshine is eight times as stronger and a reliable and fixed source. A rectifying antenna, or “rectenna,” spread over several square kilometers of land, could convert microwaves to electric current with about 90 percent efficiency, even when obstructed by clouds. The low power-to-payload ratio of a few hundred watts per kilogram makes space-based solar cost prohibitive compared.

(f) **Nanotech Solar Cells**. Materials engineered from the atoms could boost photovoltaic efficiencies. Materials laced with quantum dots might double generation. Quantum dots can put a wider range of wavelengths to useful work and can kick out as many as seven electrons for every photon. Better ways to funnel them into wires and search for dot materials that are more environmentally friendly than the lead, selenium and cadmium in today’s nanocrystals are underway. Dots are relatively inexpensive to make and high-efficiency solar cells made from silicon nanorods would be the goal.

(g) **A Global Supergrid**. Revolutionary energy sources need a revolutionary superconducting electrical grid that spans the planet. Long-distance transmission lines from superconducting wires, chilled to near absolute zero by liquid hydrogen, can transmit tremendous currents over vast distances with almost no loss. A transcontinental SuperGrid, solar arrays in Australia and wind farms in Siberia might power lights in the US and Europe but needs extensive infrastructure.

(h) **Waves and Tides**. The surging ocean offers a huge, but virtually untapped, energy resource. Tide farms dotting the coast could generate massive electricity with less capital investment, power variation and environmental impact based on predictable tidal power. A 240-megawatt (MW) tidal plant in France, 20-MW tidal station in Nova Scotia and 40-kilowatt (kW) facility in Daishan are some examples.

(i) **Designer Microbes**. Genetic engineers can create synthetic life-forms that will grow energy like food by genetically rewire organisms creating synthetic species. Microbes capturing CO2 from power plant smokestack and turn it into natural gas for the boiler or biological systems that try to produce hydrogen directly from sunlight, using photosynthesis could be engineered.

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**Cloud-based services and management of IT infrastructure**.[[10]](#footnote-10) Recovering reserves in deeper and more remote locations and being economically viable, requires greater scrutiny, analysis and testing. Creating better numerical models and simulations of the earth’s subsurface topology is necessary as the recovery process is dependent on understanding how the structural and fluid mechanics of a rock formation will interact with the effects of the drilling, completion and production phases. Innovations to develop technology that allows it to search deeper, farther and more efficiently would translate to better products, less waste and reduced environmental impact. High-performance computing (HPC) is a major contributor to success exploiting cloud computing, both global and company owned cloud to overcome drawbacks like security, resource quality and data transfer speed. Numerical simulation for seismic processing, reservoir simulation, structural analysis and computational fluid dynamics (CFD) can develop energy resources.

**Tackling Energy Security.** Rising unconventional energy reduces dependency on energy imports and energy efficiency, locally produced renewable energy and coal contributed to reducing European and US dependency on imports. Shale gas[[11]](#footnote-11) has reached a scale allowing the US, a natural gas importer transform to an exporter, reshaping strategic concepts of security. Churchill underscored the importance of diversity of oil supplies “Safety and certainty in oil lie in variety and variety alone.” Energy independence comes from a variety of alternative energy resources, such as coal, oil shale, nuclear and renewable energy, in addition to increased oil exploration and production. It implies developing alternative energy resources, and exploiting technology to convert non-petroleum energy resources into transportation fuels that can replace petroleum-based fuels. High oil consumption needs to be displaced by a combination of alternative fuels, increased fuel efficiency and conservation.

**Energy Globalisation and the Future – The Shifting Pivot.** The pivot of growth of the developed North in America, Europe and Japan has reached peak demand as a result of demographics, increased efficiency and substitution, and consumption of emerging markets is set to shift the pivot to the East. The energy-dollar nexus holds sway and attempts to diverge, as observed in events in Iran, Iraq, Venezuela etc. often generate serious repercussions. China, Russia, and India seeking currency swop arrangements for oil, the EU helping Iran bypass the SWIFT system could manifest in massive inflationary pressures on the US economy, and in turn cause a shock to the world economy in the globalized order. Thus, any changes that occur in the energy sector which undermines the primacy of the US dollar will have massive geo-political and economic consequences.

Energy globalisation should relate to a fundamental question – if the rise of empires and linkages to global currency reserves have a key linkage and with a shift of the economic pivot taking towards the East (China and India), what would be the shape of the next century if the primary energy source of the future were not linked to the US dollar…where would the center of gravity of the future global economy rest?

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