

REthinking Energy

2014



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The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. www.irena.org

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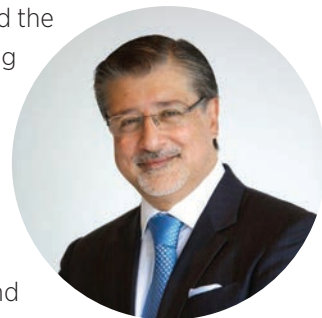
REthinking Energy

TOWARDS A NEW POWER SYSTEM



FOREWORD

The global energy system is undergoing a transformation. Around the world, renewable energy has gone mainstream and is advancing at extraordinary speed. Costs are plummeting, millions of jobs are being created, and growth in clean power is outpacing all competitors. Combined with international efforts to curb climate change, calls for universal access, and a growing demand for energy security, I believe it is no longer a matter of whether but of when a systematic switch to renewable energy takes place – and how well we manage the transition.



That is why I am delighted to launch the 2014 edition of IRENA's new series, *REthinking Energy*. It is the first instalment of what I hope will become a definitive series exploring the changes that are transforming the way we produce and use energy, and how they will affect governments, businesses and individual citizens alike.

The first edition of *REthinking Energy* focuses on the power sector. While progress is being made across the spectrum of energy use, it is electric power that has driven much of the current transformation, and which continues to make the headlines.

The power sector is changing so fast that policy makers are finding it hard to keep up. Solar photovoltaic costs alone fell by two thirds between the end of 2009 and 2013: a speed of change comparable to that seen in the IT revolution. In Denmark, wind recently became the cheapest energy source of all, beating out even coal. In Germany, almost half of all renewable generation is now owned by households and farmers, marking a profound shift in control.

This report offers a chance for opinion leaders to take stock of the state of play, to explore the drivers of this transformation, and to ask important questions about its impact. Let us make no mistake: this is no business-as-usual evolution. A world in which power generation is distributed, in which a billion more people gain access to affordable electricity, in which countries shed their dependence on imported fossil fuels, and in which harmful emissions are made a thing of the past, is a very different world to the one we have today.

It is an exciting time to be in energy. If this publication can open more eyes to the moment at hand, and give a sense of the magnitude of the transformation, it will have succeeded.

Adnan Z. Amin

Director-General
International Renewable Energy Agency

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ACRONYMS

BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BNEF	Bloomberg New Energy Finance
BoS	Balance of Systems
BRL	Brazilian Real
CIF	Climate Investment Fund
CO₂	Carbon dioxide
CSP	Concentrated Solar Power
EDF	Electricité de France
EDP	Energias de Portugal
EIB	European Investment Bank
EUR	Euro
FS	Frankfurt School
g	Gram
GCF	Green Climate Fund
GDP	Gross Domestic Product
GE	General Electric
GW	Gigawatt
GWEC	Global Wind Energy Council
GWh	Gigawatt-hour
IDCOL	Infrastructure Development Company Limited
IEA	International Energy Agency
IEA-ETSAP	International Energy Agency - Energy Technology Systems Analysis Program
IMF	International Monetary Fund
IOREC	International Off-Grid Renewable Energy Conference
IPCC	Intergovernmental Panel on Climate Change
IRELP	IRENA Renewable Energy Learning Partnership
IRENA	International Renewable Energy Agency
kWh	Kilowatt-hour

LCOE	Levelised Cost of Electricity
LCR	Local Content Requirement
LNG	Liquefied Natural Gas
MNRE	Ministry of New and Renewable Energy (India)
MW	Megawatt
MWh	Megawatt-hour
OECD	Organisation for Economic Co-operation and Development
PPA	Power Purchasing Agreement
ppm	Parts per million
PV	Photovoltaic
PwC	PricewaterhouseCoopers
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme (South Africa)
REN21	Renewable Energy Policy Network for the 21st Century
SE4ALL	United Nations' Sustainable Energy for All initiative
SHS	Solar Home System
TWh	Terawatt-hour
UN	United Nations
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	U.S. Agency for International Development
USD	U.S. Dollar
WACC	Weighted Average Cost of Capital
WHO	World Health Organization
WRI	World Resources Institute
WWEA	World Wind Energy Association

EXECUTIVE SUMMARY

An alignment of economics, demographics, climate change and technology has set in motion an ongoing transformation of the global energy system.

Growing populations, with improved living standards and increasingly concentrated in urban centres, have dramatically raised the demand for energy services. At the same time, a growing consensus over the dangers posed by climate change has prompted people and governments worldwide to seek ways to generate that energy while minimising greenhouse gas emissions and other environmental impacts.

Rapid technological progress, combined with falling costs, a better understanding of financial risk and a growing appreciation of wider benefits, means that renewable energy is increasingly seen as the answer. REmap 2030, a global roadmap developed by the International Renewable Energy Agency (IRENA), shows that not only can renewable energy meet the world's rising demand, but it can do so more cheaply, while contributing to limiting global warming to under 2 degrees Celsius – the widely cited tipping point for climate change.

A technology once considered as niche is becoming mainstream. What remains unclear is how long this transition will take, and how well policy makers will handle the change.

As this transformation gets underway, it will affect every aspect of society. *REthinking Energy*, a new series by IRENA, will explore how renewable energy is financed, produced, distributed and consumed, and will chart the changing relationships it is bringing about between states, corporations and individuals.

This first volume focuses upon the power sector. It tells a story – about the trends driving this change, how the technology is evolving, who is financing it, and the wider benefits it will bring. Finally, it examines what an energy system powered by renewables might look like and how policy makers can further support the transformation.

Why the world of energy is transforming

At the heart of the energy transformation lies demand, the aim to strengthen energy security and the imperative of a sustainable future.

Over the past 40 years the world's population grew from 4 billion to 7 billion people. An increasing proportion is middle class and living in cities. During the same period, electricity generation grew by more than 250%.

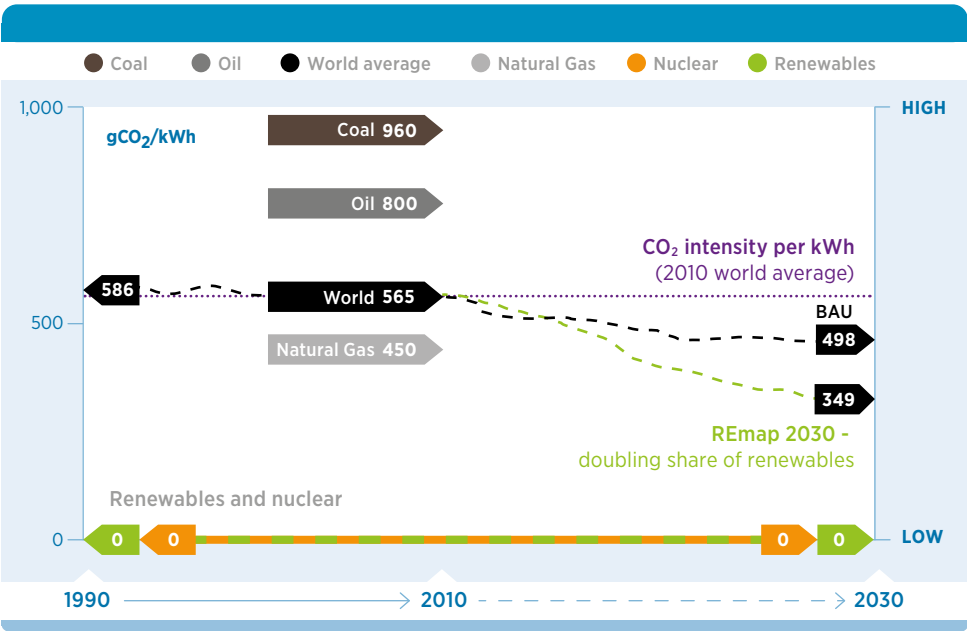
This growth will continue. In 2030 there will be more than 8 billion people, with 5 billion in urban conglomerations. Global spending by the middle classes is expected to more than double, from USD 21 trillion in 2010 to USD 56 trillion in 2030. World electricity generation is forecast to grow by 70% from 22,126 terawatt-hour (TWh) in 2011 to 37,000 in 2030.

But this energy is coming at a cost. There is growing consensus on the threat of climate change brought on by increasing atmospheric concentrations of greenhouse gases, prompting worldwide efforts to reduce emissions.

If business continues as usual, these efforts will not succeed. The average emissions intensity of electricity production has barely changed over the past 20 years. Gains from the increasing deployment of renewables, and less intensive fossil fuels such as natural gas, have been offset by less efficient power plants and the rising use of coal. Without a substantial increase in the share of renewables in the mix, climate change mitigation will remain elusive.

REmap 2030 shows that under current policies and national plans (business as usual case), average carbon dioxide (CO₂) emissions will only fall to 498 g/kWh by 2030. That is insufficient to keep atmospheric CO₂ levels below 450 parts per million (ppm), beyond which severe climate change is expected to occur. A doubling in the share of renewables could help mitigate climate change by reducing the global average emissions of CO₂ to 349 g/kWh – equivalent to a 40% intensity reduction compared to 1990 levels, as seen in the figure below.

CO₂ emissions intensity per kWh – 2030 outlook



Source: International Energy Agency (2010) and IRENA (2014a)

There is also increasing concern about the direct health impact of burning fossil fuels as fast-growing economies confront rapidly declining air quality and a sharp rise in respiratory disease. The United States Environmental Protection Agency recently

found that ill health caused by fossil fuels nationally costs between USD 362 billion and USD 887 billion annually. The European Union's Health and Environment Alliance found that emissions from coal-fired power plants cost its citizens up to EUR 42.8 billion in yearly health costs. Localised catastrophes, such as the Deepwater Horizon oil spill in the United States, or the Fukushima nuclear accident in Japan, are becoming global news with profound implications. Governments have taken note.

Countries are increasingly looking to reduce their dependence on imported fossil fuels. By reducing energy imports, countries are striving for greater energy independence; avoiding potential supply disruptions (for example, in case of conflicts or disasters), high energy prices and price fluctuations.

There is growing pressure, meanwhile, to bring electricity to the 1.3 billion people currently without electricity access, many in remote areas, for whom traditional large-scale power plants and transmission systems have not yet provided an answer. Also, 2.6 billion people rely on traditional biomass and cook using traditional stoves that cause severe health impacts.

These trends have prompted a widespread conviction that something has to change. Fossil fuels powered the first industrial revolution, but even in the new era of shale oil and gas, questions remain about their compatibility with sustainable human well-being. The stage is set for the era of modern renewable energy that is cost competitive, mainstream and sustainable.

The cost of renewable energy plummets as deployment increases

Large-scale hydro, geothermal and biomass power have been competitive for some time, but for many years wind and solar power struggled to compete with coal, oil and natural gas. Over the past decade, however, and in particular over the last five years, that picture has changed dramatically.

Renewable energy technologies have grown more robust and more efficient and are increasingly able to generate power even in suboptimal conditions such as low wind speeds and low solar irradiation. Energy storage technologies are improving fast. Buoyed by state support in Europe and the United States, and boosted by the rise of new manufacturing powerhouses such as China, costs have plummeted. These trends are illustrated in the graphic below which charts the levelised cost of electricity (LCOE) for different forms of utility and off-grid power.

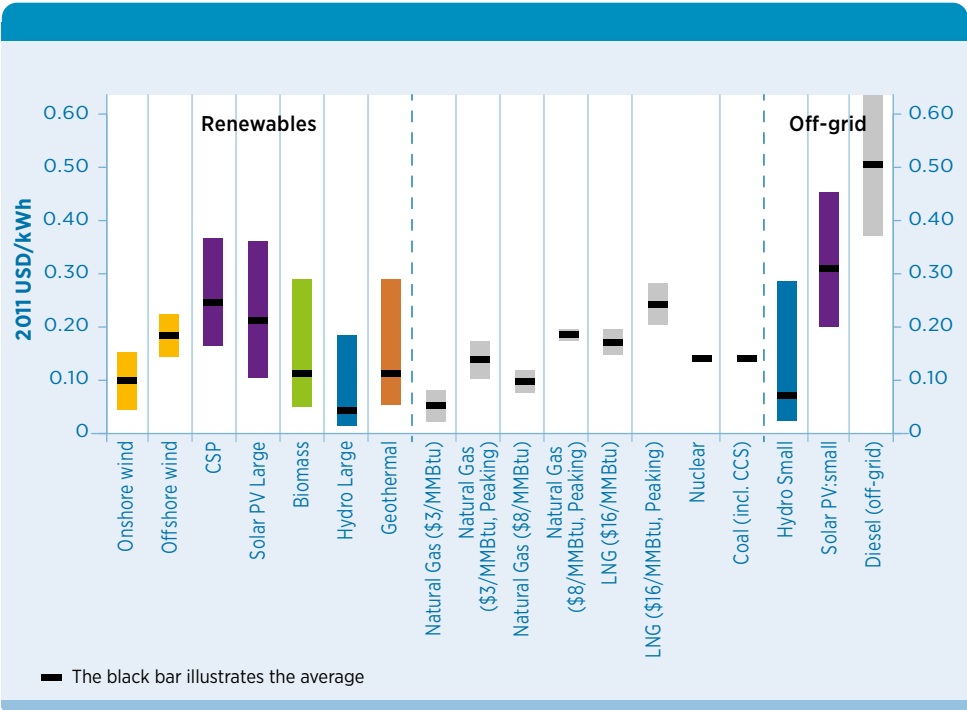
Solar photovoltaic (PV) prices have fallen by 80% since 2008 and are expected to keep dropping. In 2013, commercial solar power reached grid parity in Italy, Germany and Spain and will do so soon in Mexico and France. Increasingly, solar PV can compete

without subsidies: power from a new 70 megawatt (MW) solar farm under construction in Chile, for example, is anticipated to sell on the national spot market, competing directly with fossil fuel-based electricity. The cost of onshore wind electricity has fallen 18% since 2009, with turbine costs falling nearly 30% since 2008, making it the cheapest source of new electricity in a wide and growing range of markets. More than 100 countries now use wind power. Offshore wind is also expected to grow rapidly as costs fall, with the United Kingdom leading the market with 4.2 gigawatts (GW) of installed capacity as of mid 2014.

These and other developments have made renewables increasingly attractive in many more markets. In 2013, for the first time, new renewable capacity installations were higher in countries not members of the Organisation for Economic Co-operation and Development (OECD). China's deployment of solar PV and wind in 2013 was estimated at 27.4 GW: nearly four times more than the next largest, Japan.

Worldwide, renewable power capacity has grown 85% over the past 10 years, reaching 1,700 GW in 2013, and renewables today constitute 30% of all installed power capacity. The challenge has moved on from whether renewable energy can power modern lifestyles at a reasonable cost – which we now know it can – to how best to finance and accelerate its deployment.

LCOE for utility and off-grid power – OECD countries (ranges and average)



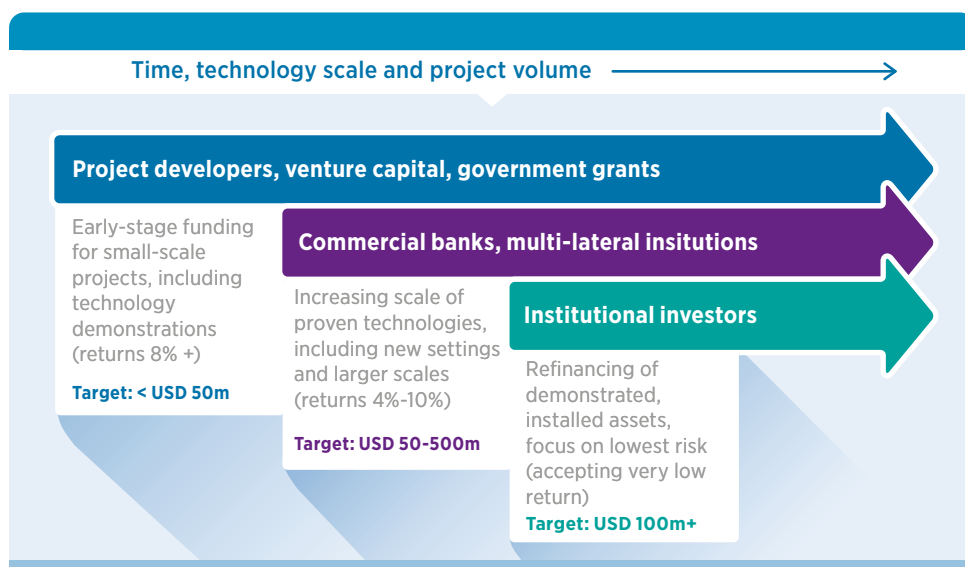
Source: IRENA Costing Alliance (n.d.) for renewable energy technologies and PwC database for non-renewable energy technologies.

Financing renewables is getting cheaper, and easier

Renewable energy is competitive on a cost per kilowatt-hour basis. As most renewable technologies have a relatively high ratio of upfront to operating costs, their viability is particularly sensitive to the cost of capital. That is why government financial support has traditionally been critical for promoting renewables. However, as the technology has grown more competitive and pressure on budgets has increased, governments have been reducing their support.

The good news is that private finance is increasingly ready to step in. Due to growing experience, developers are getting better at forecasting cash flow and financiers are more able to accurately assess risk. The cost of capital is falling and products are being tailored for a wider range of investors, from small-scale communities to large institutions. Crowdfunding initiatives can also be used to attract capital, especially in developing countries where cost of capital is traditionally high. The figure below shows how sources of renewable energy investments evolve with increasing maturity of technologies and markets.

Investment progression through technology and market development stages



At the other end of the scale, institutional investors are also starting to get interested. They are increasingly taking into account the risk attached to fossil fuels and new long-term, low-risk instruments are being created to encourage them to invest in renewables. Early-mover private developers in this space attracted USD 11 billion in 2013, up 200% in 12 months.

Large non-energy corporates are also becoming involved. For example, IKEA's turbines and solar panels now produce 37% of its energy consumption, and Google has invested over USD 1.4 billion in wind and solar – in most cases because of attractive financial returns.

But these positive trends are not yet enough. Total investment in renewable energy rose from USD 40 billion in 2004 to USD 214 billion in 2013 (excluding large hydropower). This falls short of the USD 550 billion needed annually until 2030 to double the global share of renewable energy and avert catastrophic climate change.

Policy makers have an important role to play. If they make it clear that renewable energy will be a larger part of their national energy mix, and commit to long-term, non-financial support mechanisms, they could reduce uncertainty and attract more investors. In emerging markets, public financing will remain important as domestic structures to support the deployment of renewables are developed. In this context, international cooperation and financial flows play an increasingly prominent role. With increasing competitiveness, financial support can gradually and predictably be scaled back, focusing instead on grid improvements, education and industry standards, which strengthen the market as a whole.

There is also an opportunity for traditional power utilities to do more. Joint projects between large utilities, small developers and clients could be a way forward, as business models adapt to the changing market conditions.

The wider benefits of renewable energy

There is growing evidence that renewable energy has a positive ripple effect throughout society, simultaneously advancing economic, social and environmental goals. Its costs and benefits are best understood not within traditional policy silos, but as part of a holistic strategy to promote economic prosperity, well-being and a healthy environment.

Renewables are good for a country's economy. A recent Japanese study, looking at a 2030 target of 14%-16% renewables, found the benefits were 2-3 times higher than the costs – including savings in fossil fuel imports, CO₂ emissions reductions and economic ripple effects. Spain's use of renewables avoided USD 2.8 billion of fossil fuel imports in 2010, while Germany saved USD 13.5 billion in 2012. For fossil fuel-exporting countries, deploying renewables at home makes more resources available for sale overseas.

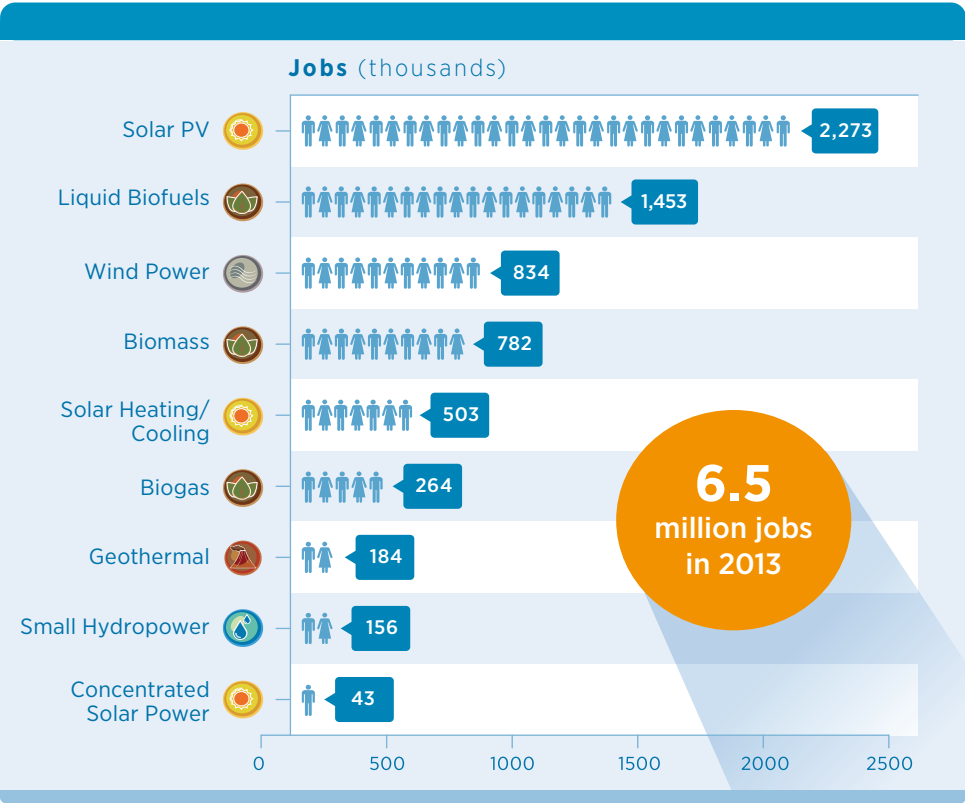
The benefits are felt through the value chain as renewable energy stimulates domestic economic activities and creates employment. In 2013, it supported 6.5 million direct and indirect jobs – including 2.6 million in China, as illustrated in the figure below.

Renewables can also bring electric power to people currently left off the grid, promoting productive uses, spurring education, allowing access to modern communications and offering a host of new opportunities.

The environmental benefits are just as compelling, on both local and global levels. Most renewables do not deplete finite resources (although water may be needed for cleaning and cooling, which can be a challenge in arid countries). Renewables also reduce the risk of ecological disasters.

Crucially, they offer a route to reducing greenhouse gas emissions, a major cause of global warming. Electricity alone accounts for more than 40% of man-made CO₂ emissions today. Solar, wind, nuclear, hydroelectric, geothermal and bioenergy are, across their lifetime, 10-120 times less carbon intensive than the cleanest fossil fuel (natural gas)

Renewable energy employment by technology



Source: IRENA (2014e)

and up to 250 times lower in carbon than coal. REmap 2030 estimates that doubling the share of renewables in the energy mix, coupled with greater energy efficiency, can keep atmospheric CO₂ below 450 ppm – the level beyond which catastrophic climate change would occur.

A new industrial paradigm?

As the share of renewable energy grows, the structure of the industry and the nature and role of power producers are undergoing change. A sector once dominated by large utilities is becoming more decentralised, diverse and distributed. In Germany, almost half of all renewable energy is now in the hands of households and farmers, and only 12% of renewable assets are owned directly by utilities.

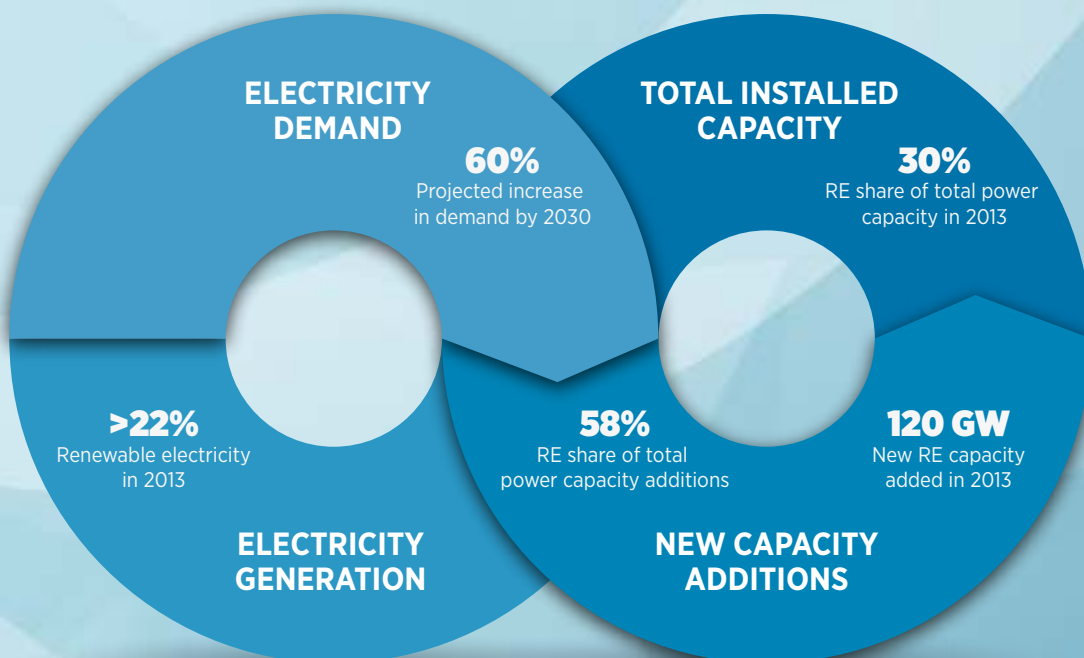
New storage technologies, and smart technologies to support better demand-side management, will grow in importance – creating a whole new ancillary industry of smart appliances. In many emerging markets, renewables are already the most economic power source for off-grid and mini-grid systems. As with the shift from fixed telephony to mobile phones, many countries have an opportunity to leapfrog the development of a fixed network by moving to a flexible system of multiple, interconnected mini-grids.

These and other trends require a different way of thinking about energy, shifting from a system dominated by a few centralised utilities, to a diverse, distributed system, where consumers are also producers, with far more control over how and when they use energy.

Policy makers can do much to either promote or hinder this vision. Renewable energy investors need stable and predictable policy frameworks, which recognise the system-level benefits renewable energy can bring. They need a level playing field, including cutting back on the substantial subsidies currently enjoyed by fossil fuels worldwide. And they need a supportive grid infrastructure, including more regional interconnections to take advantage of synergies between different forms of renewable power.

Rethinking energy means policy makers need to consider the benefits of renewable energy as a whole, linking areas previously considered unrelated – such as healthcare, rural development and governance. Herein lies the biggest change: adopting a truly holistic approach, which not only takes into account the interests of short-term growth, but provides the opportunity of sustainable prosperity for all.

The changes at hand offer the potential for a new industrial revolution – creating a renewables-based system, which enhances access, health and security, creates jobs and safeguards the environment. The technology is ready to deploy. People, businesses and governments must now embrace its potential.



1 The world of energy is transforming

Burgeoning populations, increasing urbanisation and sustained economic growth have led to an exponential rise in the demand for energy services, particularly in developing countries. At the same time, growing concerns over climate change and the environmental impact of fossil fuels are causing many governments and communities to seek lower-impact options. Rapid technological progress means that renewable energy has become an increasingly viable and cost-effective option, while contributing to energy security.

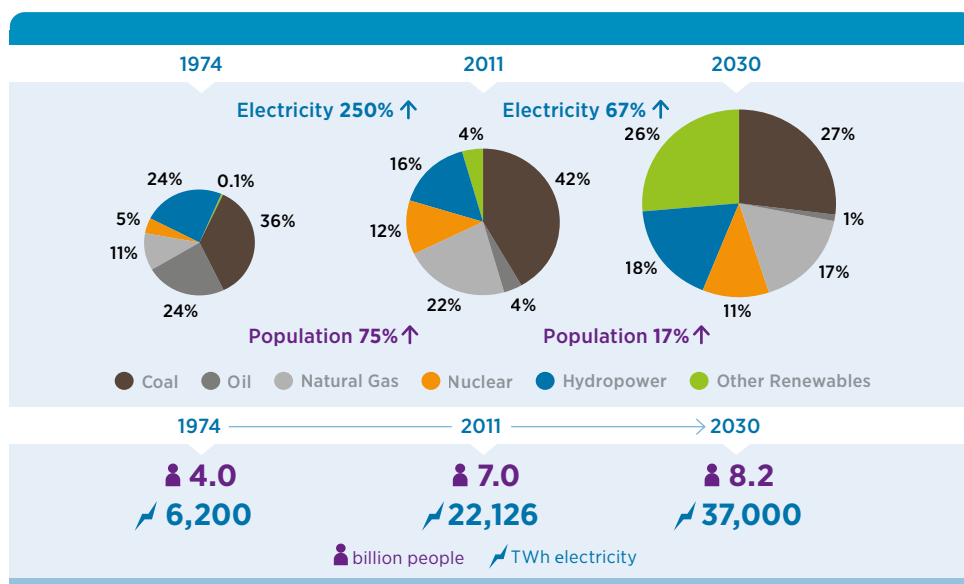
These changes are prompting a fundamental rethink of how energy is managed, most visibly in the electricity sector. This chapter lays out the main socio-economic drivers behind the change, provides evidence of the transformation to date and explains the increasing role that renewables must play.

1.1 DRIVERS OF ELECTRICITY SECTOR TRANSFORMATION

Rapidly increasing electricity demand

Over the past 40 years, demand for electricity has grown rapidly and greatly exceeded expectations, particularly due to rapid industrialisation in emerging economies (see Figure 1). The drivers of increasing electricity demand included an expanding world economy, growing demographics, a rising middle class¹, expanding urbanisation, and the widespread electrification of society.

Figure 1: Electricity generation and population growth



Source: World Bank (2014), IEA (2014a), IRENA (2014a)

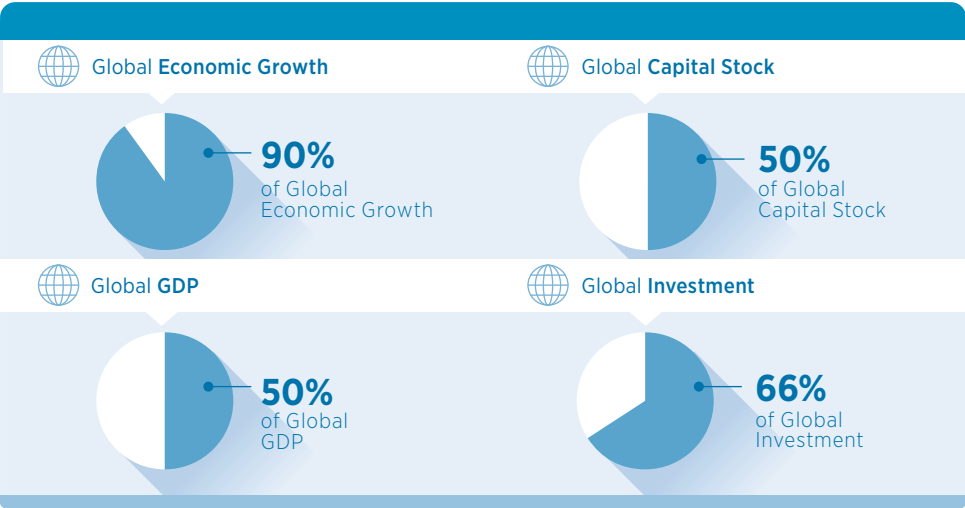
¹Middle class households have daily expenditures of USD 10-100 in purchasing power parity terms (OECD, 2010)

These trends are set to continue. The world's population is forecast to grow to around 8.2 billion in 2030 from 7 billion today, and density will increase as cities continue to expand. By 2030, municipal conglomerations will house approximately 5 billion people, 67% more than today (United Nations Department of Economic and Social Affairs (UN DESA), 2013). The middle class will grow to 4.9 billion, from just 2 billion in 2010 (OECD, 2010).

The impact of this growth on energy demand will be tremendous, as a swelling middle class aspire to more comfortable and energy-intensive lifestyles. Global middle-class spending is likely to grow from USD 21 trillion to USD 56 trillion between 2010 and 2030, of which Asia-Pacific could make up as much as 59% (OECD, 2010).

By 2030, the World Bank forecasts that today's developing countries will hold half of the global capital stock (a third in 2010), generate half of gross domestic product (30% in 2010), receive two thirds of global investment and represent 90% of annual economic growth (see Figure 2) (World Bank, 2013). With these shifting patterns of growth, the geographic spread of energy demand will change as well.

Figure 2: Developing countries – 2030 outlook



Source: World Bank (2013)

Under current consumption patterns, global electricity demand is projected to increase by 60% by 2030 and its distribution will change significantly (International Energy Agency (IEA), 2013). In developed countries energy consumption has largely plateaued and may decrease depending on population growth and energy efficiency improvements. Developing countries will make up the bulk of the energy demand increase and much of the investment in these countries will be ‘new build’, rather than grid and capacity replacements or improvements.

Improving energy efficiency could create a marked difference in demand increases. Energy efficiency measures could contain the increase in global electricity demand

closer to 40%, instead of the projected 60% by 2030 (IEA, 2012). In emerging economies electricity demand will grow significantly even with efficiency measures, while demand in the United States, the European Union and other advanced economies might slightly decline. However, even allowing for the most ambitious energy efficiency gains, significant levels of new energy supply will be needed globally.

The local and global environmental impact of conventional generation

Since the industrial revolution, the generation of electricity from fossil fuels has enabled dramatic economic growth, but has come at significant environmental costs and, for many countries, dependency on imported fuels. Today's consumers are increasingly aware of these costs and governments are keen to mitigate them.

High-profile catastrophes, such as Japan's Fukushima nuclear accident and the United States Deepwater Horizon oil spill, have heightened opposition, and consumers – while still price sensitive – are increasingly supportive of renewable energy options.

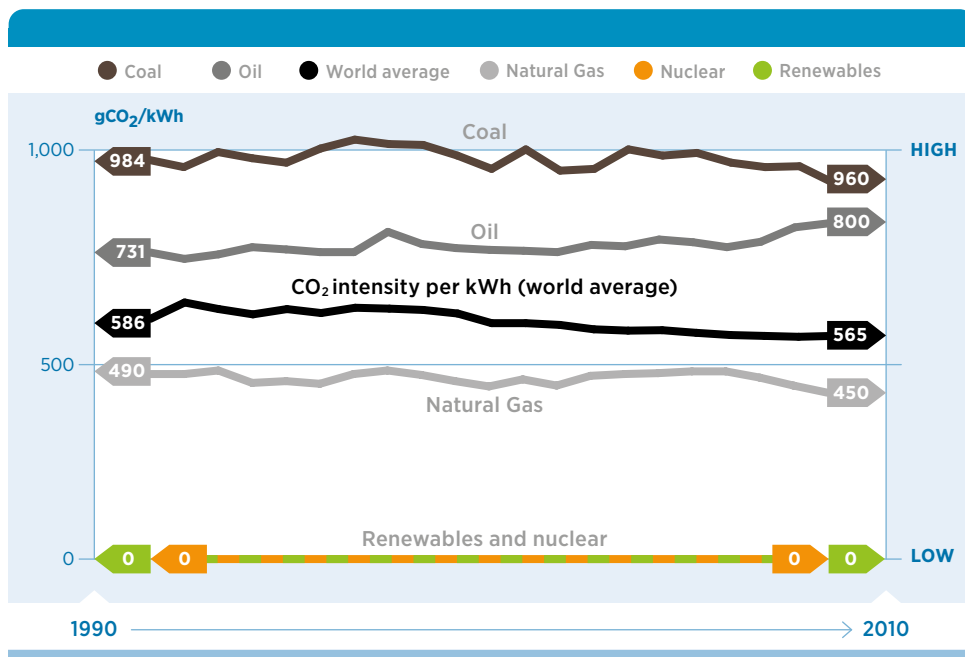
Climate change is increasingly becoming a major concern – as is apparent in national and international policy efforts such as the United Nations Framework Convention on Climate Change (UNFCCC).

These trends have led to a growing consensus that the world must move to a lower-impact energy mix as soon as possible. Yet the global CO₂ emissions intensity of electricity generation has changed little in 20 years. A kilowatt-hour generated in 1990 emitted roughly 586 gCO₂ on average. 20 years later, by 2010, the average emissions intensity was reduced by just 3.5% to 565 gCO₂/kWh (see Figure 3).

The reasons behind this are simple, although difficult to address. There is systemic inertia given the long lifetimes of the plants involved. The effect of the installation of renewables and other lower-carbon technologies (nuclear and natural gas), and improvements in efficiency of electricity production have been neutralised by the operation of existing and new installations of carbon-intensive technologies.

Highly efficient coal plants in Western European markets have been offset by less efficient coal plants in some developing countries. Natural gas has always emitted relatively less CO₂, and has remained fairly constant. Gains here come largely from a shift to closed-cycle plants. Oil plants actually emit more CO₂ per kilowatt-hour now, as they have become almost exclusively 'peaking' plants, and are therefore not running as efficiently as they could. Renewables and nuclear emit close to zero CO₂, but their net contribution to the world average is counteracted by coal.

Figure 3: Direct electricity emission intensity (1990-2010)*



Source: Based on IEA (2010)

*Renewables excludes combustible renewables, gCO₂/kWh are generation emission estimates – for review of life-cycle emissions across all technologies refer to Section 4

The health impact of fossil fuels

Localised pollution from electricity generation also has a direct impact on human health. In March 2014, the World Health Organization (WHO) reported that 7 million premature deaths annually were linked to air pollution; by comparison, the AIDS pandemic killed 2.3 million people globally in 2005, its worst year (WHO, 2014).

Asthma and other respiratory ailments now affect over 40% of Delhi residents, with air quality amongst the worst in the world. In March 2014, Chinese Premier Li Keqiang declared a ‘war on pollution’, in recognition of the increasing concern about its impact on air, water and soil. Beijing’s mayor promised 15 billion Yuan (USD 2.4 billion) to improve air quality, while the Chinese National Centre for Climate Change Strategy and International Cooperation called for the country to decisively cut its reliance on coal. In August 2014, Beijing announced a ban on coal use beyond 2020 to cut air pollution (Xinhua, 2014).

The health impact of global energy use is significant, but its economic cost is difficult to quantify. A 2013 study conducted by experts from the United States Environmental Protection Agency found that the national economic health cost caused by fossil fuels was between USD 361.7 billion and USD 886.5 billion annually (Machol and Rizk, 2013). The European Health and Environment Alliance found that emissions from Europe’s coal-fired power plants cost its citizens up to EUR 42.8 billion in health every year. Were these costs factored into policymaking, fossil fuel generation would become considerably more expensive.

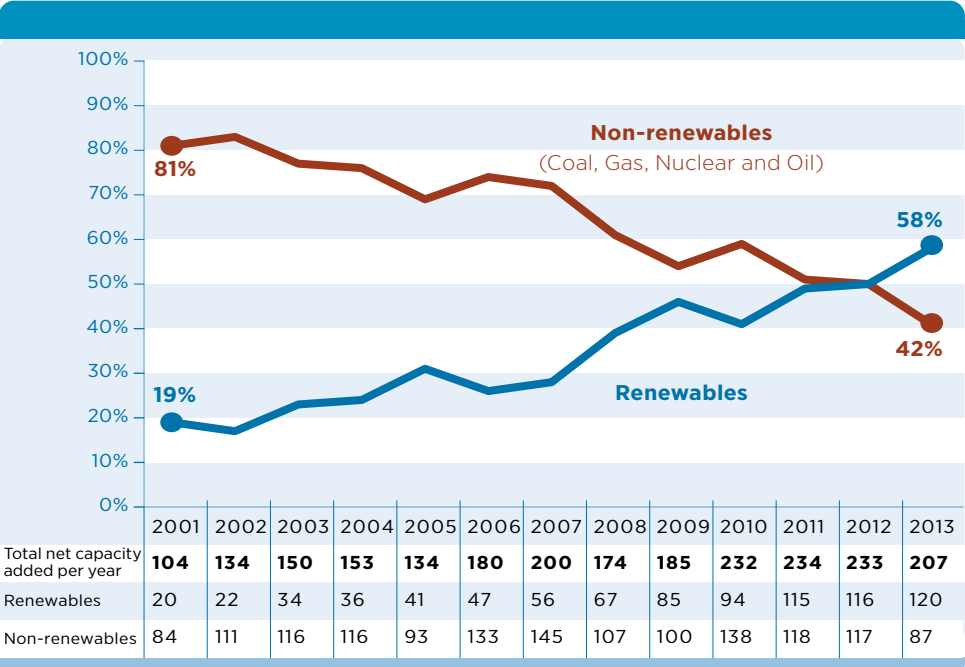
1.2 THE INCREASING ROLE OF RENEWABLE ENERGY

Moving to the majority – investment and new capacity

Worldwide, well over 100 GW of new renewable capacity has been added every year since 2011. That is equivalent to the total installed generation capacity of Brazil, or twice that of Saudi Arabia. Renewables have accounted for more than half of net capacity additions in the global power sector since 2011 – meaning more new renewables capacity is being installed than new capacity in fossil and nuclear power combined (see Figure 4). As a result of these additions, by 2013 the share of renewables in total electricity production exceeded a record 22%, of which 16.4% was hydro and 3.6% was solar PV and wind.

Renewable energy deployment in emerging countries is supporting growth globally. New renewable capacity installations outside the OECD exceeded deployment within the OECD for the first time in 2013, with China dominating new capacity additions of both solar PV and wind. In fact, 2013 marked the first time that new renewable power capacity surpassed new fossil fuel and nuclear additions in China (Renewable Energy Policy Network for the 21st Century (REN21), 2014).

Figure 4: Renewables as a share of global capacity additions (2001-2013)



Source: IRENA database

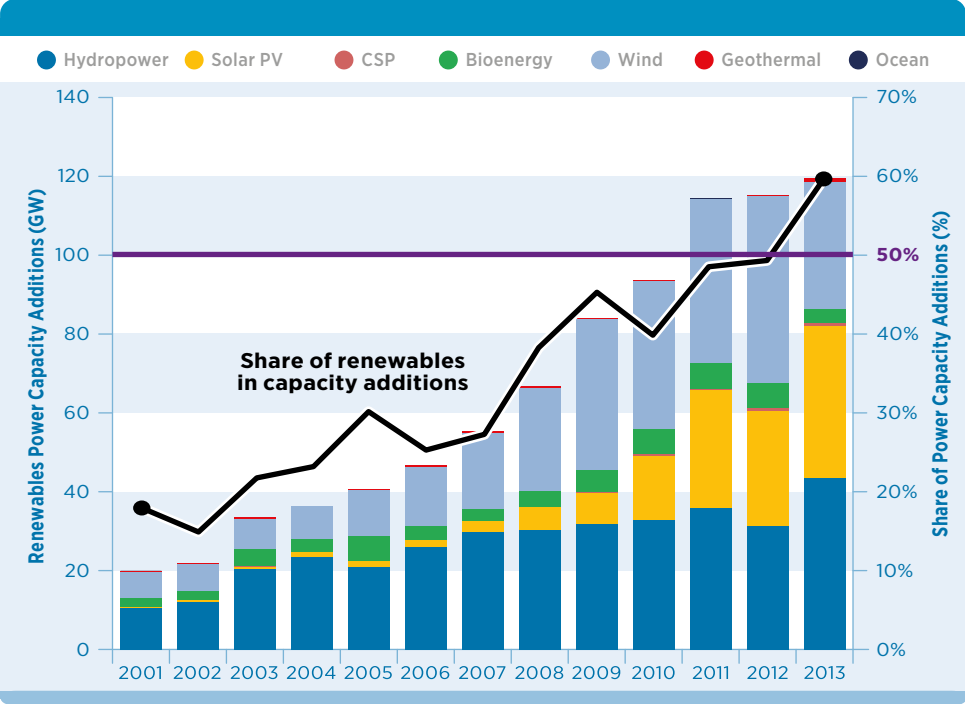
Solar deployment outpaced wind for the first time in 2013. Solar PV deployment reached around 38 GW for the year. Hydropower was also estimated to have had a strong year, with around 40 GW of new capacity (see Box 1). New wind deployment

was slightly disappointing at 35.5 GW, as policy uncertainty delayed projects (Global Wind Energy Council (GWEC), 2014 and World Wind Energy Association (WWEA), 2014). However, wind is set to bounce back following a revision of public support in certain countries, and 2014 is expected to be a record year for both solar PV and wind power. Figure 5 illustrates the annual capacity additions of renewable energy technologies.

Investment in new renewable capacity has also exceeded investment in new fossil-based power-generation capacity for three years running. Global investment in renewable generating capacity has increased five-fold over the last decade (excluding large hydro), from USD 40 billion to USD 214 billion between 2004 and 2013. A further USD 35 billion was spent on large hydropower projects in 2013 (United Nations Environment Programme (UNEP); Bloomberg New Energy Finance (BNEF); and Frankfurt School (FS), 2014).

The rapid expansion in deployment is spurred by declining costs of renewable energy technologies. As Figure 6 demonstrates, renewable energy is often competitive with fossil fuel power at utility scale, and is generally cheaper in decentralised settings. As this becomes more widely recognised, markets will expand and costs are expected to fall further. Moreover, renewables are sheltered from volatile global fossil fuel costs, and have a proven technological viability that ensures long-term cash flows for investors.

Figure 5: Annual renewables capacity addition by technology (2001-2013)



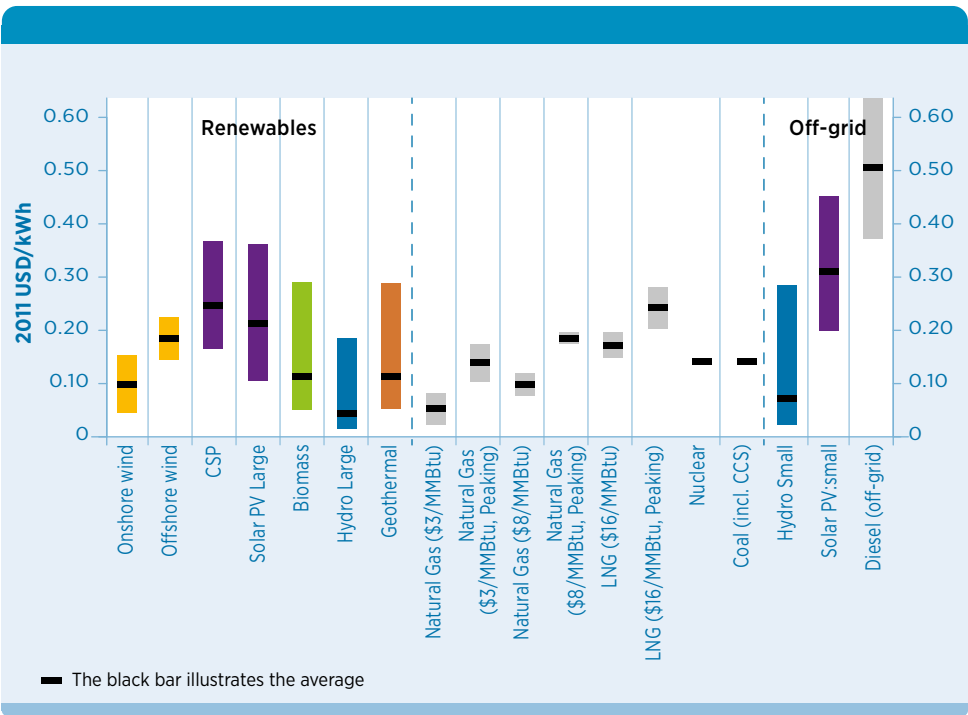
Source: IRENA database

BOX 1: THE POWER OF HYDRO

In locations with good resources, hydropower offers tremendous potential: a mature technology which in many cases is the least cost option. Furthermore, it is highly effective because it is instantaneously dispatchable, even more if it includes pumped storage capability. In 2013, the 1,140 GW of installed hydropower capacity produced 3,405 terawatt-hour of renewable electricity, or 16% of estimated global power generation.

Brazil is one of the world's leading hydropowered nations. The Itaipu Dam alone produced 98 TWh of electricity in 2013, almost 20 times Germany's total solar output in the same year (5.7 TWh). Indeed, over 75% of Brazil's electrical energy comes from large hydro installations and several more are in the pipeline, alongside a portfolio of other options – particularly wind, solar and natural gas. Brazil is pioneering more sustainable approaches for the development of new large hydropower plants, integrating river basin management within the country's integrated energy planning. New decision tools and operation procedures are taking a holistic approach to integrate economic, social and environmental impacts from the onset.

Figure 6: LCOE for utility and off-grid power – OECD countries (ranges and averages)



Source: IRENA Costing Alliance (n.d.) for renewable energy technologies and PwC database for non-renewable energy technologies.

Financial support for renewable energy provided by early adopters translated into a scale-up in deployment, thereby leading to a substantial decrease in technology costs and the development of the renewable energy industry. These countries recognised the long-term benefits brought on by renewables from an environmental, economic and social standpoint.

Renewable energy can increase energy security and reduce risks. Scaling up renewable energy diversifies countries' energy mixes, mitigating the impact of price volatility and helping to allay geopolitical risks. Financial and economic risks for government and business are reduced through a more predictable cost base for energy supply (since renewable energy technologies have lower recurring costs and lower fuel-cost volatility) and an improvement in the balance of trade for fossil fuel-importing countries.

By minimising domestic fossil fuel consumption through renewable energy deployment, fossil fuel-exporting countries can maximise their exports to the global market. Several Gulf Cooperation Council countries, for example, have set renewable energy targets in recent years which could save an estimated 3.9 billion barrels of oil equivalent between 2012 and 2030. This could result in cumulative savings of approximately USD 200 billion (Ferroukhi *et al.*, 2013).

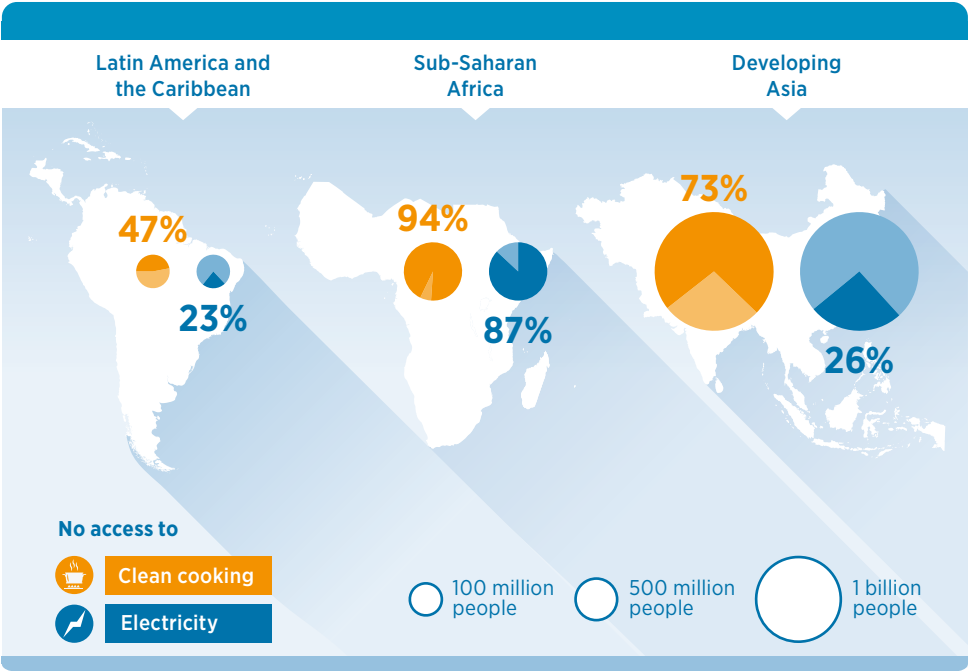
Developing countries are well placed to exploit the rapidly decreasing costs of renewable energy technologies, and this is where the greatest net increases in power capacity are needed. Many are blessed with significant renewable energy resources.

The way forward

Renewable energy plays an important role today, and can play an even more crucial role in the future of the energy sector. REmap 2030, the global roadmap from IRENA, highlights possible pathways and priority action areas to accelerate the deployment of renewable energy (IRENA, 2014a). It presents ways to double the share of renewable energy to 36% by 2030. REmap analyses all aspects of the energy system in 26 countries representing 75% of global energy consumption and provides recommendations to reach the goal.

REmap 2030 also demonstrates that renewable energy presents an affordable, reachable and established conduit to a sustainable energy future for all. Renewable energy is increasingly the most cost-effective solution for expanding rural electricity access in developing countries. This can improve living conditions for 1.3 billion people worldwide who currently lack access to electricity, and for 2.6 billion people without access to clean cooking equipment, mostly concentrated in sub-Saharan Africa and Asia (IEA, 2013) as shown in Figure 7.

Figure 7: Rural populations lacking energy and their access profiles in 2010



Source: IRENA based on IEA (2012), UN DESA (2011) and WHO (2010)

Net global population growth may almost offset current efforts to expand access to modern energy services. Without significant efforts to increase access, the IEA projects that almost 1 billion people will still be without access to electricity and 2.5 billion people will lack access to clean cooking facilities in 2030 (IEA, 2013). As recognised by the United Nations’ Sustainable Energy for All initiative (SE4ALL) (see Box 2), ensuring sufficient cost-effective energy supply is pivotal to maintaining a broad basis for economic growth and improving human living standards.

While impressive, business-as-usual renewables expansion will deliver neither the economic nor environmental outcomes needed for sustainable development. IRENA’s REmap 2030 analysis emphasises that doubling the share of renewable energy in the global energy mix is achievable, but significant new efforts are required in the power, transport, buildings and industrial sectors. Current national plans would only result in an increase to 21% of the renewable energy share in 2030, compared to 18% in 2010.

In addition to the electricity sector, heat and transport present significant opportunities for renewable energy. While not the focus of this report, these sectors could make real inroads into the cost and environmental impact of primary energy demand. At present only a few countries utilise renewable energy sources to meet a sizable share of these sectors.

BOX 2: SUSTAINABLE ENERGY FOR ALL INITIATIVE

SE4ALL is a global initiative led by the Secretary-General of the United Nations (UN) to achieve universal energy access, improve energy efficiency and increase the use of renewable energy. It was launched to coincide with the designation of 2012 as the International Year of Sustainable Energy for All by the UN General Assembly, in recognition of the growing importance of energy for economic development, climate change mitigation and improving modern energy access. Subsequently, 2014-2024 was named the Decade of Sustainable Energy for All, underscoring the importance of energy issues for sustainable development and for the elaboration of the post-2015 development agenda.

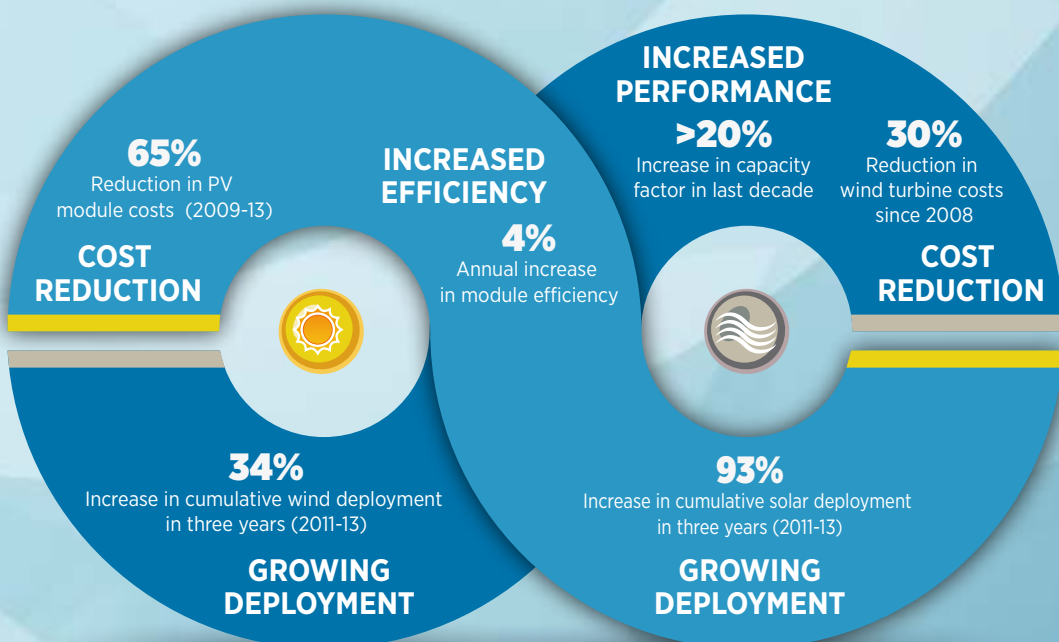
The widespread use of sustainable energy is essential to alleviate poverty. The SE4ALL initiative highlights the role sustainable energy plays in creating new forms of employment, decreasing the indoor air pollution caused by burning traditional fuels, reducing school truancy (exacerbated by the need to gather traditional biomass) and ensuring learning can happen after dark. Women and children typically bear the burden of inadequate energy access.

SE4ALL's objectives are to ensure universal access to modern energy services, double the global rate of improvement in energy efficiency and double the share of renewable energy in the global energy mix by 2030. IRENA has joined this global effort and taken the lead as the SE4ALL hub for renewable energy.

The status and trends described in this chapter clearly point to the important role renewable energy plays in the transformation. This report adopts an analytical approach centred on three key dimensions of renewable energy that will support their growing inclusion as the transformation gathers pace.

- » Technology deployment is expanding as costs decrease (Chapter 2)
- » Financing for renewable energy has come to scale for certain technologies and is becoming more accessible and affordable – but there are still significant regional variations (Chapter 3)
- » Economic, social and environmental goals can be achieved through renewable energy (Chapter 4)

In all of these areas, this report analyses some of the drivers and activities that have initiated the transformation, and identifies related challenges and opportunities. The report concludes with a synopsis of some key focus areas in the short to mid-term that need to be addressed to further support the transformation.



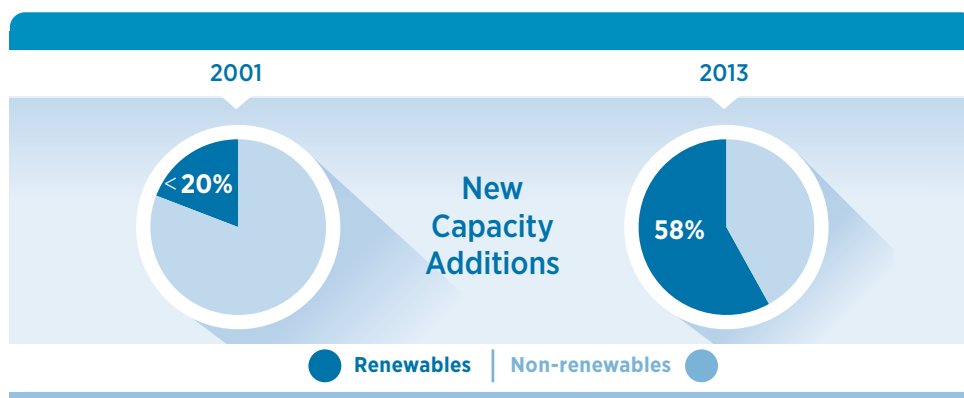
2 Renewable energy deployment is accelerating as costs fall

Developments in renewable electricity generation have long been recognised as a promising trend. However in 2013 and 2014, a number of major milestones marked its arrival in the mainstream. This chapter describes how technology innovation and related cost reductions are driving deployment and unlocking new opportunities within the power sector.

Increased efficiencies and decreasing technology costs, against a backdrop of rising electricity prices, have allowed solar PV and onshore-wind to reach new levels of cost competitiveness. Both have reached grid parity with electricity generation from fossil sources in a variety of countries and settings. Most other renewable technologies also continue to become cheaper. Despite a 22% decline in global renewables investments in 2013, falling costs allowed renewables to be deployed at unparalleled scale.

Total installed capacity of renewable power reached 1,700 GW in 2013, or 30% of total global power capacity. The renewable share of electricity generation exceeded 22% for the first time: with 16.4% hydro, 2.9% wind, 1.8% bio-power and 1.1% solar PV, concentrated solar power (CSP), geothermal and ocean (REN21, 2014). The scale of uptake has expanded greatly over the past decade, rising from under 20% to 58% of net additions to global power capacity in 2013 (see Figure 8).

Figure 8: New power capacity additions (2001 and 2013)



Source: IRENA database

The scope of renewable power has also grown, far beyond the traditional model of centralised, utility-scale generation. Renewables have become the technology of choice for off-grid applications: cheaper than alternatives reliant on fossil fuels (e.g., diesel, oil, etc.) in virtually any power system. In many mature markets, a rapid growth in decentralised grid-connected renewables is transforming traditional ownership structures within the energy sector. Over 46% of current renewable capacity in Germany, for instance, is owned by households and farmers (Agentur für Erneuerbare

Energien, 2013). Renewable technologies can also be combined with fossil fuel plants to increase efficiency, such as CSP-natural gas or CSP-coal hybrid plants. Renewables are increasingly being considered for different applications, ranging from water desalination and stand-alone street lighting to remote device charging.

2.1 THE FALLING COSTS OF RENEWABLES

Solar PV and onshore wind power have undergone an industry-wide revolution in just a few years, and are at or approaching grid parity – where electricity is equal to the price of power from the grid – in a wide variety of settings.

Between 2009 and 2013, prices for solar PV modules declined by 65%-70%, despite module prices stabilising in 2013.² The technology reached new levels of competitiveness at both distributed and utility scale. The cost of residential solar PV systems in Germany declined by 53% during the same period, and commercial solar power reached grid parity in countries including Germany, Italy and Spain, with France and Mexico due to attain parity soon (IRENA, 2014b and Eclareon, 2014).

Onshore wind is increasingly the least-cost option for new grid supply. The levelised cost of onshore wind electricity has fallen 18% since 2009 on the strength of cheaper construction costs and higher efficiency levels, with turbine costs falling nearly 30% since 2008.

When coupled with maturing market structures, falling costs have stimulated rapid year-on-year growth in both the scale and the scope of renewable energy deployment. IRENA's analysis of more than 9,000 utility-scale renewable projects, 150,000 small-scale PV projects and a range of literature sources confirms that the rapid deployment of renewables, along with the high learning rates³ for some technologies, has produced a virtuous cycle that will continue to drive down costs (IRENA Costing Alliance, n.d; see Box 3).

BOX 3: IRENA'S COSTING ALLIANCE

The IRENA Renewable Costing Alliance (www.irena.org/costing) was launched in early 2014. Alliance members recognise that a lack of accurate, transparent and reliable data on the cost and performance of renewable technologies is a significant barrier to accelerated uptake. To this end, they agree to share with IRENA, confidentially, real-world project cost and performance data, facilitating analysis based on the latest and best possible information.

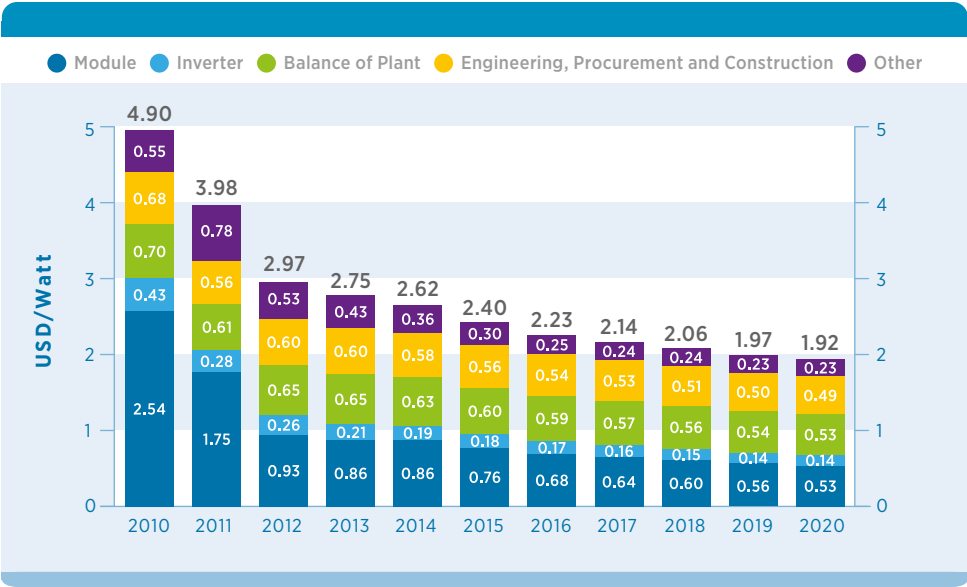
² PV module prices were stable in 2013 as manufacturers consolidated and in many cases, returned to positive margins, after a period of manufacturing overcapacity and severe competitive pressures.

³ The learning rate is the percentage reduction in costs for a technology that occurs with every doubling of cumulative installed capacity. For solar PV modules, the rate is between 18% and 22%, while for wind turbines it is around 10%.

Local environmental conditions and their impact on power generation continue to affect renewable energy capacity factors. However, improvements in technology mean that the amount of wind or solar radiation needed to generate power is falling. Meanwhile, significant investments in electricity storage technologies mean these are likely to become more widely available soon. Increased penetration of renewables has also created a wider geographic spread, meaning less favourable resource conditions in one area can be offset by more favourable conditions in another. Further interconnections and grid development will help tap into renewable resources across larger geographical areas.

Renewable energy technologies have significant potential for further improvement, depending on their maturity. Delivered costs of renewable energy decline significantly as markets grow, learning accumulates and economies of scale are achieved. These dynamics are more prominent in the case of solar PV, as indicated in Figure 9, and onshore wind. This is in contrast to less mature technologies, such as ocean energy, that are still approaching the commercialisation stage (see Box 4).

Figure 9: Projected solar PV system deployment cost (2010-2020)



Source: IRENA (2014c)

Solar PV

Solar PV systems are the most accessible renewable energy technology, as their modularity means that they are within reach of individuals, co-operatives and small-scale businesses. With recent cost decreases and innovative business models, they represent the economic off-grid solution for the more than 1.3 billion people worldwide without access to electricity.

BOX 4: LESS MATURE RENEWABLE TECHNOLOGIES

Beyond hydro, geothermal, solar and wind power, there are noteworthy emerging technologies that are only just beginning to be exploited at commercial scale. These either offer greater efficiency than their more mature predecessors or present opportunities to exploit new renewable resources.

Enhanced geothermal systems adapt existing technologies for use in a wider range of locations, using deeper drilling to target hotter temperatures closer to the earth's core. As technical and economic challenges are overcome, these could greatly expand the use of geothermal energy to provide baseload heat and power.

Ocean energy technologies are advancing quickly and the outlook for commercialisation is good. Five main wave power technologies and 5-10 tidal current power technologies are close to market readiness, while numerous concepts are in earlier development stages. However, tidal energy is among the least deployed of renewable energy sources, with around 500 MW installed worldwide, of which more than 90% comes from two tidal barrages.

Recent cost reductions have meant that at least a third of new, small to mid-size solar energy projects in Europe are being developed without direct subsidies (Parkinson, 2014). In Chile, a new 70 MW solar farm under construction is anticipated to sell on the national spot market, competing directly with electricity from fossil fuel-based sources. Technology cost reductions have been driven by:

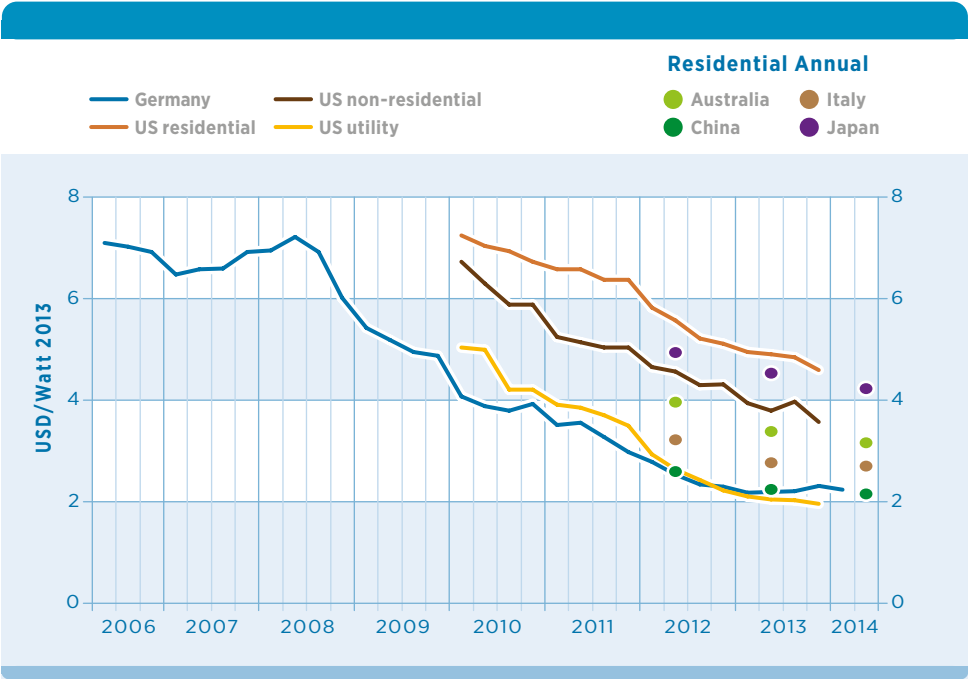
- » **Efficiency improvements:** The efficiency of solar PV modules in converting sunlight into electricity has improved by around 3%-4.5% per year for the last 10 years;⁴
- » **Economies of scale:** Integrated factories are scaling up processes, providing competitive equipment prices and amortising fixed costs over larger output;
- » **Production optimisation:** More efficient production processes and improvements in supply chain management continue to provide cost reduction opportunities.

The combination of reductions in PV module prices and balance of systems (BoS) costs has allowed the LCOE to fall rapidly. Assuming a weighted average cost of capital of 10%, LCOE for solar PV has declined to as low as USD 0.11/kWh and is typically in the range of USD 0.15 to 0.35/kWh for utility-scale projects (Fraunhofer ISE, 2013). The cost of deployment and the LCOE, however, differ from market to market. Figure 10 demonstrates these differences for installed costs of PV systems in certain key markets. The primary reason for such differentials is that BoS costs include soft or non-hardware costs, which are highly market-specific.

BoS costs now make up a larger proportion of project costs, alongside the capital costs. Improving the competitiveness of PV will therefore increasingly depend on the extent

⁴ Silicon input costs have been falling, and the amount of silicon required for a panel has fallen by 30% to just 6 grams per watt-peak in 2013 on average. These help reduce capital costs.

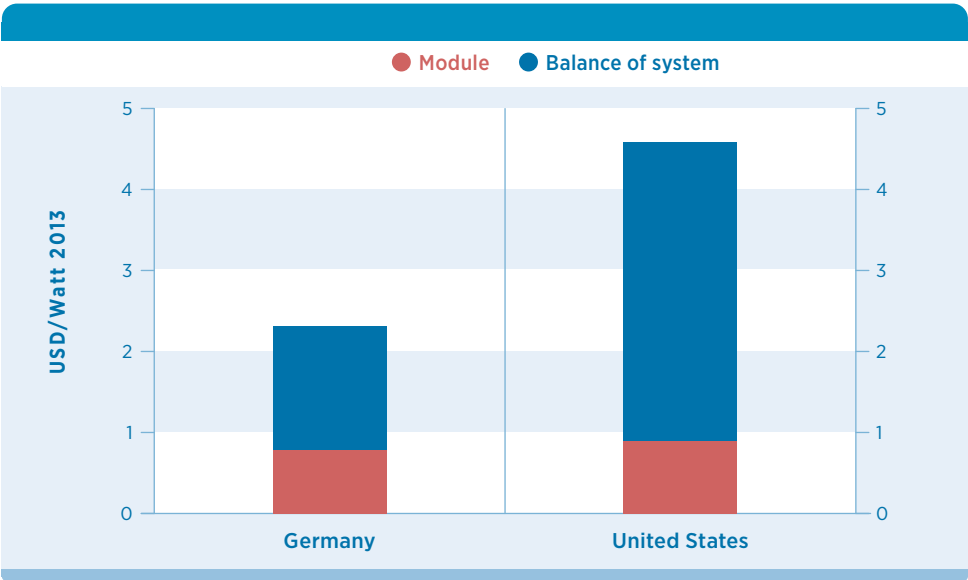
Figure 10: Solar PV system costs by country (2010-2014)



Source: IRENA Costing Alliance (n.d.)

that BoS costs can be reduced. While the trend in BoS costs is downwards at present, this is a diverse area with significant national variance. It is much cheaper to install the same solar panel in Germany than in the United States or Japan, for instance – as indicated in Figure 11. This can be a function of regulation, the availability of skilled

Figure 11: Residential solar PV cost breakdown in Germany and the United States



Source: IRENA Costing Alliance (n.d.)

installation professionals and other factors. More analysis is required to examine the reasons behind cost differentials, identify future cost reduction opportunities and formulate policy recommendations to enable success in different countries.

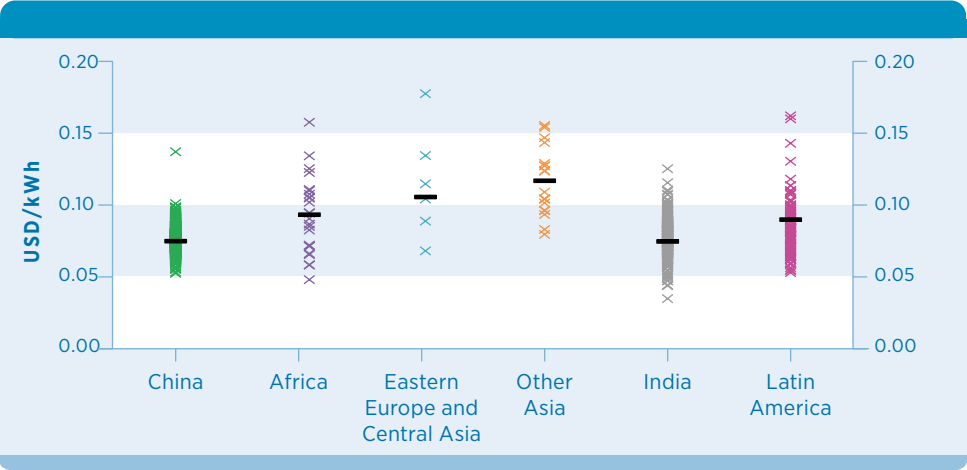
Onshore wind power

Solar PV has not been the only beneficiary of falling technology costs. Onshore wind power is also fast approaching grid parity in purely financial terms. Technical innovation and cost reductions are combining to make onshore wind the cheapest source of new electricity in a wide and growing range of markets. The LCOE for wind power is approaching wholesale electricity prices in China, Germany, Italy, Spain and the United Kingdom and has already attained parity in Brazil and Denmark. Developers of Brazilian wind farms have won 55% of contracts in electricity auctions since 2011, as prices for wind energy have fallen 41% to BRL 88 (USD 45) per megawatt-hour (IRENA, 2014c). Electricity from wind is already cheaper than nuclear power and would also be cost competitive with natural gas and coal globally if health and environmental costs were included in prices.

The range of levelised costs of wind-generated electricity is wide, but wind is increasingly the most competitive source of new generation capacity for the grid. Energias de Portugal (EDP) now reports that the LCOE for onshore wind across Europe is 20% cheaper than for natural gas and one-third cheaper than for coal (EDP, 2014). Figure 12 demonstrates the range of LCOE for wind farms in non-OECD countries.

Most of wind's competitiveness has been driven by the incredible pace of technological evolution among the world's largest turbine manufacturers. Growth in the scale of the wind market has encouraged competition, driving down costs. The capital costs of wind turbines have also declined since 2008/2009. The turbine is the single largest cost component of a wind farm (64%-84% of total cost), so this has had a material impact

Figure 12: LCOE for recently commissioned and proposed onshore wind farms in non-OECD countries



Source: IRENA Costing Alliance (n.d.)

on total project costs. Innovations allow today's turbines to harvest significantly more wind at a given site. Higher hub heights, larger swept areas and improvements in blade design and wind turbine operation have increased the capacity factors of new installations. Data for the United States and Denmark shows that the capacity factors for wind turbines (at a given wind speed) have increased by 20% or more in a decade (Islam *et. al.*, 2013)

Offshore wind

Offshore wind is an emerging field which is expected to grow rapidly as costs fall. Unlike onshore wind farms, which can be as small as a single turbine, offshore wind farms tend to be as large as possible. The average size of offshore wind farms is currently around 200 MW. At the end of 2013, over 7 GW of world wind power capacity was installed offshore, with the largest market in the United Kingdom.

The offshore sector is interesting as it benefits from higher social acceptance, has less visual or noise impact and can reach significantly higher capacity factors (40%-50%) than onshore due to stronger and more consistent winds, enhancing the ability of offshore wind to provide baseload reliability. Where densely populated areas border the sea, the proximity of load centres can make offshore wind especially attractive.

While capital costs are higher than those of a comparable onshore wind project, the investment cost for offshore wind turbines with fixed-bed foundations is projected to decline 17%-27% by 2023 (Fichtner and Prognos, 2013).⁵ The expectation is that this will result in a fall in the LCOE from approximately USD 0.17-0.20 per kWh in 2013 to USD 0.10-0.13 per kWh in 2023.

Offshore wind farms are more complicated than onshore, as grids need to be expanded further. The average distance from shore to turbine is projected to increase to 100 kilometres by 2020 (Roland Berger, 2013). As a result, the search for sites with great wind resources may provide a cheaper kilowatt-hour on site only to entail higher transmission costs. Commercial offshore turbines available today have a capacity of 5-7 MW, and turbines with a capacity up to 10 MW are being developed, which reduce overall LCOE.

There is major growth potential in the offshore wind market. In Europe alone, offshore wind capacity is projected to grow to 40 GW by 2020. Power generation giants, such as General Electric (GE) and Siemens, entering the market around 2000, introduced innovation and intense industry rivalry, resulting in advancements that few experts had thought feasible so quickly. All offshore turbines currently built have fixed-bed foundations, although floating platforms are being tested in Denmark, Japan, Norway and the Republic of Korea.

⁵ At the same time, operation and maintenance costs are projected to decline 19%-33%, the nominal weighted average cost of capital (WACC) will decline from 9.9% to 7.7%, and electricity generation per kilowatt installed will increase by around 10%.

Concentrated Solar Power

CSP uses a series of mirrors to concentrate solar energy onto a heat transfer medium, which is then used to drive a traditional turbine. Global installed capacity is nearly 3.4 GW worldwide. The LCOE of utility-scale PV is now around two-thirds that of CSP, but CSP's storage capacity is often not properly valued. Thermal storage in the form of heat, for example as molten salt, can be used to generate steam which in turn can be used to generate electricity. Today such storage is cheaper than battery storage, but it is only applicable on utility scale (IRENA and IEA-ETSAP, 2013).

CSP still faces challenges. CSP plants need capacities over 50 MW to achieve efficiencies of scale, hence the amount of land needed can be a limitation, whereas PV is evidently more scalable. CSP will therefore only be appropriate for utility-scale deployment and will likely miss out on the democratisation that has driven PV uptake. Adopting a hybrid approach by coupling fossil-fuel plants with CSP is increasingly being seen as an opportunity to overcome limitations associated with CSP development and improve efficiencies of fossil-fuel plants (see Box 5).

Developments in grid technology and energy storage

The temporal and spatial divergence of supply and demand is one of the biggest challenges facing the transformation of the energy sector.

Controllable energy storage at scale would allow renewable energy generated at one moment to be used later and greatly increase the level of penetration of variable renewables at least cost. Intelligent, utility-scale storage would significantly reduce the need for peaking provision and backup by conventional power plants, along with their impact on the environment. From a technical and economic point of view, however, the number of available grid-scale storage options remain limited. Pumped storage constitutes almost 99% of global energy storage capacity, in the range of 135-140 GW (REN21, 2014; USAID and MNRE, 2014). Battery storage technologies have developed

BOX 5: PARTNERING NEW AND OLD: HYBRID APPLICATIONS USING CSP

Hybrid CSP plants are a promising, reliable power generating technology. Hybrid plants using heat generated in CSP systems to increase the efficiency of fossil-fuel generating technologies could allow for 24-hour lower-carbon co-generation. A coal plant retrofit is being installed in Australia, and various natural gas hybrid plants are operating in North Africa, all of which incorporate CSP to improve steam cycles. Algeria's first solar-tower power plant will also be solar-gas hybrid, with a total capacity of up to 7 MW, and there are hopes to replicate this elsewhere in North Africa. CSP steam production can also supplement enhanced oil recovery operations, with CSP facilities being considered or in operation in the United States and Oman. Retrofit hybrids create many new opportunities in countries with the right climatic conditions.

over the last couple of years, and the industry can deliver operational solutions for a variety of grid and off-grid applications (IRENA, 2014d). Technical developments are expected to transform the market for energy storage from approximately USD 200 million last year to USD 19 billion by 2017 (IMS Research, 2013).

Grid upgrades will mean that low carbon generation at a decentralised level can be collected and redistributed among demand centres. Investments to do this are likely to include long-distance technical upgrades and reinforced local cables, energy imbalance markets (allowing for the trading of imbalances), technologies that increase dispatch speeds (to match the variability of renewables) and integrated forecasting tools.

Upgrading grid and storage used to cost more than generating electricity in a peaking plant. Since around 2005 though, technologies have been developed that can provide utility scale load-levelling and frequency regulation capabilities at a tolerable cost – and prices are falling fast. The benefits can include wind/solar curtailment avoidance, grid congestion avoidance, price arbitrage and carbon free energy delivery.

2.2 INCREASING DEPLOYMENT OPPORTUNITIES

Renewable technologies are effective at a variety of scales and are modular and diverse – with applications in heating, cooling and transport as well as electricity generation. Within the power sector, renewable energy is driving a shift from centralised utilities to more diverse localised production.

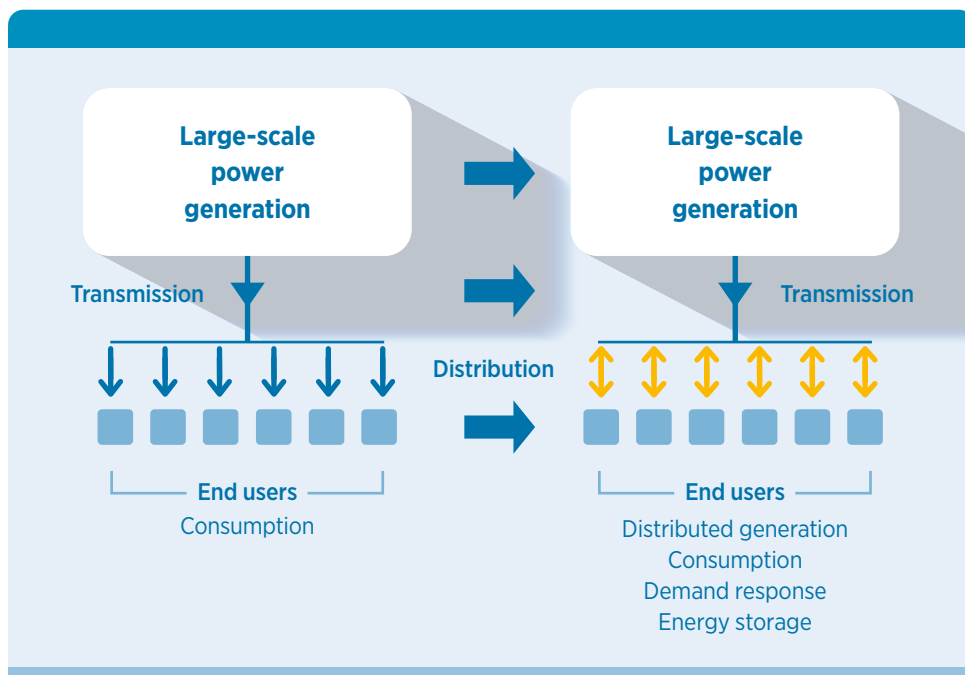
High rates of decentralised power generation are feasible in mature markets

The future of many power grids involves a broad mix of fossil fuels and renewables, decentralised generation, expanded storage capacity and improved demand and supply planning through smart, real-time data flows, as illustrated in Figure 13. This is commonly described as a smart grid.

A more distributed generation model is emerging in markets with higher renewable energy penetration, enabled by the modular nature of wind turbines and solar panels. Germany already exhibits significantly decentralised ownership of grid-connected renewables, with over 46% of capacity owned by households and farmers. Only 12% of renewable assets are owned directly by utilities (see Figure 19; Agentur für Erneuerbare Energien, 2013).

Decentralised mini-grids are seen as a way to improve grid reliability, by localising generation and reducing the risk of transmission faults – particularly during natural calamities. In the United States, for instance, weather caused 80% of all outages from 2003 to 2012, affecting around 15 million customers each year. Most of these outages come from damage to large transmission lines or substations, as opposed to smaller residential distribution networks (Climate Central, 2014). North America is the world's

Figure 13: Smart grids and renewables



Source: Based on IRENA (2013a)

leading market for mini-grids, with a planned, proposed and deployed capacity of 2,874 MW, or 66% of the global total (Navigant, 2014a).

Overall, the market is much more robust than five years ago. In the second quarter of 2014, global mini-grid capacity rose to 4,393 MW, marking an increase of over 6% in the previous two quarters (Navigant, 2014a). By 2022, global installed mini-grid capacity is forecast to rise above 15 GW. While these projected capacities need not be entirely renewables-based and only represent a fraction of global installed capacity, they demonstrate an emerging demand for decentralised technologies in mature markets, along with other niche applications in telecommunications, defence and mining.

Renewables are the technology of choice for rural off-grid applications

Off-grid renewable energy technologies, including stand-alone and mini-grid systems, are also emerging as a cost-effective alternative to centralised solutions in developing regions, where access to electricity is non-existent or unreliable (IRENA, 2013c). Their distributed nature allows them to be tailored to local conditions and deployed closer to centres of demand. This can reduce (or in some cases eliminate) the need for a centralised grid infrastructure.

Stand-alone solutions, such as pico lighting and solar home systems (SHSs), are being rapidly deployed to provide basic lighting and mobile charging services. SHSs,

for instance, have experienced sustained growth with more than 5 million systems installed (IRENA, 2013b). Bangladesh has been at the forefront of this development, deploying almost 3 million SHSs (as of April 2014) at a pace of 65,000 systems per month. Nearly 9% of Bangladesh's population, or 13 million people, now benefit from electricity access through solar solutions (IDCOL, 2014).

The global annual market for solar PV consumer products, including off-grid solar lighting, is forecast to grow from USD 551 million to USD 2.4 billion between 2014 and 2024, with unit sales of pico solar and SHSs growing from 8.2 million annually in 2014 to 64.3 million in 2024 (Navigant, 2014b and 2014c). Some of the challenges in benefiting from this opportunity are presented in Chapter 4.

Stand-alone solutions represent only a first step in meeting the aspirations of rural households and enterprises. Mini-grids – which can range from a few kilowatts to several megawatts of capacity, tapping into a single or multiple resources – will play an increasingly important role, as they cater to basic and productive uses of energy. They can also be integrated into the central grid when it arrives (subject to enabling regulatory conditions).

Falling costs and increasing maturity make renewable energy the most appropriate option both for new mini-grids and for hybridising existing fossil fuel-based mini-grids (IRENA, 2013c). Since the 1950s, China has pursued the development of small hydropower plants, first in stand-alone configurations and later integrated into the national grid. Today, China has roughly 60,000 diesel and hydro mini-grid systems. From 2003 to 2005, China's Township Electrification Programme constructed 721 solar PV and PV/wind hybrid systems, along with 146 small hydro stations, to provide electricity to 1.3 million people. The 2005 to 2010 Village Electrification Programme connected another 3.5 million people with renewable sources. By the end of 2015, China aims to provide power to another 2.7 million people without electricity, including 1.5 million by grid extension and 1.2 million by independent solar PV.

The case for renewable energy is also strong for islands. In fact, virtually all off-grid electricity systems based on fossil-fuels will see generation costs fall by integrating renewables (IRENA, 2012a). There are several hundred island mini-grids, usually powered by diesel or oil-fired generators, typically in the 1-20 MW range. Increasingly, solar PV is being added, as are wind, geothermal, biomass and ocean energy. Hybridising mini-grids reduces generation costs in all diesel systems without affecting the reliability of supply. Tokelau, for instance, has installed 4,032 solar panels and 1,344 batteries to generate 90% of its electricity from PV. The remaining 10% comes from diesel, which can be substituted by coconut oil. As storage technologies mature and costs decrease, more remote communities will be able to receive grid-quality supply through decentralised solutions.

2.3 RECOMMENDATIONS FOR POLICY MAKERS

Past and current policies have helped trigger a global expansion of wind and solar, allowing costs to decrease rapidly. Further cost reductions will be driven by a similar cycle of technology improvements and increased deployment driven by long-term policy support.

Reduced costs increase the scope, scale and competitiveness of renewables, driving more projects, leading to more technology improvements and even lower costs. This does not mean, however, markets will deliver a sustainable, cost-effective energy mix by themselves. To ensure the future growth of the sector, policy makers should consider the following:

- » **Public policies can support, and even accelerate, renewable energy cost reductions.** The technical and economic feasibility of renewable energy projects is highly dependent on the markets where they are being deployed. Renewable energy deployment can incur significant costs associated with policy, regulatory and deployment risks specific to local markets. Governments can address these risks by ensuring stability and predictability in policies, streamlining permitting and grid-connection processes, promoting capacity building to meet skills needs and introducing financial risk mitigation tools.
- » **Renewable energy technologies require tailored support along some of the stages of their life cycle,** from basic science, research and development to commercial deployment. Less mature technologies, for instance, might be supported financially for research, development and demonstration as well as innovation-support mechanisms (such as intellectual property protection) and market readiness measures (such as capacity building).
- » **A new electricity market paradigm, driven by technology advances, creates policy challenges.** Especially high shares of variable distributed electricity generation in combination with information technology and storage allow for a new way of operation. The role of centralised grids will reduce in favour of mini-grids and other off-grid solutions, especially in rural areas and remote locations, where centralised grids are uneconomic. The optimal system design and policy response is not yet evident. An informed and systematic “trial-and-error” approach with regular evaluations or lessons learned is recommended.
- » **Policies need to adapt to changing market dynamics.** The renewables sector is developing quickly. Governments need to consider new types and levels of support as it evolves. In the case of solar PV, for instance, once grid parity has been attained, non-financial support may be necessary in the form of policies such as net metering, or reducing market-induced barriers (and costs) for further deployment. In general, the impact on various stakeholders, including incumbents, needs to be adequately considered (see Section 3.4).

- » **Grid integration and management of variable renewable energy require attention.** Adequate planning is necessary for the timely development of grid infrastructure, investment in smart infrastructure and storage technologies and the formulation of enabling regulatory frameworks.
- » **Technology innovation is a key driver for broadening the renewables base, raising the resource potentials and reducing the cost of energy supply.** This is the basis for a seminal renewables transition. Therefore fostering innovation should be a key objective of the policy framework. Moreover, rapid progress in technology can impact policy strategy choice and policy makers should ensure that their decision making is based on the latest information.

TOTAL INVESTMENT

USD 214 billion

(excluding large hydro 2013)

USD 550 billion

annually to double the share of renewables in the global energy mix by 2030 (REmap)

FUNDING NEEDS

CHANGING OWNERSHIP

75%

wind turbines owned by cooperatives in Denmark

46%

RE capacity owned by individuals and farmers in Germany

43%

of total investment in developing countries (29% in 2007)

SHIFTING PATTERNS

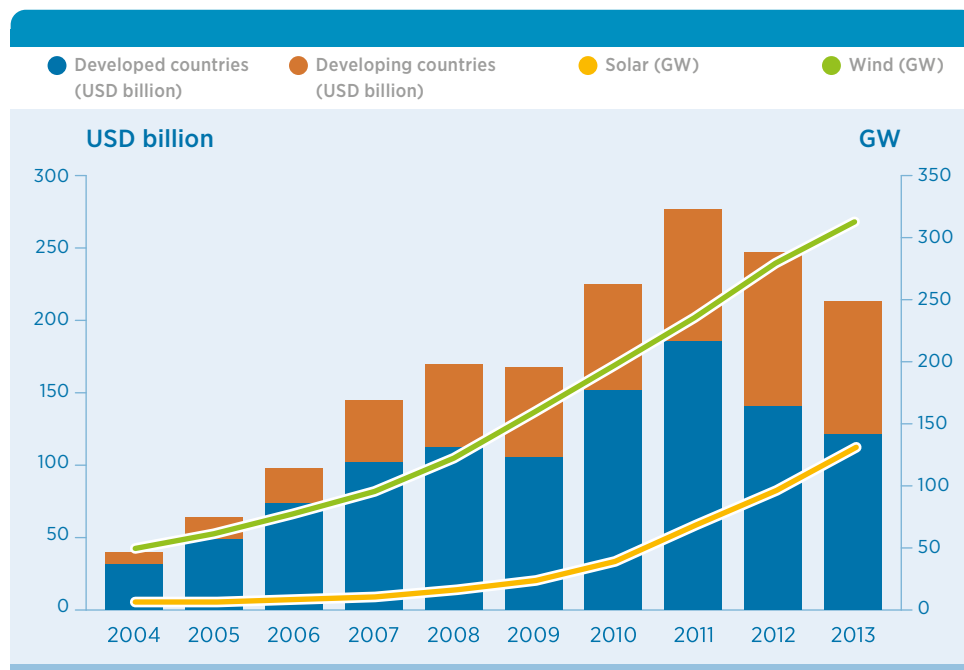
3 Financing renewable energy projects is becoming easier and cheaper – but variations remain

Investments in renewable energy have risen significantly over the past decade, from USD 40 billion to USD 214 billion between 2004 and 2013 (excluding large hydropower). Despite investments in renewable energy dipping 11% (in monetary terms) in 2013, renewable energy deployment hit record levels, with solar PV and wind capacity growing 37% and 12.5% respectively, reflecting decreasing costs (see Figure 14).

Global investment in renewables is increasingly shifting to developing countries. These countries installed around USD 107 billion of renewables in 2012, compared to developed countries' USD 142 billion. This was a dramatic change from 2006, when developed economies invested 2.5 times more than developing countries.

The investment community has gained a vast amount of experience in financing renewable energy. This has come with the increase in the absolute volume of investment over time, combined with an underlying increase in the number and type of transactions, more accurate local resource data and increasing experience with different stages of project delivery.

Figure 14: Total investment in renewable energy and cumulative installed capacity for solar PV and wind (2004-2013)



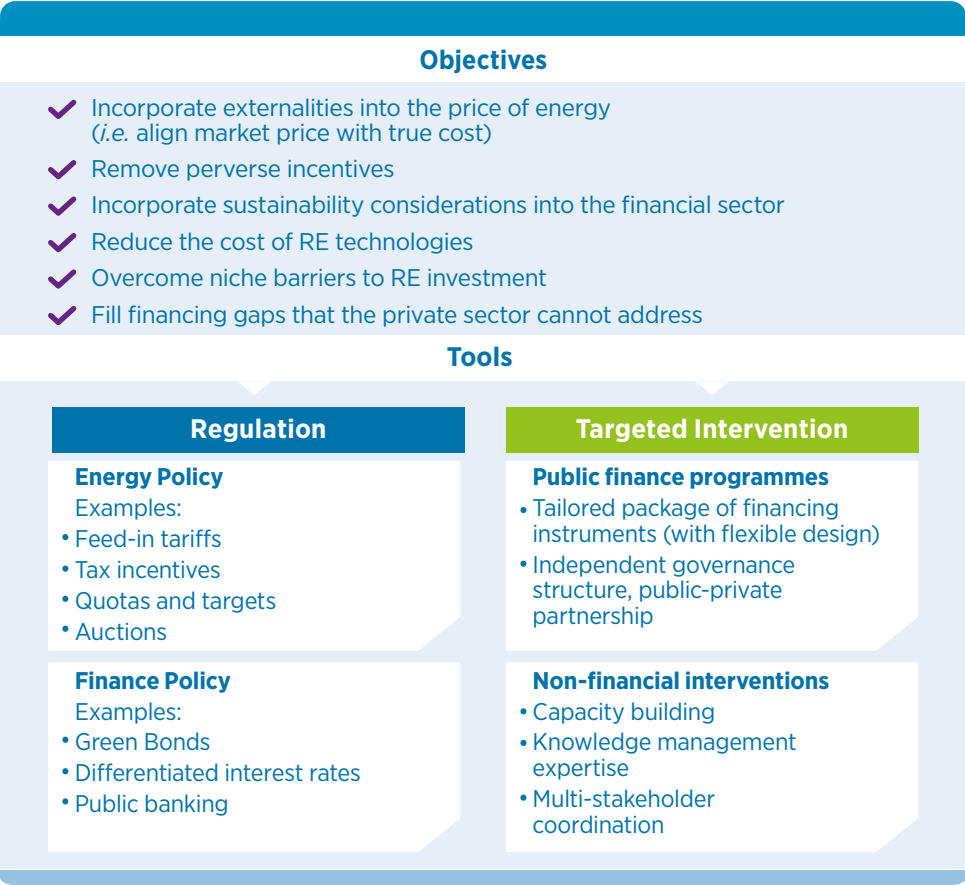
Source: IRENA based on (UNEP, BNEF and FS, 2014) and (REN21, 2014)

USD 550 billion is needed per year to scale up renewable energy to 36% or more of the total energy mix by 2030 and keep the global temperature increase at an acceptable threshold, according to IRENA’s REmap 2030 analysis (IRENA, 2014f).

The bulk of future investment in renewable energy is likely to continue to come from the private sector. Attracting investments will depend on the cost competitiveness of renewables in target markets, which is strongly influenced by: i) the cost of deploying the technology (procurement, installation and operation) and ii) market risks for financing renewable energy projects. Creating the right market conditions for attracting private investment requires coordinated efforts by governments, international financing institutions and other stakeholders.

Governments have an important role to play in fostering investment in renewables. Figure 15 suggests features of a renewable energy investment strategy: a combination of clearly stated objectives, enabling regulations and targeted financial and non-financial interventions (IRENA, 2012b). Creating an investment-friendly environment involves reducing risks, designing innovative financial products, adapting government support to changing market conditions and transforming utility business models.

Figure 15: Sample national renewable energy finance strategy



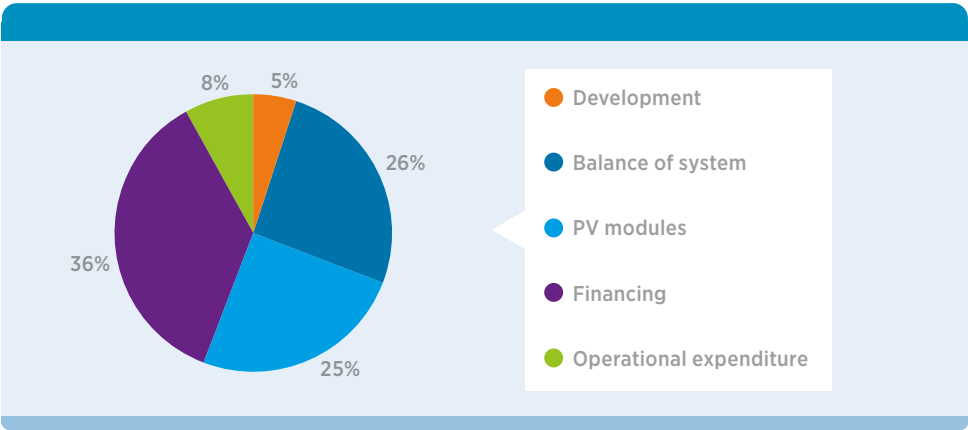
Source: IRENA (2012b)

3.1 ADDRESSING RISKS TO REDUCE THE COST OF CAPITAL

The viability of renewable energy projects is greatly affected by a market’s risk profile. Risks, actual or perceived, stem from regulatory and policy frameworks, and limited experience with new technologies. These can impact the viability of projects by increasing the cost of capital that developers are able to raise.

Traditional factors that determine energy-sector financing apply to renewable energy, only in a different manner. Compared with fossil power generation, most renewable energy technologies have a high ratio of upfront capital costs to operating costs, making their viability particularly sensitive to the cost of capital. For instance, IRENA estimates that the LCOE on a wind farm project is around 60% higher when the cost of capital is 14.5% rather than 5.5% (IRENA, 2012a). The relative impact of the cost of asset finance will continue to increase as technology costs decline. An example of the cost breakdown of a utility-scale PV plant is provided in Figure 16.

Figure 16: Cost breakdown of a utility-scale PV plant over its productive life



Source: First Solar (2013)

The cost of capital for renewable energy projects is decreasing because perceived risks are being more accurately quantified. It is likely to fall further as the investment community understands yet more about renewable technologies and the opportunities they present. Depending on the expected cash flow outputs of the project and the risks involved, market finance can currently be obtained for an average return of about 6%-10% for most renewable energy projects in developed markets, with higher returns expected in developing countries.

Globally, the cost of capital is decreasing as the volume of investment and the cumulative experience of the financing community with renewable energy projects increase. In parallel, sophisticated and tailored products (discussed in the next section) that suit a wider range of investment profiles – from small-scale community financing

to large institutional investments – are reducing investment risks and bringing in new investors. In this context, large businesses from outside the traditional energy sector are increasingly investing in renewables (Box 6).

As markets and technology mature, renewable energy projects are attracting a progressively wider range of investors, from private equity firms, project developers and governments, to commercial banks and institutional investors (see Figure 17). Box 7 charts the growing importance of multi-lateral institutions in spurring the international flow of finance.

Institutional investors are more comfortable with low-risk, long-term investment opportunities, of which there are an increasing number in the renewables sector. Of the USD 71 trillion in assets under management worldwide, approximately USD 45 trillion are invested in long-term, low-risk obligations – similar to the profile of the largest demonstrated, installed renewable energy assets. Indeed, in a choice between 10-year government securities yielding 2.5%-3%, and deployed solar and wind assets in a domestic market returning 4%-6% with Power Purchasing Agreement (PPA) backing, renewables should look increasingly attractive.⁶ However, these projects first have to meet the strict criteria of institutional investors.

BOX 6: NEW CORPORATE PLAYERS IN THE RENEWABLES MARKET

Some large non-energy companies are now major players in the renewables market. They are looking to reduce their risk in long-term operating costs, diversify their energy supply, and hedge against volatility in fossil fuel markets, while also earning a market-based return on investment. This is increasing technology demand, demonstrating new business models, and lowering the cost of capital for project developers.

At the end of 2013, **IKEA** had invested in 206 wind turbines and 550,000 solar panels in eight countries, as well as in energy efficiency. In the course of the year, IKEA renewables produced 1,425 gigawatt-hour (GWh) of electricity, equivalent to 37% of the company's total energy needs. The company aims to be 100% renewable by 2020.

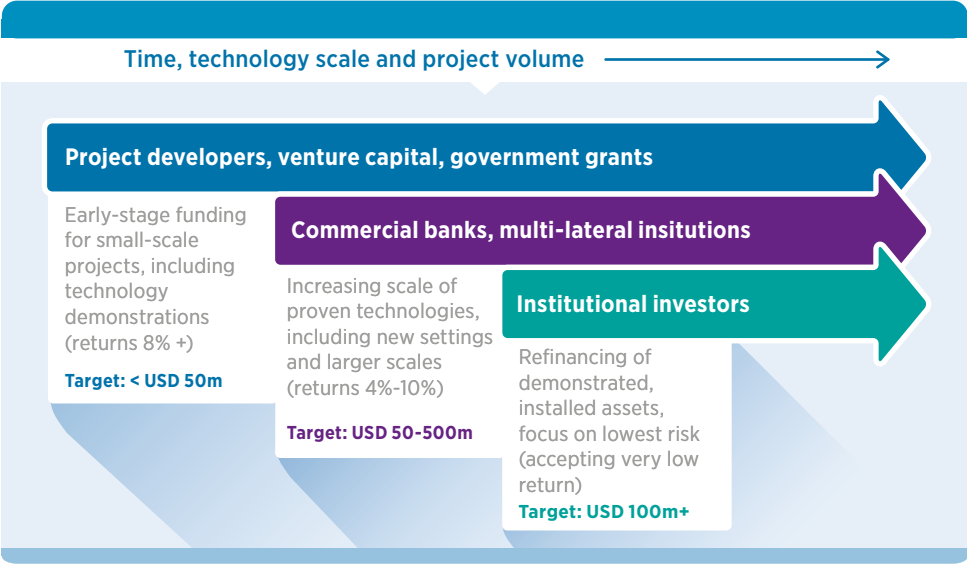
Google has invested over USD 1.4 billion in wind and solar projects. Some of this was for in-house use, some for social good and some because it “generates attractive financial returns”.

Walmart is working towards 100% renewable power. This includes generating energy at stores and facilities, reducing emissions and making the vehicle fleet more efficient. At the end of 2013, Walmart had 335 active renewable projects across its global portfolio.

More than two-thirds of Fortune's Global 100 companies have renewable energy commitments, greenhouse gas emissions reduction commitments or both, and the remainder are likely to follow suit.

⁶A 4%-6% return for an institutional investor does not represent the cost of financing to the project developer, which is significantly higher – especially in emerging economies.

Figure 17: Investment progression through technology and market development stages



BOX 7: INTERNATIONAL FINANCE INSTITUTIONS AND DEVELOPMENT BANKS

The bulk of renewable energy finance comes from private investors, including developers, commercial banks and institutional investors, and this will increase as markets mature. However, public financing will remain important in new and emerging renewable energy markets and international cooperation will play a prominent role.

International financial institutions and development banks have steadily increased their funding of renewable energy projects, to about USD 60 billion in 2012 (UNEP, BNEF and FS, 2013). Much of this came from national, sub-regional and bilateral development finance institutions, coordinated within the International Development Finance Club.

Greater funding of renewable energy has also stemmed from the climate finance activities of multilateral development banks. Regional development banks and the World Bank have been cooperating within the framework of the Climate Investment Funds (CIFs); and the Green Climate Fund (GCF), intended to be at the centre of international climate finance flows, is becoming operational. The GCF's initial resource mobilisation of around USD 5-10 billion will have been completed by the end of 2014 and some of these funds will be used to support renewable energy investments.

Both the CIFs and the GCF place emphasis on stimulating additional private investment. It is important to ensure that public funds, which can be disbursed on concessional terms, do not crowd out private investments. One key objective is to develop structured deals and devise financial instruments so that concessional public finance can address some of the risks that hinder investment in renewable energy. This will be a prominent part of the strategy to incentivise large institutional investors to enter the renewables sector at scale.

Investment thresholds and risk perceptions are significant barriers. Institutional investors traditionally like refinancing proven, long-term, low-risk opportunities with values well over USD 100 million. While many renewables projects are under construction that might eventually satisfy this, few of these projects are seeking finance today. Potential future candidates might include large-scale wind farms in Brazil, China, the United States and the North Sea plus certain large solar arrays, as well as some biofuel plants. As the total number of renewable projects increases, and their scale expands, more opportunities will arise.

Anticipation helps. Developers and governments should make sure that institutional investors' requirements regarding quality, security and resilience are taken into consideration in project design. Early, sustained engagement can ensure that when these projects do seek refinancing, institutional investors will be able to reclassify them away from alternative investments (always a smaller pool of money) into broader energy investments, and will have developed the necessary human capital to properly appraise each opportunity. Greater familiarity will result in the acceptance of lower rates of return.

Institutional investors are increasingly concerned about the longer-term risks of fossil fuel energy investments. In late 2013, a coalition of 70 investors collectively responsible for USD 3 trillion called on the world's largest fossil fuel and electricity companies to assess risks under climate action and business as usual scenarios, and specifically demonstrate how their business plans fare in the low-carbon future (Ceres and Carbon Disclosure, 2013). If climate policy tightens, renewables become more attractive relative to fossil fuels. Ceres investors⁷ say they are finding upstream fossil energy investments increasingly difficult to justify. If historical fossil investments eventually become stranded assets, policy makers will face difficult decisions around the assets held by today's biggest energy companies, particularly given their ongoing pension liabilities.

Institutional investment has a two-fold effect. More renewable energy asset finance not only ensures more projects are developed, but the increased supply also helps lower the cost of capital more generally, making other clean energy projects feasible too. Refinancing also liberates project finance from long-term assets, allowing developers and multilateral organisations to initiate new projects.

Where government financial support initiates renewables projects and commercial debt is available, the national debt rating becomes an indicator of stability and growth for a country. Institutional investors use this to help define the risk level for lending to and within the country. In short, the debt rating becomes the market's de facto evaluation of the country's ability to sustain the renewable energy support mechanism. Stable, dependable and long-term frameworks for the national energy

⁷ Ceres (www.ceres.org) is a non-profit organisation advocating for sustainability leadership mobilising a network of investors, companies and public interest groups to accelerate and expand the adoption of sustainable business practices and solutions.

mix, and national financial credibility, are crucial to risk reduction efforts. Morocco's Ouarzazate CSP plant offers a successful example. Upon completion, the plant is expected to be the largest in the world at 500 MW, with the first 120-160 MW expected to be commissioned by 2015. The project is unique in that seven lenders were involved after the government and international finance institutions partnered to reduce the project risk and demonstrate the long term future of CSP in Morocco (Climate Policy Initiative, 2012).

If project developers can meet major investors on their terms, capital is available. The European Investment Bank (EIB) reported in 2012 that there was a dearth of investment-worthy renewable energy projects available and that funding was not the problem (EIB, 2013).

There is also an issue in the type of finance sought: historically, projects were financed on a one-off basis using complex structures. Institutional investors generally don't invest directly into small projects. If bundled and structured into a portfolio of deployed assets, individual renewable energy projects' high initial costs and variable cash flows can aggregate into one steady, low-risk, long-term cash flow – approximating a bond, with which institutional investors are very familiar. Early-mover private renewable energy developers in this space attracted USD 11 billion in equity investments in 2013, up 200% in 12 months (UNEP, BNEF and FS, 2014).

If policy makers, along with other stakeholders, can foster a market that demonstrates realistic projects with appropriate levels of risk and return and makes clear that fossil fuel-powered energy will form a decreasing part of their national energy mix, many investors will be interested. Engaging the financial sector to innovate suitable investment vehicles will mean that institutional investors have significant investment opportunities. Policy makers also have the possibility to integrate environmental sustainability into monetary and financial policy, thereby stimulating additional financial resources for renewables. This has been done at national and international levels: The Bank of Japan established lower interest rates for lending into environmentally strategic sectors across the entire Japanese banking sector. At the global level, the addition of 'sustainability requirements' alongside the capital requirements in the Basel Accords⁸ could help shift new liquidity towards the renewables sector.

The financing of renewable energy projects has also changed in developing countries, shifting from development bank funding from 1990 to 2000, through state-led financing from the start of millennium up to the financial crisis, onto more commercial sources of funding today. While previously, a developer would have sought out anchor funders such as the World Bank, the EIB or the Asian Development Bank, in economies with significant renewable energy experience, project developers are more likely to obtain independent commercial (and often local) finance.

⁸ Basel Accords refer to a set of agreements set by the Basel Committee on Bank Supervision, which provides recommendations on banking regulations in regards to capital, market and operational risks.

In less experienced markets, even with coherent renewable energy strategies and low political risk, smaller-scale, decentralised projects still struggle. Scale is certainly a challenge, with a clear gap between the micro-scale of most proposals and the lowest investment thresholds of most private investors. However, there is also an issue around the project proponent's ability to satisfy investors' reporting criteria, plus concerns by investors around the difficulty of aggregating small projects.

3.2 GROWING SOPHISTICATION OF FINANCIAL PRODUCTS

Familiarity reduces perceived risk. The cost of capital can be reduced if investors are offered products they understand. New entrants to the renewable asset finance market are attracting more investors with innovative adaptations of financing tools from other sectors. These include financial hybrid instruments at a variety of scales – from local community projects to EIB's Renewable Energy Platform for Institutional Investors, and Bloomberg's Big Green Bucket concept⁹.

New aggregate products allow for the distribution of project and technology risk, integrate climate impact, or link to particular phases in renewables project development (such as early-stage technology funds). Aggregating investment opportunities can address key investment barriers such as projects being deemed too small for large investors, a lack of quality information and developers being seen as too small to warrant stable credit ratings.

The renewables sector has been highly fragmented, due to its decentralised nature, as well as the relative novelty of renewable energy technologies and the speed of progress. Project developers have traditionally had to contribute the largest share of capital, particularly in developing countries. Aggregating and reclassifying projects into products or vehicles allows developers to raise capital on the international markets and be more widely traded. Three further areas of renewables finance demonstrate particular promise: green infrastructure bonds, crowdfunding and solar leasing.

Green bonds allow investors to tap into fixed income markets and finance clean energy. In short, they are asset-backed corporate bonds issued to refinance operating renewable energy infrastructure, such as a wind farm and its grid connections, freeing the developer's capital for the next project. They are issued in sufficient quantities to be easily tradable and appraised by ratings agencies to ensure investment quality. The idea has existed for years, and there were many types of green bonds on the market, but investors struggled to differentiate. Recent developments have injected the concept with new vigour (see Box 8). The number of projects eligible to fit inside such a bond, along with the number of organisations considering issuing them, is likely to increase in the short to mid-term.

⁹ The Big Green Bucket mechanism proposes to introduce a securitisation facility, which would package the more than USD 100 billion of development bank finance currently going into projects in clean energy, transmission and power distribution globally, into high-rated bonds for sale onto to private institutional investors and sovereign wealth funds.

BOX 8: GREEN BONDS: WRITING RULES TO ATTRACT NEW PLAYERS

In January 2014, a coalition of major global banks devised a common set of principles – Green Bond Principles – to catalyse and clarify the market. By mid-2014, private green bonds had already been issued for over USD 16 billion to finance renewable energy projects, surpassing the USD 14 billion issued in all of 2013. However, this still only represents about 1% of the USD 1.4 trillion corporate bond market, so there is considerable room for growth.

At the other end of the spectrum, decentralised, co-operative renewable projects based on small-scale investment opportunities are proving highly successful, as demonstrated by US-market leader Mosaic. Crowdfunding was initially developed to finance creative projects without delivering financial returns, but innovative companies adapted the idea to allow volumes of investors to buy small stakes in renewable energy projects, usually in developed markets (see Box 9). Investments are tradable in a secondary market and have demonstrated risk/return profiles.

Crowdfunding is growing quickly, tapping into individual investors' desire to see where their investment is going and how it is benefitting a community. Specifically, in conjunction with decentralised technology, crowdfunding allows individuals and local communities to be the driving force behind the global energy transformation and to simultaneously benefit from the change. Investors own a tangible slice of a bigger project they would have been unwilling or unable to fund otherwise, usually in their own geographic area.

Crowdfunding could be adopted to lower the cost of capital for investments in developing countries too. Crowdfunding pioneer Kiva has already channelled over USD 600 million in loans to micro-entrepreneurs in 78 countries, largely without engaging the investment potential of domestic private capital in recipient countries (Kiva, n.d.). Through crowdfunding investment models, the entrepreneurial spirit in developing countries could be tapped and huge growth potential unleashed. Such platforms could

BOX 9: COMMUNITY-SOURCED CAPITAL DRIVES WIND DEPLOYMENT IN DENMARK

The Danish Renewable Energy Act has ensured that over 100 wind turbine co-operatives own roughly 75% of the country's turbines, with a portion of each project owned by local residents.

For instance, the Hvide Sande wind co-operative is 20% owned by 400 local stakeholders, provides an annual return to shareholders, pays rent to the local landowner and is expected to pay off its turbines in 7 to 10 years.

It has very high levels of local support and thanks to a law that ensures electricity generation projects must be not for profit, the price per kilowatt-hour from these community-owned wind farms is roughly half the price of electricity from offshore wind farms.

also source investment funding globally to finance specific projects in markets facing financial access challenges, helping to achieve the UN's SE4ALL objectives.

Solar leasing allows rooftop panels to be owned, installed and operated by a third party on a rooftop, with the property owner receiving payment either through a bill reduction or by direct payment. This provides cheaper and cleaner electricity to the property owner, without the need for significant initial capital outlay. Panel owners earn their returns via policy-incentive mechanisms and the sale of electricity. This financing mechanism has proved particularly successful in the United States, including SolarCity's business, Honda/Acura's partnership with FirstSolar and SunPower's alliance with Bank of America to deliver solar leasing schemes. This concept has also been successfully implemented in Italy and Bangladesh.

3.3 ADAPTING SUPPORT TO CHANGING MARKET CONDITIONS

Governments can reduce public financing while increasing renewable energy deployment, especially in advanced markets. This is primarily due to rapidly falling technology costs requiring less financial support for the same volume of deployment, and also because deployment experience has reduced political and policy risk and other barriers. Financial support to encourage new renewables projects needs to fall in line with these underlying factors to minimise the burden on taxpayers and limit the scope for windfall profits for developers. However, as discussed earlier, in energy markets with a lower penetration of renewable energy, public funding remains critical to bring forward renewable projects in their very early stages – particularly if the funding can be used to de-risk bigger projects and entice non-energy financiers (UNDP, 2014).

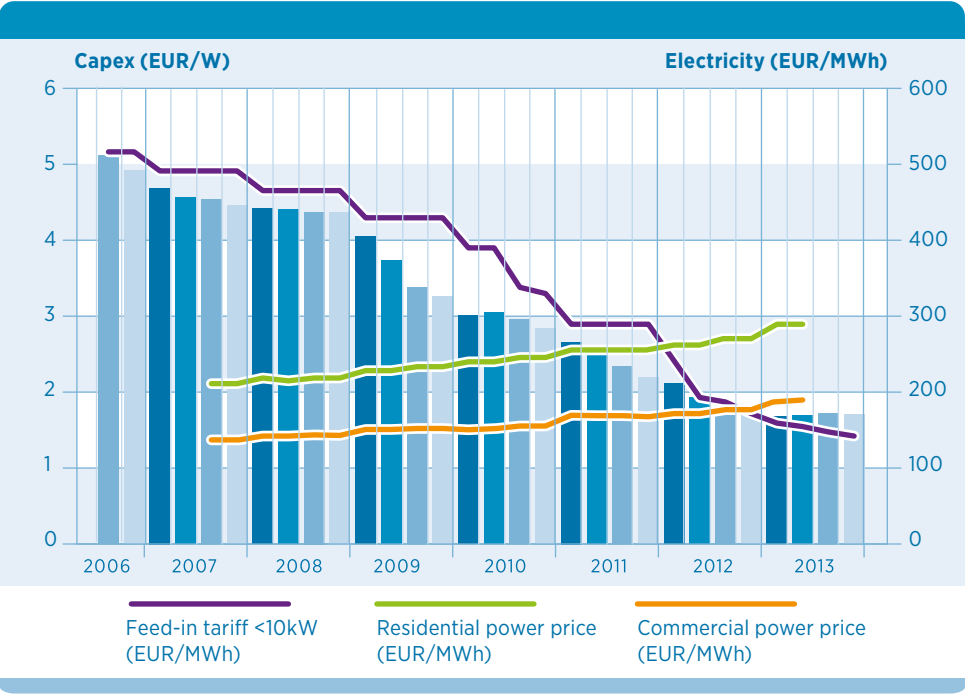
At the outset, government financial support was designed to encourage early-stage technologies through to large-scale deployment. This led to a rapid expansion in renewable deployment in many markets and falling project costs. Costs fell far more quickly than anticipated and policy makers had to move swiftly to re-evaluate support programmes. But they struggled with long lead times in policy adaptation and political decision-making. Some developed-market governments reacted with sharp subsidy cuts or revoked subsidies and tax credits altogether, sometimes with retroactive effect. This had a highly destabilising effect on local markets, as private investors rushed to complete projects before the rules changed, and on international markets, as developers wondered whether other governments would follow suit. International investors contemplating new projects shifted their attention to lower-risk locations.

As costs fall, a gradual reduction in direct financial support benefits the industry. If government finance is scaled back in a planned, predictable and clearly communicated manner, it can ensure that a stable market is maintained and deployment costs continue to fall. Degression mechanisms, wherein feed-in-tariff rates are reduced based on the

connected megawatts in the previous period, have been adopted in France, Germany and the United Kingdom. The German feed-in-tariff system as shown in Figure 18 provides a good example of decreasing government support – while still supporting growth of installed PV from 17 GW new installed capacity in 2010 to 36.6 GW in early 2014 (Bundesnetzagentur, 2014).

As renewable energy becomes more competitive, long-term and stable non-financial policies gain prominence. Non-financial policies can support purely market-driven growth of renewable energy. These include specific measures for de-risking investments, intellectual property protection, priority connection to the grid, tax legislation, education programmes and industry standards. They tend to be long-term and system-wide, harder to revoke and less susceptible to the instability of budgets. As such, these policies are pre-requisites for renewable energy deployment in any market. The National Renewable Energy Policy and Action Plan of Malaysia, for example, emphasised research and human capital development, in addition to deployment policies such as feed-in tariffs.

Figure 18: German feed-in-tariff and capex (systems <10kW), (2006-2013)



Source: IRENA (2014c)

Reducing or eliminating fossil fuel subsidies for power generation would significantly lower the costs of financing renewable energy projects, both by sending strong market signals and by improving the competitiveness of renewables. Moreover, subsidy reform frees up more public funding for renewable energy. IRENA’s REmap 2030 analysis

indicates that doubling the share of renewables in the global energy mix will require annual financial support of USD 315 billion in 2030. In comparison, global fossil energy consumption subsidies amounted to USD 544 billion in 2012, at least five times that of renewables (IEA, 2013). When considered, energy pricing reforms may need to account for the impacts on low income groups and growing economic sectors.

Carbon pricing can boost domestic renewable energy markets. The fact that conventional producers of energy are not forced to cover the externalities they cause is also a hidden subsidy. In the case of fossil fuels, this includes emissions of carbon dioxide and their climate change impact, which can be offset through effective carbon pricing policies. The reduction in carbon-emissions prices during and after the financial crisis undermined a potentially valuable source of support for renewable energy. The price of carbon fell significantly due to declining industrial output and corresponding decreases in energy demand, exacerbating the oversupply of permits as well as regulatory failures. Going forward, concerted international policy is needed to ensure that carbon is adequately priced. This would improve the overall cash-flow forecasts for renewable energy, facilitating access to capital for developers.

3.4 TRANSFORMING UTILITY BUSINESS MODELS

The speed of innovation in the renewable electricity sector is driving the reform of the regulatory process and utility business models. Decentralisation, net demand reduction and the need to apportion the costs of back-up generation are challenging utilities in many developed markets (see Box 10).

The centralised utility business model, whereby companies make profits by delivering power through a centralised grid, is shifting towards a distributed local model with increasing penetration of small-scale renewable energy. This is transforming traditional consumers into producers. In Germany, for instance, utilities own under 12% of renewable energy capacity, with nearly half owned by individuals and farmers (see Figure 19).

Many advanced markets are characterised by stable or decreasing electricity demand. In such contexts, utilities' most profitable customers are likely to reduce their power consumption as energy efficiency measures are introduced and locally produced power is promoted through policies such as net metering (see Box 11). However, these customers will probably still depend on the central grid for periods of peak demand, so utilities may be obliged to maintain costly infrastructure and power-generating capabilities even as revenues from consumption decline. In some cases this is already resulting in higher fees being charged to customers for grid access and use.

These developments do not have to mean the end for proactive utilities. There are major opportunities for utilities to build on their existing relationships with consumers, by shifting towards the provision of retail services (such as smart meter installation,

BOX 10: CHALLENGES TO TRADITIONAL UTILITY BUSINESS MODELS

The rising deployment of renewable energy and its impact on wholesale power prices is affecting the profitability of generation assets across the portfolios of energy utilities. Smart meters, energy storage and transforming ownership structures are shaking up the utility industry, changing customer expectations and obliging regulatory models to adapt.

New utility strategies require thorough organisational changes within the utilities, which have been operating under their traditional business models for decades without the need for significant business innovation.

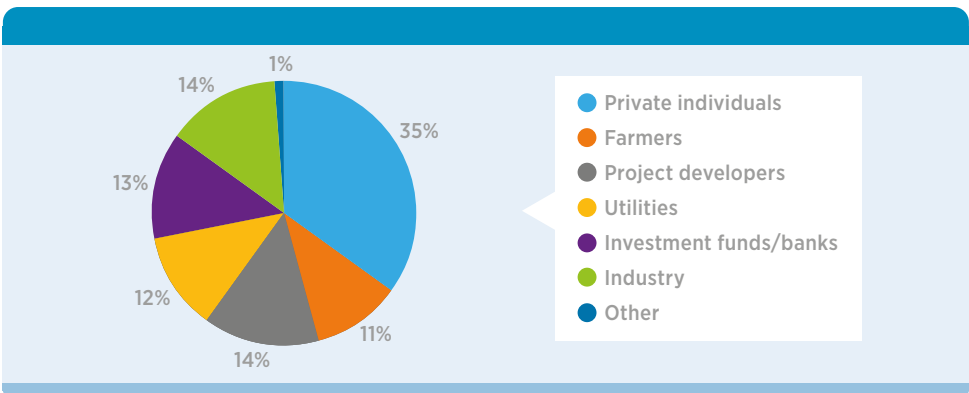
The relationship between utilities and customers is becoming more complex, creating opportunities for an array of non-utility companies to enter the market. Utilities are reacting by expanding their offering to include demand-side management (industrial and residential), smart-home management, distributed generation packages, the sale or loan of energy efficiency products, etc.

Some utilities have started expanding their geographical focus and retained their existing business models (providing power generation from fossil and renewable sources) abroad. They are targeting primarily markets with high (or growing) electricity demand, to invest in thermal or large-scale renewable generation.

energy efficiency advice and other services) as well as the direct sale of grid-tied renewable infrastructure and the provision of grid-scale storage. Utilities can help renewables with relatively low-cost capital, their expertise, their existing infrastructure and their access to homes and businesses.

Utilities can form partnerships to raise capital for renewables. Developers can reduce cash flow risks and volatility by piggybacking on utility balance sheets and credit ratings, while utilities can benefit from new business opportunities identified by smaller developers. Nationalised utilities can partner with renewable energy developers to co-finance projects at scale.

Figure 19: Germany's ownership distribution for installed renewable energy capacity (2012)



Source: Agentur für Erneuerbare Energien, 2013

BOX 11: NET METERING TO SUPPORT DECENTRALISED RENEWABLES

Net metering is a mechanism which allows individuals and other generators to export any excess production to the grid and to be compensated for their net output based on fixed or market-based prices. This enables the transformation of consumers into customers who both produce and consume electricity, and makes small-to medium-scale renewable energy investment more attractive. Policy makers like it because it can be adjusted to reflect the underlying costs of renewables, even beyond parity with the grid.

Net metering is already in place in at least 43 countries, up from just 10 in 2009. Over 1.5 GW of solar PV capacity deployed in the United States in 2012 was net metered, representing 99% of the total solar installations that year. The challenge is to distribute costs and benefits between desentralised generators, network operators and non-producing consumers in a way that sets the right incentives. Various measures are being proposed to address this, from assessing the “value of solar” (in Texas) to the imposition of surcharges on generators (in Arizona).

IRENA's *'Adapting Renewable Energy Policies to Dynamic Market Conditions'* examines net metering policies in more depth.

www.irena.org/DocumentDownloads/Publications/policy_adaptation.pdf

Utilities can also access cheaper capital directly. French utility Electricité de France's (EDF) 2013 green bond issue raised EUR 1.4 billion (25% into solar, 75% into wind, with an annual coupon of 2.25% and a maturity of 7.5 years). It was described by industry analysts as twice oversubscribed, with the bulk of potential investment coming from institutional investors (The Economist, 2014). With part of this capital, EDF entered into a joint venture with Indian solar company Acme to develop an initial portfolio of 200 MW in India.

3.5 RECOMMENDATIONS FOR POLICY MAKERS

With a better understanding of the opportunities and risks within asset finance, governments can develop more effective policies to reduce risks and attract investments into the sector.

Staying the political course is the best way to reduce financial risk. A continued reduction in the cost of capital partly depends on governments' ability to make policies transparent, credible, long-term and predictable. This can be achieved by laying out long-term statements of intent, including financial support and review windows.

To attract institutional investors in particular, policies must ensure that projects satisfy their minimum investment requirements: long-term, low-risk and demonstrated, proven technologies, ideally backed by purchase agreements.

Set out below are some ways to implement this:

- » **Policy makers are well placed to address the upfront cost of renewable energy projects.** Traditional options include revising tax credit structures or permitting accelerated depreciation, but policy makers must signpost these to market participants carefully, so as not to create boom-bust markets. Innovative approaches to financing – such as green bonds, risk sharing and aggregation – can attract further investments into the sector to bridge the funding gap.
- » **Policy makers need to ensure that policy mechanisms keep pace with the falling costs of renewable energy technologies.** This requires monitoring the market frequently, communicating regularly with industry and clearly signposting future policies. These minimise windfall profits, and avoid disproportionate liabilities for either government or consumers. The objective should be to phase out financial support for renewable energy as technologies drop under parity with fossil fuel-powered generation and the underlying conditions warranting subsidies are addressed. Without the additional stimulus of a sufficiently high carbon price, governments are likely to continue in a direct financial support role in the short term.
- » **Policy makers should continue to implement wider structural policies** (e.g. enabling infrastructure, energy pricing reform, education and training programmes, and research and development) **and specific enabling measures** (e.g. updating planning and permitting regimes, standardising Environmental Impact Assessment requirements) to facilitate renewable energy deployment.
- » **Policy makers need to be transparent and up-front on the cost of renewable energy to rate-and tax-payers.** Renewable energy support has in the past inflated bills to taxpayers, consumers and business. It may also be prudent to implement spending caps on renewable energy support, particularly for feed-in-tariff mechanisms, as has been done in the United Kingdom, Italy, Germany, the Netherlands and Malaysia.
- » **Policy makers could consider targeted fossil-fuel subsidy reforms.** Reducing fossil-fuel subsidies can significantly level the playing field for renewables, improve a country's balance of payments and ensure government finance is on hand for other initiatives. When considered, energy pricing reforms may need to focus on low-income groups and growing economic sectors.
- » **Policy makers should utilise international finance effectively to encourage, rather than displace, private investments in renewable energy.** An intelligent use of public finance would help address some of the risks that are specific to developing countries and help create the policy environment needed for private investors to scale up their engagements. International cooperation could also address the international financial rules and introduce sustainability as an additional criterion.

STIMULATING ECONOMIC GROWTH

USD 52 billion

generated by
Chinese PV industry
in 2013

15%

average increase
in GDP expected from
20GW wind in Mexico

IMPROVING ENERGY ACCESS

9%

of Bangladesh's
population is electrified
by solar

up to **250** times
less CO₂ than coal

REDUCING ENVIRONMENTAL IMPACT

6.5 million
jobs in 2013

CREATING JOBS

4 Renewables can address economic, social and environmental goals

Policies that promote renewable energy can simultaneously address economic, social and environmental objectives. A key part of rethinking energy is for policy makers to take a more holistic approach to charting the world's energy future.

There is a common view that while renewables are more environment-friendly, they are too expensive. As demonstrated earlier in this report, declining costs mean the perceived economic trade-off of 'cheap vs. clean' is becoming less important. This false dichotomy becomes even more apparent as economists develop tools to measure the broader impact of power generation, such as the cost of pollution and fuel price volatility.

Effective analysis of the costs and benefits of different forms of energy should take into account a much wider view of economic development than is now the case, including the balance of trade, industrial development, growth in gross domestic product (GDP), employment, energy access and health.

4.1 IMPROVING THE BALANCE OF TRADE

Solar, wind, hydro, geothermal and ocean energy are domestic resource endowments. Increasing the use of renewable energy can enable positive structural change in a country's balance of trade, if the reduction of fossil fuel imports, or an increase in exports, outweighs renewable technology imports. Spain's use of renewables is estimated to have avoided USD 2.8 billion of fossil fuel imports in 2010, while Germany saved an estimated USD 13.5 billion in 2012 (Deloitte and APPA, 2011; BMU, 2013; IEA, 2012; International Monetary Fund (IMF), 2013).

For fuel-exporting countries with subsidised domestic fuel prices, renewable energy deployment can minimise domestic fuel consumption and maximise the amount available for exports. The Middle East and North Africa region's endowment with abundant sunshine means that afternoon peak electricity demand, driven by air-conditioning requirements, is roughly aligned to peaking solar yields. Evening peak demand could be addressed through CSP plants with storage. At present, peak power is usually supplied by expensive back-up generation from oil or liquefied natural gas (LNG), making solar power commercially viable without any subsidy support (PricewaterhouseCoopers (PwC), Robin Mills and Emirates Solar Industry Association, 2012).

The deployment of renewable energy may not impact the trade balance positively in the short term. A deployment policy that reduces imports of fossil fuels may increase imports of renewable energy equipment (for example, solar panels produced abroad),

which could initially result in a negative impact on the trade balance. However, the imported renewable energy technologies would enable the reduction of fossil fuel imports for a significant period of time (e.g., 20 years), so that the long-term effect on the trade balance is likely to be positive. Furthermore, the development of local renewable energy industries can help localise value-adding activities such as equipment manufacturing and services for project development and operation – thus improving the trade balance.

4.2 ADDING LOCAL VALUE

A number of countries require that investments in renewable energy projects include local content (project development and design, construction and installation, operations and maintenance) to maximise value to their economies. While countries differ substantially in their level of industrial development and expertise, many can contribute a significant share of the manufacturing. All countries can provide significant local value added through the installation and maintenance of renewable energy systems.

Policy decisions aim to balance benefits which are narrower but immediate (importing lowest cost technology) with those that are broader but longer term (localising). A country's potential to produce renewable energy products or services domestically depends on several factors, including its natural resource endowment, its stage of economic and industrial development, and the size of domestic renewable energy market. While some elements of advanced technology will likely need to be imported, localising content can create jobs and develop domestic capacity.

An accurate assessment of domestic capabilities and international market potential supports good policy-making. Some countries have developed local content requirements (LCRs) as an instrument to support nascent domestic renewable energy industries (see Boxes 12 and 13 for country examples). To ensure the full-fledged development of an infant industry, LCRs should be time-bound, closely linked to a learning-by-doing process, and support the creation of an internationally-competitive domestic industry with a skilled workforce.

The full effects of LCRs are dynamic and depend to a large extent on the policies that govern deployment, industry and education; on the stage and level of deployment of a given technology domestically; and on the cost of technology. Supporting research and development and export-oriented manufacturing, as well as enhancing the business-friendliness of the country in general, may yield wider benefits when combined with policies designed to support specific renewable energy technologies. There are also risks to LCRs. If the conditions are too stringent, there may be no interest from developers or investors.

Countries do not necessarily have to produce end-product renewable energy equipment themselves in order to benefit. They may export raw materials (e.g., rare

BOX 12: LOCAL CONTENT REQUIREMENTS: CREATING AN INDUSTRY IN BRAZIL

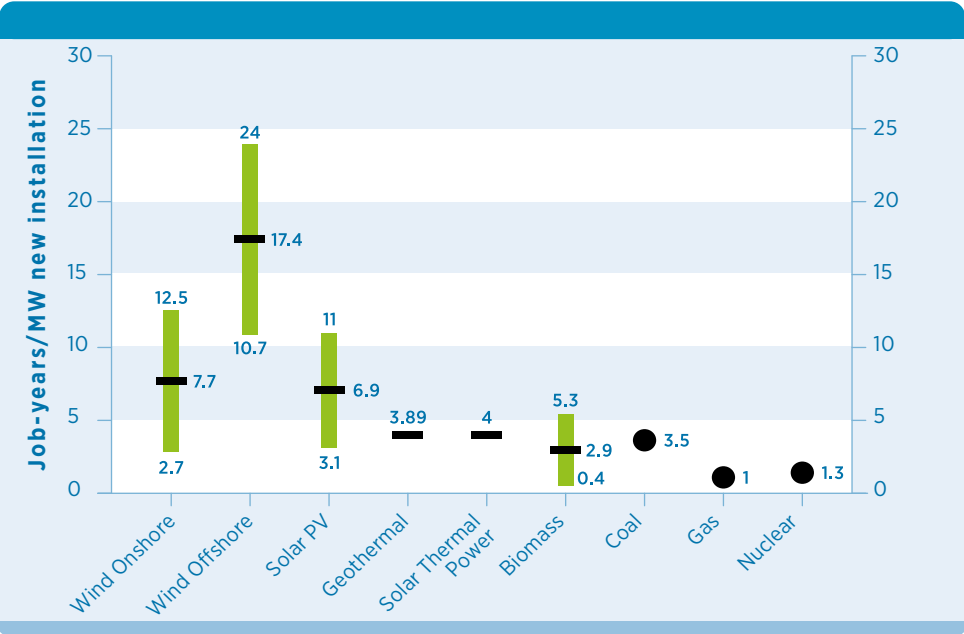
In 2009, Brazil established a requirement for bidders participating in auctions to get 40% of components from Brazilian suppliers, rising to 60% in 2012, in order to qualify for subsidised loans by the Brazilian National Bank for Development. From 2013, manufacturers have to produce or assemble at least three of the four main wind-farm elements (*i.e.*, towers, blades, nacelles and hubs) in Brazil.

As a result, international wind companies have set up local assembly plants including Alstom, GE Wind, Vestas, Suzlon and Gamesa. In addition to establishing a domestic wind industry, these auctions have resulted in deploying 370 MW in 12 months to January 2014, and taking the total to over 2.2 GW. In fact, wind power was excluded from one of Brazil's national auctions in 2013 as it would price other renewable electricity generation technologies out of the market.

earth elements, biomass), intermediate goods or capital equipment such as machine tools, which are used to produce renewable energy components.

As Figure 20 demonstrates, renewable energy technology manufacturing is more labour intensive (per MW of new installation) than coal, natural gas or nuclear. When creating energy policies, policy makers should consider the number of jobs their policies will create and how many of these can be localised. However, before deciding on local manufacturing, they may also consider the potential market size in order to avoid overcapacities and employment boom-bust cycles. Other factors to consider are the competitiveness of the market and the need to develop the necessary technological capabilities required for learning and for improving efficiency and quality.

Figure 20: Potential jobs per megawatt by technology



Source: Rutovitz and Harris (2012)

BOX 13: LOCAL CONTENT REQUIREMENTS: FOCUS ON SOCIO-ECONOMIC GOALS IN SOUTH AFRICA

The South African Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) is a competitive bidding mechanism with long term PPAs for developers. Socio-economic benefits from renewable energy deployment are maximised through the use of weighted development criteria during bid evaluation.

Job creation and local content, for instance, both have a 25% weight while assessing bids. Similarly, local ownership and development each have a 15% weight. Other criteria include preferential procurement (10%), management control (5%) and enterprise development (5%).

Early evidence suggests that REIPPPP has been successful in bringing forward the cost efficient deployment of renewable energy. Renewable energy job opportunities are increasing and local economic development impacts are being realised. South Africa's Energy Ministry estimates REIPPPP's third window will contribute approximately USD 4.4 billion towards national socio-economic development.

4.3 INCREASING GROSS DOMESTIC PRODUCT

A growing number of studies show that the impact of renewable energy on GDP is positive, particularly if renewable energy is cheaper than alternatives, or creates local industries that are competitive (see Box 14).

A comprehensive study on renewable energy deployment in Japan, assuming a 2030 target of 14%-16% renewables in the energy mix (including geothermal and hydro), concluded that the realised benefits are approximately double to triple the costs. The benefits are categorised into: 1) savings of fossil fuel imports; 2) quantified economic value of reduced CO₂ emissions and 3) indirect and induced economic ripple effects. Of these categories, the economic ripple effects are expected to account for 75%-90% of the total benefits (Japanese Ministry of Environment, 2008).

A recent analysis of the macroeconomic effects of the European Energy Roadmap 2050 shows that the transition to a more sustainable energy system could result in net job creation and positive economic impacts, alongside decreasing renewable energy technology costs.

In Malaysia, the current feed-in-tariff for selected renewable energy technologies is expected to generate cumulative income of about USD 22 billion by 2020. In China, the PV industry generated about USD 52 billion in 2013 alone and the latest job estimates indicate that it employed around 1.6 million people (IRENA, 2014e).

BOX 14: ECONOMIC IMPACT OF RENEWABLES: NEW INSIGHTS

IRENA has examined the effect of renewables on the economy. Selected case studies included China, Italy, Japan and Mexico, all of which were found to display positive net impacts from renewables deployment: lower costs, development of an export-oriented industry and increased investment

- **CHINA:** China's solar photovoltaic industry generated national income of USD 52 billion in 2013.
- **ITALY:** The USD 16 billion invested in renewable electricity technologies in Italy in 2011 contributed USD 23 billion to GDP.
- **JAPAN:** Including 14-16% renewables in Japan's energy mix would deliver double to triple the installation cost in net benefits by 2030, of which 75-90% would be purely economic.
- **MEXICO:** Developing 20 GW of wind in Mexico is projected to increase cumulative GDP by USD 7-28.5 billion by 2020, representing between 0.6% and 2.4% of 2012's GDP (depending on the level of domestic manufacturing).

The study provides further analysis on the socio-economic benefits of renewables. www.irena.org/DocumentDownloads/Publications/Socioeconomic_benefits_solar_wind.pdf

4.4 CREATING JOBS

As the slow recovery in the global economy fails to invigorate labour markets, renewable energy deployment provides an opportunity to alleviate some of the employment concerns. Job creation is gaining increasing prominence in the global renewable energy debate. However, specific analytical work and empirical evidence on this important subject remain limited. IRENA's work on renewable energy jobs (IRENA, 2012c, 2013b and 2014e) contributes to bridging the knowledge gap and provides a comprehensive view of the various dimensions of renewable energy employment.

The renewable energy sector has already become a major employer, supporting around 6.5 million direct and indirect jobs in 2013 (IRENA, 2014e). These figures exclude large hydropower (due to data limitations) which, if accounted for, would significantly boost the total employment estimate. These jobs span across solar (the largest renewables employer in 2013), bioenergy, geothermal, hydropower, wind and small hydro. The 6.5 million figure represents a 14% increase over 2012's estimate. Growth has been driven by increasing capacity additions (one-off jobs in manufacturing, construction and installation) and growing cumulative capacity (operation and maintenance jobs over project lifetime).

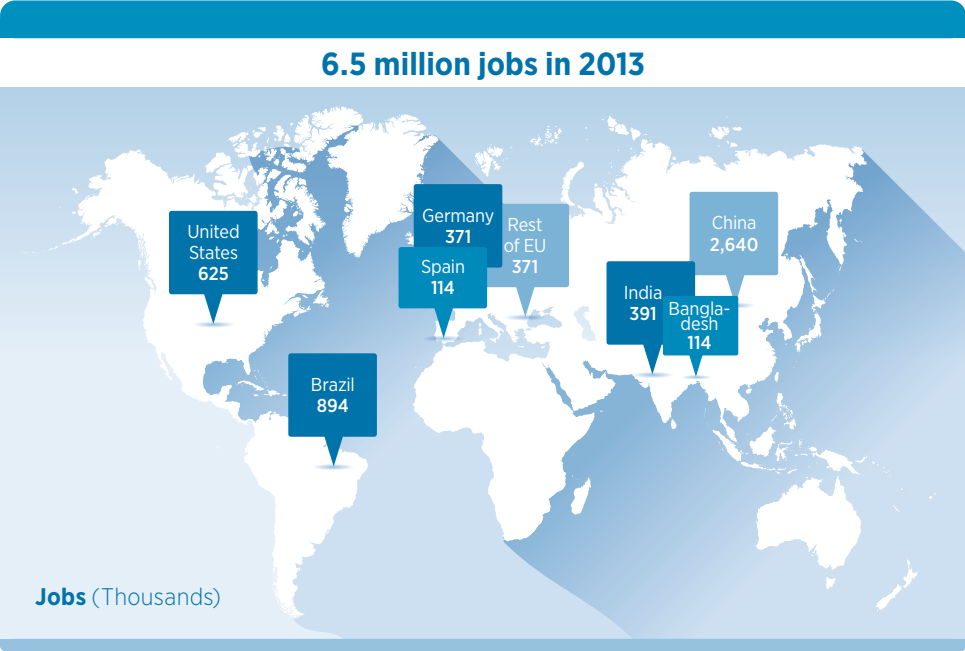
Employment trends mirror the regional shifts apparent in installation and investment, with significant growth outside OECD countries and a major focus on China. Other factors affecting employment include structural changes in industry, growing competition, advances in technologies and manufacturing processes, the impacts of austerity and policy uncertainty to name a few. Although declining prices of solar PV and wind equipment are introducing new challenges for suppliers and are shifting manufacturing jobs, they are also driving employment growth. This comes as a result of more installations being completed and the subsequent operations and maintenance requirements.

By 2014, 144 countries had defined renewable energy targets (REN21, 2014). As renewable energy spreads, so does employment in the sector – trending in line with the pace of installations. The top renewable energy employers are also the leading nations in local technology deployment – China, Brazil, the United States, India, Germany, Spain and Bangladesh (a notable success story for small solar home systems). Employment in solar PV in particular is showing substantial growth in other countries including Japan, Malaysia and Australia. Figure 21 shows where the majority of jobs in the renewable energy sector are located.

China and Brazil are leading employers in renewable energy

China is the largest renewable energy employer, with 2.6 million jobs. The Chinese PV industry alone employs 1.6 million people, a significant increase over 2011 (0.3 to 0.5 million jobs) – largely due to a 5-fold increase in annual installations. Brazil

Figure 21: Renewable energy jobs in selected countries (excluding large hydro)



Source: IRENA (2014e)

is the second largest employer, mostly associated with liquid biofuels. Employment in Brazilian wind power is also growing, but remains a distant second.

In the United States, employment in the solar energy sector has been rising rapidly, mostly in solar PV. In the wind industry, manufacturing capacity has grown strongly, but the stop-and-go nature of the national support mechanism triggers periodic fluctuations in employment.

Job developments in Europe in 2012 were mixed, with significant gains in wind and bioenergy, and a decrease in solar PV. European pioneers in renewable energy, Germany and Spain, have suffered job losses. Decreasing employment was likely driven by the economic slow-down and austerity as well as uncertainty from policy revisions (e.g., Germany's solar feed-in tariffs) or retroactive changes reducing investor confidence (e.g., Greece, Romania, Spain) (IEA, 2014b).

Several Asian countries other than China posted significant gains in renewable energy employment in 2013. Bangladesh has generated 100,000 jobs (Box 15), while Japanese support mechanisms created 60,000 solar jobs, and Malaysia created 10,000 jobs in solar manufacturing.

Solar, biofuels and wind are leading employers

Employment trends vary widely across renewable energy technologies. Jobs in solar PV have outpaced those in wind in the last three to four years and have tripled since

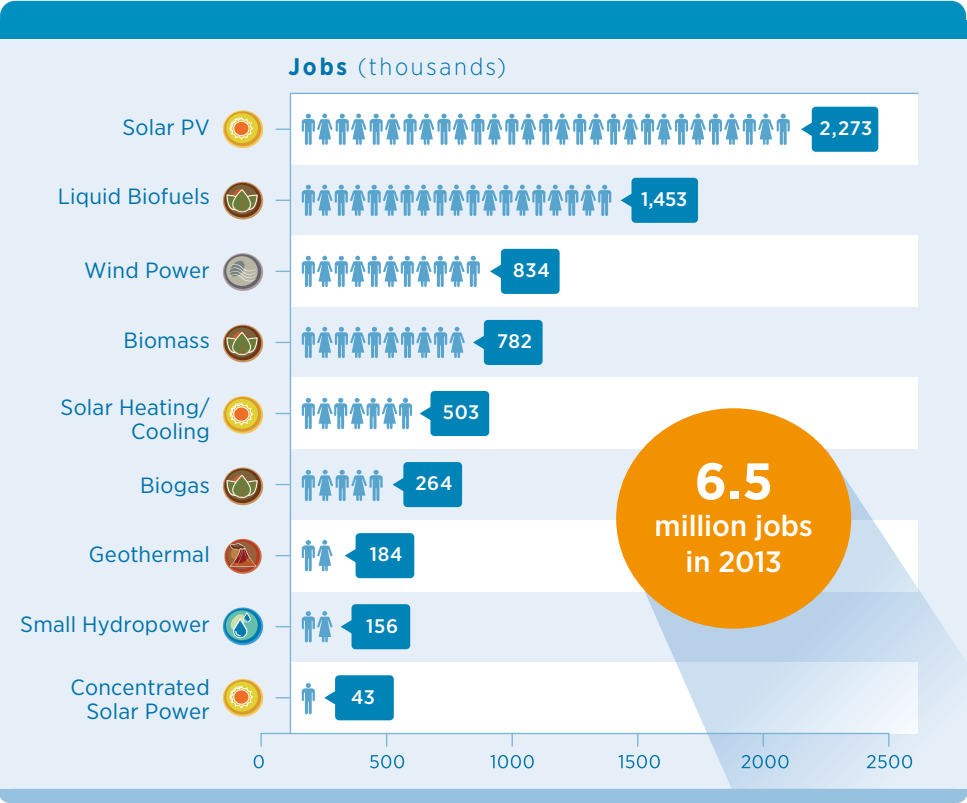
BOX 15: RENEWABLE ENERGY PROVIDES JOBS AND ENERGY ACCESS IN BANGLADESH

Bangladesh faces the twin challenge of unemployment and limited energy access. With a rapid expansion of solar home systems (SHSs), the number of people involved in the solar industry has nearly doubled in two years to reach 100,000 in 2013. Jobs are primarily for field assistants with basic technical and vocational skills to sell, install, provide maintenance and collect solar loan payments for SHSs. This success can be attributed to the following factors:

- **Training:** Vocational education and on-the-job training have built strong local capacity. The Infrastructure Development Company has trained 410,000 technicians and consumers.
- **Microfinance:** Schemes tailored to the cash flow of rural households have unlocked their buying power.
- **Local manufacturing:** Bangladesh initially imported SHS components from Singapore, India and China, but has now localised most of manufacturing.
- **Quality-control:** System standards, physical inspections, training programmes and consumers have ensured quality installations.
- **Domestic research** has reduced costs and adapted technology to local requirements.

2011. Employment in bioenergy is led by liquid biofuels despite a trend of increasing mechanisation of feedstock operations in major producing countries such as Brazil. Data are lacking for other renewable energy technologies, but expanding capacity in both geothermal and small hydro should translate into rising employment (IRENA, 2013b and 2014e). Figure 22 gives an indication of which technologies currently generate the most jobs.

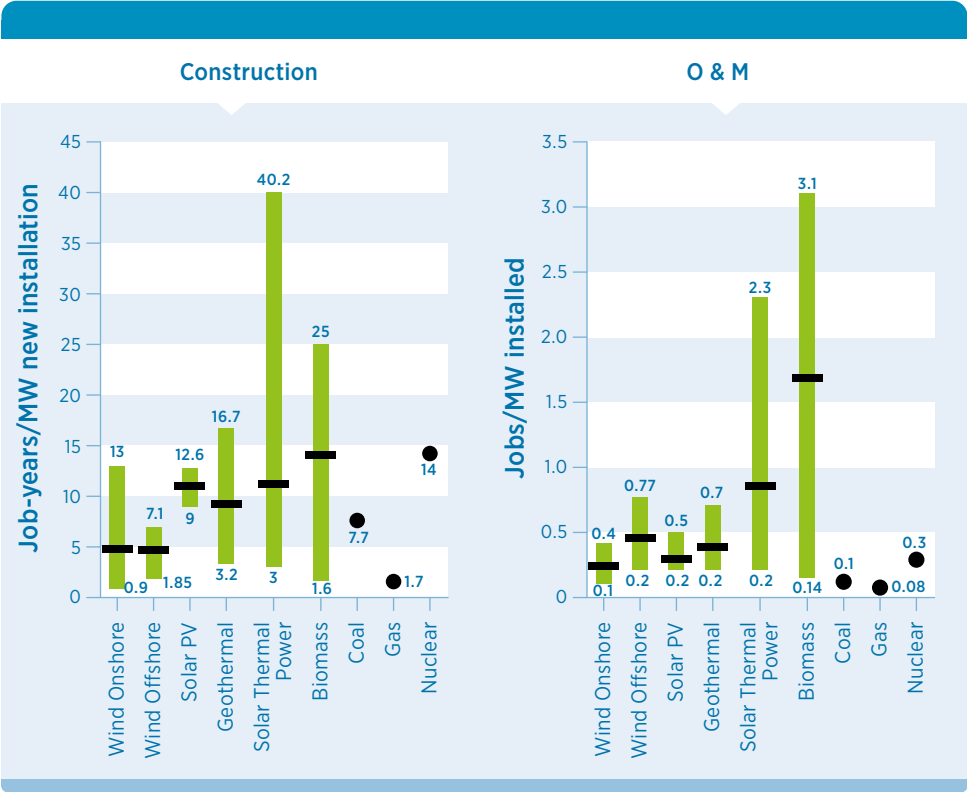
Figure 22: Renewable energy jobs by technology



Source: IRENA (2014e)

Figure 23 demonstrates the significant potential of job creation in the construction and operation and maintenance segments of the renewable energy value chain. Jobs in the construction and installation are created at the beginning of a project whereas those in operation and maintenance are created throughout the operational lifetime of a project. Data collected from various renewable energy projects indicates that, in general, renewable energy technologies create more installation jobs per MW of new installations and more operation and maintenance jobs per MW of cumulative installed capacity than their conventional energy counterparts. It should also be noted that jobs in these segments (installation, operation and maintenance) are inherently localised, compared to manufacturing jobs which require development of local industries (see Box 16).

Figure 23: New jobs created in construction, operation and maintenance of power assets



Source: Based on Rutovitz and Harris (2012)

Note: Construction/Installation jobs are created at the beginning of a project. Their jobs factors are expressed in job-years (a unit of effort much like human hours) per megawatt of new installation because the actual jobs can be created over a span of multiple year depending upon the construction period. Operations jobs are created every year during the life time of the project; therefore the unit is jobs per megawatt total installed capacity in the given year

BOX 16: DEVELOPING SKILLS FOR THE SECTOR

The renewable energy sector faces a skills shortage. A limited supply of education and training means high level skills aren't available where they are needed most.

The IRENA Renewable Energy Learning Partnership (IRELP) aims to address this by providing a one-stop-shop online for renewable energy education and training. It offers over 2,700 courses, degree programmes, training guides, internship opportunities and webinars in multiple languages. IREL P has been accessed by over 90,000 unique users since its launch in April 2012, with 7,000 visitors and 24,000 page views per month.

Coordination between policy makers and national education and training institutions is also an issue. IREL P is identifying gaps in capacity needed to meet REmap's 2030 targets. For more information on IREL P, please visit www.irena.org/irelp

4.5 EXPANDING ENERGY ACCESS

Access to modern energy is essential for economic development, yet over 1.3 billion people remain without electricity access, and 2.6 billion rely on traditional biomass for cooking and heating. In order to achieve universal access to electricity by 2030, the pace of expansion needs to double – using both on-grid and off-grid solutions (World Bank, 2013b).

The modular, scalable and decentralised nature of renewables means they can be adapted to local conditions and provide a broad range of energy services depending on the needs and purchasing power of end users. There is growing evidence that off-grid renewables can increase household income and employment opportunities both in the energy supply chain and in downstream enterprises. IRENA estimates that attaining universal access to modern energy services by 2030 could create 4.5 million jobs in the off grid renewables-based electricity sector alone (IRENA, 2013b). Many of these jobs can be created within rural communities, as most skills can be developed locally. Focusing on local capacity enhances sustainability by reducing reliance on external expertise. However, challenges remain to realising the opportunity presented by off-grid renewables and achieving the scale necessary to meet the objective of universal electricity access (see Box 17).

BOX 17: OFF-GRID SOLUTIONS: KEY TO UNIVERSAL ELECTRICITY ACCESS BY 2030

Off-grid solutions will play a major part in expanding electricity access, but scaling-up deployment is a challenge. Decentralised electrification is complex. Off-grid markets have varying demand and affordability, based on the remoteness of locations, levels of awareness, access to finance and skills. Innovative business and financing models can overcome barriers, but development has been on a project-by-project basis. A market-based approach is necessary, but requires enabling policy and regulations, customised technologies and easier access to capital. Given the large number of stakeholders, addressing these issues often requires coordination and collective action.

IRENA's International Off-Grid Renewable Energy Conference (IOREC) (www.iorec.org) raises the profile of these issues and brings together practitioners and policy makers to design and deliver effective off-grid solutions. Following the first conference in Accra (Ghana) in 2012, IRENA organised the 2014 edition in Manila, the Philippines, in collaboration with the Asian Development Bank and the Alliance for Rural Electrification. Ahead of the conference, IRENA surveyed over 400 regional stakeholders to identify challenges and opportunities in the sector. Field practitioners reported a lack in clarity on grid expansion plans and high transaction costs. While governments reported high technology costs, private sector developers have not found this a major issue, instead highlighting the need for appropriate financing and supportive policies to bring these technologies into play.

IRENA published key findings and recommendations from the first IOREC conference. www.irena.org/DocumentDownloads/Publications/IOREC_Key%20Findings%20and%20Recommendations.pdf

Considerable value can be created by improved electricity access for local businesses, gains in agricultural productivity and food preservation. Mobile phone charging, for instance, is an increasingly important local business in rural areas of developing countries (IRENA, 2012c). Nearly 500 million subscribers (as of 2010) live in off-grid areas (GSM Association, 2011), but phone charging can be difficult or expensive. This has led to a stream of rural enterprises providing affordable mobile charging services using off-grid renewable energy technologies. Although quantifying these benefits is not easy, efforts should be made to account for them when assessing the value of access to energy.

The nexus between energy, health, education and water presents important opportunities for renewable energy. Over a billion people globally are served by unelectrified health facilities. In 2010, an estimated 287,000 women died of complications from pregnancy and childbirth; many of which could have been averted with minimal lighting and appliance operating services (SE4ALL, n.d.). Modern energy access is also needed to refrigerate vaccines and other medicines in rural villages. Similar potential exists in education. More than 50% of children in developing countries go to primary schools without access to electricity. A more holistic approach to energy access is needed to look beyond households to community-based institutions, including healthcare and education.

4.6 REDUCING ENVIRONMENTAL IMPACTS

Consumers are increasingly aware of the energy supply's impact on the environment, and governments are keen to mitigate their concerns. Environmental effects can be divided into two broad categories: local and global.

Local effects concern the immediate surroundings of a power asset, including the depletion of natural resources, pollution (air, noise, water and waste), changes to land use – which include habitat or community displacement, land-value degradation and visual impact. They also include the risk of accidents. Global issues centre primarily on the emission of greenhouse gases, climate change and ocean acidification.

All forms of energy supply, including renewable energy, have an impact on the environment. However, the impact is on aggregate far lower for renewable than for non-renewable energy – from manufacturing to operation and end-of-life decommissioning, air pollution, detrimental land-use change and on ecosystems.

Most renewables do not consume fuels during the course of their operation and don't deplete finite natural resources. Bioenergy does consume feedstock which, while renewable, can be depleted if land is not properly managed. Geothermal sites can be depleted over time. Noise pollution and light strobing from onshore wind can be a local environmental issue.

While most renewables consume significantly less water compared to fossil or nuclear plants, water needs for cleaning must be considered. Solar PV and CSP installations rely on clean surfaces (glass or metal), and CSP requires cooling. This can become an environmental concern in arid regions – making it critically important to use water-efficient or waterless technologies.

Furthermore, renewable energy is associated with the lowest risk of disaster potential, especially when compared to coal mining, oil spills (such as Deepwater Horizon in 2010) or nuclear accidents (Fukushima in 2011).

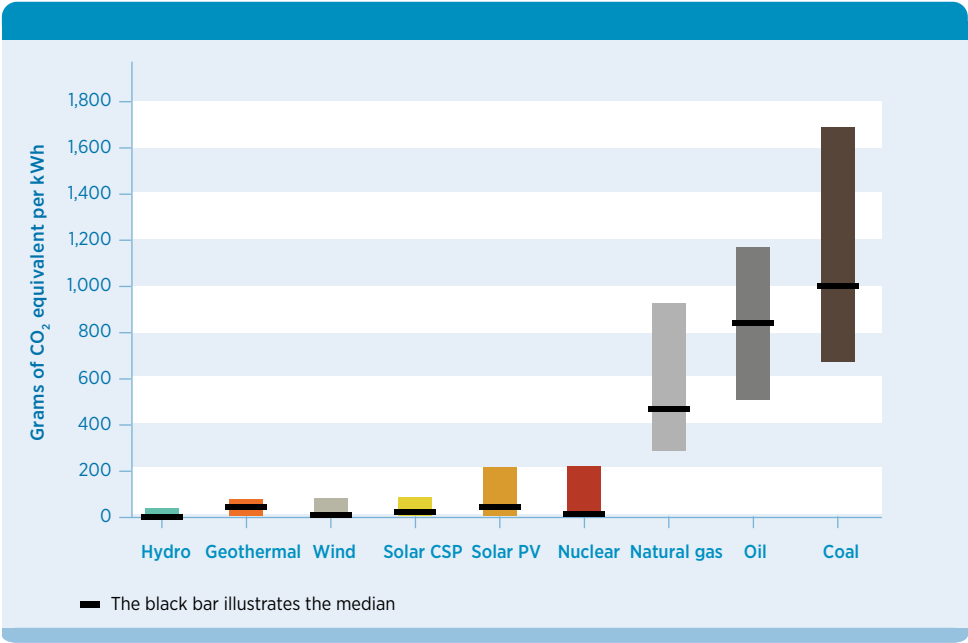
The most critical global environmental impact of energy – and electricity generation in particular – is its contribution to climate change. Electricity accounts for over 40% of man-made (combustion related) CO₂ emissions. Just as the economic costs of electricity can be compared, so can the environmental impact of different technologies in terms of carbon intensity. Using grams of carbon dioxide emitted per kilowatt-hour allows for an interesting comparison between technologies. CO₂ intensity across technologies differ vastly according to components, plant lifetimes, fuel-types and waste intensity, and can be difficult to compare.

Life-cycle emissions

Greenhouse gas emissions sources span the entire life cycle of electricity generation technology – from the manufacturing of a power plant's components and its construction, to electricity generation, to the handling of waste and the decommissioning of a power plant. Where fuels are used (biofuels, fossil fuels and nuclear) the fuel supply chain has to be considered as well as fugitive emissions during extraction and combustion (not only CO₂ but also methane and nitrogen oxides, both powerful greenhouse gases), manufacturing of equipment for exploration and production, and infrastructure and fuel transport emissions. Significant sources of greenhouse gases may come from energy – heat and electricity – required in the manufacturing process (itself depending on the source of that energy), from embodied emissions in materials (particularly steel, cement/concrete, aluminium; and fertilisers for biomass/biofuels) and from land-use change and reclamation.

The vast diversity of factors across renewable, fossil and nuclear technologies requires a more detailed look into where emissions come from. Building on approaches to life-cycle analysis used in the retail and manufacturing industries, it is clear that the carbon footprint from manufacturing solar panels needs to be considered; so does transporting natural gas from a field to the power plant; and the emissions associated with decommissioning a nuclear reactor and managing radioactive waste. Figure 24 depicts the lifetime emissions per kWh for a variety of common renewable and conventional technologies.

Figure 24: Life-cycle emission intensity of electricity generation by technology*



Source: IPCC (2011)

* Estimates of total life-cycle greenhouse gas emissions do not account for contributions from either land use change or heat production (in cases of cogeneration).

Solar, wind, nuclear, hydroelectric and geothermal are, across their lifetime, 10-120 times less emitting than the cleanest fossil fuel (natural gas) and up to 250 times lower than coal. The benefits offered by renewables in reducing carbon emissions means that their expansion must be part of any pragmatic scenario that can avoid catastrophic climate change.

4.7 RECOMMENDATIONS FOR POLICY MAKERS

The primary focus of policy makers has been on the cost of delivered electricity. However, broader issues are starting to drive the debate, including local and global environmental impact and socio-economic benefits. As policy choices across generation technologies address environmental impact, planning can take place in a more integrated manner – a much needed recognition of the energy, water and food nexus which governs the long-term sustainability of economies and quality of life.

Maximising the socio-economic benefits of renewable energy deployment, and job creation in particular, relies on a combination of policies that stimulate investment, promote education and training, support industrial development and encourage

research and innovation. These policies can only be successful if they are stable over time, tailored to country-specific conditions and supported by stakeholders. Policy makers should consider:

- » **The long-term impact of renewable energy deployment on the balance of trade.** For fuel-importing countries, renewable energy can reduce the fossil fuel bill, while reducing the risks associated with price volatility. For fuel-exporting countries, renewable energy can free up valuable resources for export. Renewables deployment can increase imports of renewable energy equipment – initially resulting in a negative impact on trade balance. In the longer term, however, the resulting reduction of fossil fuel imports should improve the balance of trade.
- » **The adoption of mechanisms that support the development of a local industry, tailored to the country's particular strengths and weaknesses.** For instance, the design of local content requirements should consider existing areas of expertise along different segments of the value chain and be directed at those with the highest development potential. Such policies should be time-bound, closely linked to a learning-by-doing process, and accompanied by measures to enhance local firm-level capabilities, develop relevant skills and support research and development.
- » **The impact of renewable energy on income and employment along all segments of the value chain.** In addition to manufacturing, considerable potential for value creation exists in the installation, operation and maintenance of renewable energy projects. To ensure stability and continued growth in employment, steadiness and predictability in governmental policies are necessary. In addition, policy makers and other stakeholders should anticipate the skill requirements and promote the provision of adequate education and training in the sector.
- » **The potential of off-grid renewable energy deployment for significantly improving rural economies in a cost-effective manner.** An integrated programmatic approach is needed, that is based on innovative business and financing models, enabling policy and regulations, customised technologies and easy access to capital.
- » **The emissions intensity of power generation, measured in gCO₂e per kilowatt-hour, to compare global environmental impact across technologies.** Policies and regulations integrating emissions-intensity measures can contribute to mitigating climate change. The benefits offered by renewables in reducing emissions means that their expansion must be part of any strategy to avoid catastrophic climate change.



5 Accelerating the energy transformation

Over the span of a single decade, a virtuous circle of technological progress, falling costs and rising investment has moved renewable energy from niche to mainstream all over the world. In a growing number of countries it has even emerged as the clear market leader in new capacity additions to the energy mix.

The speed of this advance has invited comparisons with the advent of mobile telephony and heralds changes every bit as significant. It is due in no small part to the vision of a few governments, which made a long-term commitment to safe, secure and sustainable power, and backed that with financial support. Through feed-in tariffs and other forms of support, they drove a transformation, faster than many expected or would have predicted.

As a result of these efforts, the world is standing on the brink of a new industrial revolution, in which polluting and scarce, finite fuels are replaced by clean sources of abundant energy. Renewables have accounted for the majority of global capacity additions for the last 3 to 4 years in a row, and their market share is projected to grow further.

But this ascent, while outstripping all predictions, must be further accelerated if it is to enable the world to achieve the doubling of renewable energy in the global energy mix by 2030 as championed by the SE4ALL Initiative of the United Nations. Unless governments create the enabling conditions for growth in a dynamic market setting, renewables will reach only 26% of the global power generation mix and 21% of total final energy consumption by 2030. That is far short of the levels needed to avert catastrophic climate change and bring power to millions of people living without electricity access. The technology to support this transition exists today and pathways have been identified for up to 44% renewable power globally in 2030 and much higher percentages that are technically feasible and economically viable in certain systems.

The outlook for renewable power is bright. But the mechanisms which brought renewables into the mainstream are not necessarily appropriate for the next phase of their move to the majority. Recognising the profound differences of a world run on renewables will provide the rationale and impetus for future investment supported by strong policy frameworks. To take the renewable transformation to this next level requires a different approach in terms of electricity systems planning, market design, policy frameworks, innovative funding, and providing adequate education and training.

This report is evidence for what has been achieved, a reminder of what is at stake, a roadmap for the future and an appeal to governments to grasp the opportunity at hand.

On offer is a paradigm shift, but to make it work requires a new way of doing business. Policy makers need to rethink the way they approach energy altogether.

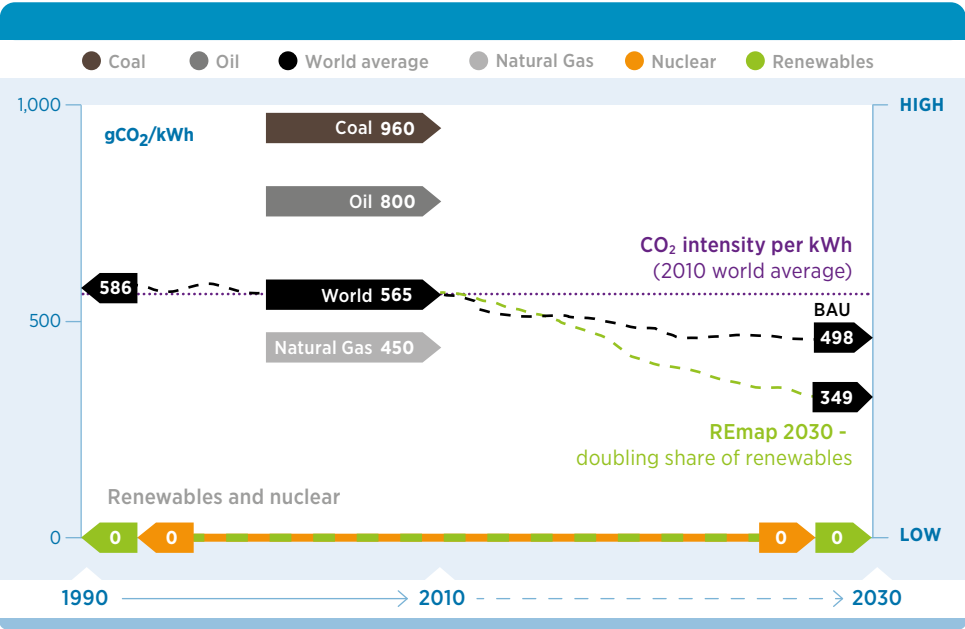
5.1 THE CLIMATE CHANGE IMPERATIVE

In any discussion of the future of energy, it is crucial to be clear about what is at stake. The electricity sector accounts for more than 40% of man-made (combustion related) CO₂ emissions today. Climate scientists have come to a stark conclusion: that substantial new approaches are needed to decarbonise the global economy and that in this regard, a systematic global shift to renewable power generation is urgently needed to avoid catastrophic climate change.

This presents policy makers with a choice. On the one hand, they can introduce measures to promote the rapid uptake of renewables, and in so doing, can generate new growth and employment while giving the world a realistic chance of keeping global temperature rise to below the critical 2 degree Celsius threshold. On the other, they can choose to carry on as usual, and lock in the existing power system for multiple generations with all that implies for carbon emissions.

REmap 2030, IRENA's roadmap for doubling the share of renewable energy in the global mix, shows that current policies and national plans will result in average CO₂

Figure 25: CO₂ emissions intensity per kWh – 2030 outlook



Source: IEA (2010) and IRENA (2014a)

emissions only falling to 498 g/kWh by 2030 (from the current 565 g/kWh). That is insufficient to keep atmospheric CO₂ levels below 450 ppm, beyond which severe climate change is expected to occur.

By contrast, if stakeholders double the share of renewable energy by 2030, global average emissions could be reduced to 349 g/kWh – equivalent to a 40% intensity reduction from 1990 levels (see Figure 25). Coupled with improvements in energy efficiency, this would be enough to avert disastrous climate change. In other words, there is an affordable solution on offer, but it will require proactive policy efforts to make it happen.

The good news is that the technology is sufficiently mature, and the economics sufficiently favourable, that the solution is entirely within countries' grasp. Even better news: the renewables solution will also improve energy access, enhance health, create jobs, promote more sustainable and equitable development, and offer greater security.

Forward thinking will play a crucial part in how this story unfolds. There is an intrinsic inertia in the energy sector, due to the scale of investments and the long lifetimes of generating assets. Even in the most progressive scenarios, a significant proportion of generation will continue to be powered by fossil fuels. The transformation will also be impacted by dynamics within the fossil fuel industry itself, such as the rapid expansion of shale gas in some markets.

In this environment, policy makers must make a firm and long-term commitment to the creation of an energy system that is diverse, resilient and environmentally sustainable and that is based on the best emerging technological and economic innovations.

5.2 SUPPORTING THE TRANSFORMATION

As the share of renewables in the energy mix rises, a structural transformation is beginning to take place. The global energy system based predominantly on renewable energy will look very different – a more decentralised, flexible and smarter system.

Flexibility and adaptability lie at the heart of the next phase of renewables development. An increasing share of variable power requires systems that can ensure consistent and predictable supply; a network of producers and consumers which can switch the direction of electricity flow in an instant, storing energy when in excess, releasing it momentarily when needed. This transformation is already taking place in a number of markets; advances in demand management and in storage technologies are likely to accelerate the shift.

New policies are urgently needed to accommodate this change. Markets, business models and technologies need to adapt, informed by clear up-to-date information. In a fast moving market, reference data need continuous updating. The plummeting cost

of solar power over the past three years serves as a potent reminder of how quickly things can change; today's emerging technology can become tomorrow's market leader. A new flexible policy framework is needed to take account of that. Arguably, the current disillusionment in many countries over renewable energy subsidies is a consequence of policies insufficiently able to react to changing circumstances rather than an inherent limit to renewables penetration.

The ongoing transformation will present challenges and opportunities. To ensure that those are adequately dealt with and that renewables play an ever-greater part in the world's energy mix, there are specific areas that warrant careful focus by policy makers.

5.3 ADOPTING A SYSTEM-LEVEL APPROACH TO POLICY-MAKING

Renewable energy costs will continue to fall and grid parity will be reached in more markets. More renewable energy technologies will be viable without subsidy support, so policy frameworks need to adapt accordingly. Support measures in a 'post-parity' era will need to shift from being purely financial-based to being integrated with the overall framework of renewables promotion and the general structure of the electricity market. A system-level approach to renewable energy will also need to consider the interests of different stakeholders in the sector. Box 18 illustrates the latest regulatory developments in Germany which are addressing some of these issues.

- » **Renewable energy deployment requires stable, transparent and predictable policy frameworks that anchor investor confidence.** National renewable energy policy choices need to be combined carefully with an eye towards the country's particular strengths and weaknesses. To ensure effectiveness and efficiency, policies need to adapt to changing market conditions in a timely manner. In doing so, it is important to avoid abrupt policy reversals which may hinder market development. Active engagement with stakeholders within the sector is necessary to clearly communicate the intended policy objectives and to better calibrate specific policy elements, such as tariff revision frequency, digression rates, etc.
- » **A forward-looking approach to electricity markets is necessary to ensure renewables can be expanded.** A restructuring of power markets may be required to support the on-going transformation as decentralised generation grows, and regulations surrounding generation, transmission, distribution and consumption of electricity need to adapt. To enable this, new power market designs will need to more closely consider demand response and storage, system flexibility options and distribution of costs for all such measures.
- » **The increase in decentralised renewable energy generation brings challenges and opportunities for incumbent stakeholders.** Decreasing profitability for traditional utilities, due to decreasing wholesale electricity prices and rising

decentralisation, is already influencing decisions over the management of existing assets, and investments in new energy infrastructure. Many utilities see opportunities here as well as threats, and are exploring new ways to leverage their expertise. These include becoming project enablers, operators and system integrators. It is essential that policy makers balance the ambitions of these established players against those of new entrants and other stakeholders in order to ensure the long-term reliability of the electricity system.

BOX 18: SUPPORTING THE ELECTRICITY SECTOR TRANSFORMATION: RECENT POLICY TRENDS FROM GERMANY

An early-adopter of renewable energy, Germany continues to calibrate its policies and regulations to ensure that renewables become the dominant source of electricity towards a more secure and environmentally friendly energy mix. Policy makers have been tasked with further expanding renewables whilst ensuring supply remains affordable and manufacturing industry competitive. In doing so, the Federal Ministry for Economic Affairs and Energy identified some focus areas for 2014-2016, which include: rethinking renewables support policies, evaluating new electricity market designs, and planning for transmission and distribution infrastructure.

- Increasing maturity of renewables and markets is prompting the adoption of competition-based promotion schemes, such as technology-specific auctions, to help identify the optimal support level for different renewable energy technologies.
- As the share of renewables increases, new electricity market designs are being considered to ensure efficient deployment of power capacity and long-term energy security. At a regional level, common solutions for local markets could offer cost advantages, thus necessitating increased coordination and engagement between governments.
- Transmission and distribution infrastructure developments are being synchronised with planned expansion scenarios for renewable energy, future market design and management of renewables generation. Robust grid planning in line with scenarios for the development of the energy system is critical for the growth of renewables. Any such planning depends on assumptions for rate of construction of additional renewables-based facilities, their geographical distribution and development of conventional power plants.

Other complementary focus areas include reform of the European Emissions Trading Scheme, strategies for energy efficiency and the buildings sector, setting up mechanisms to monitor progress of the transition and establishing platforms to facilitate stakeholder participation in policy development.

For more details, see *The energy transition: key projects of the 18th legislative term*.
<http://www.bmwi.de/English/Redaktion/Pdf/10-punkte-energie-agenda,property=pdf,bereich=bmwi,sprache=fr,rwb=true.pdf>

5.4 IMPROVING MARKET CONDITIONS

Against the backdrop of falling cost of technologies, policy makers are best placed to create an enabling environment by addressing other market-related aspects such as access to finance, permitting, grid connection, energy pricing structures and capacity building. This would further reduce the cost of renewable energy projects and accelerate the transformation. Furthermore, such an environment would support the development of local industries and bring accompanying socio-economic benefits such as jobs and income generation.

The market will enter a virtuous cycle of increasing deployment if:

- » **Government intervention is targeted at 'soft' or non-hardware costs.** With decreasing technology costs, soft costs now make up a large proportion of project costs. Therefore, the continued competitiveness of renewable energy technologies will depend on the reduction in soft costs. This can be achieved, among other ways, through streamlining permitting processes, supporting grid integration, facilitating access to finance, establishing standards and ensuring quality control as well as anticipating the skills requirements to support a growing market.
- » **The investments currently attracted by the sector can be scaled up.** The accessibility and cost of financing remains a challenge, particularly in emerging markets. This can be addressed through measures targeting the upfront cost of renewables, closing the funding gap (through green bonds, aggregation, etc.) and reducing risks to attract private capital. In this context, public financing and international climate funds will continue to play an important role. As markets and technology mature, renewable energy projects can attract a progressively wider range of investors, from private equity firms, project developers and governments, to commercial banks and institutional investors.
- » **Private sector participation is encouraged by reducing barriers to entry through appropriate regulatory frameworks.** The private sector will continue to play a crucial role in driving renewable energy deployment. The participation of the private sector is necessary for markets to achieve scale, improve competition and further drive down costs. The sector can also benefit from public private partnerships and measures to enhance firm-level capabilities and increase the level of competitiveness of domestic firms.

5.5 FACILITATING THE INTEGRATION OF RENEWABLE ENERGY

The integration of variable generation can become a pressing challenge for the sector, particularly in markets or regions with higher shares of renewable penetration. Addressing this challenge requires integration measures – in terms of physical connection and network management. These include planning for and investing in

physical grid development and enhancement, promoting grid-scale storage and smart infrastructure, and defining new market designs that consider the broad market-wide impacts of integrating variable renewables.

Effective and efficient integration can be supported through specific technical and regulatory measures such as:

- » **Timely planning for grid infrastructure development.** The lead time associated with infrastructure development can be long, and needs to be accounted for in the planning process. Lack of planning can lead to stranded generation assets, increased costs and the loss of investor confidence. Regional interconnections, where possible, can be pivotal to overcoming intermittency and integrating higher shares of renewable energy.
- » **Support for emerging technology solutions,** such as smart metering and grids, storage infrastructure and demand side management that can enhance network management capabilities and improve system flexibility. Together with enabling regulatory measures, such as mandatory forecasting, these technology solutions can reduce the overall system cost and significantly contribute to network stability.
- » **Close coordination and engagement of different stakeholders,** including regulators, governments, developers, transmission and distribution system operators, and consumers. This is vital for a steady transition towards a renewable energy-based power sector. It will also ensure the integration of different solutions, including off-grid applications which are now the most cost-effective solution for expanding electricity access in rural areas.

5.6 FORGING A JOINT VISION FOR A SECURE, PROSPEROUS PLANET

The potential prize for getting this right is spectacular. Renewables provide an answer not only to climate change, but to many of the most pressing socio-economic challenges faced by governments today.

A world run on renewables offers the prospect of abundant low-cost electricity, with lower levels of price volatility, less reliance on insecure trade flows and a raft of new educational opportunities and jobs. Doubling the global share of renewable energy – a goal well within reach by 2030 – could see global health costs fall by up to USD 200 billion, and unleash the potential of billions of people currently denied access to affordable, reliable power.

Renewables offer many countries an unprecedented opportunity to reduce their dependence on imports from regions experiencing political and economic uncertainty, an issue of growing concern for many.

The rapid progress of the past decade means this is no longer a utopian scenario. It is within reach, using proven, tested technologies, which already exist today and which continue to improve every year.

But technology alone will not be enough. This transformation requires the collective long-term commitment of all stakeholders, including governments, citizens, financiers, private companies and international agencies. International cooperation can further strengthen global efforts to accelerate the transformation by catalysing change through national renewable energy plans.

The transformation involves sweeping changes to a system that has for decades driven economic growth and prosperity. Resistance from vested interests can be expected, requiring committed advocacy and smart public information, as well as the widespread dissemination of transparent, up-to-date information.

Policy makers also need to recognise that the power sector – the focus of this first edition of *REthinking Energy* – is only one part of this picture. Huge efforts are also needed to promote the uptake of renewables in the heat and transport sectors.

The transformation has already begun, creating benefits across the globe. But in order to embrace its full potential, with sufficient speed to stave off climate change, governments need to embrace a new way of thinking, and to do so immediately.

If countries choose this path, a renewable energy future is possible. It will be cost effective and will have dramatic additional benefits for the whole of society. With sufficient commitment, a new, clean, industrial revolution lies ahead.

GLOSSARY

Balance of System (BoS) costs: all components of a photovoltaic system other than the actual panels, including wiring, switches, support racks, inverter, installation costs, planning costs, design costs, etc. This can include batteries in the case of off-grid systems and land in some instances.

Capacity factor: the ratio of a power plant's actual output over a period of time to its potential output if it were possible for the plant to operate at nameplate capacity indefinitely.

Dispatchable generation: sources of electricity that can be dispatched at the request of power grid operators; *i.e.*, generating assets that can be either switched on or off or can adjust their power output on demand.

Enhanced oil recovery: a stage of hydrocarbon production that involves use of sophisticated techniques to recover more oil than would be possible by utilising only primary production or waterflooding.

Final energy: Energy in the form that it reaches consumers (such as electricity from a wall socket).

Generation capacity: an asset's technical power output.

Gigawatt: one billion (10^9) watts.

Grid parity: when a technology can produce electricity at a cost roughly equal to the price of wholesale power from the grid, on a levelised basis. Whether or not this includes the cost of backup for intermittent renewables is controversial. [NB: hydropower projects and some geothermal technologies have been at grid parity for decades.]

Kilowatt: One thousand (10^3) watts.

Kilowatt-hours (kWh): A measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour.

Learning rates: Defined as the percentage reduction in costs for a technology that occurs with every doubling of cumulative installed capacity.

Levelised cost of electricity (LCOE): the price at which electricity is generated from a specific source over the lifetime of the project. It is therefore an economic assessment of a technology's or project's cost which includes the full span of its lifetime: initial investment, operations and maintenance, cost of fuel, cost of capital, etc.

Megawatt: One million (10^6) watts.

Micro grid: A highly localised, low voltage grouping of generation, storage, and demand, normally only for residential and potentially light commercial purposes. This can operate in connection with a traditional centralised grid, but can also function autonomously, in remote areas.

Mini grid: An integrated local generation, transmission and distribution system serving more customers than a micro-grid, but not large enough to be considered full-sized. Mini-grids often have more generation (in terms of volume and diversity) as well as more demand (usually residential and light commercial).

Non-financial policies: A broad term for any government policy that does not require direct financial support. For instance the creation of intellectual property rights legislation, a minimum efficiency standard for wind turbines or the rules of a renewable energy auction.

Off grid: not being connected to a central grid, specifically used in terms of not being connected to a national electrical grid.

Pico solar lighting systems: Refers to small PV systems rated at capacities below 10 Wp.

Power generated: an asset's generation capacity multiplied by the time it runs. A generator with a rated capacity of 1 megawatt produces 1 megawatt-hour if it runs at full capacity for an hour. It then has a capacity factor of 100%. If it lies idle for the next hour, its capacity factor is 0% for that hour and 50% for the two together.

Power Purchase Agreement (PPA): a forward contract between two parties, one who generates electricity (the seller) and one who is looking to purchase electricity (the buyer). PPAs are the principal agreements that define the revenue and credit quality of a generating project and are thus a key instrument of project finance. PPAs define the terms for the sale of electricity, including when the project will begin commercial operation, delivery schedule, penalties for under delivery, payment terms, and termination.

Primary energy: A source of energy before any conversion has taken place, such as crude oil, natural gas, rays of sunshine and lumps of coal.

Pumped hydro: A plant that usually generates electric energy during peak load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir through a conduit to turbine generators located in a power plant at a lower level.

REmap 2030: IRENA's 2014 roadmap for doubling the global share of renewable energy by 2030.

SE4ALL: Sustainable Energy for All, the UN Secretary General's initiative for global access to sustainable energy.

Smart grid: an electricity supply network that uses digital communications technology to detect and react to local changes in usage.

Socket parity: when a decentralised renewable energy technology can compete with the retail (delivered) price of electricity through the grid to the end user. This is particularly applicable for solar PV and micro-wind installations that power end-users directly.

Solar home systems (SHS): are stand-alone photovoltaic systems that offer a cost-effective mode of supplying amenity power for lighting and appliances to remote off-grid households. They are typically in the range of 10-200 Wp.

Super grid: a large, often very long-distance transmission network that makes it possible to trade significant volumes of electricity across great distances. Technically more complicated than normal grids due to the need to minimise power losses over distance.

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