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Possible Energy Transitions through 2029

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Renewable energies are experiencing rapid growth, due not only to their limited impact on the environment but also to shrinking costs. To fight climate change, new investments in low carbon technologies are necessary. Apart from its positive aspects, the energy transition carries risks, notably geopolitical. The notion of energy security will be profoundly modified. These risks can be anticipated and managed.

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The world has embarked on an energy transition that entails fundamental change in the social, economic and environmental spheres of human society. Public and private actors worldwide are increasingly engaged in the dynamics of this transition which is set to accelerate as global ambitions to combat climate change and to advance sustainable development require the rapid decarbonization of energy. These changes will also profoundly affect geopolitics, as they will have implications for the global distribution of power, relations between countries, the risk of conflict, and global stability. While the potential benefits of the transition clearly outweigh the risks overall, governments and industries need to revaluate their situation and outlook in the new world that is evolving. They have to try to steer their way to economic growth and a sustainable future, while navigating the disruption that a fast-moving transition may bring.

The energy transition

The speed of the on-going energy transition and its fundamental impact on the shape of global energy systems exceeds all expectations. Ten years ago, there was still widespread doubt that renewables were a viable and reliable source of energy that could power economies and meet growing energy demand. Instead, the prevailing perception was that renewables were a luxury which only a few industrialized countries could afford. In fact, most of the energy scenarios and projections considerably and consistently underestimated the growth potential of renewables.

But the pace of developments in the growth of renewables in the global energy mix in the last ten years leaves today little doubt about their enormous potential. Globally, the total installed renewable electricity capacity now stands at 2,179 GW, and in terms of generation, at approximately 6,000 TWh, which is about 23 percent of global electricity production. In 2017, 167 GW of additional renewable energy generation capacity was installed, which represents 70 percent of all new capacity, and more than double that of fossil fuels.[1] One of the main drivers for this energy transition is that the business case for renewables keeps getting stronger. The levelized cost of electricity (LCOE) for solar photovoltaics has fallen by more than 73 percent since 2010, and the cost of electricity from onshore wind has fallen by more than 23 percent.[2] IRENA analysis estimates that by 2020, all renewable energy technologies currently in commercial use will be cost-competitive with fossil-fuels in most parts of the world, and even undercut them significantly in many cases.[3] Technological improvements and economies of scale have played a key role in this, but policy mechanisms such as auctions have also contributed to lowering prices. Record-breaking, low prices in recent auctions for solar PV power in Dubai, Mexico, Peru, Chile, Abu Dhabi and Saudi Arabia have shown that an LCOE of $0.03/kWh is possible.[4] At such a low price, renewables are an unbeatable source of power on price alone, apart from their environmental and socioeconomic benefits.

As a result of this strengthened business case, global investment in renewables has increased rapidly in the past years. The first trillion US dollars of investment in modern renewables took about 12 years, the second trillion took three years, and the third may very well take only a year and a half.[5] Investment is rapidly moving into this sector. Globally, new investment in clean energy reached $333.5 billion last year, despite falling unit costs. In China alone, investments amounted to a record-breaking $132.6 billion. In 2015, renewable power technologies attracted more investment than all others for the first time in history, a trend that has continued subsequently. Private sources provide the bulk of renewable energy investment globally, exceeding 90 percent in 2016.[6]

An important characteristic of the ongoing energy transition is global momentum. China leads the way with a record-breaking addition

1. *Renewable Capacity Highlights*, IRENA, Abu Dhabi, 2018.
2. *Renewable Power: Climate-Safe Energy Competes on Cost Alone*, IRENA, Abu Dhabi, 2018.
3. *Renewable Power Generation Costs in 2017*, IRENA, Abu Dhabi, 2018.
4. *Id*.
5. IRENA and CPI, *Global Landscape of Renewable Energy Finance, 2018*, IRENA, Abu Dhabi, 2018.
6. *Id*.

of 53 GW of solar and 20 GW of wind power capacity in 2017.[7] In 2018, Germany twice had instances when power demand was met 100 percent with renewable energy and it is consistently operating its grids with a high share of renewables.[8] The European Union recently increased its target for the share of renewables in the energy mix from 27 percent to 32 percent by 2030.[9] With the fifth largest clean energy market in the world, India has set a target of 100 GW of solar and 75 GW of wind power by 2022.[10] Meanwhile, Morocco is working on further expanding the world's largest CSP plant in Ouarzazate. With a capacity of 510 MW of CSP and 70 MW solar PV, the plant will power the homes of over one million people, drastically reducing the country's energy import dependence and providing a template for it to be potentially an exporter of electricity in the future.[11]

Record-breaking prices in recent auctions

Even the largest oil and gas producing economies are actively seeking to harness their renewable energy potential. The energy strategy of the United Arab Emirates – where IRENA is based – targets a cut in carbon dioxide emissions by 70 percent, and 44 percent of its power being generated from clean energy by 2050.[12] Saudi Arabia has recently increased its renewables target for 2023 from 9.55 GW to 27.3 GW.[13] In 2017, the Russian Federation conducted its largest-ever renewable energy auction, awarding contracts for 2.2 GW of renewable capacity.[14]

The private sector is a key driver of the energy transition. As large-scale consumers of energy, corporations can make a noticeable difference in creating demand for renewables. Companies in the commercial and industrial sector account for two thirds of the world's final electricity demand. A recent report by IRENA entitled *Corporate Sourcing of Renewables: Industry and Market Trends* analyses the growing demand, on a global scale, of

7. *Renewable Capacity Statistics 2018*, IRENA, Abu Dhabi, 2018.
8. Climate Home News, *German Renewables meet 100 Percent of Power Demand for Second Time Ever,* 3 May 2018, available at: <www.climatechangenews.com>.
9. European Commission, *Europe Leads the Global Clean Energy Transition: Commission Welcomes Ambitious Agreement On Further Renewable Energy Development in the EU*, 14 June 2018, available at: <http://europa.eu>.
10. « MNRE Releases Roadmap for Achieving 100 GW Solar by 2022 », *PV Magazine*, 27 November 2017, available at: <www.pv-magazine-india.com>.
11. Morocco World News, *Sener to Complete Morocco's Noor Ouarzazate III Solar Plant Soon,* 9 September 2018, available at: <www.moroccoworldnews.com>.
12. *Renewable Energy Market Analysis: GCC 2019*, IRENA, Abu Dhabi, 2019.
13. Power Technology, *Saudi Arabia Resets Renewable Energy Goals*, 22 January 2019, available at: <www.power-technology.com>.
14. Power Technology, *Is Russia Finally Ready to Embrace Renewable Energy?*, 5 December 2018, available at: <www.power-technology.com>.

companies investing in renewables to meet their energy needs and power their businesses.[15] Our findings indicate that in 2017, active corporate sourcing reached a total of 465 TWh, which is in the range of the electricity demand of an entire country such as France.

This momentum includes iconic global companies such as Apple, Google and Microsoft which have already met their target of using 100 percent renewables. Beyond tech giants, manufacturers and other large industrial energy users – such as steel and cement companies, and even oil and gas companies – are also increasingly opting for renewables. Currently, the bulk of corporate sourcing originates from companies headquartered in Europe and the United States, but companies across the globe, including in the Asia Pacific region and Latin America, are starting to recognise the potential of renewables, providing many more opportunities to invest.

The ascent of IRENA as an international organization has gone hand-in-hand with the emergence of renewables as a mainstream source of energy. The formal establishment of the IRENA in 2011 created a much-needed dedicated global framework for cooperation on renewable energy. IRENA's membership has grown to 160 states and the EU, with another 23 states currently in the process of joining. In other words, after only 8 years of existence, the Agency is now approaching near-universal membership. This is a remarkably quick growth for a treaty-based intergovernmental organization at the global level. Today, IRENA serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. It is an organization that supports countries in their transition to a sustainable energy future. The Agency has established itself as the voice of renewables in international decision-making, including at the UN, the G7 and the G20.

Energy transition in the next decades

As the recent report by the Intergovernmental Panel on Climate Change (IPCC) highlighted, there are only 12 years left to keep the global temperature rise below 1.5 degrees Celsius of pre-industrial levels.[16] In combination with energy efficiency, renewables are the key to uncoupling economic growth from the increase in emissions. IRENA's *Global Energy Transformation Roadmap to 2050* shows how renewables and energy efficiency together can provide over 90 percent of the reductions in energy-related

15. *Corporate Sourcing of Renewables: Market and Industry Trends – REmade Index 2018*, IRENA, Abu Dhabi, 2018.
16. IPCC, « *Global Warming of 1.5°C* », Intergovernmental Panel on Climate Change (IPCC), Geneva, 2018.

CO2 emissions necessary to keep the global temperature rise below two degrees Celsius.[17] This would require a share of two-thirds renewables in total final energy consumption by 2050 and the share of renewable energy in electricity generation would need to increase from 25 percent in 2017 to 85 percent by 2050. As power generated from renewables becomes the preferred energy carrier, the share of electricity consumed in end-use sectors such as transport and buildings would need to double from approximately 20 percent in 2015 to 40 percent in 2050.[18]

System-wide implementation of innovation will be crucial to increase the flexibility of our power systems required to integrate these growing shares of renewable energy. Traditionally, intermittent electricity from renewables was balanced exclusively by flexibility on the supply side. Usually, this meant temporarily ramping-up the output of gas or coal-fired plants to make up for the reduced electricity generated by renewables, at times when there is too little sun or wind. But to transform our energy system towards one that is dominated by renewables, flexibility has to be harnessed in all parts of the system, including not only the supply side, but also transmission, distribution and demand. Digitization, storage, and demand-side management are some of the key ingredients to achieve this.

The use of electric vehicles (EVs) as "batteries on wheels" opens up new possibilities for system management. There are today more batteries installed in cars than stationary in power systems.[19] In fact, policymakers worldwide are paying more and more attention to the potential of electrifying end-use sectors such as buildings and transport. Electrified mobility has made significant progress in recent years. Globally, sales are rising rapidly: in the last five years, EV sales have grown at an annual rate of 52 percent. In 2017, over 1 million new EVs were sold, equal to around 1.3 percent of all vehicle sales.[20] By 2050, up to one billion electric cars could be on the road.[21]

Electrified mobility has made significant progress

Cost reductions in enabling technologies such as battery storage are providing further momentum. Our latest report on battery storage, *Electricity Storage and Renewables*, shows that, by 2030, total installed costs could fall

17. *Global Energy Transformation: A Roadmap to 2050*, IRENA, Abu Dhabi, 2018.
18. *Id*.
19. *Electricity Storage and Renewables: Costs and Markets to 2030*, IRENA, Abu Dhabi, 2017.
20. *Innovation Landscape for a Renewable-Powered Future: Solutions to Integrate Variables Renewables. Preview for Policy Makers*, IRENA, Abu Dhabi, 2019.
21. *Global Energy Transformation: A Roadmap to 2050*, *op.cit*.

by between a half to two-thirds, and utility-scale, low cost storage will dramatically increase the capacity for the system-integration of renewable electricity.[22] The efficient use of oversupply of renewable electricity by its transformation into heat and synthetic gas such as hydrogen will also play a role in the long term.

The potential of some renewable energy technologies remains largely untapped. For example, estimates set the technical potential for global geothermal power production at 200 GW,[23] whereas the installed capacity is currently only around 14 GW.[24] Moreover, increased investments in research and development are facilitating the development and commercialization of potential game-changers. A good example are thin-film technologies such as perovskite solar cells which can be incorporated into walls, windows, and other parts of the building besides just rooves.

Our analysis also shows that to achieve global climate objectives, cumulative global investment in the energy system between 2015 and 2050 would need to increase by around 30 percent, from $93 trillion according to current and planned policies, to $120 trillion.[25] This level of investment requires concerted efforts from both the private and public sectors in a targeted manner that improves the risk-return profile of projects and which brings in institutional investors and additional private capital.

Early action to channel investments into the right energy technologies is critical to reducing the scale of stranded assets. The slow progress of emission mitigation to date means that the adoption of a mitigation path as detailed in the *Roadmap to 2050* would result in stranded assets worth more than $11 trillion.[26] The more the energy transition is accelerated, the lower the unnecessary accumulation of energy assets which would otherwise be left stranded.

The deployment of renewables and energy efficiency solutions at the scale required to reach climate objectives would boost global Gross Domestic Product (GDP) by over $50 trillion, creating 11 million additional jobs along the way – not to mention the host of social benefits this would entail, such as improved health, clean water and living environments.[27]

22. *Electricity Storage and Renewables: Costs and Markets to 2030*, 2017.
23. *Geothermal Power: Technology Brief*, IRENA, Abu Dhabi, 2017.
24. *Accelerating Geothermal Heat Adoption in The Agri-Food Sector*, IRENA, Abu Dhabi, 2019.
25. *Global Energy Transformation: A Roadmap to 2050*, *op.cit*.
26. *Id*.
27. *Id*.

Renewables will have a key role to play in achieving universal access to energy, as mandated by the United Nations' Sustainable Development Goal 7. Cost reductions, technology improvements, new business models and local entrepreneurship are making off-grid renewable energy solutions the mainstream option for expanding electricity access, particularly in rural areas, where 87 percent of people who still lack electricity access live. IRENA's report on the *Off-grid Renewable Energy Solutions* estimates that the number of people benefitting from these technologies has expanded six-fold since 2011, reaching over 133 million people world-wide in 2016.[28] Creating access by means of renewable energy solutions is also an enabler of progress on the broader development agenda, including job creation, poverty alleviation, food and water security, education, health and gender empowerment.

While the potential benefits of energy transformation are enormous overall, they will not be evenly distributed and, as usual, socio-economic change could generate both winners and losers. At the same time, the scope of the transformations required is such that it can only be achieved by a collaborative process that involves the whole of society. To generate effective participation, policy-makers would need to consider how to ensure the fair distribution of the costs and benefits of energy transformation. This requires the definition and implementation of mechanisms for sharing the transition costs, while promoting and facilitating structures that allow for the distribution of its benefits. A just energy transition – both at the micro and macro levels – needs to be considered from the outset, in order to minimize the threat of negative socio-economic disruptions and instead to allow those individuals and regions that have been trapped into fossil fuel dynamics to participate fully in energy transformation.

The geopolitics of energy transition

The opportunities the transition brings, and the way they will be taken advantage of, will have very significant impacts even beyond the energy sector. In particular, the developments described above will have profound geopolitical implications, some of which are already materializing today. Just as fossil fuels have played an important role in shaping the geopolitical map over the last two centuries, the energy transition will have implications for the global distribution of power, relations between countries, the risks of conflict, as well as the social, economic and environmental drivers of geopolitical stability.

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28. *Off-grid Renewable Energy Solutions: Global and Regional Status and Trends*, IRENA, Abu Dhabi, 2018.

To understand better the dynamics of this paradigm shift and support the management of the associated challenges and risks, IRENA launched the Global Commission on the Geopolitics of Energy Transformation.[29] The Commission, which is composed of eminent government and business leaders, recently published its recommendations in a report titled *A New World: The Geopolitics of the Energy Transformation*.[30]

The transition is bound to change our very concept of energy security. Renewable energy resources are abundant globally and, if effectively harnessed, they have the power to enhance the energy security of states that currently rely significantly on imports. By switching to renewables, countries traditionally dependent on large energy imports can lower their energy costs and increase their resilience in the face of natural disasters. It is no coincidence that some countries that have been at the forefront of renewable energy deployment have traditionally been heavily dependent on energy imports. Countries that switch from imported fossil fuels to domestically generated renewable energy can improve their trade balance and enjoy significant macroeconomic benefits.

The broad availability of renewable energy sources will also reduce the importance of current energy choke points, such as the narrow channels on widely used sea routes that are critical to global oil supplies. Since renewables are available everywhere, efforts to secure resources will be secondary to the question of how to make best use of them. This means that there will be a move from a competition for resources to a race for innovation. Digitisation, big data, blockchain technologies and the application of artificial intelligence in the energy sector will further catalyse these developments. Countries that are currently at the forefront of the clean energy race can expect to benefit most from the opportunities that the transformation brings, thereby enhancing their global influence.

Solar and wind power require flexible electricity systems

Enabled by a progressive shift from fuels to electricity, producer-consumer relationships will become more variable, and bilateral relations of dependence will eventually be replaced by networks of interdependence. Because variable renewables such as solar and wind power require flexible electricity systems capable of balancing supply and demand in real-time, there are strong economic incentives to expand

29. More information on the Commission can be found at: <www.geopoliticsofrenewables.org>.
30. Global Commission on the Geopolitics of Energy Transformation and IRENA, *A New World: The Geopolitics of the Energy Transformation*, IRENA, Abu Dhabi, 2019.

grid interconnections and thereby increase the size of balancing areas. In the European Union, growing cross-border trade in electricity saves customers from €2.5 to 4 billion annually, creating new energy relationships through a new form of interdependence.[31]

Such interconnections can be strong vehicles for cooperation between countries, which is one of the reasons why clean energy corridors are being developed across Africa and Central America with IRENA's support.[32] If managed properly, these relationships could help make electricity cheaper, they could improve the efficiency of power systems, and they could increase interdependence among nations. But this will require diplomats, along with other government officials, to build the cooperative frameworks that will allow electricity to flow freely in well-regulated and transparent markets. Electricity interconnections can be made between neighboring countries, at a regional scale, and eventually even at an intercontinental scale.

The transition to renewable energy will also reshape international commerce. While trade in fossil fuels will decline, significant new opportunities will arise. Due to the expansion of grid integration across borders, trade in electricity is bound to increase dramatically. In addition, the increased deployment of renewable energy solutions and the modernization of infrastructure will entail growth in trade in clean energy goods and technologies. This includes everything from solar PV panels over smart meters to batteries, but also their components and parts (for example blades for wind turbines or water wheels for hydropower), transmission technology, and related services such as engineering and installation. The global production chain of critical materials for renewable energy technologies will require greater focus and new rules and regulations for trade in electricity and renewables technologies will be needed.

Trade in renewable energy fuels could also grow significantly. In areas that possess an abundant supply of renewable energy, the production of hydrogen formed by electrolysis may become an economically viable option. Besides hydrogen, a host of synthetic fuels could be generated from renewable electricity, including ammonia, methane and methanol. Such fuels allow seasonal storage of renewable electricity (which only pumped hydro has been able to do to date); they can make

31. A. Z. Amin, "The Age of Renewable Energy Diplomacy", *EDA Reflection*, November 2017, Emirates Diplomatic Academy and the IRENA.
32. For more information on the Clean Energy Corridors see: <https://irena.org/cleanenergycorridors>.

use of existing infrastructure such as natural gas pipelines; and also reduce emissions in hard-to-electrify sectors such as aviation and some industrial processes.[33]

While the age of renewables brings with it exciting opportunities, there are also some geopolitical risks that will need to be considered carefully. Countries and regions that have so far relied on the export of fossil fuels will have to make strong efforts to adapt to the changing circumstances and prevent negative disruption to their economies. This could upset international stability especially in regions which already struggle to ensure peace and security. Moreover, the potential accumulation of stranded assets in the fossil fuel sector could lead to instability in financial markets, entailing a crisis with unforeseeable consequences for the global economy. The digitization of the energy sector associated with the application of renewables could also bring with it vulnerability to cyberattacks that manipulate power supplies. While challenges such as cybersecurity threats are not new to diplomats, and do certainly not originate with renewables, they may come to pose specific risks as countries rely increasingly on renewable energy. It will be important for policy makers to pay careful attention to energy as they develop strategies for meeting emerging security challenges. Skilful management can ensure that the negative effects of the energy transition are minimized, allowing the world to profit fully from the age of renewables.

All in all, the benefits of renewables clearly outweigh the risks. The energy transition will promote prosperity and job creation, improve food and water security, and enhance sustainability and equity. Furthermore, it will help to alleviate competition over important natural resources, notably oil, gas, water, and food, which may lead to a decline of related conflicts; and it will help combat air pollution and climate change. Moreover, accelerating the deployment of renewables will increase energy access and offer developing economies an opportunity to leapfrog the fossil fuel-based development model and centralized grids. Renewables bring numerous benefits which address many of the root causes of poverty, marginalization, migration and political instability.

The energy transition is already well underway, bringing with it new opportunities for those who recognize the changing times in time. Considering the ongoing and impending effects of energy transition, governments and industries need to revaluate their situation and outlook

33. *Hydrogen from Renewable Power: Technology Outlook for the Energy Transition*, IRENA, Abu Dhabi, 2018.

in the new world that is evolving, and try to steer their way to economic growth and a sustainable future, while navigating the disruption that a fast-moving transition can bring. Generally, additional efforts are needed to take full advantage of renewables as a cost-effective pathway to mitigate climate change and to reap the socio-economic benefits that energy transition can provide. No one can afford to miss this opportunity.

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Renewables
Fossil fuel
Global warming