A New World

The Geopolitics of the Energy Transformation

GLOBAL COMMISSION
ON THE GEOPOLITICS
OF ENERGY TRANSFORMATION

IRENA
International Renewable Energy Agency

A New World

The Geopolitics of the Energy Transformation

www.geopoliticsofrenewables.org

With the support of

IRENA International Renewable Energy Agency

Federal Foreign Office

Norwegian Ministry of Foreign Affairs

UNITED ARAB EMIRATES MINISTRY OF ENERGY & INDUSTRY

ISBN 978-92-9260-097-6

Contents

The Commission

Aware that the growing deployment of renewables has set in motion a global energy transformation with significant implications for geopolitics, Adnan Z. Amin, the Director-General of the International Renewable Energy Agency (IRENA), with the support of the Governments of Germany, Norway and the United Arab Emirates, convened the Global Commission in January 2018.

Chaired by former President Ólafur Ragnar Grímsson of Iceland, the Commission comprises a diverse group of distinguished leaders from the worlds of politics, energy, economics, trade, environment and development. The Commission is an independent body with members serving in their individual capacity.

This Report analyzes the geopolitical implications of the global energy transformation driven by renewables. It is the culmination of ten months' deliberations by the Commission, involving four meetings held in Berlin, Oslo, Reykjavik and Abu Dhabi respectively, as well as consultations with business leaders, academics and policy thinkers. It is informed by a number of background papers drafted by experts in the fields of energy, security and geopolitics.

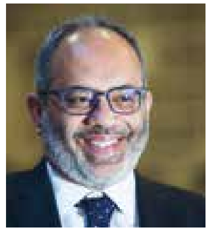
The Commission takes full and independent responsibility for this Report, which reflects the consensus of its members.

Members of the Commission

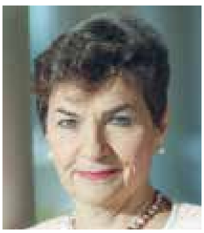
Ólafur Ragnar Grímsson
Chair, former President of Iceland

Adnan Z. Amin
Director-General of IRENA (Kenya)

Anatoly Chubais
Chairman of the Executive Board of RUSNANO (Russia)



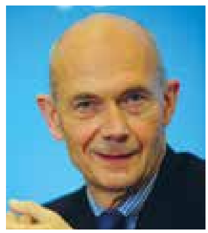
Carlos Lopes
Professor at the Graduate School of Development Policy and Practice, University of Cape Town; former Executive Secretary of the UN Economic Commission of Africa (Guinea-Bissau)



Christiana Figueres
former Executive Secretary of the United Nations Framework Convention on Climate Change (Costa Rica)

Joschka Fischer
former Minister of Foreign Affairs of Germany

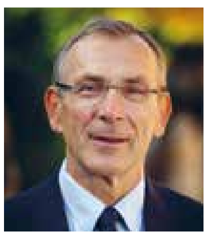
Fu Chengyu
Chair of United Nations Global Compact Network China; former Chairman for China Petroleum & Chemical Corporation (SINOPEC)



Pascal Lamy
President Emeritus of the Jacques Delors Institute; former Director-General of the World Trade Organization (France)

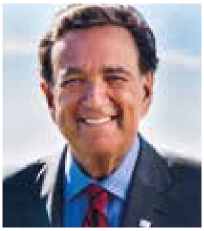
Murray McCully
former Minister of Foreign Affairs of New Zealand

Mari Pangestu
former Minister of Trade; former Minister of Tourism and Creative Economy (Indonesia)



Andris Piebalgs
Senior Fellow of the Florence School of Regulation; former EU Commissioner for Energy and for Development (Latvia)

Lapo Pistelli
Executive Vice President, International Affairs of ENI; former Vice Minister of Foreign Affairs of Italy



Bill Richardson
President of the Richardson Center for Global Engagement; former US Secretary of Energy and former Governor of New Mexico (United States)

Khalid Bin Mohammad Al-Sulaiman
former Vice President for Renewable Energy, King Abdullah City for Nuclear and Renewable Energy (Saudi Arabia)

Izabella Teixeira
former Minister of Environment of Brazil

Masakazu Toyoda
Chairman and CEO at the Institute of Energy Economics (Japan)

Maria Van Der Hoeven
former Executive Director of the International Energy Agency
(The Netherlands)

Eirik Waerness
Senior Vice President and Chief Economist, Equinor (Norway)

Representatives of supporting countries

Peter Fischer
Representative of the Government of Germany

Hans Olav Ibrekk
Representative of the Government of Norway

Fatima AlFoora AlShamsi
Representative of the Government of the United Arab Emirates

Foreword by Adnan Z. Amin, Director-General of IRENA

Energy is fundamental to our civilization and to the prosperity of nations. Its production, distribution and utilization are deeply embedded in the fabric of our economies and central to the relations between states.

The energy sources powering our societies have been undergoing a period of rapid change. Renewables have emerged as a technologically feasible, economically attractive and sustainable choice that increasingly can meet the energy needs of many countries, corporations and citizens. As tackling climate change becomes more and more critical and renewables steadily increase their capacity to meet our energy needs, the global transition to sustainable sources of energy will continue to accelerate.

Renewables enable countries to strengthen their energy security and achieve greater energy independence by harnessing the vast indigenous renewable energy sources that can be found across the planet. The rapid development of renewable technologies and their widespread deployment is certain to have significant long-term effects on geopolitical dynamics. While the establishment of the International Renewable Energy Agency (IRENA) has created a central platform for international cooperation on renewables, to date no systematic efforts have been made to examine their geopolitical implications comprehensively.

I therefore took the initiative to convene a Global Commission to address the geopolitics of energy transformation. Composed of prominent leaders from different geographical and professional backgrounds in the fields of energy and international affairs, the Commission was launched at IRENA's annual Assembly in January 2018 and deliberated over one year, drawing on the views of a broad range of public and private stakeholders and academics.

I wish to express my heartfelt appreciation to all who contributed to this process. Germany, Norway and the United Arab Emirates provided generous support that made the work of the Commission possible. President Grimsson, as Chair, ably guided the Commission's deliberations.

Commission members made time to actively participate in the Commission's discussions and provide compelling perspectives from their various areas of expertise. Last, but not least, the small but highly competent Secretariat facilitated, supported and synthesized the Commission's reflections and research.

The Report that has resulted is a vital first foray in this area that deepens our understanding of the wider geopolitical implications of the energy transformation. It invites us to rethink energy statecraft as we have known it. It maps trends in the energy sector, and considers their possible impacts on power relations, trade, the root causes of geopolitical instability, and conflict. The report also acknowledges that, given the complex and dynamic nature of the transition, it is difficult to predict precisely how events will unfold.

The Report highlights the vital need to prepare proactively for the new energy age and its geopolitical consequences. It also shows the crucial need to encourage innovation, align socio-economic structures and investment with the energy transition, strengthen international co-operation, and plan energy systems that are just and inclusive. Forward-looking choices that leaders in government and industry make today will create a more prosperous future that globally can promote sustainable economic growth, improve livelihoods, and foster social cohesion and stability.

It is my hope that this Report will help decision makers in countries to anticipate and navigate the rapidly changing global energy landscape and manage the new geopolitical environment it will create. In doing so, this Report can enable them to mitigate the potential risks and benefit from the many opportunities that transformation offers.

Foreword by Ólafur Ragnar Grimsson, Chair of the Commission

In recent years we have witnessed a transformation of the global energy system that has helped to configure the geopolitical map of the world which has prevailed for decades.

The shift from fossil fuels to renewables is driven by new technologies and falling costs, increasingly making renewables as competitive as conventional sources of energy. The energy transformation is also driven by the policies and actions of governments, businesses, cities and civil society, as well as the world-wide movement to combat climate change and dangerous air pollution.

This global energy transformation is already becoming a major geopolitical force: changing the power structures of regions and states, bringing the promise of energy independence to nations and communities, enhancing energy security and democratic empowerment.

It was to understand and analyze this new, emerging geopolitical reality that the visionary Director-General of IRENA, Adnan Z. Amin, proposed to the Assembly of more than 150 Member States, the creation of an independent Global Commission to deliver a Report on the geopolitical consequences of the global energy transformation.

It has been an honour and a privilege to serve as the Chair of the Commission and to conduct the informed dialogue of a group of distinguished and experienced individuals who brought a wealth of insights and knowledge to our collective enterprise.

This Report is the first attempt to describe the new geopolitical world that is emerging from the renewables revolution. It is therefore both historic and worthy of further debate and analysis.

It is our hope that the Report will help people in government and business, universities, think tanks, civil society organizations and the media, as well as citizens across the world, to understand better and adjust to the geopolitical changes now gathering pace.

I wish to thank the Members of the Commission for their dedication and co-operation and the capable Secretariat, supported by IRENA, for its excellent work. We also benefited from various contributions by business leaders and experts who addressed the Commission. The support provided by the Governments of Germany, Norway and the United Arab Emirates was also critical to the success of our work.

In this endeavour, I have been guided by the experience of my own country which, during my lifetime, has moved from primary dependence on fossil fuels to become one of the most successful renewable energy countries in the world - bringing prosperity to the people and serving as a foundation for constructive political relationships with countries in Asia, Africa, Europe and the Americas.

Through my service as President of Iceland, I was able to witness first hand how success in renewables can lead to new and dynamic partnerships between countries, thereby creating lasting alliances and fresh opportunities between nations that were once far apart.

My responsibility as the Chair of the Global Commission thus allowed me to see in the history of my own country a prelude to a New World.

Introduction

Fundamental changes are taking place in the global energy system which will affect almost all countries and will have wide-ranging geopolitical consequences. Renewables have moved to the centre of the global energy landscape. Technological advances and falling costs have made renewables grow faster than any other energy source. Many renewable technologies are now cost-competitive with fossil fuels in the power sector, even before taking into account their contributions to the battles against air pollution and climate change.

These trends are creating an irreversible momentum for a global energy transformation. While the surge in wind, solar and other renewables has taken place mostly in the electricity sector, new technologies are enabling this transformation in other sectors. Electric vehicles and heat pumps are extending the deployment of renewables in transport, industry and buildings. Innovations in digitalization and energy storage are expanding the potential for renewables to flourish in ways that were unimaginable just a decade ago.

The accelerating deployment of renewables has set in motion a global energy transformation that will have profound geopolitical consequences. Just as fossil fuels have shaped the geopolitical map over the last two centuries, the energy transformation will alter the global distribution of power, relations between states, the risk of conflict, and the social, economic and environmental drivers of geopolitical instability.

These far-reaching effects have not previously been considered in a comprehensive manner in any international forum or setting. To raise awareness and deepen understanding of them, IRENA established the Global Commission on the Geopolitics of the Energy Transformation, with the support of the Governments of Germany, Norway and the United Arab Emirates.

PART 1.

The global energy transformation

Renewable sources of energy—particularly wind and solar—have grown at an unprecedented rate in the last decade and have consistently surpassed expectations. The growth of their deployment in the power sector has already outpaced that of any other energy source, including fossil fuels, which include oil, coal and natural gas. Renewables, in combination with energy efficiency, now form the leading edge of a far-reaching global energy transition.[1]

This ongoing transition to renewables is not just a shift from one set of fuels to another. It involves a much deeper transformation of the world's energy systems that will have major social, economic and political implications which go well beyond the energy sector. The term 'energy transformation' captures these broader implications.[2]

The global energy transformation will have a particularly pronounced impact on geopolitics. It is one of the undercurrents of change that will help to redraw the geopolitical map of the 21st century. The new geopolitical reality that is taking shape will be fundamentally different from the conventional map of energy geopolitics that has been dominant for more than one hundred years.

Fossil fuels have been the foundation of the global energy system, economic growth and modern lifestyles. The exploitation of fossil fuels lifted global energy use fifty-fold in the last two centuries, shaping the geopolitical environment of the modern world. The geographic concentration of fossil fuels has had a significant impact on the wealth and security of nations. An energy transformation driven by renewables could bring changes just as radical in their scope and impact.

The majority of countries can hope to increase their energy independence significantly, and fewer economies will be at risk from vulnerable energy supply lines and volatile prices. Some countries that are heavily dependent on exports of oil, gas or coal will need to adapt to avoid serious economic consequences. Many developing economies will have the possibility to leapfrog fossil fuel-based systems and centralized grids. Renewables will also be a powerful vehicle of democratization because they make it possible to decentralize the energy supply, empowering citizens, local communities, and cities.

Energy transformation

Rapidly growing renewables have unquestionably started to transform the global energy landscape in an irreversible way. At the same time, considerable uncertainty still surrounds the energy transition that is taking place. As the rapid uptake in renewables shows, we live in an age of exponential change and disruption. Which technological innovations will accelerate the transformation cannot yet be foreseen. Political choices will affect the course and pace of the energy transformation, which is likely to progress at different speeds in each country and in each sector. However, three primary aspects characterize and underpin the transition: energy efficiency, the growth of renewables, and electrification.

Energy efficiency enables economic growth with lower energy inputs. In the twentieth century, the average growth rate of energy demand was 3%, about the same as the growth rate of global GDP. In recent decades, improvements in energy efficiency have broken this link. Primary energy demand is now forecast to grow at 1% a year in the period to 2040.[3]

Growth of renewables. Renewables have emerged as the fastest growing energy source.[4] The main renewable energy sources are bioenergy, geothermal, hydropower, ocean, solar and wind. Among these, solar energy and wind power are undergoing very rapid growth, while the others are growing more gradually. Solar and wind share a characteristic that is largely unique to them: the amount of power they generate varies with the weather and the time of day. This is why they are called variable renewable energy sources.

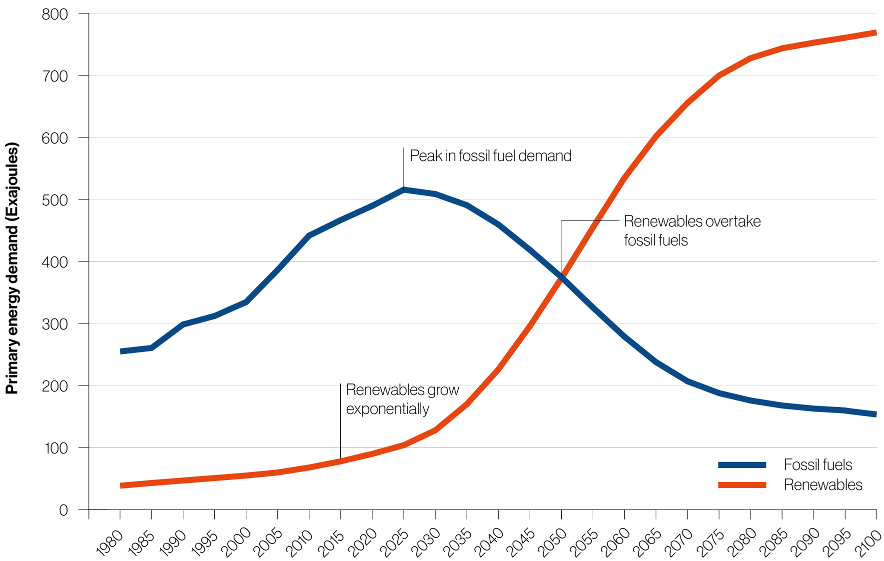
The impact of the extraordinary growth in renewables has mostly been felt in the electricity sector. Since 2012, renewables have added more new power generation capacity than conventional sources of energy.[5] Solar power added more new capacity in 2017 than did coal, gas, and nuclear plants combined.[6] Wind and solar now provide 6% of electricity generation worldwide, up from 0.2% in 2000. In the aggregate, renewables account for around a quarter of global electricity generation.[7]

Countries such as Denmark already generate more than half their electricity from variable renewable energy sources.[8] In 2017, Costa Rica's electricity was generated entirely from renewable energy for 300 days. For several days in the past year, the power systems of Germany, Portugal and Denmark were able to run entirely on renewables.

Electrification. Electricity accounts for 19% of total final energy consumption, but its share is expected to grow as increased electrification of end-use sectors takes place.[9] The deployment of heat pumps and electric vehicles, for example, permits electricity to be used for heating, cooling, and transport. Electricity has been the fastest growing segment of final energy demand, growing two-thirds faster than energy consumption as a whole since 2000. This trend is set to continue. Since 2016, the power sector has attracted more investment than the upstream oil and gas sectors that have traditionally dominated energy investment, another reflection of the ongoing electrification of the world's economy.[10]

The speed of the energy transformation is uncertain. Because of the complexity of energy systems, there are as many scenarios on the future of energy as there are forecasters. Nevertheless, scenarios that model an energy future compatible with the goals of the Paris Agreement have a similar structure: a near-term peak in fossil fuel demand, a rapid uptake of renewables, and a long decline in fossil fuel demand.[11] Figure 1 illustrates these dynamics. It is not a prediction, but shows a possible pathway which assumes that the world is able to achieve the goal of the Paris Agreement to limit temperature increase to 'well below 2°C'.

Figure 1. The energy transition framework



Note: This data is taken from the Shell Sky Scenario (2018), which has the merit of forecasting to 2100 and therefore projects the nature of the energy transformation over the course of the century. Other energy transition scenarios usually have shorter time horizons. The Sustainable Development Scenario (SDS) of the International Energy Agency (IEA), for example, only looks forward to 2040. IRENA's REmap scenario goes to 2050. Shell's forecast share of renewables and fossil fuels is similar to that of the IEA SDS scenario for 2040 as well as the DNV GL and Equinor Renewal scenarios for 2050. The IPCC 1.5 degree median scenario and IRENA REmap scenario anticipate a substantially larger share of renewables by 2050 with an earlier peak in fossil fuel demand.

Source: Shell Sky Scenario, 2018.

Even though nuclear energy is a low-carbon technology, the growth prospects for nuclear energy seem limited. After rapid expansion in the 1970s and 1980s, the growth of nuclear power has slowed in the last three decades. The share of nuclear in electricity generation declined from 17% in 2000 to 10% in 2017.[12] Around two thirds of today's nuclear power plants in advanced economies are more than 30 years old and will be shut down in the foreseeable future unless their lifetimes are extended.[13] Some countries are building new nuclear power plants, notably China, India, Russia, and the UAE. In others, governments are planning to phase out nuclear power, as in Germany, Switzerland, Spain and South Korea.

Overall, the global energy transformation is characterized primarily by a rapid growth of renewables, and in particular solar and wind. Oil, gas and coal will be affected differently by the energy transition because they have distinct characteristics and are used in a variety of sectors.

The forces of change

Six enabling trends drive the rapid deployment of renewables.

I. Declining cost

As the costs of renewable energy technologies have fallen, the business case for renewable energy has become a major driver of change. Mature renewable energy technologies, including hydropower and geothermal, have been cost-competitive for years where they operate. However, technologies such as solar and wind have also gained a competitive edge as a result of technological advances and increased investment. The steep decline in costs of renewable energy and energy storage has surprised even the most optimistic observers. Once dismissed as too expensive to expand beyond niche markets, solar and wind can now beat conventional generation technologies on cost in many of the world's top markets, even without subsidies.[14]

Since 2010, the average cost of electricity from solar PV and wind energy has fallen by 73% and 22% respectively.[15] In countries as dissimilar as Chile and Saudi Arabia, India and the United States, electricity is being produced in optimal locations for around 30 US dollars per megawatt hour (MWh). Auction prices suggest that by 2020 the average cost of electricity that is generated by solar and wind sources will be at the lower end of fossil fuel electricity costs.[16] The cost of lithium-ion batteries, which are used in electric vehicles, has fallen by 80% since 2010.[17] As a result of these cost declines, investments in renewable technologies are increasingly driven by competitive business models and the profit motive.

Significant cost declines are expected to continue over the course of the next decade. IRENA estimates that by 2025 the global weighted average cost of electricity could fall by 26% from onshore wind, by 35% from offshore wind, by at least 37% from concentrated solar power (CSP) technologies, and by 59% from solar photovoltaics (PV).[18] The cost of stationary battery storage could fall by up to 60%,[19] and there is growing confidence that electric and conventional vehicles will be sold at comparable prices by the mid-2020s.[20]

II. Pollution and climate change

The problems caused by fossil fuels—including widespread air pollution and climate change—have led governments, businesses, investors and the public to recognize the need to decarbonize the global economy. Pollution, mainly caused by the burning of oil and coal, is making the air dangerous to breathe in many cities, from New Delhi to Beijing and Paris. The World Health Organization estimates that nine out of every ten people in the world breathe polluted air that is hazardous to health and wellbeing, and that air pollution kills 7 million people every year,[21] making it the fourth largest cause of death.

Climate change poses an existential threat to humanity and the Earth's eco-systems. Unless urgent steps are taken to decarbonize the energy sector, the world will not achieve the Paris Agreement's goal to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels". A recent IPCC report sets out increasingly persuasive scientific evidence of the need to limit the temperature rise to a maximum of 1.5°C to prevent long-lasting or irreversible changes, including the loss of vital ecosystems.[22] At present, the world is on a course that, relative to pre-industrial levels, will increase global temperatures by at least 3°C by the end of the century.[23] Another recent scientific study has warned that an abrupt domino effect may tip the planet into a 'hothouse' state if global temperatures rise by more than 2°C.[24]

Most pathways to a low-carbon economy would require the rapid deployment of renewable energy and a doubling of energy efficiency, given that the energy sector accounts for two-thirds of global emissions.[25] An analysis by IRENA has shown that deployment of renewable energy combined with improved energy efficiency provides the most cost-effective way to achieve the 90% reduction in energy-related emissions that is required to meet the Paris Agreement target.[26] The Sustainable Development Goals (SDGs), adopted by world leaders at the United Nations in September 2015, contain a specific goal on energy, which aims to provide universal access to modern energy services, double the rate of improvement in energy efficiency, and increase substantially the share of renewable energy in the global energy mix by 2030.

III. Renewable energy targets

Influenced by the strengthened business case of renewables and the need to decarbonize the energy sector, numerous governments have raised their ambitions and taken steps to accelerate their deployment of renewable energy. So far, 57 countries have developed plans to decarbonize their electricity sector completely, and 179 have set national or state renewable energy targets.[27] Governments initially supported renewables through subsidies and mandates, but they are increasingly moving to competitive auctions that are delivering lower prices.[28]

Many countries are shifting to renewables because they lack oil and gas reserves and wish to be less dependent on energy imports. India, for example, is set to become ever more dependent on costly energy imports unless it changes course.[29] This is one reason why it has adopted ambitious renewable energy targets.

A number of major oil-producing countries are also setting targets for increasing the proportion of renewables in their energy mix. The United Arab Emirates' energy strategy, for example, sets an objective of 44% of renewables in its power supply and a 70% reduction in its carbon emissions by 2050. Russia auctioned 2 GW of renewables in 2017 and is planning to auction another 1 GW in 2018.

In certain countries, where central governments have been slow to establish renewable energy targets, local governments and municipalities have acted in their place. California has adopted a 60% renewable electricity target by 2030, and several cities, from Mexico City to Madrid, have announced plans to ban diesel cars.

IV. Technological innovation

Technological innovations, including higher solar photovoltaic (PV) module efficiencies and taller wind turbines, have played an important role in accelerating the deployment of renewables in the electricity sector. Patenting rates suggest that more technological innovation has taken place in the field of clean energy technologies than in traditional energy fields such as fossil fuels and nuclear.[30] In the long term, next generation biofuels and renewable hydrogen generated from electrolysis may permit renewables to extend into a growing range of hard-to-electrify sectors, such as aviation, shipping and heavy industry.[31]

Innovations in digitalization and energy storage are also opening up new frontiers. New digital technologies, such as smart grids, the internet of things, big data, and artificial intelligence, are being applied in the energy industry, helping to raise its efficiency and accelerate the use of renewable energy within emerging smart generation and distribution systems.

New energy technologies are also being developed for energy storage, vital for variable renewables such as wind and solar. Batteries, including those in electric vehicles, are expected to become an important storage technology. Electricity can also be stored in thermal form using boilers, heat pumps or chilled water. For longer-term storage, there are other options, including compressed air energy storage or hydrogen.

V. Corporate and investor action

The actions of corporations are also driving change. Investor groups such as DivestInvest and CA100+[32] are putting pressure on companies to reduce their carbon footprints. At the December 2018 climate conference in Poland, known as 'COP24', a group of 415 investors, representing over 32 trillion US dollars, reaffirmed their full support for the Paris Agreement and undertook to improve climate-related financial reporting. They called on governments to put a price on carbon, abolish fossil fuel subsidies, and phase out thermal coal power.[33]

The Norwegian sovereign wealth fund is taking steps to divest from coal, as are some private banks, including HSBC. A number of major multilateral development banks, such as the World Bank, are no longer financing coal investment. Global insurance companies such as Allianz and AXA have announced that they will phase out insurance coverage for particular coal projects.

Moreover, some of the world's leading companies are moving to obtain all their electricity from renewable sources and encouraging their supply chains to do likewise. Both Apple and Microsoft recently announced that their facilities are completely powered by renewable energy. Many other companies, including IKEA, Tata Motors and Walmart, have committed to source 100% of their electricity consumption from renewables.[34]

Major companies, including fossil fuel companies, now recognize the carbon risk to their operations.[35] Under growing investor pressure, for example, Shell set out a plan to curb its net carbon footprint, including the emissions by its consumers, by around 20% by 2035.[36] ExxonMobil, Equinor and other oil majors support the introduction of a carbon price.

VI. Public opinion

Public opinion is also a potent force for change. In countries across the world, consumers increasingly prefer to buy products and services that have a smaller carbon footprint, and civil society movements are applying pressure on governments and companies to reduce air pollution and carbon emissions. Religious leaders are adding to the moral arguments for acting on climate change. Pope Francis, for example, has endorsed phasing out fossil fuels in the encyclical *Laudato Si'*.[37]

Public opinion is not only being expressed through words but also through direct actions. Demonstrations against air pollution have taken place in numerous cities, from Beijing to London. Approximately 15,000 Australian school children took part in a school strike to demand action by their government against climate change.[38] New social movements, such as Extinction Rebellion and the Sunrise Movement, are campaigning for radical action to tackle climate change.[39]

Litigation is on the rise too. A court in the Hague ordered the Dutch government to reduce the Netherlands' greenhouse gas emissions by at least 25% by 2020 compared to 1990 levels.[40] Some of the world's leading oil and gas companies are embroiled in legal disputes with cities, states and even children over the industry's role in global warming.[41]

As a result of these dynamic forces of change, the global energy transformation is gathering momentum and accelerating.

Why renewables will transform geopolitics

The main story of the energy transition is the rise of renewables, particularly solar and wind, and the future decline of fossil fuels. Renewables differ in many respects from fossil fuels, and these differences will have geopolitical consequences.

First, renewable energy resources are available in one form or another in most countries, unlike fossil fuels which are concentrated in specific geographic locations. This reduces the importance of current energy choke points, such as the narrow channels on widely used sea routes that are critical to the global supply of oil.

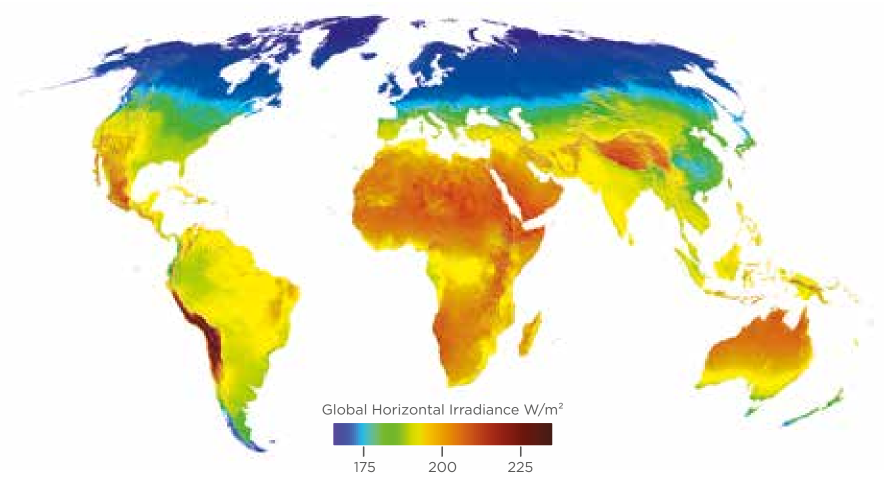
Second, most renewables take the form of flows, whilst fossil fuels are stocks. Energy stocks can be stored, which is useful; but they can be used only once. In contrast, energy flows do not exhaust themselves and are harder to disrupt.

Third, renewable energy sources can be deployed at almost any scale and lend themselves better to decentralized forms of energy production and consumption. This adds to the democratizing effects of renewable energy.

Fourth, renewable energy sources have nearly zero marginal costs, and some of them, like solar and wind, enjoy cost reductions of nearly 20% for every doubling of capacity.[42] This enhances their ability to drive change but requires regulatory solutions to ensure stability and profitability in the power sector.

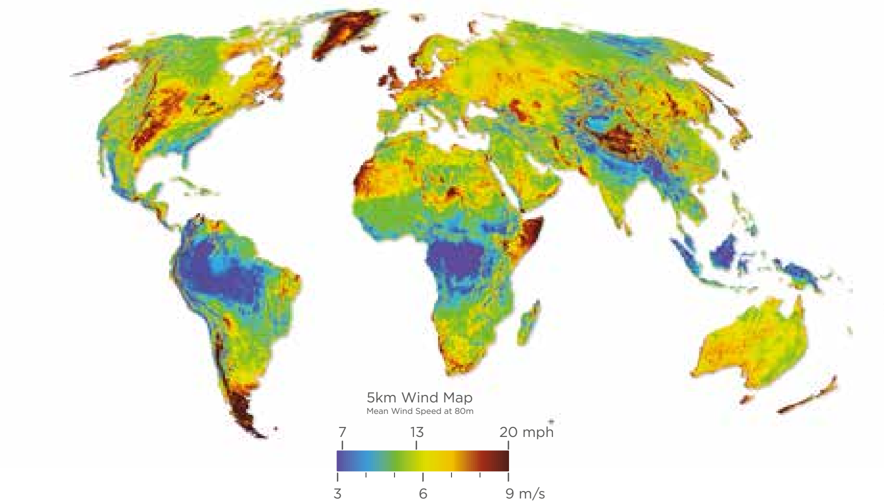
The energy transformation will be one of the major elements that reshape geopolitics in the 21st century, alongside trends in demography, inequality, urbanization, technology, environmental sustainability, military capability, and domestic politics in major states.

Figure 2. World solar potential



Source: Vaisala.

Figure 3. World wind potential



Source: Vaisala.


P

PART 2.

Redrawing the geopolitical map

Power shifts

For two centuries, the geographic concentration of oil, natural gas and coal reserves has helped configure the international geopolitical landscape. Coal and steam power drove the Industrial Revolution which, in turn, shaped geopolitics in the 19th century. Since then, control over the production of and trade in oil has been a key feature of 20th century power politics. A transition from fossil fuels to renewable energy could transform global power relations no less than the historical shifts from wood to coal and from coal to oil.

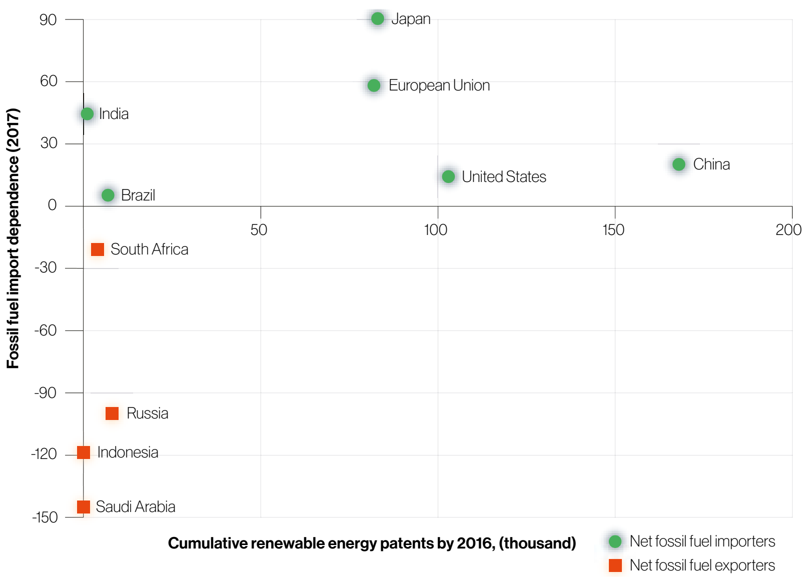
Repositioning of states

A state's relative position in the international system is influenced by a range of attributes, including its GDP, population, land size, natural resources, geostrategic location, military resources, and 'soft power'. Having control over and access to significant energy resources and markets is an important asset because it enables states to protect vital national interests at home, and leverage economic and political influence abroad. States without such assets, by comparison, have less leverage and are more vulnerable.

The rapid growth of renewable energy is therefore likely to alter the power and influence of some states and regions relative to others, and to redraw the geopolitical map in the 21st century.

How different countries fare in the context of the energy transition depends in no small part on how exposed they are to changes in fossil fuel trade flows. Equally important is their position in the clean energy race, the commercial race to become a leader in renewable energy technology. Although the issue is highly complex, innovation will be a key determinant of the pace of change and its effect can be illustrated in Figure 4.

Figure 4. Impact of the energy transition on selected countries and groupings



Source: BP, IRENA.

- **The Y-axis** depicts the share of oil, gas, and coal imports in total primary energy consumption in 2017. It situates selected countries, as well as the European Union, in the energy economy of today, which is dominated by fossil fuels. The higher the share, the more dependent a country is on fossil fuel imports. Net fossil fuel exporting countries have negative shares.

- **The X-axis** shows the cumulative number of patents for renewable energy technologies that had been registered by the end of 2016. This indicator provides a way to assess the position of selected countries, and the European Union, in the clean energy race.

Countries and groupings in the upper right quadrant of Figure 4 stand to gain the most from the energy transition: they are highly dependent on imported fossil fuels but have positioned themselves at the forefront of the clean energy race.

Figure 4 gives rise to a number of observations.

- **The United States** is close to energy self-sufficiency, largely due to the shale revolution. It became a net exporter of natural gas in 2017 and is projected to become a net oil exporter early in the 2020s. The US is well positioned in the clean energy race: US companies hold strong positions in new technologies, including robotics, artificial intelligence, and electric vehicles.

- **China** will gain from the energy transformation in terms of energy security. It has a leading position in manufacturing, but also in innovation and deployment of renewable energy technologies. It is the biggest location for renewable energy investment, accounting for more than 45% of the global total in 2017.[43] Currently, it remains highly dependent on oil imports which have been growing steadily.

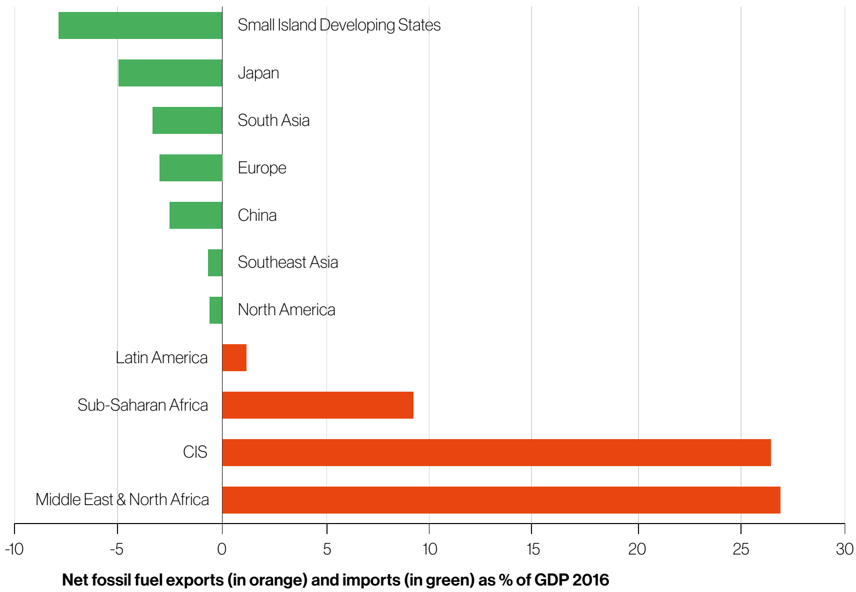
- **Europe and Japan** are major economies which are very dependent on fossil fuel imports. They also hold strong positions in renewable technologies. In Europe, Germany leads the way with almost 31,000 renewable energy patents. Germany's domestic Energiewende, or 'energy transition', has made the country a frontrunner in renewable energy deployment.

- **India** has been among the fastest-growing economies in the world in the last few years, lifting millions out of poverty. It is projected to have the world's largest population by 2024[44] and is poised to overtake China as the world's largest energy growth market by the end of the 2020s.[45] India has set itself an ambitious target of 175 GW of renewables by 2022.[46] This represents a massive increase, considering that India's total installed power generation capacity in October 2018 was only 346 GW.[47]

- **Russia**, the world's largest gas exporter and second largest oil exporter, may face challenges in adapting to a world increasingly powered by renewables. Russia's economy is larger and more diversified than any of the Middle Eastern oil producers, but oil and gas rents are a vital component of the state budget, accounting for around 40% of fiscal revenues.[48] Even though Russia is stepping up renewable energy deployment and is investing in research and development, it still lags far behind China and the US in terms of patents for renewable energy technologies.

To assess the impact of the energy transition on different regions, Figure 5 shows each region's net fossil fuel exports and imports as a share of GDP.

Figure 5. Regional impact of the energy transition



Source: World Bank, IMF.

While the graph above masks differences within regional groupings, it has the advantage of uncovering major differences between regions and country groupings.

- The **Middle East and North Africa**, together with **Russia and other countries in the Commonwealth of Independent States** (CIS),[49] are the regions most exposed to a reduction in fossil fuel revenues. On average, these regions have net fossil fuel exports of more than a quarter of their GDP. Declining export revenues will adversely affect their economic growth prospects and national budgets. To prevent economic disruption, they will need to adapt their economies and reduce their dependence on fossil fuels.

- The majority of countries in **Sub-Saharan Africa** (SSA) will benefit from reducing fossil fuel imports and generating renewable energy domestically, because this will boost job creation and economic growth. The exceptions to this are the two biggest oil producers in the region, Nigeria and Angola, which are at risk because they depend heavily on fossil fuel rents. Because of their size and large fossil fuel exports, they skew the data for SSA as a region. In the long-term, however, African countries have a unique opportunity to leapfrog the fossil fuel-centred development model despite recent discoveries of oil and gas.
- **Small Island Developing States** (SIDS) will benefit most of all if they adopt renewable energy sources rather than fossil fuels. The import of fossil fuels now amounts to 8% of their GDP. Many SIDS are also extremely vulnerable to the effects of climate change. SIDS possess ample renewable energy sources and renewable technologies can meet most of their domestic energy needs. The shift would cut import bills, promote sustainable development, and increase their resilience. International cooperation to support SIDS' renewable energy ambitions is growing substantially, and 13 SIDS have established 60-100% renewable electricity targets.
- **South Asia** spends more than 3% of its GDP on imports of fossil fuels, and demand for fossil fuels is rising rapidly from a low base. These countries will benefit from the energy transformation primarily by reducing their fossil fuel import bills, which would otherwise grow dramatically and weigh on their economies.
- **Europe, China and Japan** are currently heavily reliant on fossil fuel imports but would increase their energy independence as renewable energy shares grow. Japan is the most dependent; its net fossil fuel imports amount to 5% of GDP.
- **North America and Latin America** are net neutral when combined. On a continental scale, in light of both their domestic resources and international trade in energy, their economies are largely energy independent.

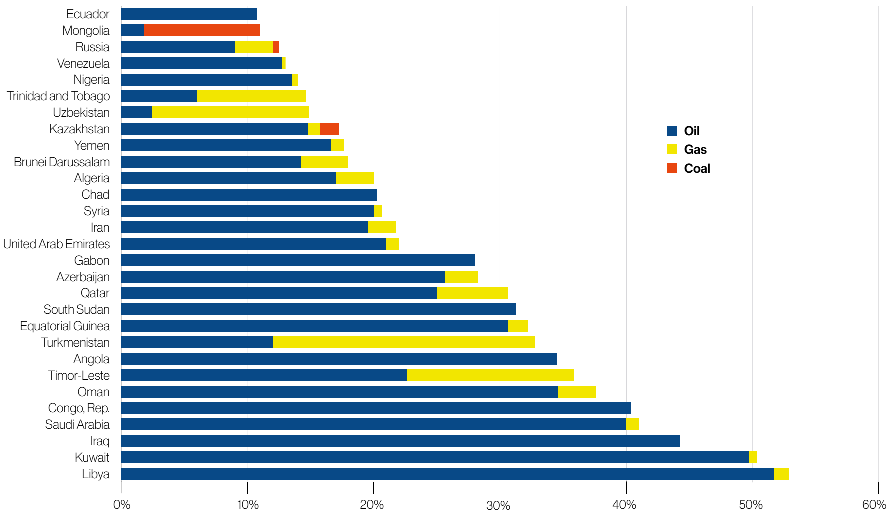
The vulnerability of fossil fuel exporters

Countries that have historically enjoyed geopolitical influence because they supply fossil fuels are likely to see a decline in their global reach and influence unless they can reinvent their economy for a new energy era.

Many fossil fuel-rich countries are able to project considerable international power. They can employ their fossil fuel rents (the difference between cost of production and market price of fossil fuels) to finance socio-economic development and economic diversification, significantly strengthen their military capabilities, or invest in foreign assets such as US securities.

The energy transformation is expected to put pressure on fossil fuel prices and related rents.[50] If fossil fuel revenues decline, these countries will need to rethink their national priorities and strategies. Figure 6 lists countries that derive much of their GDP from fossil fuel rents.

Figure 6. Fossil fuel rents as a percentage of GDP (average 2007-16)



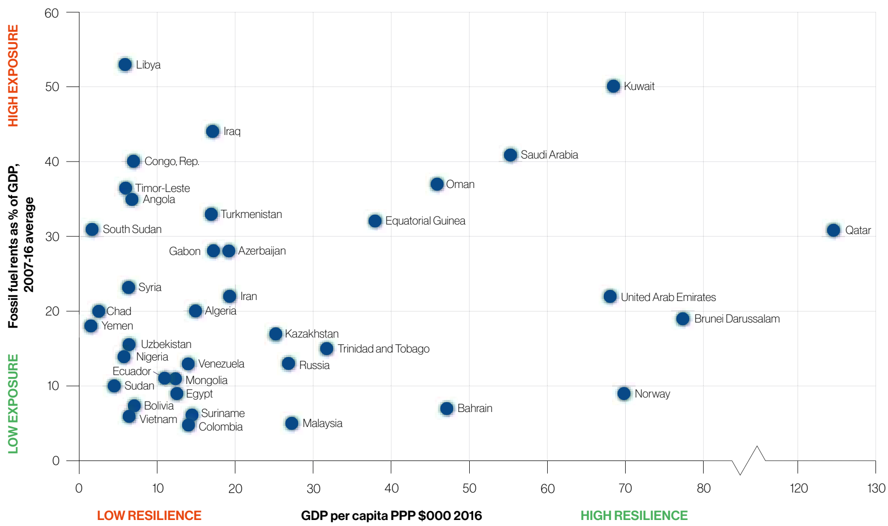
Source: World Bank.

Figure 6 shows clearly that oil rents have generally been much larger than natural gas rents and coal rents. Among the countries whose fossil fuel rents amount to over 10% of GDP, natural gas rents are higher than oil rents in only three: Turkmenistan, Uzbekistan, and Trinidad and Tobago. In just one country, Mongolia, coal rents are the highest fraction. In all other countries, including large gas exporters such as Russia, oil rents dominate.

A decline in fossil fuel rents has the potential to profoundly destabilize countries that have not prepared their economies sufficiently for the consequences. The loss of oil rents in countries with weak governance could lead to fractures in society and political instability. The drop in oil price in the 1980s was one of the factors that contributed to the decline and eventual fall of the Soviet Union, which in turn led to the end of the Cold War, arguably the biggest geopolitical shift since the end of the Second World War.

Figure 7 shows fossil fuel exporters' preparedness, based on exposure and resilience.[51] Exposure captures the degree to which countries rely on rents from fossil fuels.[52] Resilience measures income in relation to population in order to capture how robustly an economy can respond to the risks posed by the energy transition.[53]

Figure 7. The relative preparedness of fossil fuel producing countries for the energy transition



Note: The chart includes countries in which fossil fuel rents account for more than 5% of GDP. The GDP of Syria dates from 2010.

Source: IMF World economic outlook database April 2018, World Bank.

Four groups of countries can be distinguished:

- **Highly exposed, low resilience countries**
  These countries are highly dependent on fossil fuel rents, which typically account for more than 20% of their GDP. They also lack resilience because their per capita GDP is low and they have limited financial buffers. The countries in this group include Libya, Angola, Republic of Congo, Timor-Leste, and South Sudan.

- **Highly exposed, highly resilient countries**
  These countries are highly dependent on fossil fuel rents but have sufficient income and capacity to be able to reinvent themselves and adapt to the energy transition. They include Gulf states, such as Saudi Arabia, Qatar, Kuwait, and the United Arab Emirates (UAE), and Brunei Darussalam.

- **Moderately exposed, moderately resilient countries**
  These countries are quite exposed, but their economies are moderately resilient. As a result, they should be able to manage the transition, provided they implement effective policies to diversify their economies. This group includes Russia, Iran, Algeria and Azerbaijan.

- **Relatively low exposure countries**
  Fossil fuel rents in these countries are less than 10% of GDP so they should be less vulnerable to the energy transition. This group includes Malaysia, Bahrain, Colombia and Norway.

In many oil producing countries, there is an implicit social contract in which the authority of the state stems from providing generous subsidized services. If their oil income falls for a long period, these governments will struggle to provide the socio-economic programmes that citizens have come to expect. Austerity can potentially fracture the state's legitimacy, possibly leading to social unrest, political infighting and even violence. In such cases, domestic political turmoil could spill across national borders with consequences for neighbouring states. Indeed, the emergence of a power vacuum in petrostates is potentially the biggest geopolitical risk of the energy transition.[54]

Vulnerability is probably greatest in countries where the dependence on oil rents is highest and where there are high levels of youth unemployment. Recent upheavals in the Middle East indicate the formidable nature of the governance challenges in these states, which will become even more difficult to resolve as oil revenues decline. Nigeria is vulnerable in this regard as well. It has long struggled with poor governance and poverty, and now faces a youth bulge: the average age of the population is 18 years and the country is expected to overtake the United States to become the third-most populous country in the world by 2050.[55]

The loss of oil rents may cause painful adjustments in the short term. In the long run, however, fossil fuel-driven economies have the opportunity to reduce the risks posed by oil dependence, and create a more stable, equitable and productive economic future for their peoples. Studies show that large oil rents can undermine growth, distort the economy, capture democratic institutions, stimulate corruption, impede the development of domestic industry, and aggravate conflict.[56] While most of these adverse effects can be avoided through good governance, the rule of law and sound policies,[57] they nevertheless remain a significant risk for many oil-rich states.

Economic diversification to reduce dependence on oil rents has been a long-standing policy goal of many oil-exporting countries. The economic diversification and decarbonization strategy of the UAE, for example, shows how enlightened decision-making can reduce risks. The energy policy of the UAE foresees a 44% share of clean energy and 70% decarbonization of the economy by 2050. However, few countries have successfully invested their resource windfalls and constructed a strong and diversified economy. With the exception of Malaysia and the UAE, few oil exporters have followed Hartwick's rule which states that, to preserve long-term per capita consumption, subsoil assets (such as oil, gas and coal) should be transformed into reproducible surface assets (such as human or physical capital).[58]

In recent years, in recognition of the new reality, several oil exporting countries have developed plans to diversify their economies and increase their resilience (see Table 1).

Table 1. Diversification plans of the Gulf Cooperation Council (GCC) countries

Year	Country	Plan
1995	Oman	Oman 2020: Visions for Oman's Economy
2008	Bahrain	Economic Vision 2030
2008	Qatar	Qatar National Vision 2030
2009	Kuwait	State Vision Kuwait 2035
2010	UAE	Vision 2021
2016	Saudi Arabia	Saudi Vision 2030
2017	Kuwait	New Vision 2035

Oil- and gas-rich states will derive many benefits from diversifying their economies. They will strengthen their long-term growth prospects and shield their economies from the vagaries of international commodity prices, a key source of macroeconomic volatility.[59] An open economy and competitive private sector will generate more sustainable growth. They will also create more productive jobs, an important priority in countries where large numbers of young people are unemployed. Finally, diversification will help to prepare these countries for the looming peak in oil demand.

A tailored strategy is needed to create a secure path to economic transformation and diversification, particularly as each country has unique characteristics and faces particular challenges which require specific solutions to resolve them. Policy interventions that encourage diversification include fiscal and monetary discipline, investment in human capital and infrastructure, and support for the private sector.[60]

Energy security for fossil fuel importers

On the eve of World War I, Winston Churchill made a daring choice: he converted the fuel used by the British fleet from domestic coal to imported oil. Ever since, energy security—the uninterrupted supply of energy at affordable prices—has been a critical strategic issue for all energy-importing states. No less than 80% of the world's people live in countries that are net importers of fossil fuels.[61]

Concerns over energy security have marked the conduct of international relations, the formation of alliances, the protection of national interests, and defence planning. Oil interests have shaped the relations between the United States and the Middle East for decades.[62] Similarly, China's need to secure oil supplies and other natural resources to sustain its growth has led it to foster new and deeper ties with countries in Asia, Africa and Latin America, as well as diversify its domestic energy supply with renewables.

In a renewable energy economy, most countries will be able to achieve energy independence: they will have greater energy security and more freedom to take the energy decisions that suit them. Since some form of economically viable renewable energy potential is available in most places, countries that currently depend heavily on fossil fuel imports will be able to use renewables to reap strategic and economic benefits.

In strategic terms, fossil fuel importing countries are vulnerable to risks of supply disruption and price volatility caused by political instability, terrorist attacks, or armed conflicts that may occur in oil- and gas-exporting nations. Smaller energy-importing countries may also be subject to pressure or coercion with regard to their energy supply and therefore have less freedom to determine their own strategic priorities and goals.

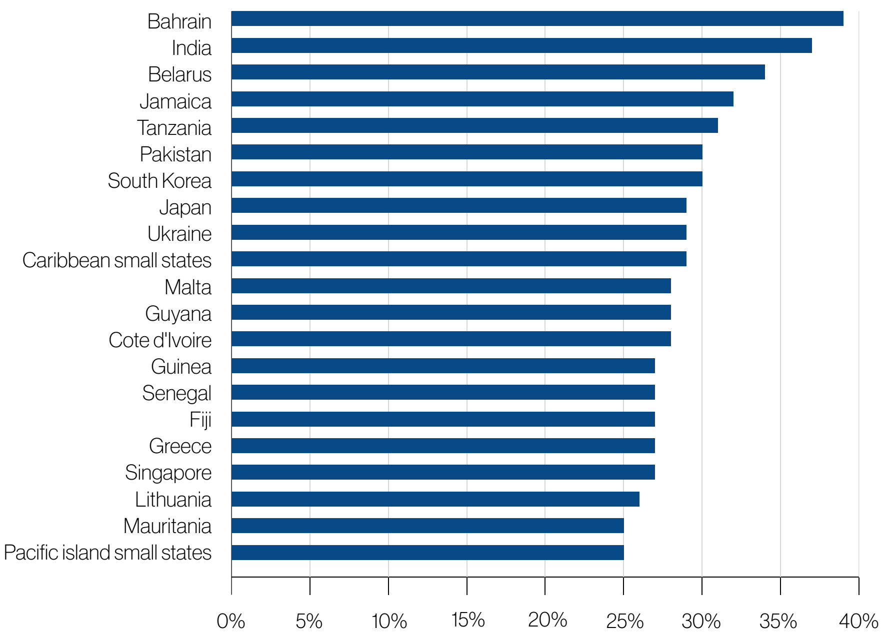
By contrast, countries that are able to develop their own renewable sources of energy are better placed to achieve energy security. An example is the Brazilian ethanol programme which was put in place after the oil shock of 1973 to reduce the country's oil imports and shield the economy from volatile prices and supply disruptions. This programme has played a vital role in Brazil's efforts to achieve energy self-sufficiency and has helped transform it into the world's second largest producer and largest exporter of ethanol.

In economic terms, a high degree of import dependence also generates costs and risks. Countries that import most of their energy are exposed to currency fluctuations and volatile fuel prices that can result in balance-of-payment problems. The oil price shocks in the 1970s, for example, squeezed many industrial economies and sowed the seeds of a debt crisis that many developing countries suffered in the decade that followed, with serious social and economic consequences. Increasing the share of renewables in the energy mix can mitigate such risks and provide new pulses of economic growth.

Iceland is a good example of the benefits that can accrue from an economic transformation based on renewables. During the 20th century, it evolved from being one of Europe's poorest countries, highly dependent on imported coal and oil, to a country with a high standard of living, which derives 100% of its electricity from hydro and geothermal energy.[63] The effective development of its renewables has enabled Iceland to bolster its energy security, widen its economic base, and attract new industries to the country, including aluminium smelting, data storage and greenhouse agriculture.[64]

Fossil fuel imports can also impose a huge burden on the trade balance of some importing countries. Data from the World Trade Organization (WTO) indicate that in 2015, despite a significant drop in oil prices, the global cost of gross fossil fuel imports was 1.9 trillion US dollars.[65] Figure 8 shows that Bahrain, India, Belarus, Jamaica, Tanzania, Pakistan, and South Korea were among the countries most dependent on fossil fuel imports.

Figure 8. Share of fossil fuel imports in all merchandise imports (average 2007-16)



Source: World Bank.

Countries that switch from imported fossil fuels to domestically generated renewable energy will significantly improve their trade balance. India, for instance, is expected to overtake China as the largest growth market for energy in the 2020s. Its fossil fuel import bill (calculated as a proportion of total export earnings) grew from 35% in 2000-01 to 60% in 2012-13. Fossil fuel imports contributed to a trade deficit of 190 billion US dollars over the same period.[66]

From the perspective of consumers, high energy import bills transfer large amounts of wealth abroad.[67] Energy importers are vulnerable to price swings, often as a result of remote geopolitical events. High oil prices can also stifle economic growth by importing inflation, curbing consumer spending, and raising the cost of doing business. Lower oil prices, conversely, can help to stimulate an importer's economy.[68]

Developing countries that lack domestic fuel reserves stand to benefit the most from exploiting their renewable energy resources. Small island developing states (SIDS), for example, rely heavily on imported fuels for their electricity needs.[69] SIDS also sit on the frontline of climate change despite having done the least to cause it. To increase their resilience in the face of extreme weather events, as well as bolster their energy security and reduce prohibitive import bills, 13 SIDS including Cabo Verde, the Cook Islands, Fiji, Saint Vincent and the Grenadines, Samoa, and Vanuatu, have announced plans to increase the contribution of renewable energy to between 60% and 100% of the power they consume.[70]

Achieving an electricity supply that is 100% renewable is technically feasible in places where diverse sources of renewables are available, and the variability of renewable electricity generation can be managed on the grid. Some countries, such as Albania, Ethiopia, Lesotho, Norway, Paraguay and Tajikistan, already obtain all or almost all of their electricity from hydropower, which is an established technology that provides stability in the transmission system. Others have achieved similar results using a mix of renewables. Brazil, Costa Rica, New Zealand and Kenya, for example, generate more than 80% of their electricity from a combination of hydro, geothermal, wind, biomass and solar power.[71]

Countries such as Chile, Jordan and Morocco are also reducing their dependence on energy from abroad, in order to enhance their energy security and correct the structural trade imbalances that energy imports exacerbate. Morocco currently imports over 90% of the energy it consumes.[72] It plans, however, to exploit its consistent sun and strong winds to reduce these imports and eventually become a net exporter of electricity to European and African markets. It has set a target of 52% renewables in its electricity mix by 2030.

Energy independence does not imply complete self-sufficiency or autarchy.[73] Even if a country is able to generate renewable energy, it will not necessarily choose to do so because it will focus on its comparative advantages. Even when a country's energy needs are supplied entirely from home-grown sources, it will still benefit from international value chains and trade in technologies, goods and services.

Increasing energy security through renewable energy deployment may change the dynamics between energy exporters and importers. It will also diminish the role of oil and gas in international politics. Ensuring the security of energy supply becomes more a matter of domestic governance, rather than an international security priority. Countries that achieve energy independence will also be less vulnerable or beholden to their suppliers and will therefore be able to pursue their strategic and foreign policy goals more independently.

The rise of renewable energy leaders

Countries that are able to take advantage of new renewable energy technologies can expect to enhance their global influence and reach. Three types of countries have the potential to emerge as new renewable energy leaders.

First, countries with high technical potential for renewable energy generation stand to gain if they are able to become significant exporters of renewable electricity or fuels. Australia's economically demonstrated solar and wind energy resources are estimated to be 75% greater than its combined coal, gas, oil and uranium resources.[74] In the Atacama Desert, Chile has among the world's best solar resources, as well as high potential for wind, hydropower, geothermal and ocean energy. In both cases, however, the remoteness of these locations will probably constrain electricity exports.

Some countries are already net exporters of electricity generated by renewables. Brazil is already a major exporter of renewable electricity from hydro. Norway exports electricity to its neighbours and the Netherlands, and is building new transmission cables to Germany and the United Kingdom. Laos and Bhutan also export electricity generated from hydropower to neighbouring countries. Bhutan's power exports to India raised more than 27% of government revenue and 14% of Bhutan's GDP.[75]

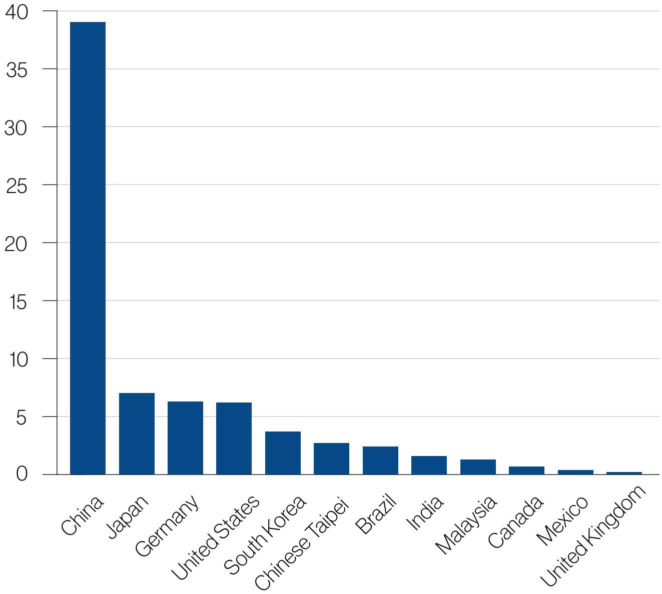
Second, mineral-rich countries such as Bolivia, Mongolia, and the Democratic Republic of Congo (DRC) have an opportunity to become part of the global production and value chains necessary for renewable technologies. Doing so will boost their economic development, provided they put the right policies and governance frameworks in place.

Third, leaders in technological innovation are positioned to gain the most from the global energy transformation. No country has put itself in a better position to become the world's renewable energy superpower than China. In aggregate, it is now the world's largest producer, exporter and installer of solar panels, wind turbines, batteries and electric vehicles, placing it at the forefront of the global energy transition.

Figure 9 shows the total clean energy manufacturing value added by four technologies: wind turbine components, crystalline silicon PV modules, LED packages, and lithium-ion battery cells. It confirms that China is by far the largest global manufacturer of these clean energy technologies. In addition, it leads the world in renewable energy patents (see Figure 10).

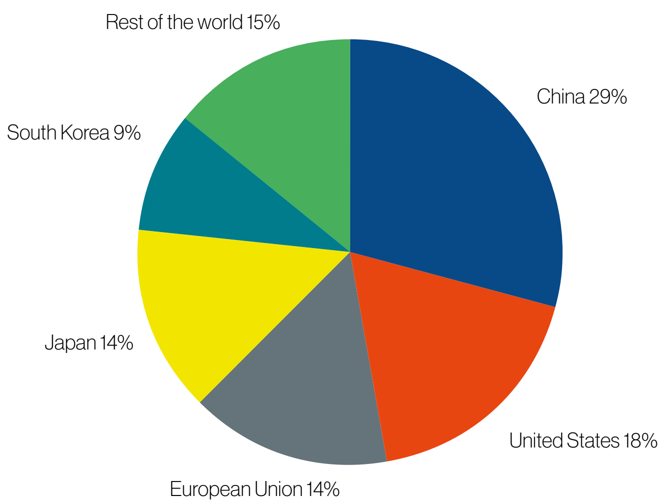
China's concerted efforts to research, develop and invest in renewable energy and clean transport offer its industry the opportunity to overtake US and European companies, which have been dominant in sectors such as cars and energy machinery. This will give China a comparative advantage in trade and lend impetus to the country's economic growth.

Figure 9. Clean energy manufacturing value added (2014, US$ billion)



Source: Clean energy manufacturing analysis center.[76]

Figure 10. Cumulative share of renewable energy patents end 2016



Source: IRENA.

By taking the lead on renewables, China has improved its geopolitical standing in several respects. By producing more of its own energy, China is reducing its reliance on fuel imports and the risks of energy disruption which could put a brake on its economic ambitions. Its technological expertise in renewables has established it as a leading exporter of clean energy technology, creating a balance of trade advantage.

The clean energy technology race could result in a situation of technology dominance. In some respects, that outcome can already be seen in mobile technology where a few companies (Huawei, Samsung, Apple) compete for global leadership. If a small number of players were to dominate clean energy technology in a similar way, it would raise concerns that concentration could stifle competition, suppress innovation, and distort markets. Countries that do not control key energy technologies may become heavily dependent on the few countries and companies that do. In this context, industrial policy becomes increasingly important; countries will need to create a competitive manufacturing value chain around certain technologies within a fair and rules-based trading system.

Apart from the risk of technology dominance in specific areas, renewable energy leaders are unlikely to gain the degree of market dominance that fossil fuel leaders have enjoyed, due to the ubiquitous nature of renewable energy sources.

New actors: citizens, cities and corporations

The shift to renewable energy may reshuffle political and economic power, because renewables tend to decentralize and democratize energy systems. Due to the falling cost of solar PV and wind power, as well as smart distribution systems, almost anyone with a rooftop or some land can produce electricity, either for self-consumption or for the grid. These developments will generate a more diverse energy ecosystem. The role of the centralized state in the energy system may change, while many new actors and new business models are likely to emerge and flourish. Local and distributed forms of energy generation give households and communities more autonomy than centralized grid systems.

As more people install solar panels, batteries and smart software, formerly passive consumers of electricity may become consumers and producers of electricity in an interconnected grid. Innovation in market design and smart grid technologies, including storage, permit stable management of variable renewable electricity on the grid. Advances in communication technology may lead to the emergence of an 'energy internet', allowing hundreds of millions of people to produce electricity in their homes, offices and factories and share it peer-to-peer.[77] The number of grid-connected smart devices is projected to rise from 26 billion in 2017 to over 75 billion by 2025, enabling intelligent demand side management.[78] In this new world of 'prosumers', energy assets will no longer be owned exclusively by centralized utilities or the state.

In a centralized energy system, the financial benefits of energy also tend to be centralized and concentrated in the hands of corporations and governments. A decentralized, renewable electricity system, by contrast, gives consumers a true choice of energy sources and a share in its economic benefits, while enhancing social acceptance of renewables investments. Germany provides a case in point. In 2016 private citizens owned 31.5% of installed renewable power capacity, making them the largest 'bloc' of investors in the sector.[79]

Decentralized renewables can also help to increase the resilience of local communities against environmental disasters. Higashi-Matsushima, a Japanese city affected by the earthquake and tsunami in 2011, chose to rebuild its energy infrastructure around microgrids and decentralized renewable energy. In the United States, microgrids became popular after Hurricane Sandy knocked out power for 8.5 million people in 21 states.[80]

Cities occupy a central role in the energy transformation. By the middle of this century, 70% of the world's population is expected to live in cities.[81] Cities consume around two-thirds of generated energy and produce 70% of the world's carbon emissions. They are also especially vulnerable to the effects of climate change, including coastal flooding and urban heat island effects.[82] At the same time, they have the means to shape the new energy landscape. By 2030, the fifty largest cities will have a bigger economic footprint than many small- and medium-income countries, making them major economic and political players on the international stage in their own right.

Cities are already taking decisive action. In 2017, more than one hundred towns and cities were sourcing up to 70% of their electricity from renewables, compared to 42 in 2015.[83] Several capital cities are among them, including Oslo (Norway), Dar es Salaam (Tanzania), Quito (Ecuador) and Wellington (New Zealand). Yokohama, Japan's second largest city, is deploying a smart city project that has led to a roll out of smart grids, solar PV panels and electric vehicles.[84] New megacities are being announced and built to run entirely on renewable electricity, such as Neom, which will be constructed near the Red Sea and Aqaba Gulf.[85]

Cities and local municipalities are also forming global alliances and networks, including C40, ICLEI and the global covenant of mayors.[86] Together with the actions of other non-state actors, such as California's Global Climate Action Summit of September 2018, they are adding a new layer of global governance that is driving action to achieve decarbonization, sustainability, and greater resilience through renewables.

There is ample evidence that private corporations are responding to the realities of the energy transformation by restructuring and adjusting, and increasing renewables generation. Following dramatic declines in market capitalization, Germany's largest utility companies, RWE and E.ON, both split their businesses into two parts, one focused on renewables and the other on thermal generation. Danish Oil and Natural Gas (DONG) changed its name to Ørsted after selling off its oil and gas business. Total is diversifying into solar and battery technology. Shell is growing its natural gas portfolio relative to oil. BP and other oil companies are buying into electric vehicle charging infrastructure. In 2017, barely seven years after its initial public offering, Tesla became the most valuable US car maker, overtaking General Motors, a company over one hundred years old. Some global technology companies already source 100% of their electricity from renewable energy.[87] These trends indicate that global technology companies are becoming important players in the new energy landscape.

In short, the renewable energy transformation goes hand in hand with a dispersion of power. The modern nation state and the fossil fuel economy have evolved alongside one another. The decline of the fossil fuel era and the advent of decentralized power generation in an increasingly electrified world may have profound implications for the role of the nation state.

New relations between states

Renewable energy will not merely influence the balance of power between countries. It will also reconfigure alliances and trade flows, and create new interdependencies around electric grids and new commodities.

Shifting alliances

If global demand for fossil fuels declines, alliances built on fossil fuels are likely to weaken. Alliances may be maintained for various other reasons, but the energy pillar will become relatively less important.

The Organization of the Petroleum Exporting Countries (OPEC) is a prime example of a fossil fuel-based grouping. It was created in 1960 as a forum for oil-exporting countries to exchange information and coordinate their interactions with the international oil companies that dominated international oil trading at the time. OPEC countries started to coordinate their oil production policies from the early 1980s.

OPEC has displayed enormous resilience to shocks, including a range of price crises and conflicts between and within member countries. The current cooperation between OPEC and non-OPEC countries, underpinned by the rapprochement between Saudi Arabia and Russia despite their differing geopolitical priorities, can be understood as an attempt to sustain the organization in the face of rising US shale production. OPEC might reinvent itself in some guise; nevertheless, in a world that has a growing range of energy alternatives, it is likely to decline in importance.[88] Qatar's recent decision to leave, to focus more on export of natural gas, illustrates the challenge that OPEC faces amid rapid and structural changes in the market.

Bilateral relations between states will also undergo change. The alliance between the United States and Saudi Arabia is a prime example of a strategic relationship in which oil plays a key role. This alliance dates back to 1945, when King Abdul Aziz ibn Saud and US President Franklin D. Roosevelt came to an understanding that the US would provide military assistance in exchange for access to Saudi oil. Relations between the two states may evolve significantly as economies across the globe become less dependent on oil.

Countries are also beginning to rethink their energy diplomacy. The foreign energy strategy of Japan no longer concentrates exclusively on securing fossil fuel imports but also includes renewables,[89] hydrogen in particular.[90] Germany spearheaded the creation of IRENA in 2009 and has developed bilateral energy partnerships with a number of countries in which renewable energy features prominently.[91] The United Arab Emirates (UAE), a major oil-exporting country, has also assumed a leadership position on renewable energy by hosting IRENA, funding renewable energy projects in developing countries via the Abu Dhabi Fund for Development,[92] and investing in renewable energy projects in developed countries.

Several new alliances and initiatives are emerging to promote multilateral cooperation and boost specific renewable technologies. The Paris 2015 climate conference alone gave birth to the International Solar Alliance,[93] the Global Geothermal Alliance,[94] and Mission Innovation.[95] Initiated by governments or intergovernmental entities, these bodies bring together countries, private sector actors and non-governmental organizations to accelerate the adoption of renewables.

While many of these alliances are at an early stage of development and focus on technological cooperation, they are likely to gain in geopolitical impact. At the launch of the first Assembly of the International Solar Alliance (ISA), India's Prime Minister, Narendra Modi, said that the "ISA will play the role of OPEC in the future".[96] While the ISA is still in its formative stage, India hopes to forge deeper trade and political ties with the developing world through solar diplomacy.[97]

New geographies of trade

Renewables will configure new geographies of connections and dependencies between countries and regions. In broad terms, the weight of energy dependence will shift from global markets to regional grids. Countries that today import oil from the other side of the world will seek to develop renewables at home and to integrate their grids with those of neighbouring countries.

The transition to renewable energy will put electricity centre stage. Unlike oil and liquefied natural gas (LNG), which are traded globally, electricity is currently a regionally traded commodity. With current technology, much electricity is lost when it is transported over long distances. Global energy markets are therefore likely to become more regional. Innovations in ultra-high-voltage transmission that minimize losses could nevertheless help to enhance trade in electricity over longer distances.

Trade in fossil fuels currently accounts for almost 15% of all merchandise trade.[98] If less fossil fuel is traded, more of the energy-related trade that persists will be in renewable energy technologies and electricity rather than fuels. Exceptions to this may include fuels such as hydrogen (generated both by renewables and conventional energy), synthetic fuels, and biomass (see Box 1).

Unlike trade in fossil fuels, trade in renewable energy technologies would be shaped by 'normal' rather than 'natural' comparative advantages. A country has a natural comparative advantage when it has natural resources (such as oil fields) that are required to extract or produce a product. Since renewables are much less geographically concentrated, a country will specialize in those aspects of renewable energy trade in which it has a comparative advantage based on factors such as technology, relative price, and cost of transport.

As energy trade routes redraw themselves, the geopolitical map will take new forms. In a world in which energy can be produced at most locations, a single hegemon will be less able to exert influence by controlling the high seas or strategic chokepoints such as the Straits of Hormuz or Malacca. Some maritime trade routes will therefore become relatively less important.

Control over grid infrastructure will become vital for national security and for projecting global influence and power. Grid infrastructure includes physical assets such as power lines and storage facilities, and virtual interconnections that will multiply as the sector digitalizes. A country's connectivity and networks may complement its land, sea and air power.[99]

BOX 1. HOW RENEWABLES CREATE NEW TRADE PATTERNS

The transition to renewable energy will create new trade patterns. While trade in fossil fuels will decline, trade in at least three other areas will grow:

1. **Trade in renewable energy-related goods and technologies.** These include a wide range of goods and technologies, from solar PV panels to smart meters and batteries, as well as their components and parts (for example, blades for wind turbines or water wheels for hydropower) and related services (for example, engineering and installation services).
2. **Electricity trade** will increase because additional interconnections make grids more stable and resilient. Variable renewables, such as solar and wind power, require flexible and interrelated power systems that can balance supply and demand in real time. Electricity interconnections can be made between neighbouring countries, at a regional scale and possibly even inter-continentally.
3. **Trade in renewable energy fuels** may also grow significantly.[100] An example is hydrogen formed by electrolysis in regions that possess an abundant supply of renewable energy, such as Patagonia or the Australian desert. Besides hydrogen, a host of synthetic fuels may also be generated from renewable electricity, including ammonia, methane and methanol. Such fuels permit seasonal storage of renewable electricity (which only pumped hydro has been able to do to date), and use existing infrastructure (such as natural gas pipelines). They also have the potential to reduce emissions in hard-to-electrify sectors such as aviation and some industrial processes.[101]

While the potential to increase trade exists, the number of trade disputes related to renewable technologies has grown in recent years. Trade in renewable energy goods may be hampered by tariffs, discriminatory subsidies, and conflicting technical standards. Members of the WTO have started negotiations to open trade in environmental goods and services further. In the future, consideration will need to be given to governance issues, particularly standards and rules, to ensure a level-playing field in renewable energy trade.

With projects in nearly 80 countries, China's 'Belt and Road Initiative' (BRI) is a strategic global plan. Supported by over a trillion US dollars of dedicated financing over its lifetime, it is one of the world's most ambitious infrastructure development programmes. The BRI aims to create a network of ports, railways, roads, pipelines and industrial parks that will link China to cities as far away as Bangkok and Rotterdam. No less bold is the ambition of State Grid, China's largest state-owned company, to create a global supergrid called the 'Global Energy Interconnection' (GEI) that will link every continent with undersea transmission cables to power the world with green electricity.[102]

The BRI and the GEI have strategic objectives. China hopes to reduce its dependence on energy and commodity imports that pass through chokepoints such as the Straits of Malacca and the South China Sea. China's infrastructure diplomacy could be as important to 21st century geopolitics as the protection of sea lanes was to the hegemony of the United States in the 20th century. While the BRI has been embraced by many countries, it has also caused disquiet in some countries about China's growing influence.[103] Other concerns that have been expressed relate to indebtedness, transparency, the prominent role of Chinese contractors and the environmental sustainability of these projects.[104]

In recent years, other major countries have promoted their own infrastructure plans. Japan, the United States and India have advanced their 'Free and Open Indo-Pacific' strategies,[105] under which the US will invest 113.5 million US dollars in infrastructure and connectivity projects. The countries of the Association of Southeast Asian Nations (ASEAN) have developed a strategy called 'Connectivity 2025',[106] while the EU recently unveiled a 'Strategy on Connecting Europe and Asia'.[107]

Given the range and ambition of these developments, infrastructure links and the internet may become new battlegrounds for influence and control between competing powers. They may also serve as a geopolitical glue, bringing nations and their citizens closer together in new interdependencies. To emerge and endure, a networked community needs a high degree of confidence and trust; but, once established, physical and human interconnections can become conduits for cooperation and coexistence, as well as stability and prosperity.

Rethinking energy statecraft

States have long used energy resources as instruments of foreign policy, a practice known as energy statecraft. In a world powered mostly by renewables, energy resources will lose much of their currency as geopolitical instruments. In the words of former US President Jimmy Carter: "No one can ever embargo the sun or interrupt its delivery to us". At the same time, a reliance on other commodities, such as electricity, biofuels, emerging fuels like hydrogen, or critical materials, could create new forms of dependence and vulnerability.

Oil and gas as foreign policy instruments

One possible consequence of the energy transformation will be to reduce the geostrategic importance of oil and gas as tools of foreign policy. On occasion, countries have intervened in oil and gas markets to further their foreign policy goals.[108] One way in which they have done this is through supply embargoes. In October 1973, for example, member countries of the Organization of the Arab Petroleum Exporting Countries (OAPEC) declared an oil embargo against some Western states in the wake of the Arab-Israeli conflict. Another example is the oil embargo against apartheid-era South Africa.

Some countries have also put embargoes in place to leverage pressure on oil exporters. The US government's re-imposition of oil sanctions against Iran, after President Trump's decision to withdraw from the 2015 Iran nuclear deal, is a recent example. Some sanctions do not curtail a country's current exports, because doing so would raise global prices and inflict equal pain on consuming countries. Instead, sanctions are targeted to hinder development of future production capacity. This approach underpinned the oil sanctions that Western states and Japan imposed on Russia in 2014.

Countries have sometimes tried to exert geopolitical influence, not by withholding supplies of oil and gas or by raising their price unilaterally, but by doing exactly the opposite. After oil prices fell dramatically in 2014, for instance, OPEC did not move to cut production because it preferred to maintain its market share in the face of growing US shale production.

Oil and gas have not only been used as 'sticks' to hurt or deter foes, but also as 'carrots' to reward allies and ensure their allegiance. Venezuela's Petrocaribe scheme, for example, granted large discounts on crude and oil product deliveries to small Caribbean states in an effort to counter US influence in the region.

It is not just the energy resources themselves which have been the object of geopolitical competition, but also their transit routes. In the 1990s, for instance, the US promoted the Baku-Tbilisi-Ceyhan (BTC) pipeline to bolster its strategic influence in the region at the expense of Russia and Iran. For more than a decade, the EU has supported the construction of a Southern Gas Corridor to reduce its reliance on Russian gas, while both Russia and some European countries have promoted alternative gas corridors, such as Nord Stream, to circumvent existing transit routes.

Electricity cut-offs as a geopolitical weapon

The spread of renewable energy will increase electrification and stimulate cross-border trading in electricity. Variable renewable sources of electricity, including wind and solar, require flexible power systems that are able to cope with fluctuations of demand and supply in real time. Innovations in market design, smart grids, and storage technology, together with high-voltage direct current electricity interconnections between countries, can effectively meet this need for flexibility.

Some argue that countries that dominate electricity grids may exercise undue control over their neighbours, and that inter-state electricity cut-offs will become an important foreign policy tool, applied strategically in the same way as oil and gas sanctions.[109]

Notably, however, electricity trading tends to be more reciprocal than trade in oil and gas. Whereas oil and gas flow in one direction, from an exporter to an importer, the trade in electricity between countries flows both ways. A country that generates solar power may import energy from a neighbouring country when it rains, but export energy to that neighbour when the sun shines.

Unlike trade in natural gas, which requires a fixed transportation infrastructure such as pipelines or LNG terminals, the relationship between sellers and buyers of electricity is less exclusive. When Russia cut off gas supplies to

Ukraine in 2009, hitting consumers downstream in Europe, European states had limited access to substitutes for Russian gas. In the future, however, as more countries produce clean electricity and build interconnections, they are unlikely to be caught out by a boycott because they will be able to produce more electricity locally or to import it from a variety of alternative sources.

Even if an exporter of renewable electricity acquires a dominant position with respect to an importing country, that asymmetry cannot easily be used as an instrument of geopolitical pressure. This is because countries will have alternative options at their disposal: they can either produce the electricity themselves, for instance by deploying renewable energy at home, or import electricity from neighbouring countries.[110] As a result, renewable energy exporters will always be part of a complex web of interdependencies between importers and exporters that would tend to curtail the potential to use renewable electricity as a geopolitical weapon.

An alternative view is that cross-border electricity trading will create opportunities for regional cooperation, and the creation of 'grid communities'. Illustrations of these include the Scandinavian countries, which have traded electricity between themselves for decades. Regional electricity pools are also being developed in Asia (the ASEAN power grid), Africa (five subregional power pools), Central America (SIEPAC[111]), and the Middle East (the Gulf Cooperation Council power grid). In recent years, several renewable energy supergrids have been proposed, including the Asia Super Grid, the Desertec project and the North Sea Offshore Grid.[112]

Lack of trust is a major impediment to creating cooperative grid connections between states. In order to build confidence during the Oslo peace process, a proposal to construct grid connections between Israel and its Arab neighbours was put forward. These plans did not materialize because there was insufficient trust between the parties.[113] Israel remains an 'electricity island' as a result. In another example, the Baltic states want to synchronize their grids with those of continental Europe in order to decouple their electricity systems from Russia, a move that has geopolitical motives.[114]

To govern cross-border grids, governments will need to develop appropriate arrangements to enable electricity to flow freely in well-regulated and transparent markets.[115] Examples already exist. In Europe, the EU Agency for the Cooperation of Energy Regulators (ACER) helps to ensure that the single

European market in electricity functions properly. IRENA's Clean Energy Corridors (CEC) initiative, which is incorporated in NEPAD's Programme for Infrastructure Development in Africa, promotes cross-border trade in electricity across energy markets.[116] The Continental Free Trade Area which is being developed in Africa also provides new opportunities for regional and sub-regional integration and interconnections.

Biofuel trade risks

Biofuels have become important commodities in world markets, particularly since 2006, and are part of the energy transition strategy of some countries. Ethanol has been traded globally in significant volumes for decades. Biodiesel trade is less established and continues to consist primarily of trade in feed-stocks (such as soya beans and vegetable oil) rather than fuel.[117] Some concerns have been raised about the environmental impact of biofuels and the potential conflict between biofuels and food, but many countries are taking steps to address this, including through the development of next-generation biofuels based on crop residues or algae.

Despite these concerns, the characteristics of this market make it unlikely that trade in biofuels will be used as a geopolitical weapon:

- Some feedstocks (such as sugar cane) are non-tradable or perishable.
- Only a small proportion of biofuels is traded internationally.
- The biggest producers of biofuels are also the biggest consumers.
- Tariff and non-tariff barriers continue to hamper market access in a number of countries.
- Sudden changes in crop yields or regulation can alter the direction and volume of trade flows.[118]

Bottlenecks in critical materials

Renewable technologies and batteries require certain minerals for their production, such as cobalt, lithium, and rare earth elements.[119] Some fear that countries which have rich endowments in these critical minerals may use them to exert pressure on countries that lack them.

This view was given credence in 2008 when China restricted the supply of rare earths to foreign buyers. Markets panicked and international prices soared, because China controlled a substantial part of the global supply of rare earth minerals.

In fact, most of the 17 rare earth minerals are not geologically rare. They are abundant and widely distributed, though they are expensive and polluting to mine and produce. This is partly why the US has refrained from contesting Chinese predominance over rare earth production since the 1990s.

Rare earths were perceived to be scarce partly because, like all commodity markets, rare earth markets are cyclical. When demand rises, supply takes time to respond because new mining projects have long lead times; the time lag causes prices to spike; high prices can lead companies to overinvest, so a boom is followed by a price collapse and a new cycle starts. This is exactly what happened in the wake of China's export restriction: as prices rose, investment flowed into mining projects, leading prices to collapse in 2012.[120]

Furthermore, there are alternatives to the use of rare earths and other critical metals in renewable technologies. Efforts are being made to create cobalt-free batteries, and only a small minority of wind turbines (less than 2% in the US) are built with rare earth elements. Some minerals can also be recycled, re-used and stockpiled, thereby further reducing their perceived scarcity.[121]

These factors combine to make it unlikely that cartels will emerge to control these critical materials. Cartels are hard to form and sustain. In the 20th century, oil was the only major commodity whose price did not fall in real terms, even though cartels were active in tin, coffee, sugar, and rubber. International trade rules also impede cartelization. In 2014, the US, Japan and the European Union appealed to the WTO and successfully challenged China's decision to restrict the export of rare earths.

In sum, the energy transformation driven by renewables will provide fewer instances of 'energy statecraft', the use of energy resources as an instrument of foreign policy. Electricity, biofuels and other materials critical to the new energy system are unlikely to acquire the geopolitical role and weight of oil and gas.

Energy and conflict

The pivot to renewables could reduce the incidence of certain kinds of conflict, and alleviate competition for important natural resources, notably oil, gas, water, and food. On the other hand, cybersecurity and access to important minerals may generate increased concern and tension.

Reduction in oil- and gas-related conflict

Fossil fuels, especially oil, have made a considerable imprint on patterns of conflict over the last hundred years. As the world shifts to renewables, and the relative importance of fossil fuels declines, a geopolitical shift in the incidence and geographic location of conflict may occur. Global and local confrontations over contested hydrocarbon reserves, for example in the South China Sea or the Eastern Mediterranean, may diminish or result in fewer conflicts. To this extent, the global energy transformation may generate a peace dividend.[122]

Fossil fuels are rarely a direct cause of conflict between states, but they are often an aggravating factor in armed conflicts within states. Some African countries that produce oil have experienced serious internal turmoil and conflict in recent decades. Oil can reinforce existing inequalities and create opportunities for external actors to further exacerbate grievances in oil-producing regions, particularly when central governments redistribute wealth away from them. Armed groups can also capture natural resources and related supply chains to finance their activities. Other natural resources (diamonds and tropical timber, for example) may also drive local conflict; however, the evidence links conflicts to oil more robustly than to any other natural resource.[123]

If oil and LNG become less strategic for security, maritime chokepoints—narrow shipping lanes such as the straits of Hormuz or Malacca—may become less critical as a consequence (see Figure 11). The Strait of Hormuz is the world's most important oil artery, which links Middle East crude producers to key global markets. At its narrowest point, it is only 21 miles wide and the shipping lane is only 2 miles wide in either direction. Each day, around 30% of all seaborne traded crude oil passes through it, as well as a significant volume of LNG. There have been several military incidents in the Strait. In 2018, Iran hinted it could disrupt oil flows through the Strait in response to the oil sanctions announced by the US.[124]

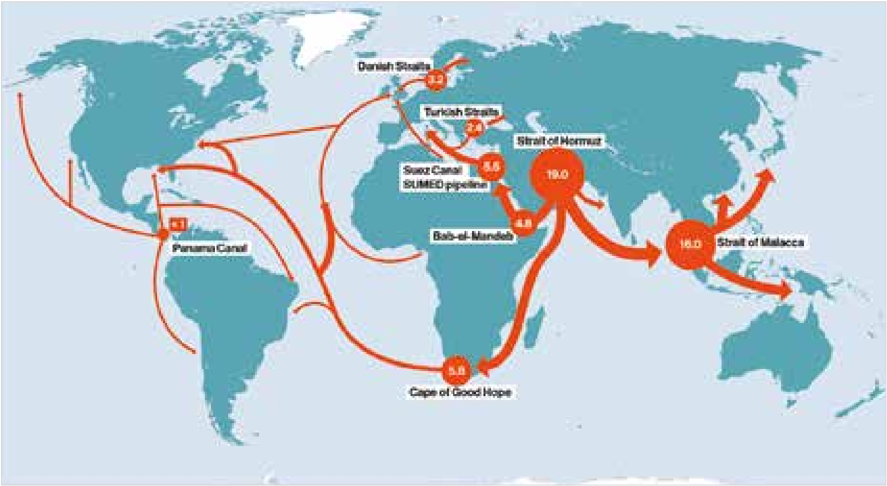
BOX 2. RENEWABLE ENERGY AND THE MILITARY

The global energy transformation could affect the way in which military operations and bases are run. In some countries, the military has blocked the deployment of wind turbines because they are alleged to interfere with radar surveillance. Yet militaries increasingly perceive renewables to be an opportunity. The US Department of Defense (DoD) is promoting energy resilience through energy efficiency, use of renewables, battery-storage, mini-grids and alternative fuels. The DoD has set a goal to produce or procure 25% of its total facility energy use from renewable sources by 2025.[125]

The push into renewables is driven by defence and military requirements. The US military is one of the world's largest consumers of oil. In 2017, it used over 85 million barrels of fuel to power ships, aircraft, aircraft carriers, combat vehicles, and contingency bases.[126] This level of consumption is costly and dangerous because fuel supply lines can be vulnerable to attack, especially in forward operations in combat zones. Even at home, US military bases are increasingly exposed to the threat of cyber attacks, as well as more frequent and extreme weather events due to climate change. In October 2018, Hurricane Michael devastated the Tyndall Air Force Base in Florida.

The US DoD is not the only defence organization to explore the potential of renewables. The North Atlantic Treaty Organization (NATO) adopted its 'Green Defence' framework in February 2014. The militaries in countries including the United Kingdom and South Korea also plan to expand their use of renewable energy.

Figure 11. Daily transit volumes through world maritime oil chokepoints



Note: All estimates in million barrels per day. Includes crude oil and petroleum liquids. Based on 2016 data.

Source: U.S. Energy Information Administration.

Cybersecurity

The energy transition is occurring alongside another revolutionary trend: digitalization. New digital technologies are transforming the energy sector by making it more connected, intelligent, efficient, reliable and sustainable. The electricity sector is at the heart of this process. As the contribution of variable and distributed energy sources grows, digitalization plays a key role in keeping grids balanced. It enables smart responses to electricity demand and blurs the distinction between generation and consumption.

However, the growth of digitalization in the energy sector can raise security and privacy risks in the absence of an international rules-based framework. Criminal groups, terrorists, or the security services of hostile countries may hack into the digitalized systems that control utilities and grids, either for criminal purposes such as fraud and theft, or to commit military or industrial espionage. In the most extreme case, cyber attackers may attempt to interrupt, sabotage, or destroy industrial infrastructure, including the power supply.

The growth of the 'internet of things' (which allows users to connect household appliances, electric vehicles, communications equipment, and the energy infrastructure) provides additional entry points and targets for digital assault.

A case often cited is the December 2015 cyber attack against Western Ukraine's power grid. Hackers were able to install malware on the computer systems in power distribution centres and take 30 substations offline, leaving more than 230,000 people in the dark for up to six hours. Considered the first of its kind, this incident highlights the risks of potential cyber attacks against electricity-based digital systems.[127]

More recently, 'national security' justifications were invoked by authorities to prevent State Grid (the world's largest utility company and China's largest state-owned enterprise) from purchasing shares in certain electricity networks and utility companies, including in Australia (Ausgrid), Belgium (Eandis), and Germany (50Hertz). While the reasons were never fully elaborated, the assessed risks probably included a high threat of cyber espionage as well as unwillingness to allow a third country to acquire partial control over critical national infrastructure.

While the threat of cyber attacks is real, it should be placed in perspective. Cybercrime is a risk that predates the energy transformation. Traditional electricity grids are also exposed to cyber intrusion, while other digital systems, such as banking and the internet, are equally vulnerable. In reality, everything connected to the internet is inherently vulnerable to hacking and cyber weapons.

Although vulnerabilities and cyber risks will always exist and evolve, effective counter-measures can be developed and implemented to protect grids and related assets from attack. Grid providers around the world are already taking steps to prevent unauthorized access to energy systems. System operators have established standards to protect the grid, and companies are becoming more vigilant and developing contingency plans to protect against cyber attacks. New smart grid systems are being developed that prioritize cybersecurity in their design. To minimize the risk further, it would be prudent for the global community to take effective steps to develop common cybersecurity norms and rules.

Minerals

The widespread adoption of renewable energy and related technologies, such as solar panels, wind turbines, electric vehicles, and energy storage technologies, will increase the demand for a range of minerals and metals required for their production. (See Table 2.)

In theory, the regions that possess substantial reserves of these minerals should benefit from the energy transformation. Latin America has huge reserves of copper, iron ore, silver, lithium, aluminium, nickel, manganese, and zinc. Africa is rich in platinum, manganese, bauxite, and chromium. In the Asia-Pacific region, China has metal reserves; India has iron ore, steel and titanium; Indonesia, Malaysia and the Philippines possess bauxite and nickel; and New Caledonia has enormous reserves of nickel.[128]

Advances in prospecting and mining have also made it feasible to exploit minerals located under the seabed, raising thorny issues of sovereignty and governance.[129] As deep sea mining expands, international norms and standards will be needed to mitigate the risks of environmental damage and conflict.

However, the largest reserves of metals and minerals required for renewable technologies are found in weak states with poor governance records. More than 60% of the world's cobalt supply originates in the Democratic Republic of the Congo (DRC). Unaccountable external actors have sometimes caused or aggravated conditions that have maintained lawlessness and conflict in some of these mineral-rich regions, with devastating social, economic, political and environmental consequences. In Colombia, a country in which the longest-running internal armed conflict has taken place, various armed groups have controlled and exploited illegal tin, tungsten, tantalum and gold mining resources.

Efforts have been made to address the issue of so-called conflict minerals. Most of these strategies attempt to increase transparency and accountability along the global supply chain. The OECD, for example, has published due diligence guidelines for companies that mine or trade in minerals[130] and the UN Security Council has called for such measures to be applied in Cote d'Ivoire, the DRC, Sudan, and other conflict-affected states.[131] Well-regulated and transparent exploitation of mineral deposits can make a major contribution to the economic development of these countries.

Table 2. Minerals required for green energy technologies

	Solar technology	Wind technology	Electric vehicles, energy storage
Bauxite and aluminium	x	x	x
Cadmium	x		
Chromium		x	
Cobalt		x	x
Copper	x	x	x
Gallium	x		
Germanium	x		
Graphite			x
Indium	x		
Iron	x	x	x
Lead	x	x	x
Lithium			x
Manganese		x	x
Molybdenum		x	
Nickel	x		x
Rare earths		x	x
Selenium	x		
Silicon	x		x
Silver	x		
Tellurium	x		
Tin	x		
Titanium			x
Zinc	x	x	

Source: IISD, *Green Conflict Minerals*, August 2018.

PART 3.

Addressing root causes of geopolitical instability

The global energy transformation will affect social, economic and environmental factors that are often among the root causes of geopolitical instability and conflict. Climate change, rapid urbanization, high unemployment, discrimination, inequality and other major trends can create conditions that increase poverty and exclusion, promote the mass movement of people, cause violent conflict, and political extremism—all forces that have the potential to affect geopolitical stability. While the characteristics and rapid growth of renewables will generate new risks, the energy transformation will also create opportunities to overcome some of these challenges.

Economic and social tensions

The energy transition involves a profound economic, industrial and societal transformation. It could affect prosperity, employment, and social organization as much as the first Industrial Revolution. The shift to renewables brings several macroeconomic advantages. For example, by 2050, the cost of energy could fall from 5% of global GDP to a little over 2% of a much larger world economy.[132] However, it may also create new social divisions and financial risks that could reverberate through the international system and be geopolitically significant.

Mitigating social dislocation

While the switch to renewable energy has the potential to create an additional eleven million jobs in the energy sector by 2050,[133] it may at the same time reduce employment in specific sectors such as coal mining. The most labour-intensive form of fossil fuel extraction, the coal sector employs a global workforce of at least 9 million people, more than half of whom are employed in China.[134] Coal mining jobs are threatened by structural market forces including cheaper alternatives and automation, and by government regulation to protect human health and the environment.

In China, the world's largest coal producer, coal mining accounted for around 5 million jobs in 2016, out of a work force of some 800 million.[135] However, coal jobs are concentrated in particular regions and labour is the least mobile factor of production. Mine closures frequently have a deep and long-term impact on local communities and economies, causing marginalization, social dislocation, and disputes between workers and employers.

The energy transformation may deepen existing political divisions or create new ones that in their turn create geopolitical consequences. Coal miners were among the most vocal supporters of Donald J. Trump during the 2016 US Presidential elections; and recent cabinet changes in Australia and France can be linked directly to disagreements over the energy transition.[136] In 2013, the Bulgarian government resigned amid a wave of violent protests over rising electricity prices, partly due to an overgenerous feed-in-tariff to renewables.

In China, protests against air pollution have spurred the government to make the fight against it a political priority.[137] In many of the countries in which governments have attempted to phase out fossil fuel consumption subsidies, protesters have frequently taken to the streets to oppose such reforms.[138] More than a quarter of a million French people protested in late 2018 against a rise in fuel prices tied to a new carbon tax.

There is some evidence that, while difficult to put into practice, policies that facilitate a 'just transition' can help to address the serious socio-economic difficulties faced by coalminers and their families and other communities of work whose skills are made redundant by new technologies.[139] Measures that have been developed include the establishment of national or regional transition bodies, transition funds, on-the-job retraining programmes, infrastructure investments, and programmes to develop skills, education, and assist with relocation.[140] Spain recently provided an example of what can be achieved with enlightened leadership and progressive policies. The government came to an agreement with trade unions to shut down all coal mines by the end of 2018, while investing 250 million Euros in affected mining regions over the next decade.

Stranded assets

The global fossil fuel system has a built asset value estimated at 25 trillion US dollars[141] and continues to add one trillion dollars of assets each year.[142] A giant network of oil wells, coal fields, power stations, pipelines, oil tankers and refineries extends across the world. Yet no more than a quarter of total coal, oil, and gas reserves can be burned before the 'well below 2°C' target of the Paris Agreement is exceeded.[143]

Parts of the fossil fuel system could become 'stranded assets' as a result of policy action and the falling costs of renewable technologies. Asset stranding occurs when assets have suffered unanticipated or premature write-downs, devaluations or conversion to liabilities.[144] IRENA has noted that electricity generated from renewables will become cheaper than electricity generated by new fossil fuel assets in all major locations by 2020.[145] It is therefore only a matter of time in many parts of the world before green electricity becomes cheaper than electricity generated from existing assets, at which point it would make sense to close down fossil fuel generators.

The process has already started. Since 2010, Europe's electricity sector has already suffered impairments valued at more than 150 billion US dollars from write-downs of its thermal generating capacity.[146] In the last five years, Engie has written off 35 billion Euros in fossil fuel assets.[147]

The risk of stranded assets might not be fully reflected in the value of companies that extract, process or distribute fossil fuels. Moreover, these assets are counted when countries calculate their national resources. Were the risks to be priced in, the value of these companies, and the credit ratings of certain countries, could experience a sudden drop. This might have systemic consequences, even trigger a climate 'Minsky moment',[148] given the large sums involved. One study found that no less than 12 trillion US dollars of financial value could be lost in the form of stranded assets.[149] To provide context, the Great Recession of 2008 was sparked by losses in the US subprime mortgage market of 0.25 trillion US dollars.

International bodies, such as the Financial Stability Board, are strongly encouraging firms to increase their disclosure of risks relating to climate change.[150] By September 2018, institutions with over 100 trillion US dollars of assets under management had declared their support for the recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD).

Climate, water and food security

Renewables will also induce geopolitical effects by mitigating climate change. Climate change will have widespread effects that defence and security experts call 'threat multipliers' because they can worsen scarcity of food and water, increase poverty, and aggravate risks of conflict and political instability. The UN Security Council has examined the impact of climate change on international peace and security since 2007.

Climate change can threaten the stability of countries in a number of ways. It causes rainfall variability, droughts, floods, hurricanes and fires. Rising food prices and water shortages can result in political and social unrest. Sea level rise is already threatening the survival and existence of many Small Island Developing States (SIDS). The destabilizing impacts of climate change can also lead to increased displacement and migration as people move to avoid extreme weather events or find water, food, land, jobs and a more secure life. These outcomes are already being felt in many countries, irrespective of their level of economic development or geopolitical standing.

Accelerating climate change will increasingly exacerbate geopolitical competition for water and food. Rapid economic and population growth are already increasing demand for those resources, especially in developing countries. By 2050, the demand for water and food is expected to rise by over 50%.[151] The interplay between water, energy and food supply systems—the *nexus*—creates major geopolitical challenges for countries at a time of accelerating climate change.

Hydropower is the world's largest source of renewable electricity and has its own geopolitical dynamics, particularly when transboundary rivers and water resources are involved. These dynamics are increasingly impacted by climate change. The damming of major rivers, for example, will increase the energy security of upstream states that benefit, but could harm water supplies, agricultural productivity and fish stocks in states downstream, which may already be experiencing rising water stress. Planned dams along the Nile, Mekong, Tigris and Himalayan river systems could all have major impacts on water availability downstream and create tensions among riparian states as a result. There are also examples of hydropower benefits. The Itaipu dam enables Brazil and Paraguay to trade electricity and share water, so enhancing sub-regional cooperation and stability.

Renewable forms of energy can help to reduce water stress. Renewables require water withdrawals 200 times lower than conventional energy.[152] One study has found that, by 2030, if they combine renewables with improved plant cooling technologies, Chinese power generation could reduce water intensity by as much as 42% and emissions intensity by up to 37%.[153] Renewable energy technologies also offer increasingly attractive solutions to power desalination, a vital issue for many countries in arid regions, including the countries of the Gulf Cooperation Council.

Vulnerabilities in water and energy supply also pose critical risks for food security, since severe droughts and fluctuations in energy prices can affect the availability, affordability, accessibility, storage, and use of food over time. Integrating renewables in agriculture (through solar pumps for irrigation or geothermal energy for food drying) can improve agricultural yields, reduce post-harvest loss, and ultimately enhance food security.

Any significant increase in competition for food, water, land, clean air, and other resources essential for life can create social and economic tensions that could in turn have geopolitical consequences. These can increase tensions between states but may also foster new forms of cooperation to tackle these challenges collectively.

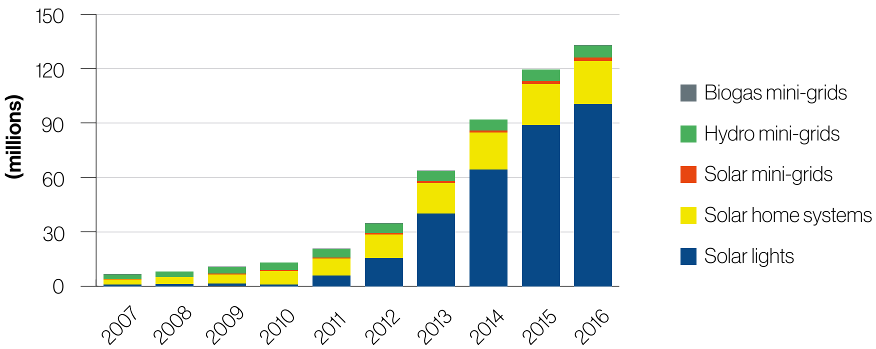
A new development path

Social and economic tensions in a country can worsen if growth is not inclusive, services are captured by elites, or industrialization generates imbalances between regions. To achieve stability and prosperity over time, a country's development needs to be inclusive and sustainable. In this sense, peace and development are two sides of the same coin. Both require policies and institutions to address environmental risks, reduce inequalities and ensure equity and social cohesion.

Energy lies at the heart of human development. It is a critical factor in economic activity and essential for the provision of human needs, including adequate food, shelter and healthcare. Energy also fuels productive activities in the wider economy, including agriculture, industry and commerce. In the last twenty years, millions of people have gained access to electricity. Developing countries in Asia, led by China and India, have made significant progress. Yet to achieve universal energy access by 2030, as agreed in the SDGs, these efforts will need to accelerate. On current trends, about 674 million people, mainly in Africa, could still be without power in 2030.[154]

Historically, national electrification programmes have relied on large-scale, centralized power stations and line extensions powered by fossil fuels. Since around 2011, however, renewable energy has become an increasingly realistic alternative due to the confluence of two major trends: falling costs and mobile banking. A quiet energy revolution is now underway, providing light and power to households and entrepreneurs via off-grid renewable energy systems (see Figure 12). Estimates suggest that off-grid solutions (standalone and mini-grids) could supply approximately 60% of the additional generation needed to achieve the goal of universal energy access by 2030.[155]

Figure 12. Population served by off-grid renewable energy solutions



Source: IRENA.

Improving access to energy brings numerous benefits that are vital for human development and therefore helps to create the conditions necessary for geopolitical stability. Energy poverty is typically considered a development concern because, for both individuals and communities, it reduces the quality of life and opportunities. However, it also compromises security. It poses a direct threat to the many women and children who are daily at risk of injury and violence when they gather fuel. More broadly, it is a threat multiplier,[156] because it causes or exacerbates a wide range of problems, including poverty, marginalization, social unrest, population displacement, and environmental fragility.

Renewables also offer developing economies an opportunity to leapfrog, not only fossil fuels, but, to some extent, the need for a centralized electricity grid. Countries in Africa and South Asia have a golden opportunity to avoid expensive fixed investments in fossil fuels and centralized grids by adopting mini-grids and decentralized solar and wind energy deployed off-grid—just as they jumped straight to mobile phones and obviated the need to lay expensive copper-wired telephone networks.

Most importantly, renewables improve human welfare in ways that are not captured by GDP statistics. Properly designed, they can be applied to promote social justice and human welfare, encourage local empowerment and local wealth generation, contribute to a safer climate, improve public health, and advance gender equality and educational opportunities. The adoption of renewable energy will ease progress towards all 17 of the Sustainable Development Goals, not just the goal that relates to universal, affordable and clean energy.[157]

Conclusion

This Report argues that the global energy transformation driven by renewables will have significant geopolitical implications. It will reshape relations between states and lead to fundamental structural changes in economies and society. The world that will emerge from the renewable energy transition will be very different from the one that was built on a foundation of fossil fuels.

Global power structures and arrangements will change in many ways and the dynamics of relationships within states will also be transformed. Power will become more decentralized and diffused. The influence of some states, such as China, will grow because they have invested heavily in renewable technologies and built up their capacity to take advantage of the opportunities they create. By contrast, states that rely heavily on fossil fuel exports and do not adapt to the energy transition will face risks and lose influence.

The supply of energy will no longer be the domain of a small number of states, since the majority of countries will have the potential to achieve energy independence, enhancing their development and security as a result.

While the precise scope and pace of the energy transformation cannot be predicted, its impact on countries, communities and companies will be profound.

The transition will generate considerable benefits and opportunities. It will strengthen the energy security and energy independence of most countries; promote prosperity and job creation; improve food and water security; and enhance sustainability and equity. Some states will be able to leapfrog technologies based on fossil fuels. The number of energy-related conflicts is likely to fall.

Countries must prepare for the changes ahead and develop strategies to enhance the prospects of a smooth transition. At the same time, the energy transformation will generate new challenges. Fossil fuel-exporting countries may face instability if they do not reinvent themselves for a new energy age; a rapid shift away from fossil fuels could create a financial shock with significant consequences for the global economy; workers and communities who depend on fossil fuels may be hit adversely; and risks may emerge with regard to cybersecurity and new dependencies on certain minerals.

Despite difficulties, the energy transformation will ultimately move the world in the right direction by addressing climate change, combating pollution, and promoting prosperity and sustainable development.

As the world gets ready for the geopolitical consequences of the energy transformation, this Report can provide leaders of governments, business and all sectors of society with a foundation for dialogue and debate, thereby contributing to policy development and new courses of action.

Endnotes

1 IRENA, OECD/IEA and REN21, *Renewable Energy Policies in a Time of Transition*, International Renewable Energy Agency, Organization for Economic Co-operation and Development, International Energy Agency, Renewable Energy Policy Network for the 21st Century, 2018.

2 We use the term 'energy transition' to refer to the shift from fossil fuels to renewable energy sources. We use the term 'energy transformation' to refer to the broader implications of this shift.

3 IEA, *World Energy Outlook 2018*, New Policies Scenario, International Energy Agency, 2018. Global GDP growth in the same period is now forecast to grow at 3.4 % per year.

4 IEA, *Global Energy and CO_2 Status Report*, International Energy Agency, March 2018.

5 IRENA, *Renewable Energy Statistics 2018*, International Renewable Energy Agency, 2018.

6 IRENA, *Renewable Energy Statistics 2018*, International Renewable Energy Agency, 2018; UNEP and BNEF, *Global Trends in Renewable Energy Investment 2018*, UN Environment Programme and Bloomberg New Energy Finance, 2018.

7 IRENA, *Renewable Energy Statistics 2018*, International Renewable Energy Agency, 2018.

8 IRENA, *Renewable Energy Statistics 2018,* International Renewable Energy Agency, 2018.

9 IEA, *World Energy Outlook 2018*, International Energy Agency, 2018.

10 IEA, *World Energy Investment 2018*, International Energy Agency, 2018.

11 See, for example, Shell Global, *Sky Scenario 2018 – Meeting the goals of the Paris Agreement*, Shell Global, 2018; IEA, *Sustainable Development Scenario*, International Energy Agency, 2018; Equinor (2018), Energy Perspectives 2018; IRENA, *REmap – Renewable Energy Roadmaps*, International Renewable Energy Agency, 2018; DNV-GL, *Energy Transition Outlook 2018*, DNV-GL, 2018; and "Mitigation pathways compatible with 1.5°C in the context of sustainable development", Chapter 2 of IPCC, *Special Report: Global Warming of 1.5°C*: *An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty,* Intergovernmental Panel on Climate Change, 2018.

12 IEA, *World Energy Outlook 2018*, International Energy Agency, 2018, p. 292.

13 IEA, *World Energy Outlook 2018*, International Energy Agency, 2018.

14 BNEF, *New Energy Outlook 2018*, Bloomberg New Energy Finance, 2018; Marteka, M., A. Slaughter, C. Amon, "Global renewable energy trends: solar and wind move from mainstream to preferred", Deloitte Insights, Deloitte, Sept. 13, 2018.

15 IRENA, *Renewable power generation costs in 2017*, International Renewable Energy Agency, 2017.

16 IRENA, *Renewable power generation costs in 2017*, International Renewable Energy Agency, 2017.

17 BNEF, *New Energy Outlook 2018*, Bloomberg New Energy Finance, 2018.

18 IRENA, *The power to change: solar and wind cost reduction potential to 2025*, International Renewable Energy Agency, 2016.

19 IRENA, *Electricity storage and renewables*, International Renewable Energy Agency, 2017.

20 Hodges, J., "Electric cars may be cheaper than gas guzzlers in seven years", Bloomberg, 22 March 2018, at: www.bloomberg.com/news/articles/2018-03-22/electric-cars-may-be-cheaper-than-gas-guzzlers-in-seven-years.

21 WHO, *How Air Pollution is Destroying Our Health*, World Health Organization, 2018, at: www.who.int/air-pollution/news-and-events/how-air-pollution-is-destroying-our-health.

22 IPCC, *Special Report: Global Warming of 1.5°C*, Intergovernmental Panel on Climate Change, 2018.
23 UNEP, *Emissions Gap Report 2018*, UN Environment Programme, 2018.
24 Steffen W. et al., "Trajectories of the Earth System in the Anthropocene", in *Proceedings of the National Academy of Sciences of the United States of America*, 9 August 2018.
25 IPCC, *Special Report: Global Warming of 1.5°C*, Intergovernmental Panel on Climate Change, 2018.
26 IRENA, *Global Energy Transformation: A Roadmap to 2050*, International Renewable Energy Agency, 2018.
27 REN21, *Renewables 2018 – Global Status Report*, Renewable Energy Policy Network for the 21st Century, 2018.
28 IRENA, *Renewable Energy Auctions: Analysing 2016*, International Renewable Energy Agency, 2017.
29 IEA, *World Energy Outlook 2018*, International Energy Agency, 2018.
30 EPO, UNEP and ICTSD, *Patents and clean energy: bridging the gap between evidence and policy*, European Patents Office, UN Environment Programme and International Centre for Trade and Sustainable Development, 2010, p. 30.
31 IRENA, *Innovation outlook: advanced liquid biofuels*, International Renewable Energy Agency, 2017; IRENA, *Hydrogen from renewable power: technology outlook for the energy transition*, 2018; Energy Transitions Commission, *Mission Possible: Reaching net-zero emissions from harder-to-abate sectors by mid-century*, 2018.
32 CA100+ has the support of 310 investor groups, representing over 32 trillion US dollars in assets under management.
33 2018 Global Investor statement to governments on climate change.
34 RE100 website; IRENA, *Corporate sourcing of renewable energy: market and industry trends*, International Renewable Energy Agency, 2018.
35 Today, over 7,000 of the world's largest companies, representing some 55% of global market value, disclose information on climate change. See: www.cdp.net.
36 "Shell yields to investors by setting target on carbon footprint", *Financial Times*, 3 December 2018.
37 *Encyclical letter Laudato si' of the Holy Father Francis on care for our common home*; Vatican, 2015, para. 165, at: http://w2.vatican.va/content/dam/francesco/pdf/encyclicals/documents/papa-francesco_ 20150524_enciclica-laudato-si_en.pdf.
38 "Climate change strike: thousands of school students protest across Australia", *Guardian*, 30 November 2018.
39 www.sunrisemovement.org; https://rebellion.earth.
40 www.urgenda.nl/en/themas/climate-case.
41 Nachmany, M., J. Setzer, "Global trends in climate change legislation and litigation: 2018 snapshot", Policy Brief, Grantham Institute on Climate Change and the Environment, at: http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2018/04/Global-trends-in-climate-change-legislation-and-litigation-2018-snapshot-3.pdf; Hasemeyer, D., "Fossil Fuels on Trial: Where the Major Climate Change Lawsuits Stand Today", *Inside Climate News*, 6 November 2018, at: https://insideclimatenews.org/ news/04042018/climate-change-fossil-fuel-company-lawsuits-timeline-exxon-children-california-cities-attorney-general.
42 DNV-GL, *Energy Transition Outlook 2018*, DNV-GL, 2018.
43 Frankfurt School-UNEP Centre and BNEF, *Global Trends in Renewable Energy Investment 2018*, Frankfurt School-UN Environment programme Centre and Bloomberg New Energy Finance, 2018.
44 UN DESA, World Population Prospects: The 2017 Revision, United Nations Department of Economic and Social Affairs, Population Division, 2017.

45 IEA, *World Energy Outlook 2018*, International Energy Agency, 2018.
46 IEA/IRENA joint policies and measures database.
47 Government of India, Ministry of Power, Central Electricity Authority, Installed capacity, October 2018, at: www.cea.nic.in/monthlyinstalledcapacity.html.
48 IEA, Outlook for Producer Economies, in *World Energy Outlook 2018*, International Energy Agency, 2018, p. 38.
49 Under the World Bank's classification system, the CIS includes Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, and Tajikistan.
50 IEA, Special excerpt: outlook for producer economies, in *World Energy Outlook 2018*, International Energy Agency, 2018.
51 Two indicators have been selected to show the relative position of different states, while recognizing that many factors influence a country's preparedness for the energy transition. For a more detailed analysis of this issue, see World Bank, *Crossroads - Climate strategies of fossil fuel-dependent countries*, World Bank, 2018.
52 Fossil fuel rents are calculated as a percentage of GDP. To normalize the effect of volatile oil prices, average rents in the last 10 years (2007-2016) were used.
53 GDP per capita was used, calculated in terms of power-purchasing parity in 2016.
54 Remark made by General Tom Middendorp, former Chief of Defence of the Armed Forces of the Netherlands, Oslo, June 24, 2018.
55 UN DESA, World Population Prospects, United Nations Department of Economic and Social Affairs, Population Division, 2017.
56 Sachs, J. D., and A. M. Warner, "The curse of natural resources" in *European Economic Review*, 2001, *45*(4-6), 827-838; Ross, M., *The Oil Curse: How petroleum wealth shapes the development of nations*, Princeton University Press, 2012; Colgan, J. D., *Petro-aggression: When oil causes war*, Cambridge University Press, 2013.
57 Norway, a significant producer of oil and gas, tops international league tables for its economic performance and the quality of its governance.
58 World Bank, *The Changing Wealth of Nations - Measuring Sustainable Development in the New Millennium*, The World Bank, 2011.
59 Lederman, D. and W. Maloney, "Trade Structure and Growth", in D. Lederman and W. Maloney (eds.), *Natural Resources: Neither Curse nor Destiny*, The World Bank, 2007.
60 Ross, M. L., What do we know about economic diversification in oil-producing countries? (Unpublished manuscript, 2017).
61 Authors' calculations based on data from the World Bank.
62 Evidence for this includes the Eisenhower Doctrine of 1957 and the Carter Doctrine of 1980. Under the Eisenhower Doctrine of 1957, the US offered economic and military aid to Middle Eastern countries if another state threatened them with armed aggression. This was motivated in part by the Soviet Union's growing influence in the region after the Suez crisis of 1956. The Carter Doctrine of 1980 was a response to the Soviet invasion of Afghanistan. It proclaimed: "An attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force".
63 Iceland National Energy Authority.
64 Exports of electricity may become a new source of revenue. A proposal to connect Iceland's electricity grid to Scotland via a submarine cable is one of the European Union's key energy infrastructure projects. European Commission, Projects of Common Interest, April 2018.
65 WTO, *International Trade Statistics*, World Trade Organization, at: data.wto.org.
66 Pachauri, R. K. et al. *Building the Future we want*, New Delhi: TERI, 2015.

67 IMF Research Department, *The Impact of Higher Oil Prices on the Global Economy*, International Monetary Fund, December 2000.
68 For example, the large drop in oil prices in 2014 generated a one-off boost to the EU economy and an estimated GDP increase of 0.8% in 2015 and 0.5% in 2016. Source: European Commission, Energy Prices and costs in Europe, Report from the European Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2016) 769 final, 30 November 2016.
69 UNCTAD, *The Least Developed Countries Report: Transformational energy access*, UN Conference on Trade and Development, 2017.
70 IRENA, Finding a way to transform energy on islands, 13 January 2017, at: www.irena.org/newsroom/ articles/2017/Jan/Finding-a-Way-to-Transform-Energy-on-Islands.
71 IEA, *Electricity Information: 2018 Edition*, International Energy Agency, 2018.
72 World Bank, World Development Indicators. At: http://datatopics.worldbank.org/world-development-indicators/.
73 Autarchy implies a complete absence of foreign trade.
74 Beyond Zero Emissions, *Renewable Energy Superpower: Zero carbon Australia*, Beyond Zero Emissions, 2015.
75 IHA, *2016 Hydropower Status Report*, International Hydropower Association, 2016.
76 www.manufacturingcleanenergy.org/images/cemac-benchmarks-figures/es-3.jpg.
77 The trend is gathering momentum. Consider, for instance, swarm electrification in Bangladesh, which allows owners of solar home systems to trade power with their neighbours.
78 IHS Markit, *The Internet of Things: A movement, not a market*, IHS Markit, at: https://cdn.ihs.com/www/pdf/IoT_ebook.pdf.
79 Agentur für Erneuerbare Energien, "Bürgerenergie bleibt Schlüssel für erfolgreiche Energiewende", Press Release, 1 February 2018.
80 Microgrids are energy networks that can operate even when the grid cannot.
81 UN DESA, *2018 Revision of World Urbanization Prospects*, UN Department of Economic and Social Affairs, 16 May 2018.
82 UCCRN technical report, *The future we don't want: How climate change could impact the world's greatest cities*, Urban Climate Change Research Network, C40 Cities, Global Covenant of Mayors, and Acclimatise, 2018.
83 www.cdp.net/en/cities/world-renewable-energy-cities.
84 www.city.yokohama.lg.jp/ondan/english/yscp.
85 www.neom.com.
86 www.c40.org; www.iclei.org; www.globalcovenantofmayors.org.
87 IRENA, *Corporate sourcing of Renewables: Market and Industry Trends*, Remade Index 2018, International Renewable Energy Agency, 2018.
88 Van de Graaf, T., "Is OPEC dead? Oil exporters, the Paris agreement and the transition to a post-carbon world", in *Energy Research and Social Science*, 2017, 23, pp. 182-188.
89 Opening remarks by Taro Kono, Minister for Foreign Affairs of Japan, at an International Seminar on 'The Age of Renewable Energy Diplomacy and Japan's Course' (Tokyo, 12 March 2018). At: .
90 Nagashima, M., *Japan's hydrogen strategy and its economic and geopolitical implications*, Etudes de l'IFRI, Institut français des relations internationales, October 2018.
91 Westphal, K., "Globalising the German Energy Transition", SWP Comments, Stiftung Wissenschaft und Politik, December 2012; Roehrkasten, S and K. Westphal, "IRENA and Germany's foreign renewable energy policy", SWP Comments, Stiftung Wissenschaft und Politik, September 2013; Van de Graaf, T., "Fragmentation in Global Energy Governance: Explaining the creation of IRENA", *Global Environmental Politics* 13(3), pp. 14-33.

92 Weatherby, C., B. Eyler and R. Burchill, *UAE Energy Diplomacy: Exporting Renewable Energy to the Global South*, Trends Research and Advisory and the Stimson Centre, 2018.
93 http://isolaralliance.org.
94 www.globalgeothermalalliance.org.
95 http://mission-innovation.net.
96 "ISA could replace Opec as key global energy supplier in future: PM Modi", *The Times of India*, 3 October 2018, at: https://timesofindia.indiatimes.com/india/isa-could-replace-opec-as-key-global-energy-supplier-in-future-pm-modi/articleshow/66044985.cms.
97 "Will India find its place in the sun with solar power?", *Stratfor*, 22 August 2018, at: .
98 This share includes trade in mining products. WTO, *World Trade Statistical Review*, World Trade Organization, 2018, p. 11.
99 The European Commission defines 'connectivity' as follows: "Connectivity is essentially about networks. These can be in the form of transport links: by air, land or sea. Connectivity can be digital networks: mobile or fixed, from cables to satellites, from the internet backbone to the last mile. Connectivity also includes energy networks and flows: from gas, including liquefied natural gas (LNG) to electricity grids, from renewables to energy efficiency. Finally, connectivity has a very obvious human dimension: from cooperation in education, research and innovation to travel and tourism." European Commission, Explaining the European Union's approach to connecting Europe and Asia, *Fact Sheet*, European Commission, September 2018.
100 In general, these green fuels are often referred to as 'power-to-X', where 'X' stands for any fuel or feedstock from renewable power via electrolysis.
101 The World Energy Council Germany estimates that a mature global market for synthetic fuels can supply between 10,000 and 20,000 TWh per year by 2050. This corresponds to about half today's global demand for crude oil. Frontier Economics, International aspects of a power-to-X roadmap, World Energy Council Germany, October 2018.
102 For more information, see the website of the Global Energy Interconnection Development and Cooperation Organization (GEIDCO), at: www.geidco.org/html/qqnycoen/index.html.
103 Andrew Small. "The Backlash to Belt and Road," *Foreign Affairs*, Feb. 16, 2018.
104 Hillman, J., China's Belt and Road Initiative: Five Years Later, Statement before the US-China Economic and Security Review Commission, US Senate, January 25, 2018; Hurley, J., S. Morris, G. Portelance, "Examining the Debt Implications of the Belt and Road Initiative from a Policy Perspective", CGD Policy Paper, Center for Global Development; "China's Belt and Road Initiative is falling short", *Financial Times*, 29 July 2018.
105 US Department of State, "Advancing a Free and Open Indo-Pacific", press release, 30 July 2018.
106 ASEAN, Master Plan on ASEAN Connectivity 2025, Association of Southeast Asian Nations, August 2016.
107 EU, Joint Communication: Connecting Europe and Asia – building blocks for an EU Strategy, European Union External Action, 19 September 2018.
108 These points are inspired by Carlos Pascual, *The new geopolitics of energy*, Center on Global Energy Policy and School of International and Public Affairs, Columbia University, 2015.
109 O'Sullivan, M., I. Overland, D. Sandalow, *The Geopolitics of Renewable Energy*, Working Paper, Columbia Center on Global Energy Policy and Harvard Belfer Center for Science and International Affairs, 2017.
110 Scholten, D. and R. Bosman, "The geopolitics of renewables; exploring the political implications of renewable energy systems", in *Technological Forecasting and Social Change*, 2016, 103, pp. 273-283.

111 Sistema de Interconexión Eléctrica de los Países de América Central.
112 IEA, *Large-scale electricity interconnection: Technology and prospects for cross-regional networks*, International Energy Agency, 2016. See also, Scholten, D., R. Bosman, "The geopolitics of renewables: Exploring the political implications of renewable energy", in *Technical Forecasting and Social Change*, Volume 103, February 2016, pp. 273-83.
113 Fischhendler, I., L. Herman, J. Anderman, "The geopolitics of cross-border electricity grids: The Israeli-Arab case", in *Energy Policy*, 2016, 98, pp. 533-543.
114 European Union, "Synchronisation of the Baltic States' electricity grid with the continental European system", press release, 14 September 2018.
115 IEA, *Electricity security across borders*, International Energy Agency, 2016.
116 It has been endorsed at the highest level in Eastern and Southern Africa (ACEC), in West Africa (WACEC) and in Central America (CECCA). See: www.irena.org/cleanenergycorridors.
117 UNCTAD, *The state of the biofuels market: regulatory, trade and development perspectives* UN Conference on Trade and Development, 2014.
118 UNCTAD, see note above.
119 The term 'rare earths' refers to 17 elements often found in the same ore deposits: cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, neodymium, praseodymium, promethium, samarium, scandium, terbium, thulium, ytterbium and yttrium.
120 Overland, I., "The geopolitics of renewable energy: Debunking four emerging myths*, in *Energy Research & Social Science*, 49, pp. 36-40.
121 Lovins, A., "Clean energy and rare earths: why not to worry", *Bulletin of the Atomic Scientists*, 23 May 2017.
122 Goldthau, A., M. Keim and K. Westphal, *The Geopolitics of Energy Transformation: Governing the Shift - Transformation Dividends, Systemic Risks and New Uncertainties*, Comment No. 42, German Institute for International and Security Affairs, October 2018.
123 Ross, M., "A closer look at oil, diamonds, and civil war", in *Annual Review of Political Science*, 2006, 9, pp. 265-300.
124 "Strait of Hormuz: the world's most important oil artery", *Reuters*, 5 July 2018.
125 National Defense Authorization Act of 2010, Section 2842
126 www.acq.osd.mil/eie/OE/OE_index.html.
127 Overland, I., "The geopolitics of renewable energy: Debunking four emerging myths*, in *Energy Research & Social Science*, 49, pp. 36-40.
128 World Bank, The growing role of minerals and metals for a low-carbon future, World Bank, 2017.
129 The 1982 UN Convention on the Law of the Sea (UNCLOS) declared that the seabed area beyond national jurisdiction and its mineral resources are the "common heritage of mankind". All mineral exploration and exploitation activities must be approved by the International Seabed Authority, which has began to develop regulations and guidance to govern the future exploitation of seabed minerals.
130 OECD, *Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas*, Organization for Economic Cooperation and Development, 2016.
131 www.oecd.org/corporate/mne/mining.htm.
132 DNV-GL, *Energy Transition Outlook 2018*, DNV-GL, 2018.
133 IRENA, *Global Energy Transformation: A Roadmap to 2050*, International Renewable Energy Agency, 2018.
134 World Bank, *Crossroads - Climate strategies of fossil fuel-dependent countries*, World Bank, 2018.

135 National Bureau of Statistics of China, *China Statistical Yearbook*, 2017.

136 “French environment minister Nicolas Hulot resigns”, *Financial Times*, 28 August 2018; “Australia’s recent climate change policy: A brief history of seven killings”, *ABC news*, 22 August 2018.

137 2018-20 Three Year action plan for winning the blue sky war, 2018. At: www.gov.cn/zhengce/content/2018-07/03/content_5303158.htm.

138 Skovgaard, J., H. van Asselt, *The Politics of Fossil Fuel Subsidies and Their Reform*, Cambridge University Press, 2018.

139 ILO, *Guidelines for a just transition towards environmentally sustainable economies and societies for all*, International Labour Organization, 2015.

140 Sartor, O., *Implementing coal transitions: Insights from case studies of major coal-consuming economies*, Climate Strategies and the Institut du développement durable et des relations Internationales (IDDRI), 2018.

141 Shell, Presentation by Brian Davis in Oxford (June 2017).

142 IEA, *World Energy Investment*, International Energy Agency, 2018.

143 The total amount of carbon in fossil fuel reserves amounts to 3,500 Gt (BP, *Statistical Review of World Energy*, BP, 2018). The IEA and IRENA estimate the total carbon budget for the energy sector to be 790 Gt, if we want to have a 66% chance of staying below 2°C. See IEA and IRENA, *Perspectives for the energy transition: Investment needs for a low-carbon energy system,* International Energy Agency and International Renewable Energy Agency, 2017, p. 48. Significantly, the most recent IPCC report has increased the carbon budget for the 66% 2°C scenario to 1320 Gt. See IPCC, *Special Report: Global Warming of 1.5°C*, Intergovernmental Panel on Climate Change, 2018. This is nevertheless 2.5 times smaller than the carbon content of existing fossil fuel reserves. On the different impact on specific fuels and regions, see McGlade, C., and Ekins, P., “The geographical distribution of fossil fuels unused when limiting global warming to 2 C^{0}”, in *Nature*, 2015, 517 (7533), p. 187.

144 Caldecott, B., Howarth, N., P. McSharry, *Stranded assets in agriculture: Protecting value from environment-related risks*, Smith School of Enterprise and the Environment, University of Oxford, 2013. See also: IRENA, *Stranded Assets and Renewables - How the energy transition affects the value of energy reserves, buildings and capital stock*, International Renewable Energy Agency, 2017.

145 IRENA, *Renewable power generation costs in 2017*, International Renewable Energy Agency, 2018, p. 3.

146 IEA, *World Energy Investment Report*, International Energy Agency, 2017.

147 Thierry Lepercq, Executive Vice President of Engie, presentation in Oslo to the Commission in June 2018.

148 “Mark Carney warns of climate change threat to financial system”, *Guardian*, 6 April 2018. The term ‘Minsky moment’ refers to the work of the economist Hyman Minsky, who showed that a sudden major collapse of asset values can generate a credit or business cycle.

149 Mercure, J., H. Pollitt, J. Vinuales, et al., “Macroeconomic impact of stranded fossil fuel assets” in *Nature Climate Change*, 2018.

150 www.fsb-tcfd.org.

151 IRENA, *Renewable Energy in the Water, Energy and Food Nexus*, International Renewable Energy Agency, 2015.

152 IRENA estimates that, if renewables are widely deployed, by 2030 the energy sector could reduce its water consumption by nearly half in the United Kingdom, by more than a quarter in the United States, Germany and Australia, and by more than 10% in India. IRENA, *Renewable Energy in the Water, Energy and Food Nexus*, International Renewable Energy Agency, 2015.

153 IRENA, Water Use in China's Power Sector: Impact of Renewables and Cooling Technologies to 2030, *Brief*, International Renewable Energy Agency, 2016.
154 IEA, *Special Report: Energy Access Outlook* in *World Energy Outlook 2017*, International Energy Agency, 2017. See also: IEA, IRENA, UN Statistics Division, World Bank, WHO, *Tracking SDG7: The Energy Progress Report 2018*, World Bank, 2018.
155 IEA, *Special Report: Energy Access Outlook* in *World Energy Outlook 2017*, International Energy Agency, 2017.
156 Bazilian, M. D., "Power to the poor: Provide energy to fight poverty", in *Foreign Affairs*, March/April 2015, pp. 133-139.
157 IRENA. *REthinking Energy 2017: Accelerating the global energy transformation*, International Renewable Energy Agency, 2017, p. 96.

Abbreviations

ASEAN	Association of Southeast Asian Nations
BRI	The Belt and Road Initiative
C40	C40 Cities Climate Leadership Group
CA 100+	Climate Action 100+
CIS	Commonwealth of Independent States
CSP	Concentrated solar power
DRC	Democratic Republic of Congo
EU	European Union
GCC	The Gulf Cooperation Council
GDP	Gross domestic product
GEI	Global Energy Interconnection
GEIDCO	Global Energy Interconnection Development and Cooperation Organization
GW	Gigawatt
ICLEI	Local Governments for Sustainability
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
LED	Light-emitting diode
LNG	Liquefied natural gas
MWh	Megawatt hour
NATO	North Atlantic Treaty Organization
NEPAD	The New Partnership for Africa’s Development

OECD	The Organization for Economic Co-operation and Development
OPEC	The Organization of the Petroleum Exporting Countries
PV	Photovoltaic
REMap	Renewable Energy Roadmap
SDGs	Sustainable Development Goals
SDS	Sustainable Development Scenario
SIDS	Small Island Developing States
SSA	Sub-Saharan Africa
UAE	United Arab Emirates
WHO	World Health Organization
WTO	World Trade Organization
UN	United Nations
US DoD	United States Department of Defense

Acknowledgements

Many individuals contributed to the Global Commission's work over the course of its deliberations. The Commission is grateful for their support and acknowledges all their contributions.

Three Member States of IRENA—Germany, Norway and the United Arab Emirates—provided important political and financial support for the Commission's activities, for which the Commission is extremely grateful. Additional financial support was received from the Government of the Netherlands.

A small Secretariat was responsible for all aspects of the Global Commission's work. The Secretariat was led by Ruth McCoy and included Kingsmill Bond, Heather Carney-Graham, Abas Moussa, Marcin Scigan and Thijs Van de Graaf. Substantive research for the Commission's report was carried out by Thijs Van de Graaf, who served as lead writer for the report, and Kingsmill Bond, expert analyst. Ahmed Abdel-Latif, Nazik Elhassan, Ruth McCoy, Marcin Scigan and Adrian Whiteman also provided inputs for the preparation of the report. The Secretariat received vital support from Ahmed Abdel-Latif and Mohamed El-Farnawany at IRENA throughout the process.

The Commission would like to recognize with gratitude the important contributions of several individuals who participated in a dialogue with Commission Members at their second meeting in Oslo: Ditlev Engel of DNV GL, Auke Lont of Statnett, Thierry Lepercq of Engie, Simone Mori of Enel, Helle Kirstoffersen of Total, Henrik Sætness of Statkraft, General Tom Middendorp, former Chief of Defense of the Armed Forces of the Kingdom of the Netherlands, and Amory Lovins, the co-founder and chief scientist of the Rocky Mountain Institute. The Commission also wishes to thank the Mayor of Reykjavik, the Minister of Communications, the Minister of Science, Reykjavik Energy and the Blue Lagoon for their hospitality during its third Meeting in Iceland.

The Report draws on various presentations and background papers from the following experts: Dolf Gielen, Adil Najam, Indra Overland, Daniel Scholten, Kirsten Westphal, Morgan Bazilian, Meghan O'Sullivan, Henning Wuester, Andreas Kraemer, Frank Radtke and Karen Smith Stegen. Written contributions from Luiz Barroso, Rafael Ferreira, Sebastián Kind, Bent Erik Bakken, Sven Behrendt and the Climate Policy Initiative were gratefully received. Valuable feedback during the review process was received from Anna Charles, Rabia Ferroukhi, Neil MacDonald, Indra Overland, Elizabeth Press, Daniel Scholten, Kirsten Westphal and Adrian Whiteman. Robert Archer edited the Report, and Fairouz El Tom was responsible for its design and layout.

The Commission is also grateful for the support of the team at IRENA in Abu Dhabi, namely Damian Brandy, Daria Gazzola, Zoheir Hamedi, Manuela Stefanides, Sina Tabrizi, and staff from various departments including Communications, Finance, General Services, ICT and the Governance Support Office. Valuable assistance was also provided by the aides of the three supporting member countries and the Chair: Reshma Francy, Kerstin Klee, Kirsten Hammelbo, and Ástríður Jónsdóttir from the secretariat of the Arctic Circle.

Photographic credits

Page 1	**Onshore wind farm, Spain** (Ikpro/Shutterstock.com)
Page 11	**Transmission power lines** (konstantinks/Shutterstock.com)
Page 13	**Solar PV power plant** (hlopex/Shutterstock.com)
Page 25	**Electric vehicle charging station** (Sopotnicki/Shutterstock.com)
Page 61	**Geothermal power plant, Iceland** (IRENA)
Page 71	**Noor Solar Power Plant, Morocco** (IRENA)