

**WORLD
ENERGY
COUNCIL**

World Energy Resources | 2016



ABOUT THE WORLD ENERGY COUNCIL

The World Energy Council is the principal impartial network of energy leaders and practitioners promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all.

Formed in 1923, the Council is the UN-accredited global energy body, representing the entire energy spectrum, with over 3,000 member organisations in over 90 countries, drawn from governments, private and state corporations, academia, NGOs and energy stakeholders. We inform global, regional and national energy strategies by hosting high-level events including the World Energy Congress and publishing authoritative studies, and work through our extensive member network to facilitate the world's energy policy dialogue.

Further details at www.worldenergy.org and @WECouncil

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ABOUT THE WORLD ENERGY RESOURCES

The World Energy Resources have been produced by the World Energy Council for over 80 years. The details and analysis provide a unique data set that allows governments, private sector and academia to better understand the reality of the energy sector and the resource developments.

The assessments are compiled with our network of member committees in over 90 countries along with a panel of experts who provide insights from across the globe. With information covering more than 180 countries this is the 24th edition of the World Energy Resources report.

FOREWORD

Sufficient and secure energy is the main enabler for welfare and economic development of a society. As energy-related activities have significant environmental impacts, it is indispensable to provide an energy system which covers the needs of the economies and preserves the environment.

Fundamental structural changes in the energy sector, called energy transitions, occur worldwide. Motivation, objectives and priorities for implementing energy transitions differ, but could mostly be related back to the Energy Trilemma. Securing the energy supply, increasing competitiveness by using least-cost approaches, environmental concerns or a mixture of these aspects are the main drivers.

The diversification of technologies and resources, now applied in the energy sector, creates many opportunities, but the enlarged complexity also leads to increased challenges. With the existing level of volatility, relying on solid facts and data as basis for strategic decision making by the relevant stakeholders, such as governments, international organisations and companies, is becoming even more important than in the past.

In principal, the need for solid foundations is nothing new. In 1923, the founders of the World Energy Council came together to better understand the reality of the energy landscape. One of the most-established flagship programs is the Survey of Energy Resources (SER). The first edition of the SER was published in 1933. Since then this report has been released during the World Energy Congress. World Energy Resources 2016 is the title of the new publication and in fact is the 24th edition, celebrating 83 years of existence.

The reputation and value of the study rests on three main factors: the study presents unbiased data and facts from an independent and impartial organisation, it covers the technological, economic and environmental aspects of conventional and renewable sources, and it provides assessments on global, regional and country levels prepared by an international network of respected experts. The quality of the report has been further enhanced by the collaboration with a number of international organisations and companies in our Knowledge Networks. In particular, IRENA for renewable energy technologies and the German Federal Institute for Geosciences and natural resources on fossil and nuclear fuels data.

The report includes 13 chapters, which cover oil, gas, coal, uranium & nuclear, hydro power, wind, solar, geothermal, marine, bioenergy, waste-to-energy and two cross-cutting topics, energy storage and CC(U)S. Each of the chapters follow a standard

structure with sections on definitions and classification, technologies, economics and markets, socio-economics, environmental impacts, outlook and data tables by countries.

The world around us has changed over the past three years since the previous WER was published. The following principal drivers can be mentioned which have been shaping energy supply and usage in recent years:

- The climate pledges in connection with the Paris Agreement which form a milestone in international efforts to tackle climate change
- The record deployment of renewable energies, in particular wind and solar capacity for power generation, which increased globally by 200 Gigawatt between 2013 and 2015
- The halving of the world market price for oil, from more than 100 US\$/Barrel to less than 50 US\$/Barrel
- The shale gas boom in North America
- The decrease in the global coal consumption, which occurred in 2015 for the first time in the current century, mainly caused by China's transition to a less energy-intensive society
- The achieved progress in the implementation of CC(U)S technologies, in particular in North America
- The growing electrification, in particular in the transport sector, with 1 million electric vehicles on the roads, still well under 1 % of the global car fleet, but getting stronger

I am deeply grateful to all those who helped to produce the 2016 report, including Study Group Members, World Energy Council Member Committees, leading energy institutions and individual experts. My special thanks for the coordination, guidance and management to the the Council Secretariat with excellent and highly professional contributions from Zulandi van der Westhuizen, Deputy Director, Scenarios & Resources.



Hans-Wilhelm Schiffer
Executive Chair World Energy Resources

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EXECUTIVE SUMMARY

The past 15 years have seen unprecedented change in the consumption of energy resources. Unexpected high growth in the renewable energies market, in terms of investment, new capacity and high growth rates in developing countries have changed the landscape for the energy sector. We have seen the growth of unconventional resources and improvements in technology development for all forms of energy resources. This has contributed to falling prices and the increased decoupling of economic growth and GHG emissions. Most countries have achieved a more diversified energy mix with a growth in community ownerships and an evolution of micro grids.

To better understand these unprecedented changes the 2016 World Energy Resources report highlights the key trends and identifies the implications for the energy sector.

KEY FINDINGS



SOLAR

Global installed capacity for solar-powered electricity has seen an exponential growth, reaching around 227 GW_e at the end of 2015, producing 1% of all electricity used globally.

The total capacity for solar heating and cooling in operation in 2015 is estimated at 435 GW_{th}.

As solar PV module prices have declined around 80% since 2007 (from ~ US\$4/W in 2007 to ~ US\$1.8/W in 2015), the cost associated with balancing the system represents the next great challenge for the Solar PV industry.



E-STORAGE

E-storage has been characterised by rapid change, driven by reduced costs (especially batteries) and increased industry requirement to manage system volatility.

As of end-2015, the global installed storage capacity was 146 GW, consisting of 944 projects. There are already around 25 000 residential-scale units in Germany alone.

Bottom-up projections suggest a global storage market of 1.4 GW/y by 2020, with strong growth in electro-mechanical technologies in particular.



MARINE ENERGY

0.5 GW of commercial marine energy generation capacity is in operation and another 1.7 GW under construction, with 99% of this accounted for by tidal range.

The total theoretical wave energy potential is said to be 32 PWh/y, but is heterogeneous and geographically distributed, technology costs for marine energy are still very high, hindering deployment.



URANIUM AND NUCLEAR

Global uranium production increased by 40% between 2004 and 2013, mainly because of increased production by Kazakhstan, the world's leading producer.

As of December 2015, 65 nuclear reactors were under construction with a total capacity of 64 GW. Two-thirds (40) of the units under construction are located in four countries: China, India, Russia and South Korea.

Currently there are more than 45 Small Modular Reactors designs under development and four reactors under construction.



WASTE-TO-ENERGY

Despite Waste-to-Energy (WtE) occupying less than 6% of the total waste management market, the global WtE market was valued at approximately US\$25 billion in 2015 and is expected to reach US\$36 billion by 2020, growing at CAGR of around 7.5% between 2015 and 2020.



HYDROPOWER

Hydropower is the leading renewable source for electricity generation globally, supplying 71% of all renewable electricity at the end of 2015. Undeveloped potential is approximately 10 000 TWh/y worldwide.

The global hydropower capacity increased by more than 30% between 2007 and 2015 accounting to a total of 1209 GW in 2015, of which 145 GW is pumped storage.



OIL

Oil remained the world's leading fuel, accounting for 32.9% of global energy consumption. Crude oil prices recorded the largest percentage decline since 1986 (73%).

Roughly 63% of oil consumption comes from the transport sector. Oil substitution is not yet imminent and is not expected to reach more than 5% for the next five years.

Unconventional oil recovery accounts for 30% of the global recoverable oil reserves and oil shale contains at least three times as much oil as conventional crude oil reserves, which are projected at around 1.2 trillion barrels.



NATURAL GAS

Natural gas is the second largest energy source in power generation, representing 22% of generated power globally and the only fossil fuel whose share of primary energy consumption is projected to grow.



WIND

Global wind power generation capacity reached 432 GW in 2015, around 7% of total global power generation capacity (420 GW onshore, 12 GW offshore). A record of 63 GW was added in 2015 and total investment in the global wind sector was US\$109 billion in 2015.



COAL

Coal production declined with 0.6% in 2014 and with a further 2.8% in 2015, the first decline in global coal production growth since the 1990s.

Coal still provides around 40% of the world's electricity. However, climate change mitigation demands, transition to cleaner energy forms and increased competition from other resources are presenting challenges for the sector.

Asia presents the biggest market for coal and currently accounts for 66% of global coal consumption.



CCS

CCS is an essential element of any low carbon energy future, but policy is the main issue, not technology. The world's first large-scale application of CO₂ capture technology in the power sector commenced operation in October 2014 at the Boundary Dam power station in Saskatchewan, Canada.

There are 22 large-scale CCS projects currently in operation or under construction around the world, with the capacity to capture up to 40 million tonnes of CO₂ per year (Mtpa).



GEOTHERMAL

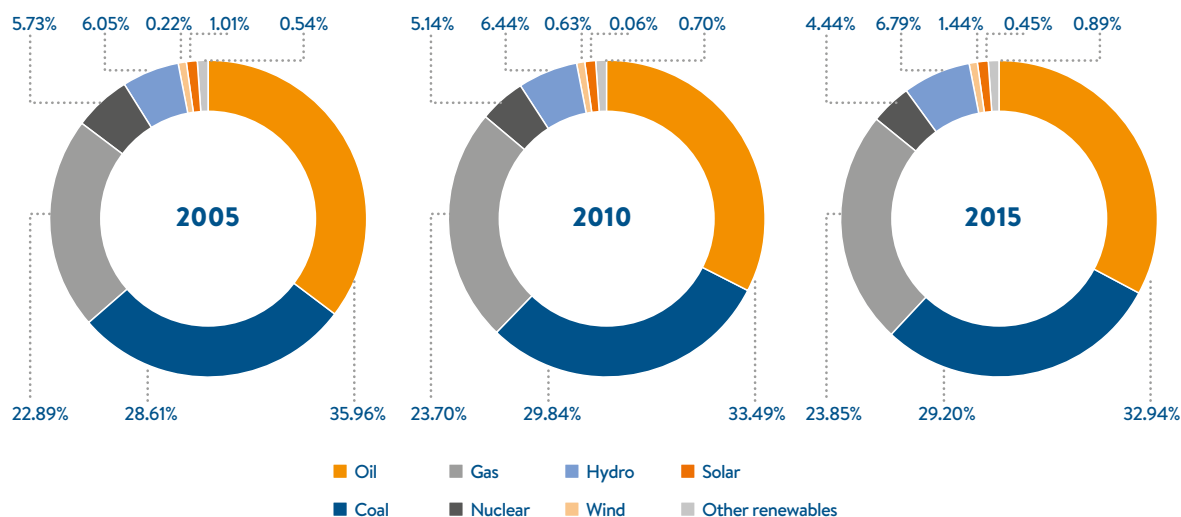
Geothermal global output is estimated to be 75 TWh for heat and 75 TWh for power, but is concentrated on geologic plate boundaries.



BIOENERGY

Bioenergy is the largest renewable energy source with 14% out of 18% renewables in the energy mix and supplies 10% of global energy supply.

FIGURE 1: COMPARATIVE PRIMARY ENERGY CONSUMPTION OVER THE PAST 15 YEARS



IMPLICATIONS FOR THE ENERGY SECTOR

There is already significant transition in the sector, however there are some challenges that remain:

Despite some notable progress, the rate of improvements towards cleaner energy is far slower than required to meet emissions targets. Public acceptance remains a challenge, regardless of the energy source, with an increased ‘Not in my back yard’ (‘NIMBY’) attitude to the development of energy sources. Increased commodity and energy price uncertainty, that results in higher risk, and larger investments with long lead times are less appealing.

Without diversification and review of business models, national and international oil and gas companies could struggle over the medium to long term. Incentive-assisted renewable energy companies have created a boom in certain countries and regions. However, as incentives are decreased, some companies might not be viable anymore.

Rare earth elements, used in especially renewable energies, create new dependencies in the value chain and could represent possible future barriers to growth. Change is at its slowest at the moment, but our research identifies that technologies will change a lot quicker and the regulatory system is not keeping up, which may also become a barrier.

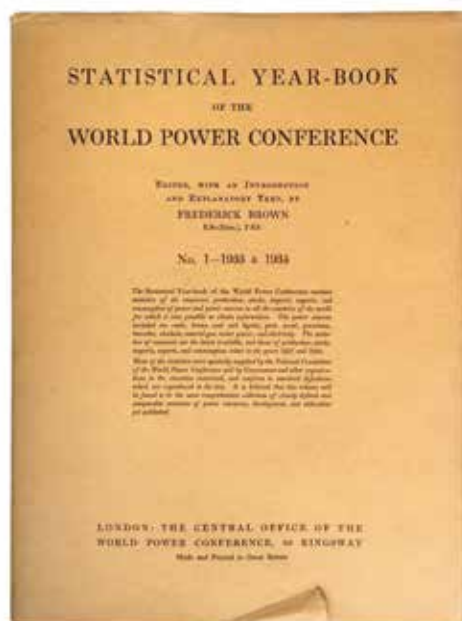
Liberalised markets could reach their limit, as the lowest cost generation in the short term can be perceived to provide the highest value. There is a significant need to balance other aspects of the Energy Trilemma such as environmental considerations, including increased resilience and security of supply. This is particularly important for long-term planning in short-term power operations, with the lack and lag of new, expanded, upgraded and smart infrastructure offering the potential to hinder new energy developments.

Heat generation and cooling technologies are lagging behind in terms of innovation. Increased use of natural gas combined with decreased use of coal will see energy-associated carbon dioxide emissions from natural gas surpass those from coal. Failure to timeously plan for replacement of decommissioned baseload power plants might pose a risk to energy reliability in some countries.

All of this creates a highly dynamic context for the energy sector.

INTRODUCTION

In 2016 we are celebrating 83 years since the first publication World Energy Resources (WER) in 1933. In this edition (24th) we cover 11 energy resources, together with Carbon Capture and Storage (CCS) and energy-storage as two relevant technologies.



This report presents a short summary of the full World Energy Resources report that comprises a comprehensive and unique set of global energy resources data and related information. This information allows energy decision-makers to better understand the reality of the energy sector and the resource developments. With more than 3 million downloads per year, the WER flagship study is a reference tool for governments, industry, investors, IGOs, NGOs, academia and the general public.

The various chapters are compiled with our network of member committees in over 90 countries along with a panel of experts who provide insights from across the globe.

WHAT HAS CHANGED?

Since the previous publication, some emerging energy issues have solidified the level and extend of their impact on the energy environment. This would include the CoP 21 Agreement in Paris; the continued increase in demand in China and India; continued increase in growth in renewable energies; and growth in unconventional

oil and gas. During this time, we have also experienced new developments such as the low oil and gas price; the role of new technologies and the rise of community ownership and co-operatives in the energy sector.

With long investment and long lead times, the energy industry has traditionally been a long-term industry and therefore change could take a fairly long time, especially on a global scale. When the global primary energy consumption numbers over the past 15 years are compared, the changes are quite remarkable. Although the global energy transition towards cleaner energy production is not moving at the speed we would like, it is definitely gaining momentum. Figure 1 shows the increased growth in renewable energy consumption in the context of the other primary energy sources and Figure 2 gives the percentage of renewable energy in electricity production in the various regions. Given that roughly 25% of global greenhouse (GHG) emissions come from the electricity sector, this is a very positive development. The transport sector consumes about 27% of energy demand, but is roughly responsible for 14% of GHG emissions. This compares relatively well to industry, consuming about 28% of energy demand and being responsible for 21% of GHG emissions.

With buildings consuming approximately 34% of energy demand, being responsible for 6% of GHG emissions, and urbanisation increasing in most areas of the world, it is clear that innovative technologies and design in urban areas can be instrumental in achieving long term sustainability of the global energy system.

FIGURE 2: SHARE OF RENEWABLE ENERGY (INCLUDING HYDRO) IN ELECTRICITY PRODUCTION

Region	Share of renewable energy in electricity production (incl. hydro) (%) in 2005	Share of renewable energy in electricity production (incl. hydro) (%) in 2010	Share of renewable energy in electricity production (incl. hydro) (%) in 2015
Africa	16.9%	17.4%	18.9%
Asia	13.9%	16.1%	20.3%
CIS	18%	16.7%	16.1%
Europe	20.1%	25.7%	34.2%
Latin America	59.3%	57.7%	52.4%
Middle East	4.3%	2.0%	2.2%
North America	24%	25.8%	27.7%
Pacific	17.9%	18.6%	25.0%

Source: Enerdata (2016) Energy Statistical Yearbook

Shale oil and gas technology is unlocking development of more resources at lower costs. In addition to potentially vast shale oil and gas resources, the development of renewables is increasing and becoming cost competitive. Also, energy efficiency is increasing while energy intensity is decreasing, but this is counteracted by population growth, economic growth and increased access to electricity, in especially developing areas of the world.

The effects of Brexit on the EU and the UK energy policy still remain uncertain and major changes cannot be expected in the near future. Planned investments and financing of energy infrastructure is likely to be delayed in the UK, and if some European utilities or investors decide to leave the UK, it could mean a reallocation of capital into Europe and elsewhere.

For oil and gas producers around the world, 2016 is a year of further cost cutting, restructuring, refinancing when possible, and, in some cases bankruptcy. The transition to cleaner energy means funding for fossil fuel projects are becoming more difficult and therefore it warrants a closer look at possible future impacts of the CoP21 Agreement.

The role of the Paris Agreement on shaping energy developments

Deemed as a historic breakthrough in international climate policy, Article 2 of the Paris Agreement defines the three purposes of the instrument: to make mitigation effective by holding the increase of temperature well below 2°C, pursuing efforts to keep warming at 1.5°C above pre-industrial levels; to make adaptation possible for all parties; and to make finance available to fund low carbon development and build resilience to climate impacts. These three outcomes have an impact on energy developments, primarily through the adoption of commitments labelled as Nationally Determined Contributions (NDCs), which are only “intended” (hence INDCs) until the Agreement enters into force.

The temperature target of Paris requires a profound transformation process and an inherently new understanding of our energy systems. Credible and effective national policies are crucial to translate the pledges made at Paris into domestic policy. New policies will need to be put in place and old ones revisited: carbon emissions will be priced; energy production and consumption technologies will be regulated; funding for research and development will be made available; and low carbon assets will be nurtured by financial markets. Key market disruptions will be experienced by market participants and governments alike, including stranded assets and technology innovation.

Energy prices

It is crucial to have a level playing field where all energy sources can compete on equal terms, but providing, at the same time, the right signals to energy consumers. In this respect subsidies play a significant role and need to be reviewed carefully.

Acknowledging the importance of a strong carbon price signal will be key to promote adequate consumer behavior and to enable a growth path in low-carbon investments that is consistent with the 2°C scenario. This includes incentives for investments in climate solutions for supply (i.e. renewables) and demand (i.e. enhancing energy efficiency) and ensuring protection of the environment.

Stranded assets

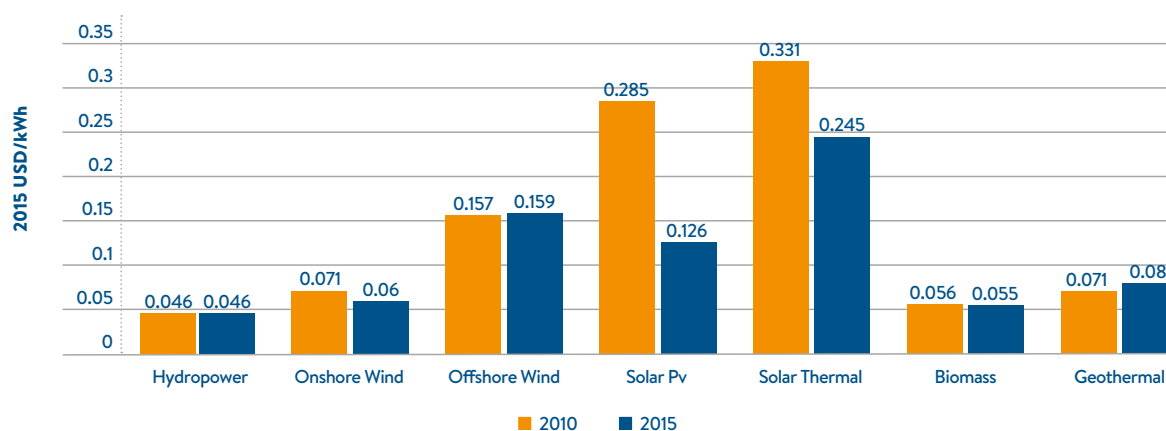
One of the main risks of climate change mitigation strategies is the appearance of stranded assets due to the combination of increased societal pressures, stricter environmental regulation (such as carbon taxes and new standards), and technological development (i.e. cleaner energy, renewable energy or new storage technologies). Such stranded assets can already be observed in Europe with recent gas power plants being mothballed or decommissioned due to overcapacity caused by penetration of renewables supported by FiTs and other schemes.

According to the journal Nature, the untapped coal, oil and natural gas reserves that would remain unexploited in order to meet the 2°C target could amount to 88%, 35% and 52% of global reserves respectively. The market values of the firms that own fossil fuels assets may undergo major changes because of the reduction both of future revenues and the firms' balance sheets due to the loss of value of those assets affected by climate change mitigation actions.

Technology disruption

More options and innovative solutions that reduce carbon emissions on a large scale are needed to make a real difference in the years ahead. Research and development (R&D) in clean energy technologies is crucial and increased investments are required to move from the laboratory to reality.

FIGURE 3: TRENDS IN GLOBAL RENEWABLE ENERGY LEVELISED COST OF ELECTRICITY (LCOE) IN THE TIME PERIOD FROM 2010 UNTIL 2015



Source: IRENA (2016)

1. COAL

The world currently consumes over 7700 Mt of coal which is used by a variety of sectors including power generation, iron and steel production, cement manufacturing and as a liquid fuel. Coal currently fuels 40% of the world's electricity and is forecasted to continue to supply a strategic share over the next three decades. The tables below show the top coal producing countries and regions in the world for 2014 and 2015.

TABLE 1: TOP COAL PRODUCING COUNTRIES

Country	Production	
	Total production 2014*	Total production 2015**
Australia	503.3	485
China	4000	3747
Germany	186.5	184
India	659.6	677
Indonesia	470.8	392
Kazakhstan	115.6	106
Poland	136.9	136
Russia	357	373
South Africa	253.2	252
USA	906.9	813

TABLE 2: TOP COAL PRODUCING REGIONS

Region	Production	
	Total production 2014*	Total production 2015**
Total Africa	265.7	266
Total Asia Pacific	5 651.4	5440
Total CIS	544.8	527
Total E.U.	8 795.2	528
Total Middle East	2.8	1
Total North America	989.9	888
Total S. & Cent. America	103	98
World	8,176.4	7861

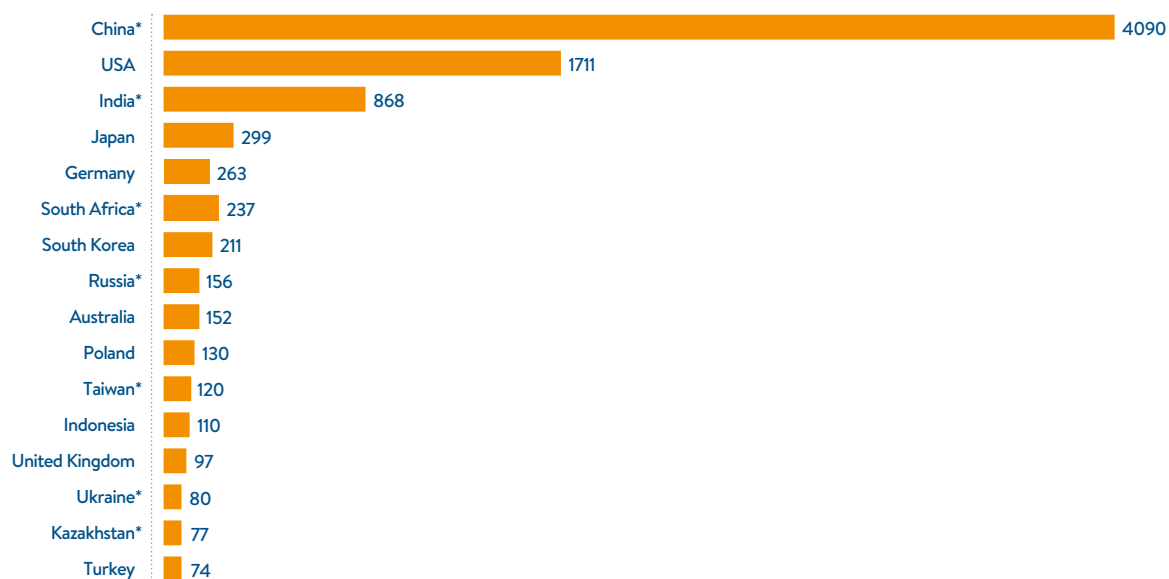
* BGR

** BP Statistical Review of World Energy 2016

KEY FINDINGS

1. Coal is the second most important energy source, covering 30% of global primary energy consumption. Coal is predominantly an indigenous fuel, that contributes to security of supply of a country. The oversupply and price of natural gas have negatively impacted the coal industry.
2. 75% of the global coal plants utilise subcritical technology. An increase in efficiency throughout the world from today's average of 33% to 40% could cut global carbon dioxide emissions by 1.7 billion tonnes each year.
3. The implementation of carbon capture utilisation and storage (CCUS) is one of the elementary strategies for climate protection.
4. Global coal consumption increased by 64% from 2000 to 2014. That classified coal as the fastest growing fuel in absolute numbers within the indicated period. 2014 and 2015 witnessed the first annual decrease in global thermal coal production of 0.7% and 2.8% respectively, since 1999.
5. China contributes 50% to global coal demand and is shifting to clean coal technologies. India's coal consumption is set to increase, while the US is closing or replacing coal with gas in power plants.

FIGURE 4: 2014 COUNTRY RANKING: COAL-FIRED POWER GENERATION (TWH)



Source: IEA, Electricity Information, Paris 2015 (*for Non-OECD-countries numbers for 2013)

2. OIL

Oil remains the world's leading fuel, accounting for 32.9% of total global energy consumption. Although emerging economies continued to dominate the growth in global energy consumption, growth in these countries (+1.6%) was well below its ten-year average of 3.8%.

Several structural changes are underway in the oil industry, the emergence of non-OPEC supply, the trends in energy efficiency, the diminishing role of high-sulphur oil with the environmental pressures in the marine fuel industry and in the power generation sector, and the emergence of unconventional oil (shale oil, heavy oil, tight oil and tar sands), and increased production both from mature and frontier fields.

TABLE 3: GLOBAL OIL DEMAND 2014 – 2018 (MB/D)

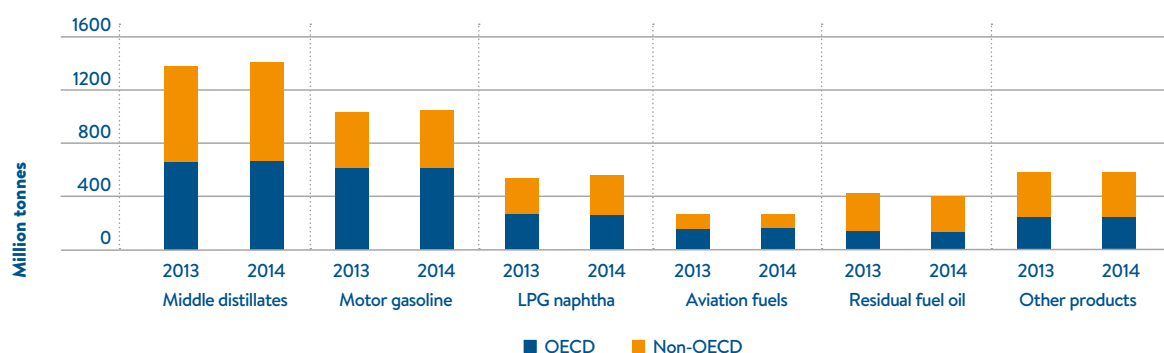
Region	2014	2015	Change from '14-'15 in %	2016	Change from '15-'16 in %	2017	Change from '16-'17 in %	2018	Change from '17-'18 in %
OECD Americas	24.1	24.2	0.004%	24.3	0.004%	24.4	0.004%	24.5	0.004%
OECD Asia Ocean.	8.1	8.0	-0.012%	7.9	-0.012%	7.9	0%	7.9	0%
OECD Europe	13.4	13.3	-0.007%	13.3	0%	13.2	-0.07%	13.1	-0.07%
FSU	4.8	4.6	-0.041%	4.7	0.021%	4.7	0%	4.8	0.021%
Other Europe	0.7	0.7	0%	0.7	0%	0.7	0%	0.7	0%
China	10.4	10.6	0.019%	10.9	0.028%	11.2	0.027%	11.5	0.026%
Other Asia	12.1	12.5	0.033%	12.9	0.216%	13.3	0.031%	13.7	0.03%
Latin America	6.8	6.9	0.014%	7.0	0.014%	7.1	0.014%	7.2	0.014%
Middle East	8.1	8.3	0.024%	8.5	0.024%	8.8	0.035%	9.0	0.022%
Africa	3.9	4.1	0.051%	4.2	0.024%	4.4	0.047%	4.5	0.22%
World	92.4	93.3	0.009%	94.5	0.012%	95.7	0.012%	96.9	0.012%

Source: IEA

KEY FINDINGS

1. Emerging economies account for 58.1% of global energy consumption and global demand for liquid hydrocarbons will continue to grow. Chinese consumption growth slowed to 1.5%, while India (+5.2%) recorded robust increase in consumption. OECD consumption increased slightly (+0.1%) and a rare increase in EU consumption (+1.6%), offset declines in the US (-0.9%) and Japan (-1.2%), where consumption fell to the lowest level since 1991.¹
2. The growth of population and the consumer class in Asia will support oil demand increase and the main increase in consumption will come from transportation sectors. Substitution of oil in the transport sector is not yet imminent and is not expected to reach more than 5% for the next five years.
3. Despite the temporary price drop, the fundamentals of the oil industry remain strong. Price fluctuations seen of late have been neither unexpected nor unprecedented. The main drivers of price changes have been the gradual building up of OPEC spare capacity and the emergence of non-OPEC production, especially US Light Tight Oil (LTO).
4. New and increased use of technologies such as high-pressure, high-temperature (HPHT) drilling; multi-stage fracking; development in flow assurance for mature fields; greater sophistication in well simulation techniques, reservoirs modelling; 3-D seismic technologies, EOR developments are having a positive impact on safety and E&P possibilities.

FIGURE 5: PRODUCT-MARKET CONSUMPTION TRENDS



Source: IEA Medium Term Oil Report 2015

1. IEA (2016) Oil Briefing

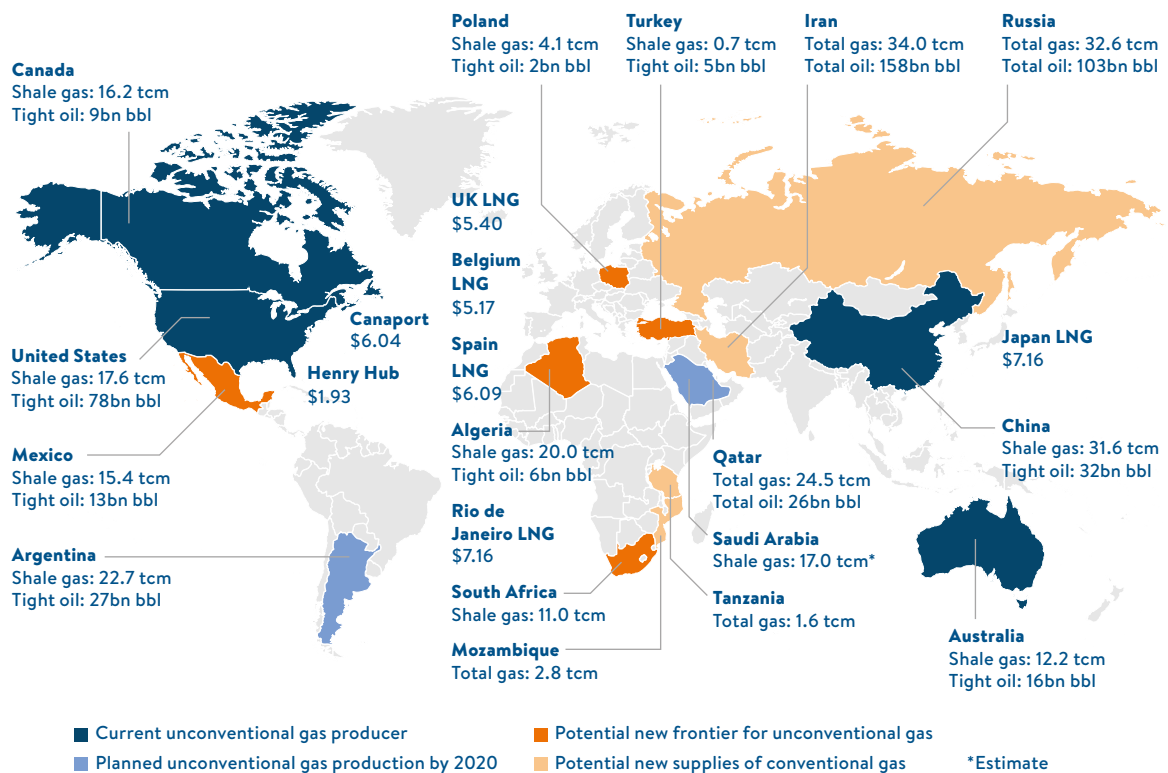
3. NATURAL GAS

Natural gas is the only fossil fuel whose share of the primary energy mix is expected to grow and has the potential to play an important role in the world’s transition to a cleaner, more affordable and secure energy future. It is the number three fuel, reflecting 24% of global primary energy, and it is the second energy source in power generation, representing a 22% share.

Advances in supply side technologies have changed the supply landscape and created new prospects for affordable and secure supplies of natural gas. Natural gas markets are becoming more interconnected as a result of gas-to-gas pricing, short-term trade and consumer bargaining power.

The future of demand is highly uncertain, new policy frameworks and continued cost improvements will be needed to make gas more competitive. Infrastructure build out, government support and the closure of regulatory gaps are needed to unlock the socioeconomic and environmental benefits of natural gas.

FIGURE 6: NEW SUPPLY LANDSCAPE (TECHNICALLY RECOVERABLE RESERVES)



Sources: BP Statistical Review of World Energy, EIA, FERC and Reuters

KEY FINDINGS

1. Demand projections for natural gas exports to Asia, particularly China and Japan, have been revised down as importing nations push to improve energy security and reduce the impact of volatile commodity markets.
2. In particular, unconventional gas, shale and CBM, reflected more than 10% of global gas production in 2014 and is entering global markets as LNG, disrupting the global supplier landscape and creating increased competition in regional natural gas markets.
3. The shifting dynamics in natural gas pricing in recent years can be attributed to regional supply and demand imbalances. North America prices collapsed in 2009, driven by a domestic oversupply, while from 2011-2013, the Japanese nuclear drove prices higher in Asia.
4. Currently, the fall in demand in Asia and growing export capacity in Asia and North America, have created an oversupply globally. As further supplies come to the market, it appears likely that the current market oversupply and low price environment will continue in the short to medium-term.

TABLE 4: REGIONAL NATURAL GAS DATA BY REGION

2015 Region	Proved Reserves		Production		R/P Ratio
	Bcm	Bcf	Bcm	Bcf	Years
Africa Total	14064	496666.5	211.8	7479.2	66.4
Asia Pacific Total	15648.1	552607.7	556.7	19658.2	28.1
Europe & Eurasia Total	56778.4	2005109.3	989.8	34955.2	57.4
LAC Total	7591.5	268091.0	178.5	6302.1	42.5
Middle East Total	80040.9	2826617.7	617.9	21821.1	129.5
North America Total	12751.8	450326.0	984.0	34750.4	13.0
Global Total	186874.7	6599418.0	3538.6	124966.2	52.8

Sources: BP Statistical Review of World Energy 2015, OPEC Annual Statistical Bulletin 2015, EIA International Energy Statistics, CIA: The World Factbook, and published national sources

4. URANIUM AND NUCLEAR

The Fukushima accident in March 2011 resulted in a developmental hiatus and a nuclear retreat in some countries. However, with the benefit of five years of hindsight, the true proportions of that accident are becoming clearer: a barely perceptible direct impact on public health, but high economic and social costs.

The assessments of global uranium resources show that total identified resources have grown by about 70% over the last ten years. As of January 2015 the total identified resources of uranium are considered sufficient for over 100 years' of supply based on current requirements.

The development of nuclear power is today concentrated in a relatively small group of countries. China, Korea, India and Russia account for 40 of the 65 reactors that the IAEA records as under construction in December 2015. The countries that have historically accounted for the majority of nuclear power development are now under-represented in new construction. Currently there are more than 45 Small Modular Reactors designs under development and four reactors under construction.

TABLE 5: URANIUM PRODUCTION AND RESOURCES

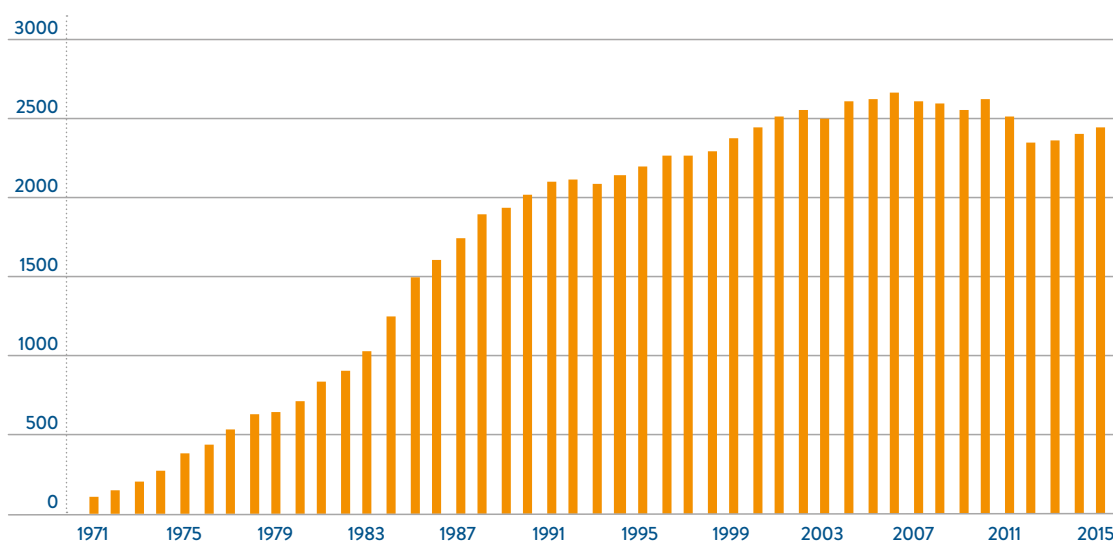
Country	2014 Production tU	Uranium resources (tU)<US\$130/Kg
Australia	5001	1174000
Canada	9134	357500
China	1500	120000
Kazakhstan	23127	285600
Namibia	3255	248200
Niger	4057	325000
Russia	2990	216500
USA	1919	207400
Uzbekistan	2400	59400
Total	56252	3698900

Source: "Uranium 2014: Resources, Production and Demand" OECD-NEA & IAEA, 2014. Uranium: From Mine to Mill, World Nuclear Association, 2015

KEY FINDINGS

1. Global nuclear power capacity reached 390 GW_e at the end of 2015, generating about 11% of the world electricity. As of December 2015, 65 reactors were under construction (6 more than in July 2012) with a total generating capacity of 64 GW.
2. The key drivers and market players defining the future of nuclear power are different from those 20 – 30 years ago and the emerging non-OECD economies (mainly China and India) are expected to dominate future prospects. The increasing need to moderate the local pollution effects of fossil fuel use, means that nuclear is increasingly seen as a means to add large scale baseload power generation while limiting the amount of GHG emissions.
3. The low share of fuel cost in total generating costs makes nuclear the lowest-cost baseload electricity supply option in many markets. Uranium costs account for only about 5% of total generating costs and thus protect plant operators against resource price volatility. Generation IV reactors promise to remove any future limitation on fuel supply for hundreds of years.
4. Nuclear desalination has been demonstrated to be a viable option to meet the growing demand for potable water around the globe, providing hope to areas in arid and semi-arid zones that face acute water shortages.

FIGURE 8: WORLD NUCLEAR ELECTRICITY PRODUCTION, TWH



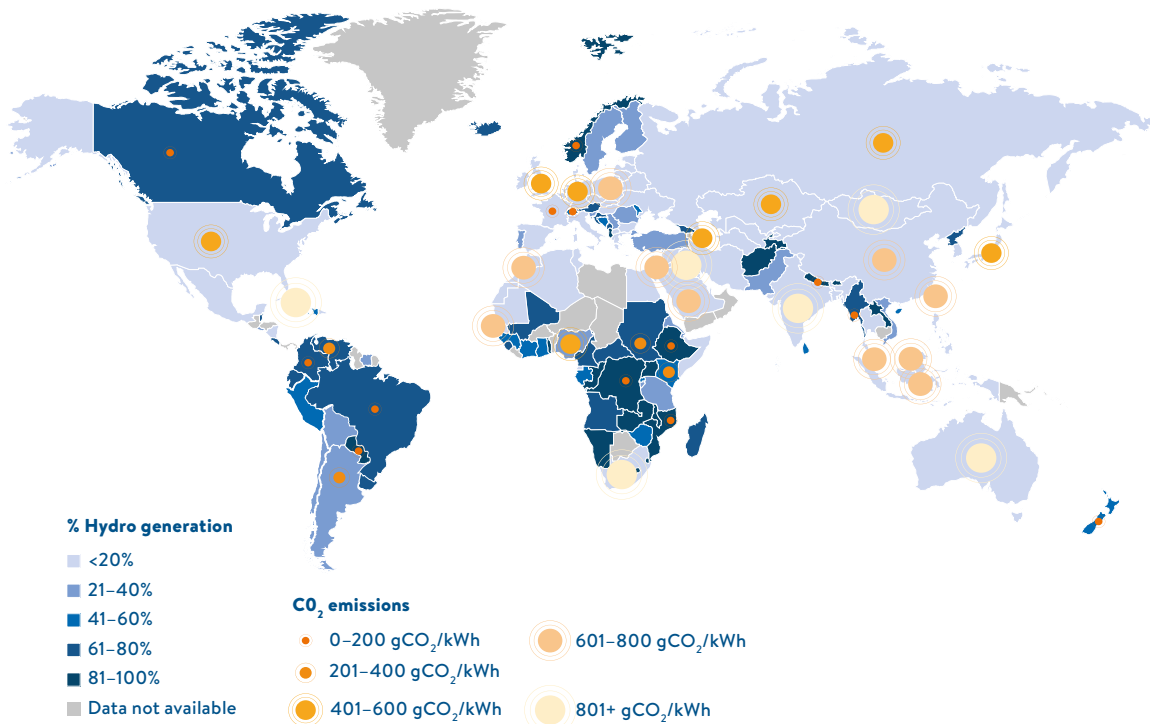
Source: International Atomic Energy Agency, Power Reactor Information System

5. HYDROPOWER

There has been a major upsurge in hydropower development globally in recent years. The total installed capacity has grown by 39% from 2005 to 2015, with an average growth rate of nearly 4% per year, with most of the growth concentrated in developing countries.

It is estimated that 99% of the world’s electricity storage capacity is in the form of hydropower, including pumped storage.² It provides an array of energy services beyond power, including black start capability, frequency regulation, inertial response, spinning and non-spinning reserve and voltage support, which are increasingly important to the stability of the energy system. Technological innovation in hydropower include: a) increasing the scale of turbines (1000 MW turbine in development), b) advanced hydropower control technologies that enable renewable hybrids, c) both conventional and pumped storage hydropower increasingly utilised as a flexible resource for balancing variable renewable resources.

FIGURE 9: THE CONTRIBUTION OF HYDROPOWER TO A LOW CARBON FUTURE



Sources: BP Statistical Review of World Energy, EIA, FERC, and Reuters

2. IEA (2014)

KEY FINDINGS

1. Hydropower is the leading renewable source for electricity generation globally, supplying 71% of all renewable electricity. Reaching 1 064 GW of installed capacity in 2016, it generated 16.4% of the world's electricity from all sources.
2. Significant new development is concentrated in China, Latin America and Africa. Asia has the largest unutilised potential, estimated at 7 195 TWh/y, making it the likely leading market for future development. China accounted for 26% of the global installed capacity in 2015, far ahead of USA (8.4%), Brazil (7.6%) and Canada (6.5%).
3. As hydropower has good synergies with all generation technologies, its role is expected to increase in importance in the electricity systems of the future. This is especially true of pumped hydro used as storage, but also increasingly to balance the volatility caused by increased renewable energy in the system.
4. Consideration of water management benefits offered by hydropower facilities includes flood control, water conservation during droughts or arid seasons.

TABLE 6: TOP HYDROPOWER CAPACITY AS OF 2015

Country	Total Capacity end of 2015 (GW)	Added Capacity in 2015 (GW)	Production (TWh)
China	319	19	1,126
USA	102	0.1	250
Brazil	92	2.5	382
Canada	79	0.7	376
India	52	1.9	120
Russia	51	0.2	160

Source: REN21, IHA (2015)

6. BIOENERGY

The World Energy Council defines bioenergy to include traditional biomass (example forestry and agricultural residues), modern biomass and biofuels. It represents the transformation of organic matter into a source of energy, whether it is collected from natural surroundings or specifically grown for the purpose.

In developed countries, bioenergy is promoted as an alternative or more sustainable source for hydrocarbons, especially for transportation fuels, like bioethanol and biodiesel, the use of wood in combined heat and power generation and residential heating. In developing countries bioenergy may represent opportunities for domestic industrial development and economic growth. In least developed countries traditional biomass is often the dominant domestic fuel, especially in more rural areas without access to electricity or other energy sources. There are multiple challenges and opportunities for bioenergy as a potential driver of sustainable development.

Lower energy prices do not favour short- to medium-term development of first-generation biofuels and investment in research and development (R&D) for advanced biofuels produced from ligno-cellulosic biomass, waste or non-food feedstock is also set to decline. Decreases in crude oil and biofuel feedstock prices should lead to a decline in ethanol and biodiesel prices. Global ethanol and biodiesel production are both expected to expand to reach, respectively, almost 134.5 and 39 billion litres by 2024. Subsequently, both ethanol and biodiesel prices are expected to recover in nominal terms close to their 2014 levels.

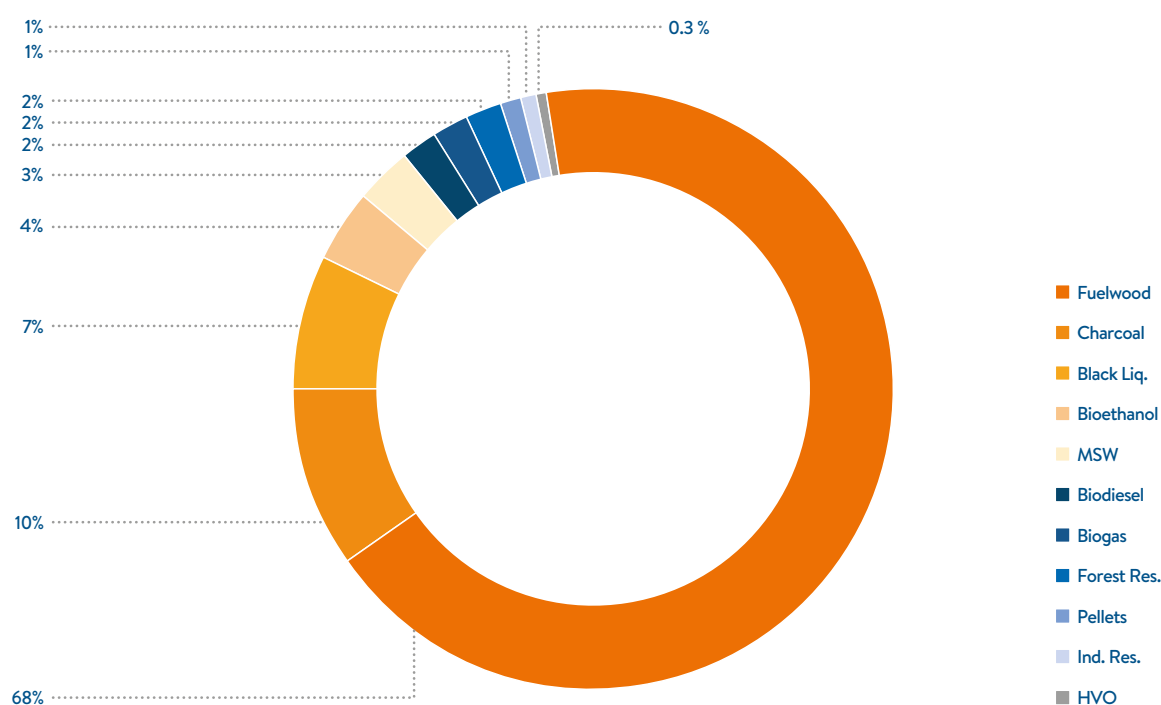
TABLE 7: SHARE OF BIOFUELS PRODUCTION BY REGION

Region	Percentage			
	1993	2003	2013	2014
Asia Pacific		3.3%	9.5%	10.5%
Africa				1.0%
Middle East				
Europe & Eurasia	1.1%	11.1%	17.1%	16.5%
S. & Cent. America	71.4%	49.2%	28.5%	28.7%
North America	27.4%	36.4%	44.8%	44.1%

KEY FINDINGS

1. Bioenergy is the largest renewable energy source with 14% out of 18% renewables in the energy mix and supplying 10% of global energy supply. In contrast to other energy sources, biomass can be converted into solid, liquid and gaseous fuels. It is shifting from a traditional and indigenous energy source to a modern and globally traded commodity.
2. The primary energy supply of forest biomass used worldwide is estimated at about 56 EJ and overall woody biomass provides about 90% of the primary energy annually sourced from all forms of biomass. Wood is also the source of more than 52 million tonnes of charcoal used in cooking in many countries, and for smelting of iron and other metal ores.
3. International trade is driven by pellets (27 million tonnes in 2015) and liquid biofuels. With biofuels being the most viable and sustainable option in replacing oil dependency, future demand will come from the need for renewables in transport, followed by heating and electricity sectors.

FIGURE 9: PRIMARY ENERGY SUPPLY OF BIOMASS RESOURCES GLOBALLY IN 2013



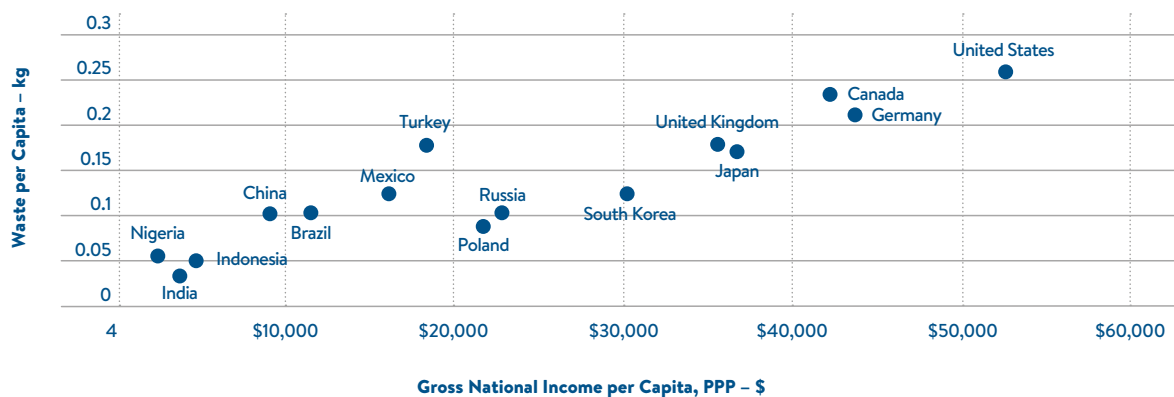
Source: Based on data from World Bioenergy Association (2016)

7. WASTE-TO-ENERGY

The global WtE market was valued at US\$25.32 billion in 2013, a growth of 5.5% on the previous year. WtE technologies based on thermal energy conversion lead the market, and accounted for 88.2% of total market revenue in 2013. The global market is expected to maintain its steady growth to 2023, when it is estimated it would be worth US\$40 billion, growing at a CAGR of over 5.5% from 2016 to 2023.

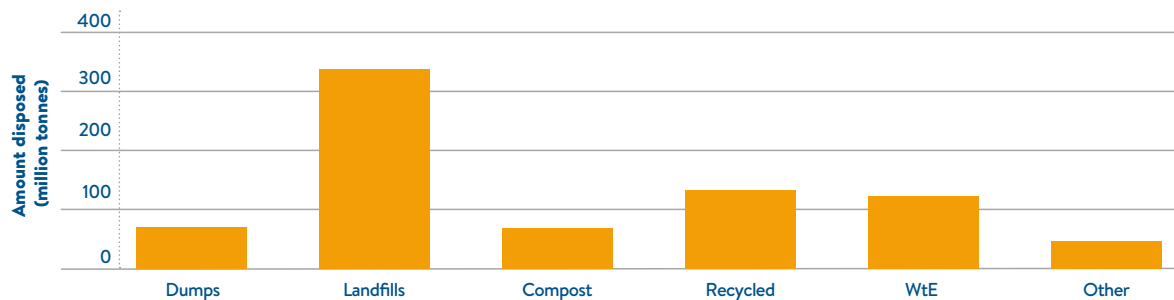
WtE remains a costly option for waste disposal and energy generation, in comparison with other established power generation sources and for waste management. Combustion plants are no longer a significant source of particulate emissions, owing to the implementation of governmental regulations on emission control strategies, reducing the dioxin emissions by 99.9%.

FIGURE 10: WASTE GENERATION PER CAPITA (KG/DAY) TO GROSS NATIONAL INCOME (GNI) RATIO IN 2014



Source: Navigant Research, World Bank (2014)

FIGURE 11: AMOUNT OF WASTE DISPOSED IN 2012, BY TECHNIQUE

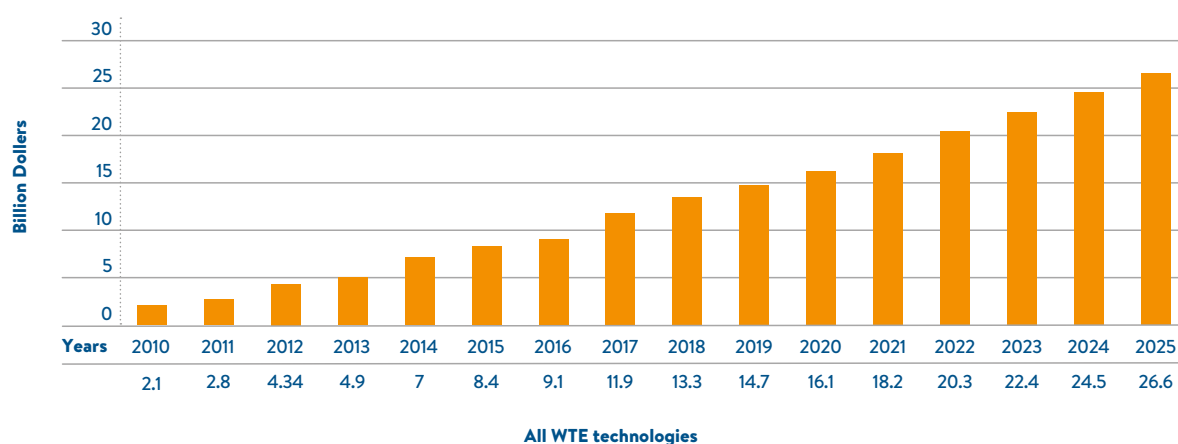


Source: Hoornweg & Bhada-Tata (2012)

KEY FINDINGS

1. Europe is the largest and most sophisticated market for WtE technologies, accounting for 47.6% of total market revenue in 2013. The Asia-Pacific market is dominated by Japan, which uses up to 60% of its solid waste for incineration. However, the fastest market growth has been witnessed in China, which has more than doubled its WtE capacity in the period 2011 – 2015.
2. Biological WtE technologies will experience faster growth at an average of 9.7% per annum, as new technologies (e.g. anaerobic digestion) become commercially viable and penetrate the market. From a regional perspective, the Asia-Pacific region will register the fastest growth (CAGR of 7.5%), driven by increasing waste generation and government initiatives in China and India and higher technology penetration in Japan.
3. It is estimated that global waste generation will double by 2025 to over 6 million tonnes of waste per day and the rates are not expected to peak by the end of this century. While OECD countries will reach ‘peak waste’ before 2050, and East Asia and Pacific countries by 2075, waste will continue to grow in Sub-Saharan Africa. By 2100, global waste generation may hit 11 million tonnes per day.

FIGURE 12: GROWTH OF ALL WTE TECHNOLOGIES GLOBALLY WITH A CONSERVATIVE FORECAST UP TO 2025



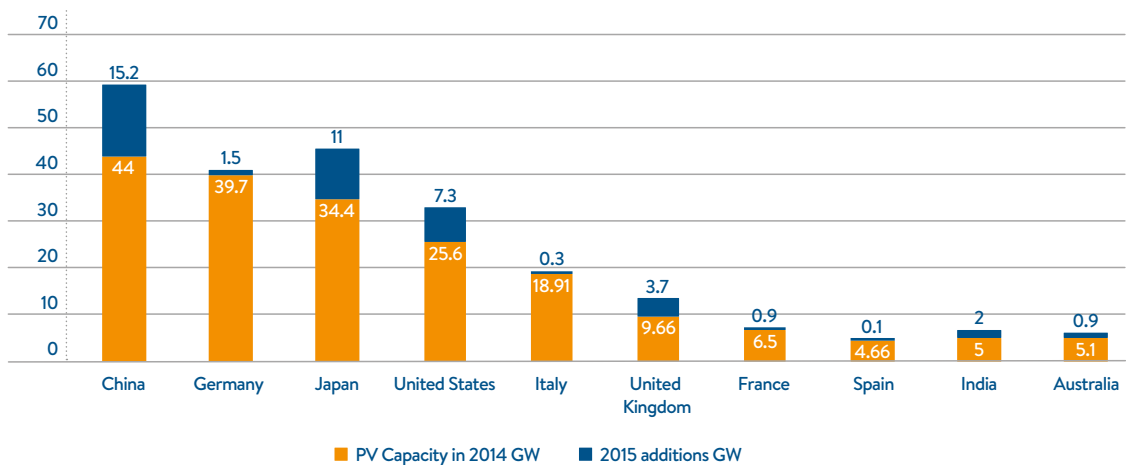
Source: Ouda & Raza (2014)

8. SOLAR ENERGY

Global installed capacity for solar-powered electricity has seen an exponential growth, reaching around 227 GW_e at the end of 2015. It produced 1% of all electricity used globally. Major solar installation has been in regions with relatively less solar resources (Europe and China), while potential in high resource regions (Africa and Middle East) remains untapped. Germany has led PV capacity installations over the last decade and continues as a leader followed by China, Japan, Italy and the United States.

Expansion of solar capacity could be hindered by existing electricity infrastructure, particularly in countries with young solar markets. Solar PV and other renewable technologies are highly dependent on rare earth elements, which, besides general unsustainable mining practices, also carries a high risk of some supply disruption.

FIGURE 13: SOLAR PV CAPACITY IN 2014 AND ADDITIONS IN 2015, TOP 10 COUNTRIES, (GW)

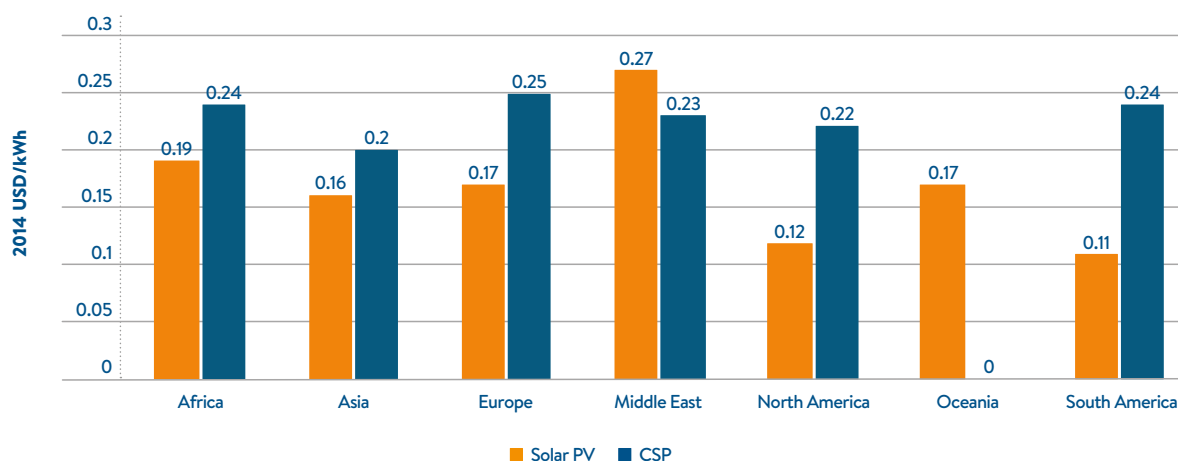


Source: REN21 (2016)

KEY FINDINGS

1. Costs for solar power are falling rapidly and “grid parity” has been achieved in many countries, while new markets for the solar industry are opening in emerging and developing countries. Policy and regulatory incentives, oversupply of installation components, and advancements in technology are driving the reduction in cost.
2. Technology is constantly improving, and new technologies such as Perovskite³ cells are approaching commercialisation. While there has been continuous improvement in the conversion efficiency of PV cells, concentrated photovoltaics (CPV) may hold the key in enabling rapid increases in solar energy efficiency, recently reaching 46% for solar cells.
3. In order to prevent environmental damage from solar PV, there is a need for strict and consistent regulation on processes over the entire life-cycle of infrastructure. Disposal and recycling must be considered as more modules reach the end of their lifespan.

FIGURE 14: AVERAGE LEVELISED COST OF ELECTRICITY FOR SOLAR PV AND CSP IN 2014, BY REGION



Source: IRENA (2016)

3. Perovskite cells include perovskite (crystal) structured compounds that are simple to manufacture and are expected to be relatively inexpensive to produce. They have experienced a steep rate of efficiency improvement in laboratories over the past few years.

9. GEOTHERMAL ENERGY

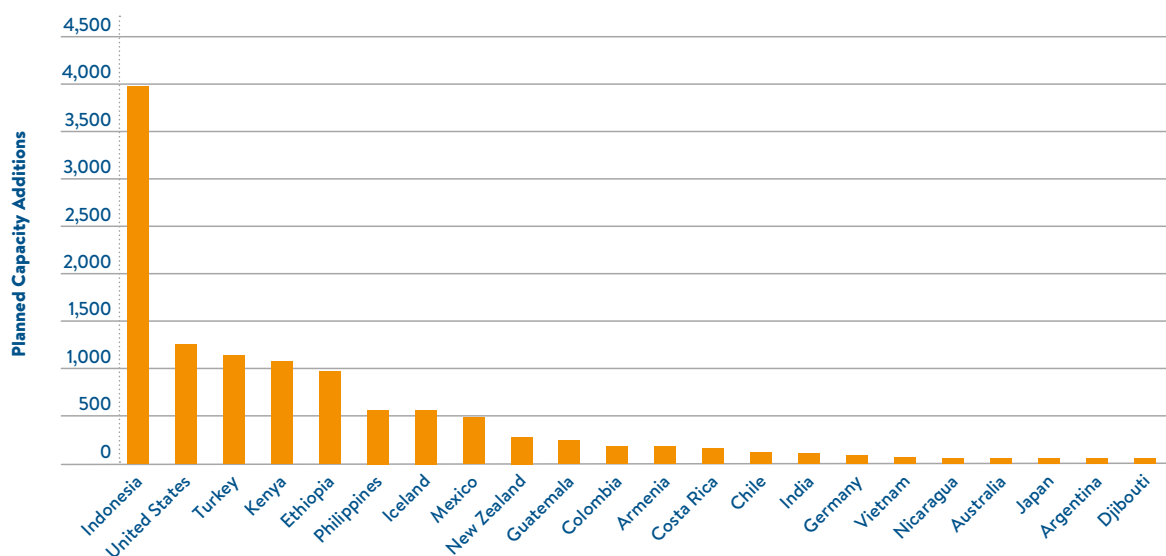
Geothermal energy contributes a small proportion of the world’s primary energy consumption. Geothermal energy produces less than 1% of the world’s electricity generation output. There were 315 MW of new geothermal power capacity installed in 2015, raising the total capacity to 13.2 GW.

Turkey accounted for half of the new global capacity additions, followed by the US, Mexico, Kenya, Japan and Germany. In terms of direct use of geothermal heat, the countries with the largest utilisation, accounting for roughly 70% of direct geothermal in 2015, are China, Turkey, Iceland, Japan, Hungary, the US and New Zealand.

The earth estimated stored thermal energy down to 3 km within continental crust, is roughly 43×10^6 EJ, which is considerably greater than the world’s total primary energy consumption.

A disproportional percentage of installed generation capacity resides on island nations or regions (43%), providing not only a valuable source of power generation, but also both heat and heat storage over a wide spectrum of conditions.

FIGURE 15: CAPACITY UNDER DEVELOPMENT BY COUNTRY (MW)

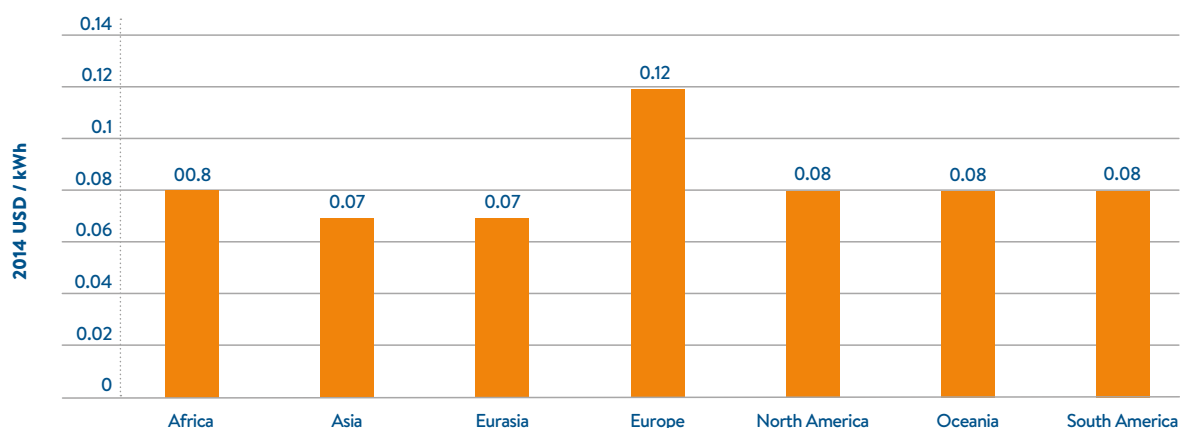


Source: GEA (2016)

KEY FINDINGS

1. In 2015, total power output totalled 75 TWh, the same number being also valid for total heat output from geothermal energy (excluding ground heat pumps). World geothermal heat use (direct & storage) reached 563 PJ in 2014.
2. Global investment in 2015 was US\$2 billion, a 23% setback from 2014. During the period 2010 – 2014, around US\$20 billion were invested in geothermal energy by 49 countries for both direct use and electric power.
3. Geothermal energy currently finds itself burdened by higher installation costs and longer development periods, relative to solar and wind. As a result, in many countries, geothermal energy projects have been and are reliant on government incentives in order to compete against both natural gas and other renewable generation.
4. The pace of geothermal development has been conditioned by legal frameworks and particularly by conservation legislation. However, the pace of development might accelerate due to climate change concerns and the increasing need to decarbonise the energy sector.

FIGURE 16: AVERAGE LEVELISED COST OF ELECTRICITY FOR GEOTHERMAL IN 2014, BY REGION



Source: IRENA (2016)

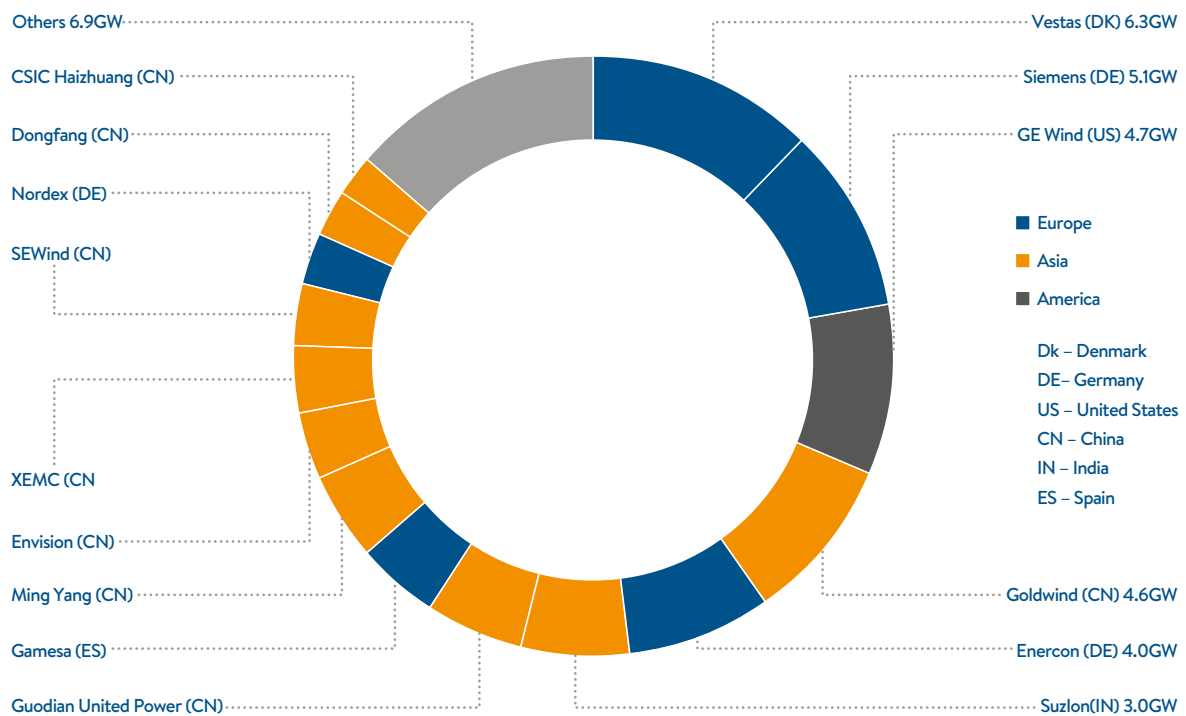
10. WIND ENERGY

World wind power generation capacity has reached 435 GW at the end of 2015, around 7% of total global power generation capacity. A record of 64 GW was added in 2015. The global growth rate of 17.2% was higher than in 2014 (16.4%).

Global wind power generation amounted to 950 TWh in 2015, nearly 4% of total global power generation. Some countries have reached much higher percentages. Denmark produced 42% of its electricity from wind turbines in 2015, the highest figure yet recorded worldwide. In Germany wind power contributed a new record of 13% of the country's power consumption in 2015.

Global installed capacity of offshore wind capacity reached around 12107 MW end-2015, with 2739 turbines across 73 offshore wind farms in 15 countries. Currently, more than 92% (10936 MW) of all offshore wind installations are in European waters. Floating foundations technologies are in development and several full-scale prototype floating wind turbines have been deployed.

FIGURE 17: SHARE OF THE GLOBAL TURBINE MANUFACTURER MARKET, WITH RESPECTIVE CAPACITY ADDITIONS, IN 2014

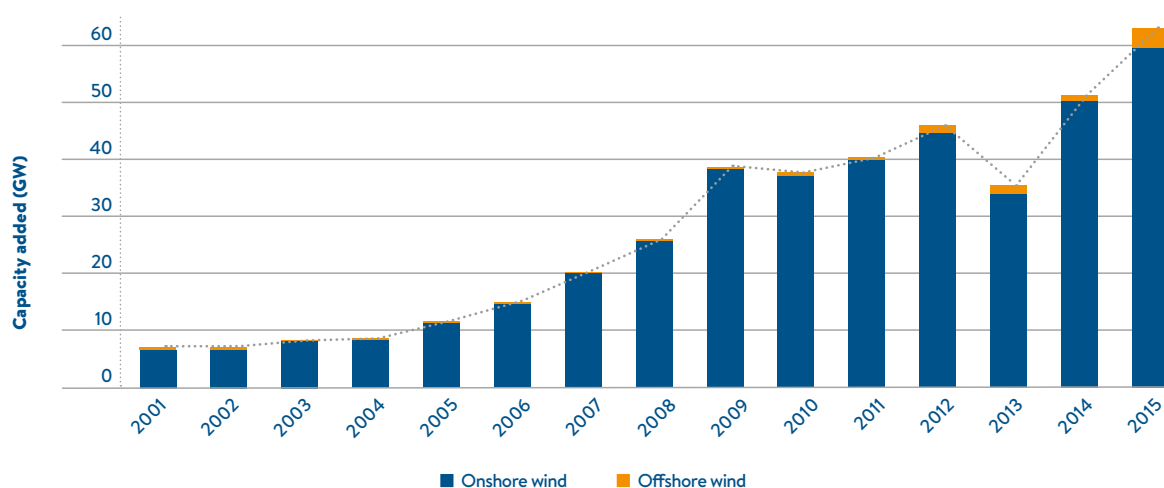


Source: BTM Navigant (2015)

KEY FINDINGS

1. With current policy plans, global wind capacity could grow from 435 GW in 2015 to 977 GW in 2030 (905 GW onshore and 72 GW offshore wind). The global leaders in wind power as at end-2015 are China, the US, Germany, India and Spain. The total investments in the global wind sector reached a record level of US\$109.6 billion over the course of 2015.
2. For onshore wind, China has the lowest weighted average LCOE with a range between US\$50/MW – US\$72/MW, while the highest weighted average LCOE are found in Africa, Oceania and Middle East with US\$95/MW, US\$97/MW and US\$99/MW.
3. Wind deployment continues to be dominated by onshore wind, supported by continual cost reductions, innovations are also reducing costs for offshore wind. Floating foundations could be game changers in opening up significant new markets with deeper waters.
4. Trends within the supplier industry in recent years show strong consolidation of the major companies and the shift in the global wind market eastwards to China and India.

FIGURE 18: ANNUAL NET GLOBAL WIND CAPACITY ADDITIONS, 2001 – 2015



Source: IRENA, GWEC

11. MARINE ENERGY

To date only a handful of commercial ocean energy projects have been delivered, reflecting the current immaturity and high costs of these technologies. 0.5 GW of commercial ocean energy generation capacity is in operation and another 1.7 GW under construction, with 99% of this accounted for by tidal range. Whilst relatively few commercial scale wave, tidal stream or OTEC projects are operational, three tidal stream commercial projects accounting for 17 MW of capacity are to be commissioned shortly, (two in Scotland and one in France) and a 1 MW commercial wave energy array in Sweden.

Sweden has begun construction of the world's largest commercial wave energy array at Sotenas. It will incorporate 42 devices and deliver 1.05 MW of capacity. They have also recently installed a second project in Ghana consisting of 6 devices, together providing 400 kW of capacity.

TABLE 9: REGIONAL THEORETICAL POTENTIAL OF WAVE ENERGY

REGION	Wave Energy TWh/yr
Western and Northern Europe	2800
Mediterranean Sea and Atlantic Archipelagos (Azores, Cape Verde, Canaries)	1300
North America and Greenland	4000
Central America	1500
South America	4600
Africa	3500
Asia	6200
Australia, New Zealand and Pacific Islands	5600
TOTAL	29500

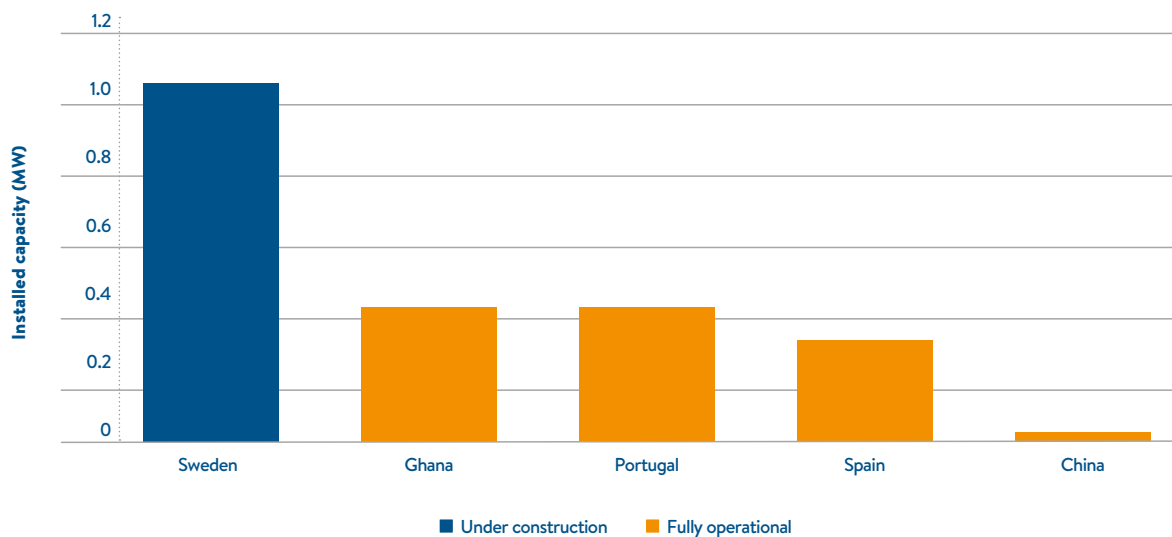
Source: (Mørk et al. 2010)

Note: The total resource potential is less than 32,000 TWh/yr quoted previously as the table accounts for only theoretical wave power $P \geq 5$ kW/m and latitude $\leq 66.5^\circ$

KEY FINDINGS

1. 2015 estimates the LCOE of wave energy at approximately US\$500/MWh whilst tidal sits at approximately US\$440/MWh. The LCOE for small-scale OTEC plants (1–10 MW) ranges somewhere between US\$190/MWh and US\$940/MWh, however if the facility were to be scale up to between 50–400 MW the cost would fall dramatically and likely range between US\$70/MWh and US\$300/MWh.
2. The high costs illustrate the immaturity of these technologies and the relatively short gestation period that ocean energy technologies, with the exception of tidal range, have undergone. Despite positive developments, a large number of projects have been suspended as public and private funds have been withdrawn, but many of the cost issues could be addressed through ongoing RD&D efforts.
3. There is 15 GW of ocean energy projects at various stages of the development pipeline with, the majority of these are tidal range (11.5 GW) followed by tidal stream (2.6 GW), wave (0.8 GW) and OTEC (0.04 GW).

FIGURE 19: WAVE ENERGY INSTALLED CAPACITY IN OPERATION OR UNDER CONSTRUCTION



Source: (OES 2016a)

12. CARBON CAPTURE AND STORAGE (CCS)

The world's first large-scale application of CO₂ capture technology in the power sector commenced operation in October 2014 at the Boundary Dam power station, Canada. In the US, two additional demonstrations of large-scale CO₂ capture in the power sector, at the Kemper County Energy Facility in Mississippi and the Petra Nova Carbon Capture Project in Texas are planned to come into operation in 2016 – 2017.

CCS is currently the only available technology that can significantly reduce GHG emissions from certain industrial processes and it is a key technology option to decarbonise the power sector.

In terms of the scale of CCS deployment, there are 22 large-scale CCS projects currently in operation or under construction around the world, with the capacity to capture up to 40 million tonnes of CO₂ per year (Mtpa). These projects cover a range of industries, including gas processing, power, fertiliser, steel-making, hydrogen-production (refining applications) and chemicals. They are located predominantly in North America, where the majority of CO₂ capture capacity is intended for use in EOR.⁴

TABLE 10: SELECTED KEY ESTIMATES OF EFFECTIVE STORAGE RESOURCES

Nation	Estimated storage resource (Gigatonnes)	
	Deep saline formations	EOR/depleted fields
USA ⁵	2,379 to 21,633	186 to 232
Europe ⁶	96	20
China ⁷	3,000*	2.2
Australia ⁸	33 to 230	17

Note: the example resource estimates above have been calculated based on geological characteristics and do not account for economic or regulatory factors.

*Resources only calculated at theoretical level

4. Projects data is sourced from the Global CCS Institute. www.globalccsinstitute.com

5. US DOE/NETL (2015) Data refers to the USA plus parts of Canada.

6. Vangklide-Pedersen (2009)

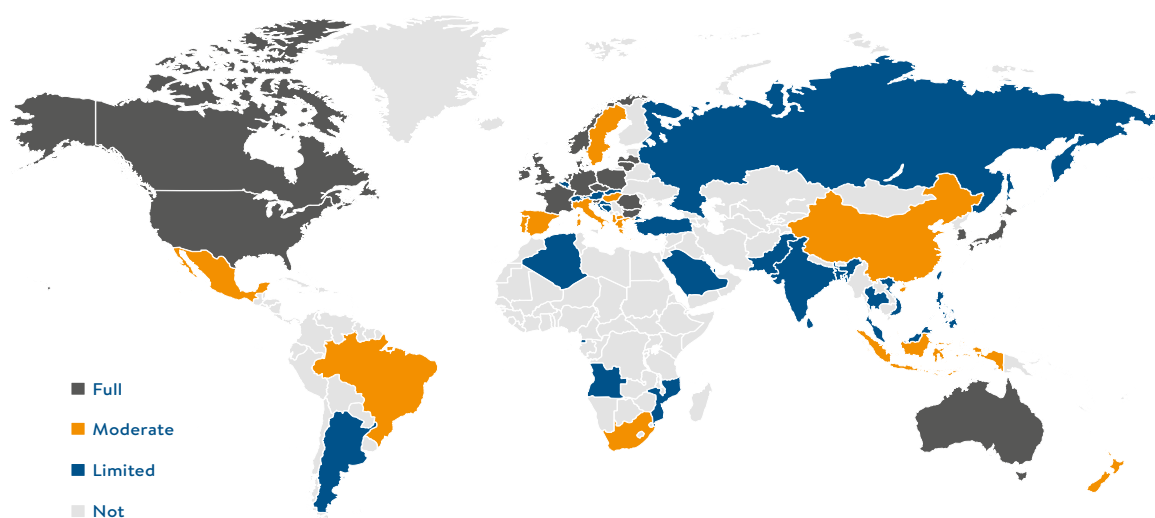
7. Dahowski et al. (2009)

8. Carbon Storage Taskforce (2009)

KEY FINDINGS

1. Even though the cost of CO₂ transportation is relatively low compared to the cost associated with capturing and storing the CO₂, the scale of investment in CO₂ transportation infrastructure required to support large-scale deployment of CCS will be considerable.
2. Total global CO₂ capture capacity of projects in operation or under construction is around 40 Mtpa. The large-scale projects in operation around the world demonstrate the viability of CCS technology.
3. The Japanese Government is collaborating with technology providers in industry to examine suitable storage sites and the economic feasibility of CCS deployment. The South Korean Government CCS Master Plan includes a large-scale CCS demonstration project operating within certain cost parameters by 2020, and commercial CCS deployment thereafter.
4. In Australia, considerable project activity continues. The Gorgon Carbon Dioxide Injection Project is expected to be operational in 2017. It will be Australia's first large-scale CO₂ injection project and the largest in the world injecting CO₂ into a deep saline formation. The Middle East has two large-scale CCS projects. Main project efforts are centred in Saudi Arabia and Abu Dhabi, although Qatar is also examining CCS opportunities.

FIGURE 20: STATUS OF NATIONAL ASSESSMENTS OF REGIONAL STORAGE RESOURCES



Source: Global CCS Institute, 2015: *The Global Status of CCS 2015*

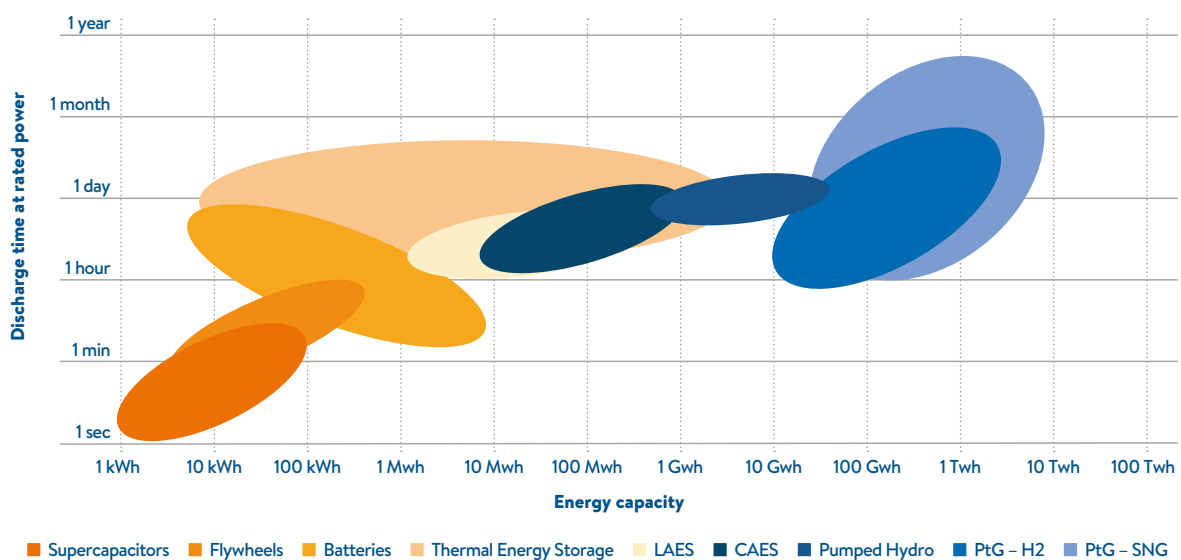
13. E-STORAGE

The concept of energy storage is not new, though development has been mainly restricted to one technology until recently. Pumped hydro storage accounts for well over 95% of global installed energy storage capacity. Compressed air energy storage currently has only two commercial plants (in Germany and the US), in total 400 MW, with a third under development in the UK.

Battery storage capacity is increasing: for example, there are around 25 000 domestic installations in Germany alone in conjunction with solar PV installations, with total capacity of 160 MWh. The total battery capacity in electric vehicles is also growing rapidly. Millions of water heaters have been operated in France for decades; they provide a massive benefit in reducing peak demand, by shifting 5% i.e. 20 TWh from peak periods to low-demand periods. These small-scale energy storage installations are not necessarily well represented in global statistics.

Large batteries are also being developed with installed capacity amounting to almost 750 MW worldwide. Sodium-sulphur became the dominant technology in the 2000s, accounting for nearly 60% of stationary battery projects (441 MW). In recent years, lithium-ion technology has become more popular. Flow batteries, if developed further, could be a game changer in the medium term.

FIGURE 21: MAPPING STORAGE TECHNOLOGIES ACCORDING TO PERFORMANCE CHARACTERISTICS



Source: PwC (2015) following Sterner et al. (2014)
 CAES: Compressed Air, LAES: Liquid Air, PtG: Power to Gas.

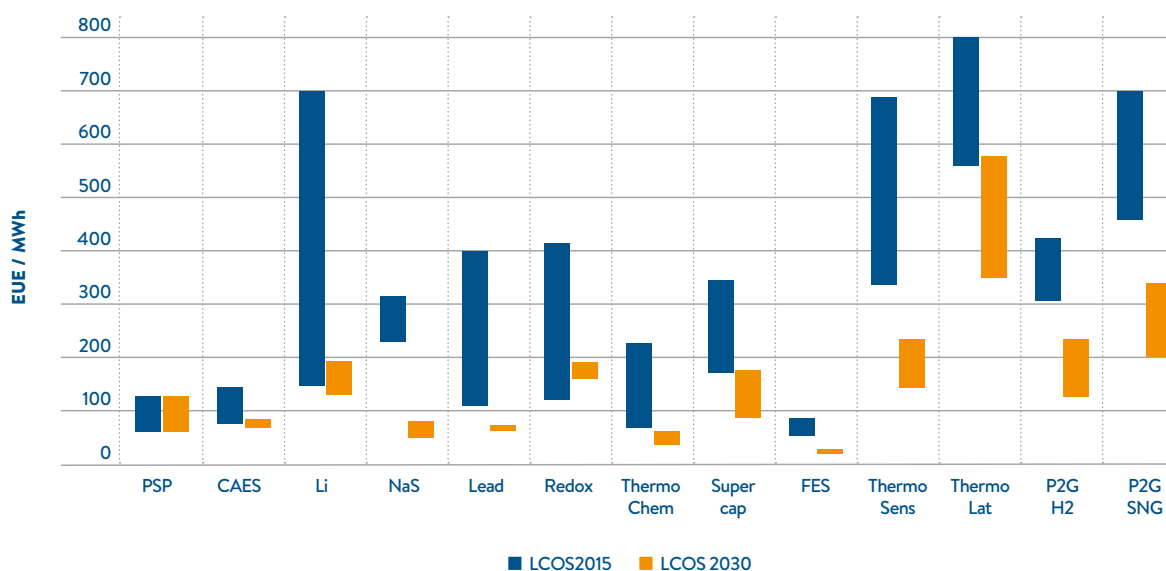
KEY FINDINGS

1. The main areas of growth in the next five years are likely to be:
 - Small-scale battery storage in conjunction with solar PV. There are already around 25 000 residential-scale units in Germany alone, and this could grow to 150 000 by 2020.
 - Utility-scale electricity storage, for multiple purposes, especially frequency response.
 - Electric vehicles.
 - Commercial, communications and software capabilities to allow multiple small distributed storage, demand response and distributed generation sources to be aggregated, in a ‘virtual powerplant’ or ‘swarm’.
 - Pumped storage hydro, especially in south-east Asia, Africa and Latin America.
 - Isolated electricity systems such as islands, to aid integration of renewables in order to save fuel costs.

2. Most commercial interest is in battery storage and the costs of several storage technologies will fall as production volumes increase.

3. The future outlook for energy storage markets is good due to an increasing need, but the regulatory and legal frameworks are failing to keep pace.

FIGURE 22: LEVELISED COST OF STORAGE IN 2015 STUDY PERIOD AND 2030 (€ 2014)



Source: PwC, 2015

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