IRENA
International Renewable Energy Agency

Accelerating the global energy transformation

EXECUTIVE SUMMARY

Renewable energy is a fundamental and growing part of the world's ongoing energy transformation.

Governments all over the world are joining that consensus. The use of renewables is their prime choice for enhancing access to affordable, reliable and cleaner sources of modern energy services.

More than 170 countries have established renewable energy targets, and nearly 150 have enacted policies to catalyse investments in renewable energy technologies. Many are looking to partner with an increasingly active private sector.

Recent studies by the International Renewable Energy Agency (IRENA) and its partners have shown clearly that renewables are competitive, attractive to investors and creating millions of new jobs. They present a compelling business case.

This edition of *REthinking Energy,* the third in IRENA's series, examines the dramatic changes under way in the energy sector in many countries. Among them is the growing maturity of the renewable energy market, coupled with technology advancements and policy refinement. Together, these developments provide an opportunity to develop an energy system that underpins sustainable development objectives.

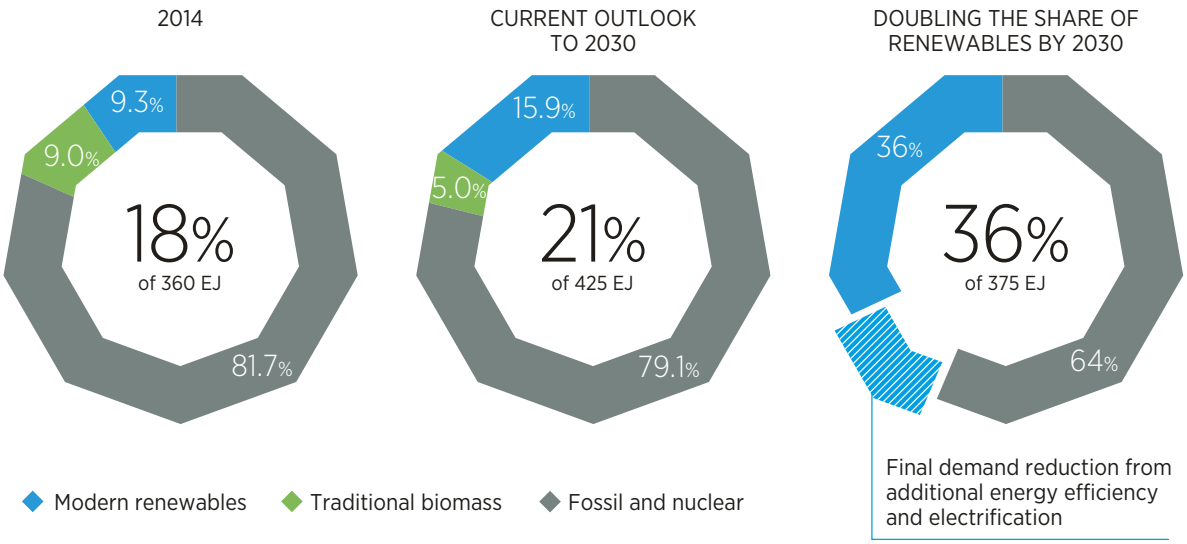
The foundations exist for accelerating the global energy transition, but efforts need to step up to achieve long-lasting change. Policy commitments still need to be strengthened, additional investments catalysed, and technological innovation fostered if new markets are to be geared up, efficiency enhanced and costs driven down even further.

According to nearly every measure, renewable energy is gaining ground. Today, one out of every five units of energy delivered to consumers comes from renewable sources. This is remarkably visible in the power sector, where renewables are growing at unprecedented rates, far outpacing growth in conventional technologies. Since 2012, new generating capacity fuelled by renewables has exceeded that fuelled by non-renewables by a widening margin. At 154 gigawatts (GW), capacity from renewables represented 61% of all new power generating capacity added worldwide in 2015.

Renewables are now the first-choice option for expanding, upgrading and modernising power systems around the world. Wind and solar power, which commanded about 90% of 2015 investments in renewable power, are now competitive with conventional sources of electricity, as their costs have plunged in recent years. The cost of wind turbines has fallen by nearly a third since 2009 and that of solar photovoltaic (PV) modules by 80%. These developments are reflected in the levelised cost of electricity with some renewable technologies having reached grid parity. Currently, onshore wind, biomass, geothermal and hydropower are all competitive or cheaper than coal, oil and gas-fired power stations, even without financial support and despite relatively low oil prices.

Great potential remains for renewables. Currently, the share of renewable energy in total final energy consumption stands at 18.3%. About one-half of this portion is made up of modern renewables, evenly split between electricity and direct heat applications. The other half consists of traditional biomass used for heating and cooking. If all current national plans and policies are fully implemented without additional measures, the share of renewable energy in the total global final energy mix will rise only slightly by 2030 – from 18.3% to 21% – a measure of the extent of unexploited potential (see figure 1).

Figure 1 Estimated and projected share of renewable energy in total final energy consumption, 2014 and 2030, under current outlook and doubling scenario



Renewables will increasingly power the world's growing cities

IRENA envisions a far more ambitious pursuit of all available renewable energy options and of energy efficiency, one that will result in a doubling to a 36% energy share for renewables by 2030. This doubling can be reached with available policy, investment and innovation interventions, while also achieving universal access to modern energy without unsustainable use of biomass. This ambitious goal will require accelerated deployment of modern renewables and energy efficiency measures.

Accelerating the deployment of renewable energy will fuel economic growth, create new employment opportunities, enhance human welfare and contribute to a climate-safe future. Renewables already are a significant source of new employment, accounting for an estimated 9.4 million jobs in 2015 (including large hydropower). Asia is the leading region, and solar PV and bioenergy are the leading technologies. Were the share of renewables to reach 36% by 2030, employment could amount to an estimated 24.4 million.

The socio-economic benefits go well beyond jobs. Doubling the share of renewables could raise global GDP in 2030 by more than a percentage point over the baseline projection, or United States dollar (USD) 1.3 trillion in 2015 dollars – equal to the current combined economies of Chile, South Africa and Switzerland. Doubling would also save up to USD 4.2 trillion annually in avoided expenditures related to climate change and air pollution. In addition, cumulative savings of energy-related carbon dioxide ($CO_{2)}$ emissions could reach 12 gigatonnes.

As the energy transformation quickens its pace, broader and deeper decarbonisation efforts are required. Beyond the power sector, more emphasis needs to be placed on the use of renewable energy for heating and cooling in buildings and industry and for transportation. The growing inclusion of renewables in all end-use sectors will rely on an enabling environment centred on the key dimensions of policy, finance and investment, technology and energy access. Each dimension is presented below.

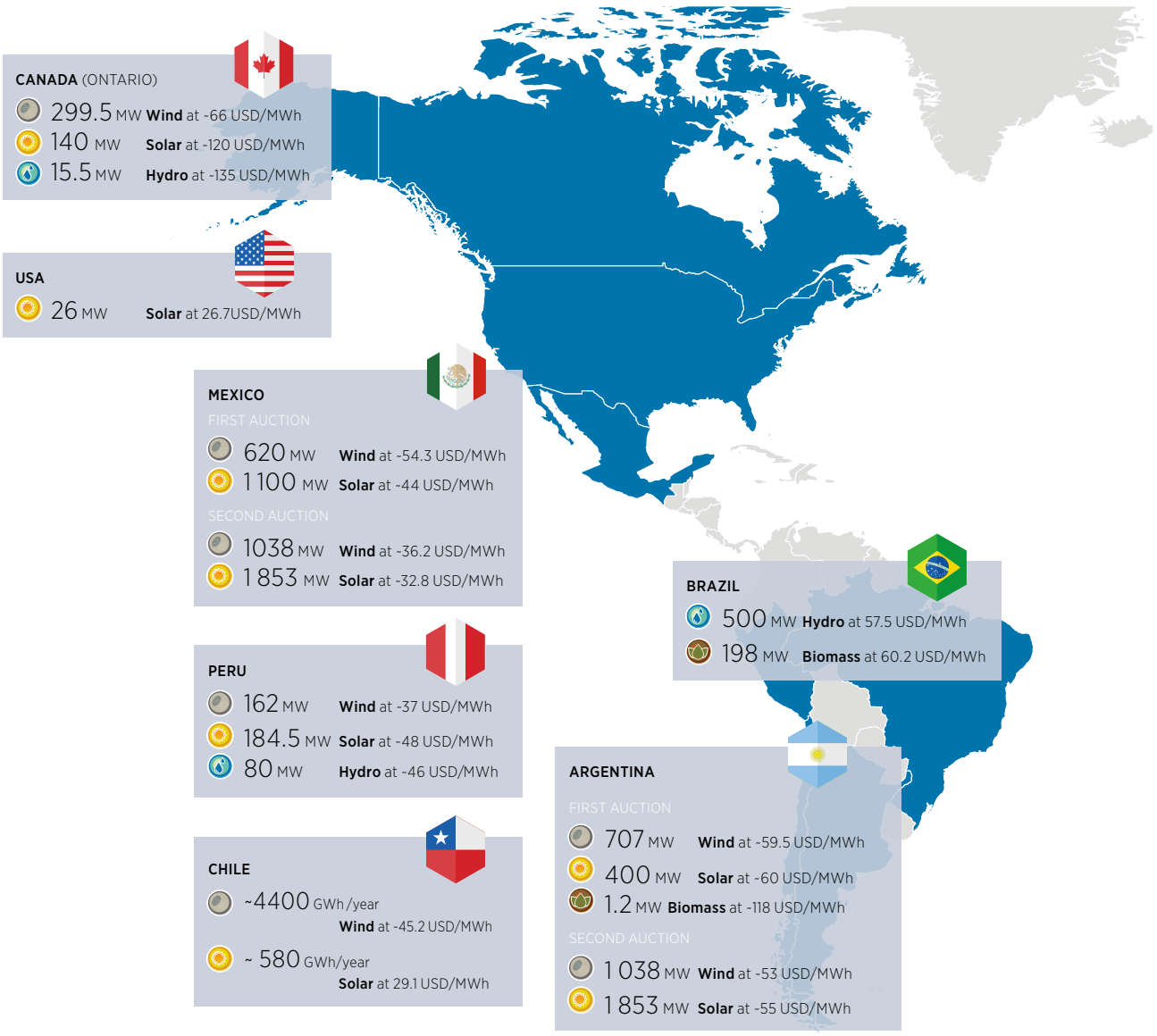
Modern bioenergy has a crucial role to play in the energy transition

Accelerating the energy transformation through policy

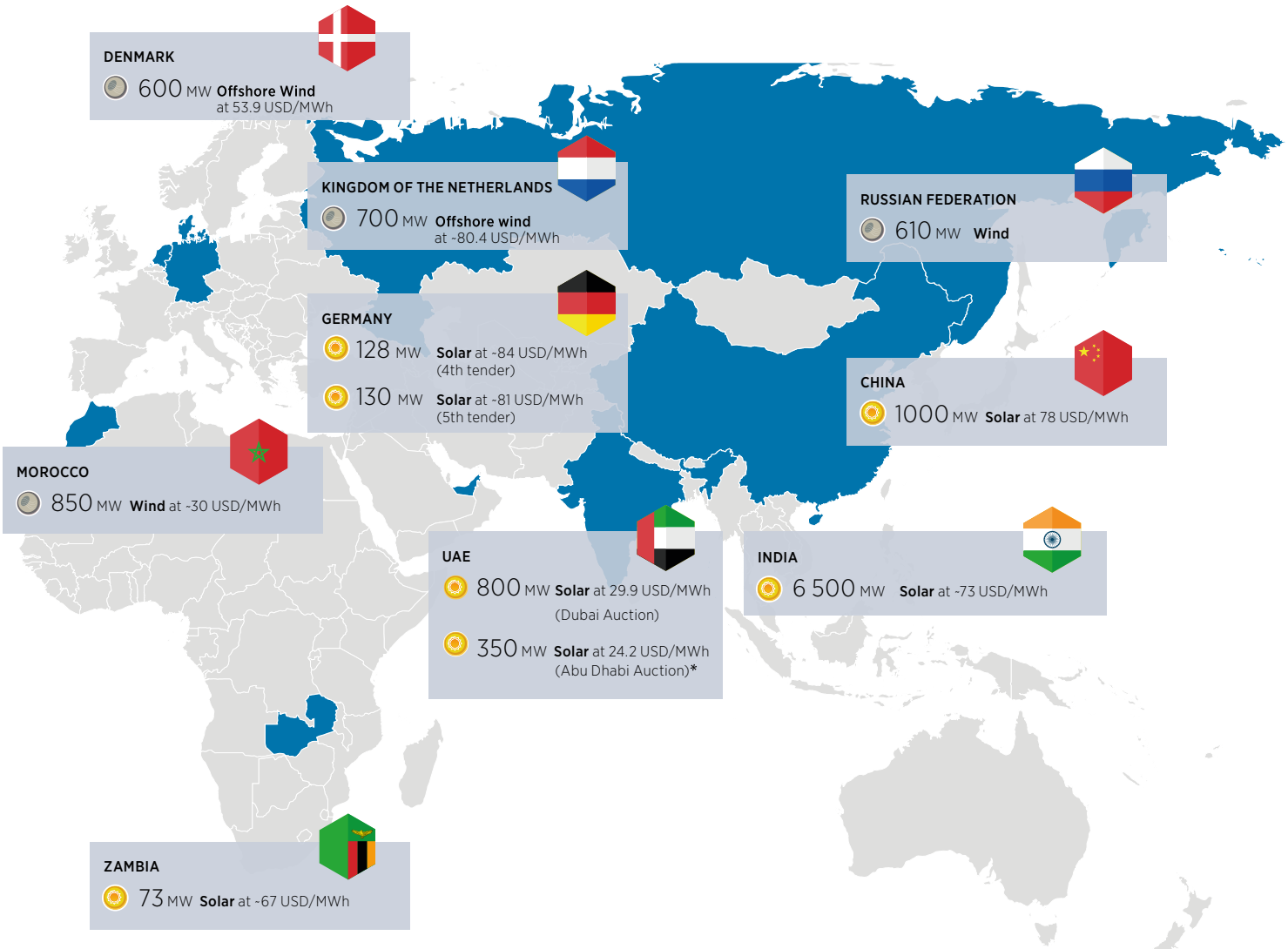
Policies and regulations remain crucial to advance market development. As the renewable energy sector matures and expands, policies are being adapted regularly to suit changing market conditions. Significant recent policy trends have been the gradual shift in the power sector from tariff-based mechanisms to auctions, and the increasing need for additional flexibility measures into the power system.

A growing number of countries have held auctions to deploy renewables in a well-planned but flexible, cost-efficient and transparent manner. At the end of 2016, at least 67 countries had held such auctions, up from only six in 2005. Renewable power auctions throughout 2016 resulted in record-low prices for both solar PV and wind power (see figure 2). Some of the lowest wind power prices were recorded in North Africa, with Morocco achieving a median price at USD 30 per megawatt-hour, for example. Solar PV achieved new price lows in several countries, with a record-breaking bid in the United Arab Emirates (USD 29.9 per megawatt-hour). Understanding the factors behind such results can support the design of future auctions and drive accelerated deployment.

Figure 2 Highlights in renewable energy auctions, 2016



Renewable power increasingly comes from variable and distributed sources. As deployment of solar PV and wind power capacity surges, variable and distributed generation present challenges and opportunities. To capitalise on the opportunities, adjustments are required in power market design, system regulations, and operating procedures. Some of these relate to physical infrastructure, and others are defined by market design regulation. Some draw on supply resources, while others draw on demand-side resources. Some integrate the two. Some solutions are more long term, while others are more or less stop-gap measures. What they all have in common is that they introduce some measure of additional flexibility into the power system. They can be grouped into six categories: supply side, demand side, transmission and distribution networks, storage, market design and system operation and management. Some solutions towards the integration of distributed and variable renewable energy (VRE) sources are already being implemented in some states in the United States and in Denmark, Italy and Germany, for example.



*Based on REN21 (2010-2015) and recent announcements; see **Renewable energy auctions: Analysing 2016** (forthcoming)*

MW megawatts
GW gigawatts
GWh gigawatt-hour

Countries that have awarded renewable energy auctions in 2016

~ Indicates average price resulting from auction

** Reported in March 2017, following initial 350 MW bid (described as "under negotiation" in **REthinking Energy** report released January 2017)*

*** Price undisclosed at time of auction*

The term "country" as used in this material also refers, as appropriate, to territories or areas.

Regulators have begun making the changes needed to integrate variable, distributed renewable power on a large scale. Experience to date indicates that integrating large shares of VRE is not as technically challenging as often thought. Grid operators have successfully integrated VRE well above 30%, and without significantly increasing storage. For example, the grid operated by the German utility 50 Hertz TSO can absorb up to 70% VRE penetration without storage. Denmark, Ireland, Italy, Portugal and Spain have integrated VRE into their national grids successfully. In that process, system design and operation must ultimately be moulded to accommodate the rise of VRE rather than the other way around. At the same time, solutions must be economically efficient, serve system reliability and adequacy, and result in fair and equitable sharing of costs and benefits among all consumers.

Policy makers need to look more closely at heating and cooling for buildings and industry, and at the potential of renewables to fuel transport. Together, these end-use sectors account for most (60%) of energy-related CO_2 emissions. The good news is that some cost-effective renewable energy options are already available to meet these needs. Indeed, electric mobility as well as renewables-based thermal solutions will play a critical role in the future energy system. In addition, potential synergies between the power sector and end-use sectors call for a more holistic approach to energy policy. Combined with continued advances in energy efficiency, sector coupling will likely become the key to realising the full potential of renewable energy in the overall energy system.

Variable renewable sources can be integrated successfully on a large scale with existing power grids

Scaling up investment for a renewable future

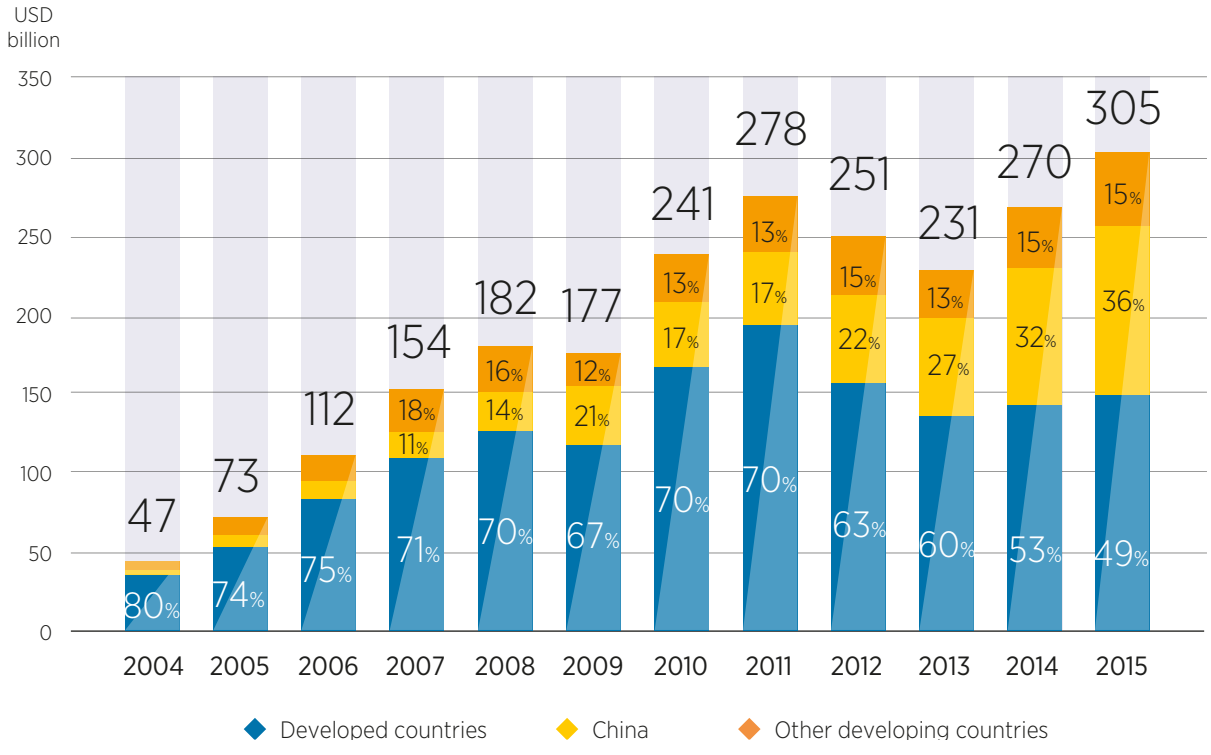
Global investment in renewables has shown steady growth for more than a decade, rising from less than USD 50 billion in 2004 to a record USD 348 billion in 2015 (BNEF, 2016a), including large-scale hydropower (see figure 3). For the first time, in 2015, developing countries attracted the majority of renewable energy investments, with China alone accounting for about one-third of the global total. Growth in 2015 was due primarily to solar and wind power, which together accounted for about 90% of total global investments.

Current investment levels, however, are insufficient to meet international climate goals. Despite the new records set in 2015, total investment in renewable energy falls short of the estimated average annual investment of at least USD 770 billion that will be needed between 2016 and 2030 to double renewable energy's share in the global energy mix.

Targeted use of public funds to cover early-stage financing and offer guarantees for some of the investment risks can have a significant impact on the sector's attractiveness to private investors. To achieve a major scaling up of investment, limited public funds need to be used in a way that maximises the mobilisation of private finance, including from large-scale institutional investors. This means a shift from traditional public financial instruments (*e.g.* grants and loans) toward risk-mitigation instruments such as guarantees that cover political, currency and power-offtake risks.

New capital-market instruments are helping to increase available finance by offering new groups of investors access to renewable energy investment opportunities. Green bonds for example have grown very rapidly over the past few years. In 2015, nearly half of the USD 41.8 billion in green bond–labelled proceeds went to renewable energy, with India and China at the forefront of expansion. The yield company (yieldco) is an instrument that helps to mobilise equity finance for renewable energy and improve market liquidity. After a period of consolidation in 2015, the market seems to be picking up again.

Figure 3 Global investment in renewables, and share by geography, 2004-2015



Institutional investors are increasingly moving into renewable energy investment. Particularly in Europe, several pension funds have invested in large wind projects. In principle, renewables are an appealing asset class for institutional investors because they offer stable returns over the long term. But the relatively small size of projects and the limited track record of renewables in new markets must be overcome. Certain institutional investors have shown growing interest in renewables in emerging markets, driven by strong support policies and regulations, and good resource potential, among other factors. In these same markets, domestic pension funds may become an important source of capital. Unlocking large-scale investments by domestic and foreign institutional investors will require continued focus on building pipelines of large-scale, investment-grade projects or through aggregation portfolios of smaller projects.

New business models promise new ways to finance renewable energy. The use of leasing is spreading beyond the solar PV market in the United States to Europe, China, India, the Pacific and, more recently, Africa. Leasing, with or without securitisation, has helped bridge the divide between investors and users of decentralised solar PV installations.

In a similar way, energy service companies (ESCOs) are reducing financial and other long-term risks related to large-scale renewable heating and cooling systems. Another emerging business model involves corporate sourcing of renewable energy. More and more large corporations are opting for direct procurement of renewable electricity to power their operations and supply chains – often through power purchase agreements.

Renewable energy brings a broad array of socio-economic benefits

Ground-breaking and affordable technologies

Technological advances and falling costs are driving the adoption of renewable energy around the world, with the power sector leading the way. No technology shows this more clearly than solar PV. Global PV capacity soared from 40 GW in 2010 to 219 GW in 2015, when it accounted for approximately 20% of all newly installed power generation capacity.

Dramatic cost reductions have opened new markets for rapid growth. Solar PV costs – now half of what they were in 2010 – could fall by another 60% over the next decade. Utility-scale projects are economically competitive with new fossil-fuel generation, and solar PV is competing without financial support even in regions with abundant fossil fuel resources. Solar PV is poised to revolutionise the electricity system, enabling consumers to produce power for their own needs and feed surplus energy into the grid.

Electricity from small-scale distributed PV already is cheaper than power from the grid in several countries, and PV is often the least-expensive option for remote or off-grid regions. Innovations in production techniques and in the development of technologies that are more efficient, more adaptable, lighter and cheaper will enable the use of solar PV not only on the ground and on rooftops, but also on building facades, windows, roads and other surfaces – developments that will make possible large-scale integration of solar PV into the world's cities and beyond.

Solar PV will grow the fastest in terms of capacity and output. Solar PV will account for as much as 7% of global power generation by 2030 – a six-fold increase from today. Ongoing technological innovations, continuing economies of scale, additional automation in production, and economic pressures all will push costs down further. IRENA estimates that the levelised cost of electricity for utility-scale PV could fall by more than half between 2015 and 2025, and that global solar PV capacity could reach 1,760 GW by 2030.

New means for storing electricity will open the door for vast growth in VRE generation. Storage can add flexibility to power system infrastructure, operation, and market design, bridging gaps between supply and demand across space and over time. Among storage technologies, batteries have shown the most growth in recent years, driven primarily by the fast-growing market for electric vehicles and the deployment of VRE capacity. Batteries will play an important role in integrating VRE into existing electric grids and in the ongoing effort to provide access to the millions of people who are still without electricity.

Battery storage for electricity could increase from less than 1 GW today to 250 GW by 2030, according to IRENA estimates. The market value of battery storage reached USD 2.2 billion in 2015 and is expected to rise to USD 14 billion by 2020. In parallel, the costs of battery storage are declining. The cost of lithium-ion batteries, for example, has dropped to USD 350 per kilowatt-hour (kWh) (a 65% decline since 2010) and is expected to fall below USD 100/kWh in the next decade. Further advances in electricity storage can be unlocked through standards and policies that recognise and reward its present viability and future potential.

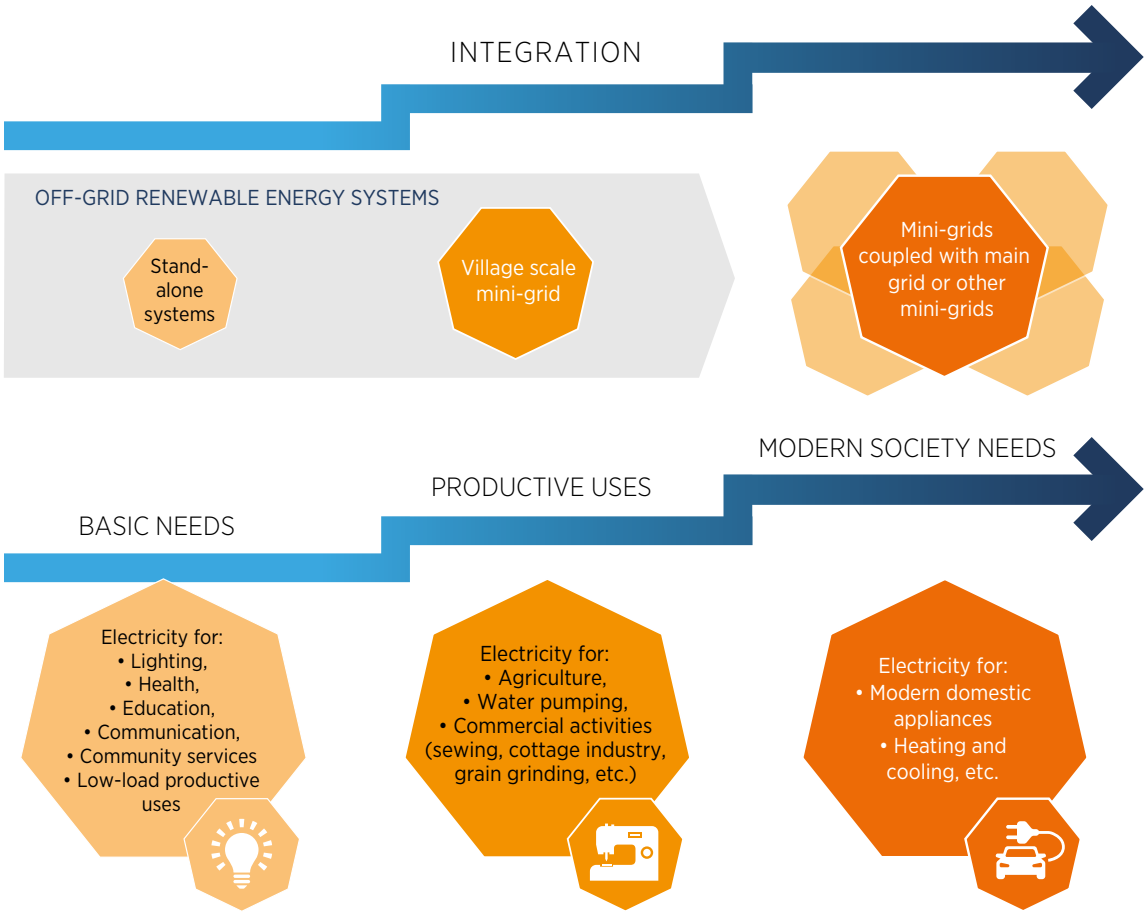
Modern, renewable-based energy services for all

Given the likely pace of grid-extension efforts, nearly 60% of the additional power generation needed to achieve universal electricity access by 2030 will come from off-grid solutions. Stand-alone and mini-grid solutions powered by renewables already provide electricity to nearly 90 million people[1] and meet a hierarchy of needs, from basic lighting to productive uses, thereby enabling people to climb the energy ladder. They are cost-effective and can be installed in modular fashion, linked to grid-extension plans (see figure 4).

Off-grid deployment depends on the right combination of policies, financing, technology and institutional capacity. Experience to date highlights the importance of stable policy and regulatory frameworks dedicated to the off-grid market; focused, adequate and streamlined institutional structures and procedures; relevant skills and training; customised financing and business models tailored to the electricity services required and to local conditions; and innovative technologies that capitalise on the scalability of renewables and on opportunities for demand-side management and efficiency.

Recent experience with mini-grids suggests the need for changes in policies and regulations. Legal and licensing provisions, for example, should be designed to minimise development costs and uncertainties. The risk to project developers of early arrival of the main grid should be mitigated through a combination of reliable rural electrification master plans and well-defined interconnection and compensation mechanisms. In addition, policy measures to facilitate access to finance are needed to improve access to equity, debt and grant financing at different phases of mini-grid development.

Figure 4 Off-grid renewable energy and energy access



[1] Bloomberg New Energy Finance and Lighting Global (2016), *Off-grid Solar Market Trends Report 2016,* commissioned by World Bank Group, Washington, D.C

Renewables in support of the Sustainable Development Goals (SDGs)[2]

Renewables are key to the goal of ensuring "access to affordable, reliable, sustainable and modern energy for all" (SDG7). Many energy solutions based on renewables are cost-effective, readily available, and easily customisable, providing sources of energy services that sustain livelihoods and improve human well-being.

Sustainable energy deployment reinforces other key goals (see figure 5). Renewables contribute to environmental sustainability by mitigating the local and global environmental impacts associated with energy consumption.

They create conditions to further human development by facilitating access to basic services, improving human health and enhancing incomes and productivity. Renewables also create new jobs and spawn new local industries.

Figure 5 Affordable and clean energy supports all Sustainable Development Goals

[2] Adopted as part of the United Nations-backed *2030 Agenda for Sustainable Development* and reinforced by the Paris Climate Agreement.

Renewables offer equally powerful solutions to problems of local and global environmental sustainability. At the global level, the most critical environmental impact of energy production and use is its contribution to climate change (SDG13). Renewable energy, combined with energy efficiency, gives the world a realistic chance of keeping the rise in global temperature below 2°C while also reducing air pollution. At the local level, renewables have a key role to play in the transition to sustainable urban energy (SDG11), including energy for heating and cooling, local power generation and powering electric vehicles. Well-designed renewable energy projects can avoid negative effects of energy production and use on ecosystems and biodiversity (SDG15).

Renewable energy contributes to human development and well-being. By providing basic energy needs in a clean and sustainable manner, renewables bring wider benefits for health, gender equality and educational opportunity. More than four million people die prematurely each year from illnesses attributable to indoor air pollution from cooking with traditional biomass and inefficient cookstoves. This hazard can be alleviated by off-grid renewables for household uses, combined with improved cookstoves (SDG3). For the one billion people who depend on health facilities in remote and rural areas that presently lack electricity[3] renewable energy can improve health services. By reducing or eliminating the time required to gather firewood, modern renewables can also free up time for women and girls to pursue an education (SDGs 4 and 5) or income-generating activities. Electricity also provides high-quality lighting at school and at home, as well as access to information technology.

A new paradigm is forming

The rapid growth of renewables reflects commitment by governments around the world in response to pressing challenges and emerging opportunities. Most countries have adopted national targets, formulated ambitious policies, and devised innovative investment and technology strategies. The private sector is also playing a critical role in scaling up deployment, signalling a near-global consensus that renewable energy technologies will be the engines of sustained economic growth and development.

Accelerating the pace of the energy transition and expanding its scope beyond the power sector will bring substantial social, economic and environmental benefits. With renewables, the economic growth on which the world's poor have pinned their hopes can be achieved in sustainable, environmentally friendly ways. Without them, international efforts to arrest climate change cannot succeed.

We are already embarked on a far-reaching transformation of the global energy system that presents a historic opportunity. If we are able to enter a grand global bargain that offers for the first time a real chance to overcome the developmental, environmental and social challenges of today's world with a technologically feasible and economically beneficial pathway to a sustainable future, we will have secured the future for our children and grandchildren.

See the **REthinking Energy 2017** report: **www.irena.org/rethinking**

[3] World Health Organization and World Bank (2014),
Access to Modern Energy Services for Health Facilities in Resource-Constrained Settings, WHO, Geneva

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