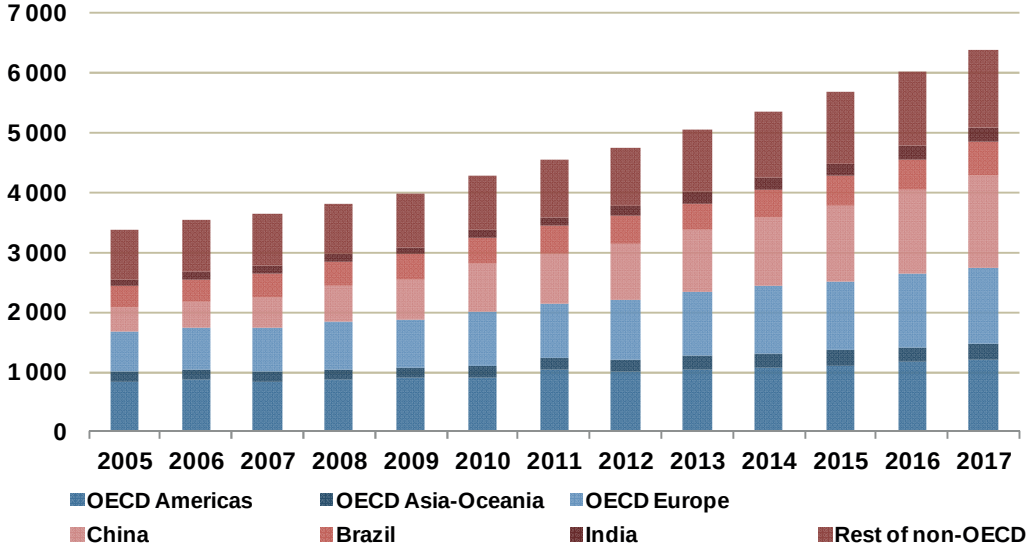
EXECUTIVE SUMMARY

Building on several years of strong deployment, renewable electricity growth should accelerate over the medium term. From 2011 to 2017 renewable electricity generation should expand by 1 840 terawatt-hours (TWh), almost 60% higher than the 1 160 TWh growth registered over the 2005-11 period. Global power generation from renewable sources stood at 4 540 TWh in 2011, 5.8% higher than in 2010, and is projected to reach almost 6 400 TWh in 2017 (+5.8% annually). Even as the annual average growth in renewable generation accelerates – to 5.8% over 2011-17 versus 5.0% over 2005-11 – expansion trends and geographies remain specific to technologies. For non-hydropower sources (solar photovoltaics [PV], concentrating solar power [CSP], wind, bioenergy for power, geothermal and ocean), the average percentage increase, at 14.3% annually, is somewhat slower than the 16.2% growth from 2005-11 as technologies continue to mature. Yet absolute growth for these sources is much higher (+1 100 TWh from 2011-17 versus +530 TWh over 2005-11).

The outlook stems from the persistence of supportive policy and market frameworks as well as increased economic attractiveness for renewable technologies in an increasing range of countries and circumstances. Moreover, technology cost developments, grid and system integration issues, and the cost and availability of financing will also weigh as key variables. Overall, a high level of economic and policy uncertainty in some key areas of the world characterises the forecast. At the time of writing, the outlook for the global economy, particularly in Europe, remains cautious while several countries are debating significant changes to renewable energy policy or deeper electricity market reform.

Figure 1 Global renewable electricity production, by region (TWh)



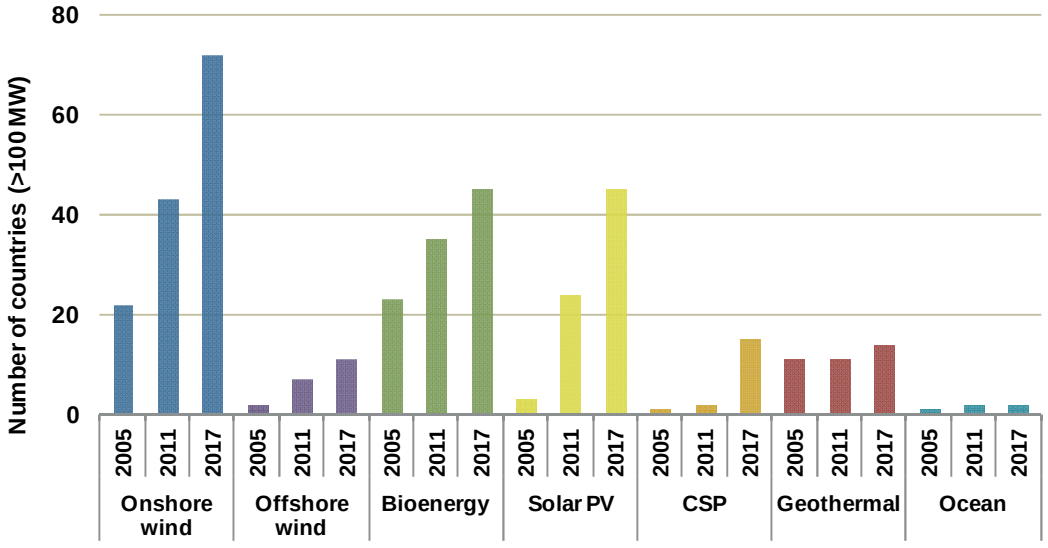
Note: unless otherwise indicated, all materials in figures and tables derive from IEA data and analysis.

Non-hydro renewable deployment is becoming increasingly widespread, with growth shifting beyond traditional support markets in Europe. In 2017, the number of countries with cumulative renewable electricity capacities above 100 megawatts (MW) increases significantly for most non-hydro technologies. Onshore wind, already widespread in many countries in 2011, is deployed in at

least 70 countries in 2017. Deployment of solar PV and bioenergy at the 100 MW level is reached in around 45 countries by 2017, up from about 25 and 35 in 2011, respectively. Geothermal and CSP are deployed in roughly 15 countries each by 2017, while offshore wind should be in 11 countries.

Of the 710 gigawatts (GW) of global renewable electricity capacity additions expected over 2011-17, China accounts for almost 40%, or 270 GW, with the United States (+56 GW), India (+39 GW), Germany (+32 GW) and Brazil (+32 GW) following as the largest deployment markets. In 2017, non-OECD countries should account for 65% of hydropower generation and almost 40% of non-hydro generation. Ambitious policy targets, fast-growing electricity demand and ample financing underpin China's expansion. In the United States, state-level renewable mandates combined with improving economics will drive growth, even amid uncertainty about federal incentives and persistently low natural gas prices. India's favourable policy environment and rural electrification needs should encourage strong deployment of on- and off-grid renewable electricity capacity. In Germany, wind power should grow strongly while annual growth of solar PV slows with assumed decreased feed-in tariffs. With favourable economics, Brazil's hydropower and wind should grow strongly.

Figure 2 Number of countries with non-hydro renewable capacity above 100 MW



Hydropower production has grown by 630 TWh since 2005, and in 2011 it accounted for 80% of total renewable generation. Going forward, hydropower will remain the largest contributor to total renewable generation. Although its share should diminish over time, the absolute increase in hydropower generation accelerates versus the previous decade. At 4 380 TWh in 2017, it should account for almost 70% of renewable electricity output. Over 2011-17, hydropower generation should grow on average by 120 TWh per year (or +3.1%) as capacity rises from 1 070 GW to 1 300 GW.

Hydropower represents an economically attractive source of renewable energy in countries with good resource potential. Indeed, untapped hydropower potential remains large on a global scale. For emerging and developing countries, deployment of hydropower is a good option for scaling up renewable generation and meeting power needs. For many of the countries highlighted in this report, hydropower growth should also provide the flexibility needed for the integration of a projected, large amount of variable renewable electricity. On the regional level, non-OECD Asia

grows by 150 GW, with China (+110 GW) and India (+13 GW) accounting for most of the expansion. Large capacity additions should also take place in Latin America (+32 GW), with 21 GW in Brazil; OECD Europe (+19 GW); and Africa (+14 GW).

Figure 3 Global hydropower historical cumulative additions (2005-11)

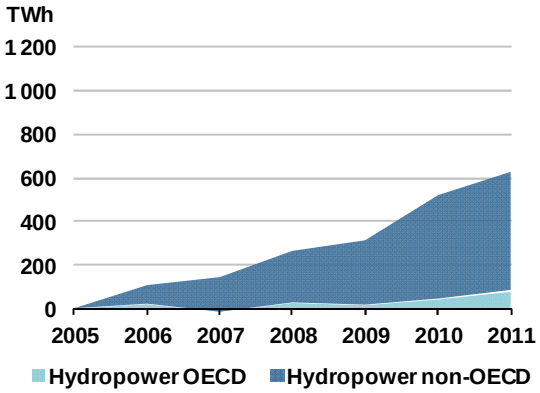
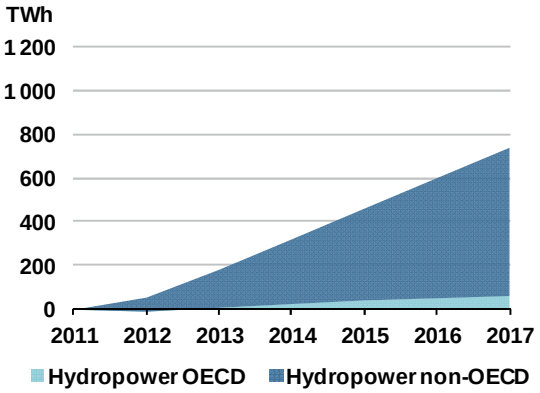


Figure 4 Global hydropower forecast cumulative additions (2011-17)



Renewable energy technologies outside of hydropower continue to grow at a faster rate. Of these, wind power (onshore and offshore) should make the largest contribution to global renewable electricity generation in 2017, at 16.7%. Over 2011-17, wind power should grow on average by 100 TWh per year (+15.6%). Onshore wind accounts for 90% of this growth, as its capacity rises from 230 GW to over 460 GW. Onshore wind has emerged as a mature technology, which is increasingly competitive with conventional alternatives. The current availability of global manufacturing capacity combined with the maturity of the manufacturing industry suggests that supply-side availability should not act as a deployment bottleneck. Other factors, such as licensing procedures, policy uncertainty and financing costs, may have a more profound impact. China should lead capacity growth, adding 104 GW over 2011-17. Despite uncertainty over the durability of a federal production tax credit, the United States should add 27 GW over this period. India (+17 GW), Brazil (+8 GW) and the United Kingdom (+7 GW), among others, should also see significant deployment.

As a more nascent technology, offshore wind faces larger deployment challenges. Capacity should increase significantly from a low base, from 4 GW in 2011 to 26 GW in 2017, supported by generous incentives from governments committed to offshore development. Though the availability of wind turbines should not act as a bottleneck, tight markets for other supply chain components, such as subsea transmission cables and construction vessels, may constrict development in some cases. Offshore projects also carry increased construction and technology risk. All these challenges tend to raise costs and restrict the availability of project financing. Capacity growth should be led by China (+6.7 GW), the United Kingdom (+5.3 GW), Germany (+3.8 GW) and France (+1.5 GW).

Bioenergy should account for 8.3% of renewable power in 2017. Power generation from bioenergy, which includes solid biomass, biogas, liquid biofuels and renewable municipal waste, should rise on average by 37 TWh per year (+9.6%) as capacity grows from 70 GW in 2011 to 119 GW in 2017. Increased use of agricultural and municipal wastes in dedicated power and co-generation (*i.e.* electricity and heat production) plants should drive the expansion, with ample feedstock availability acting as an enabler. Bioenergy co-firing with conventional fuels should play an increasing

role in countries with large coal-fired assets. Capacity growth in bioenergy should occur across a range of countries, given the widespread nature of feedstock. The largest increments are projected in China (+18 GW), the United States (+3 GW), Brazil (+3 GW), Austria (+2 GW) and India (+2 GW).

Figure 5 Global non-hydropower cumulative additions (2005-11)

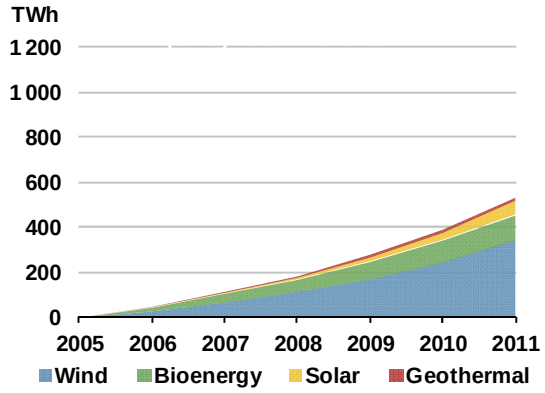
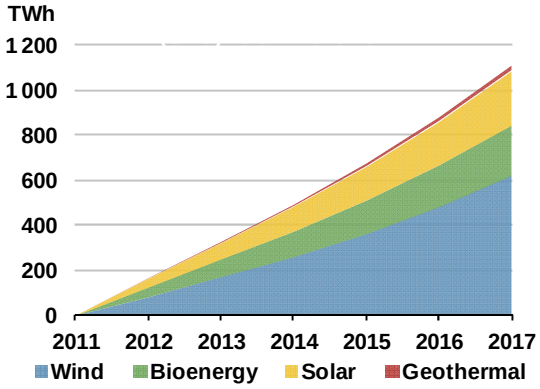


Figure 6 Global non-hydropower cumulative additions (2011-17)



In 2017, solar technologies should make a contribution of 4.9% to renewable generation. Of these, solar PV should scale up the quickest. Over 2011-17, solar PV generation should grow on average by 35 TWh per year (+27.4%) as capacity rises from 70 GW to 230 GW. Improved competitiveness with retail electricity prices and ease of installation should guide strong deployment of solar PV systems in the residential and commercial sectors in a number of countries, in addition to expected utility-scale expansions in areas with good resources. The supply availability of panels and components should remain ample, helping system costs to continue falling over the medium term. Still, the solar PV manufacturing sector should experience several years of consolidation in the face of weak profit margins. Installed capacity growth should be led by China (+32 GW), the United States (+21 GW), Germany (+20 GW), Japan (+20 GW), and Italy (+11 GW). Given past boom-and-bust cycles in several countries, the degree of dynamic approach to policy support will remain a key forecast variable.

Concentrating solar power should grow from near 2 GW total capacity in 2011 to 11 GW in 2017, a rapid increase from a low base, but slower than the industry has anticipated. Projects are typically utility scale and concentrated in arid and semi-arid areas. The technology faces several challenges, including increased price competition from solar PV, which has more deployment flexibility; complex environmental permitting; and grid connections. Still, the storage and hybridisation (*i.e.* merging with a fossil fuel plant) capabilities of CSP provide value that is enhancing project attractiveness. Over the medium term, deployment should be led by the United States (+4 GW), Spain (+1 GW) and China (+1 GW), with smaller developments taking place in the Middle East, North Africa and South Africa.

While outside of this edition's primary focus on renewable electricity, it is important to note that solar thermal heating, a mature technology, should continue to grow strongly over the medium term. Installed capacity should rise from 196 gigawatt thermal capacity (GW_{th}) in 2010 to over 500 GW_{th} in 2017, led by China, Germany, the United States, Turkey and India.

Power from geothermal sources should remain a small segment of renewable generation, at 1.4%, though output is expected to increase steadily over the medium term. Geothermal generation

should grow by 3 TWh per year (+4.2%) as capacity rises from 11 GW in 2011 to 14 GW in 2017. A long-standing source of base-load power, geothermal technology should continue to enjoy low power production costs and high capacity factors, aiding its deployment in areas with good resources. However, projects are characterised by long lead times and a high degree of exploration risk, for which associated financing is scarce. As such, medium-term additions are modest and concentrated in only a few countries; Indonesia, Kenya, the United States, Japan and New Zealand should lead deployment.

Given its relatively early stage of maturity, ocean power does not contribute significantly to renewable generation over the medium term. Most deployment should continue at the demonstration level. However, projects should scale up from single- to multi-device plants, representing an important step towards commercialisation of tidal and wave technologies. Canada, the United Kingdom, China, the United States and Sweden should all see small additions over the medium term.

While renewable electricity remains generally more expensive than conventional sources and economic incentives play a large role in sustaining development, leading technologies are becoming increasingly attractive. Indeed, renewable deployment is starting to transition from a phase in which it is more reliant on subsidy support to one in which projects are competing on their own merits. In general, established technologies such as large and small hydropower, geothermal and onshore wind compete well with new coal- and gas-fired plants in many areas. Small-scale distributed and off-grid applications, such as biogas and solar PV, enjoy good economic attractiveness versus small diesel generators. Moreover, residential solar PV competes increasingly well with retail prices in areas with good solar resources. Ultimately, the competitiveness of renewable generation depends on local conditions, cost structures, resources and the prices of alternatives, making global comparisons difficult. Yet renewable sources are clearly becoming more economically attractive in an increasing number of countries and circumstances.

Table 1 World renewable electricity generation (TWh)

	2005	% Total Gen	2011	2012	2013	2014	2015	2016	2017
Hydropower	3 018	16.5%	3 644	3 698	3 824	3 962	4 102	4 239	4 378
Bioenergy	198	1.1%	308	352	387	421	457	494	532
Wind	103	0.6%	447	527	617	705	807	927	1 065
Onshore	102	0.6%	434	509	591	672	765	868	985
Offshore	1	0.0%	12	18	26	33	43	58	80
Solar PV	4	0.0%	65	102	131	164	198	236	279
Solar CSP	1	0.0%	4	6	10	16	21	25	31
Geothermal	58	0.3%	71	73	75	78	82	87	91
Ocean	1	0.0%	1	1	1	1	1	1	1
Total RES-E	**3 381**	**18.4%**	**4 539**	**4 759**	**5 046**	**5 347**	**5 668**	**6 009**	**6 377**

Notes: unless otherwise indicated, all material in figures and tables derives from IEA data and analysis. Hydropower includes pumped storage; 2011 data are estimates; the split for onshore and offshore wind is estimated for 2005 and 2011; RES-E = electricity generated from renewable energy sources.

The cost and availability of financing will act as a key variable to renewable electricity investment over the medium term. In 2011, global new investment in renewable electricity generation increased to USD 250 billion, a rise of 19% from USD 210 billion in 2010. The quarterly pattern showed a fall-off in global new investment during the first quarter of 2012, though part of this drop could relate to cost reductions and the exclusion of small distributed capacity from the data. Looking ahead, increased macroeconomic risk and tighter bank capital requirements amid uncertainty about policy support in

some areas could constrain funds from traditional sources – European bank project financing and utility balance sheet investment. An assumption of easing economic conditions combined with the emergence of new sources and structures of renewable financing should sustain overall investment over the forecast period. However, the attractiveness of new investment will depend on the evolution of policy and technology risk going forward. In those countries with more uncertain policy supports, the cost of capital tends to remain relatively high, undermining project economics. Moreover, investors still perceive some renewable technologies as risky, particularly offshore wind and CSP.

Table 2 World renewable electricity capacity (GW)

	2010	2011	2012	2013	2014	2015	2016	2017
Hydropower	1 033	1 067	1 103	1 142	1 184	1 223	1 263	1 302
Bioenergy	63	70	77	85	93	102	110	119
Wind	194	234	276	311	350	392	439	490
Onshore	191	230	270	303	339	378	420	464
Offshore	3	4	6	8	11	14	20	26
Solar PV	40	70	91	115	140	167	197	231
Solar CSP	1	2	3	4	7	8	9	11
Geothermal	11	11	11	12	12	13	14	14
Ocean	0	1	1	1	1	1	1	1
Total RES-E	**1 342**	**1 454**	**1 562**	**1 670**	**1 786**	**1 905**	**2 032**	**2 167**

Notes: capacity data are presented as cumulative installed capacity, irrespective of grid connection status. However, solar PV capacity corresponds to installed, grid-connected capacity, which includes small distributed capacity.

Box 1 Defining the analytical framework for the *Medium-Term Renewable Energy Market Report*

This first edition of the *Medium-Term Renewable Energy Market Report* (*MRMR*) forecasts developments in renewable energy across eight technologies – hydropower, bioenergy for power, onshore wind, offshore wind, solar photovoltaics (PV), concentrating solar power (CSP), geothermal and ocean. The analysis focuses on renewable energy in the power sector, though solar thermal heating is also examined. For 2012, biofuels for transport remain in the *Medium-Term Oil Market Report*, to be published in October. Data availability and resource constraints drove this year's *MRMR* focus. Future editions will aim to expand the analytical breadth, including renewable heat and biofuels for transport.

Renewable energy data present unique challenges

As a relatively young and rapidly evolving sector, renewable energy presents a number of statistical challenges. The size and dispersion of some renewable assets create measurement problems. Small-scale and off-grid applications, such as in solar PV and bioenergy, are difficult to count and can often be under-represented in government reporting. Identifying the renewable portion from multi-fuel applications, such as in co-firing with fossil fuels or municipal waste generation, also remains problematic. Moreover, the increased geographic spread of renewable deployment, particularly within the non-OECD, creates the challenge of tracking developments in less transparent markets.

This report aims to provide a complete view of renewable generation and capacity trends over time. Still, historical data points, including 2011, may reflect estimates that are subject to revision. While official IEA statistics provide the basis for much of the data analysis, they also carry measurement limitations. As such, this report's historical series represent an amalgam from multiple sources, which include work by IEA implementing agreements, reporting by industry associations and consultancies, and direct contact with governments and industry operating in a given area.

Box 1 Defining the analytical framework for the *Medium-Term Renewable Energy Market Report* (continued)

Hydropower generation data include output from pumped hydropower. While electricity used for pumping may not necessarily come from renewable origins, this accounting corresponds to that of IEA annual renewable statistics. In general, capacity data for renewable sources are presented as cumulative installed capacity, irrespective of grid connection status. Solar PV, however, is a notable exception – capacity corresponds to grid-connected capacity, which includes small distributed capacity.

Country-level approach underpins the analysis

Given the local nature of renewable development, the approach begins with country-level analysis. For this edition, *MRMR* examines in detail 15 key markets for renewable energy, which currently represent about 80% of renewable generation, while identifying and characterising developments that may emerge in other important markets. Forecasts stem from both quantitative and qualitative analysis. For each of these 15 markets, *baseline case* projections are made for renewable electricity capacity by source through 2017. Generation projections are then derived using country- and technology-specific capacity factors, while recognising that resource quality, the timing of new additions, curtailment issues and weather may cause actual performance to differ from assumptions.

Country-level examinations start with a total power demand outlook based on expectations for real gross domestic product (GDP). This analysis is done in close coordination with other IEA medium-term outlooks. Assumptions for GDP growth stem from the International Monetary Fund's *World Economic Outlook*, released in April 2012. For some countries, *e.g.* emerging markets, power demand growth acts as a driver for renewable generation; for others, *e.g.* more developed countries, demand growth (or lack thereof) can act as a neutral variable or even a constraint on renewable development.

Forecasts at the country level under the report's *baseline case* are carried out in the context of the current policy environment as of May 2012 and do not try to anticipate policy changes going forward.

The electricity market frameworks and renewable policies for several countries, such as Germany, India, Italy, Japan and the United Kingdom, remain in flux as of writing, complicating the analysis. For each country, the policy environment is benchmarked against IEA best-practice principles, as set out in *Deploying Renewables 2011*, helping to determine the degree that prevailing policies may enable or hinder deployment.

Aside from policy, *MRMR* looks at country-level issues of economic attractiveness and power system integration as deployment factors. Attractiveness assessments stem from a number of variables, including policy incentives, economic resource potentials, macro-level economic developments, and the structure and market design of the power system. Moreover, for each country forecast, an assessment is made as to whether the power grid can absorb the projected generation mix and variability.

Table 3 IEA best-practice policy principles

• Predictable renewable energy policy framework, integrated into overall energy strategy.	
• Portfolio of incentives based on technology and market maturity.	
• Dynamic policy approach based on monitoring of national and global market trends.	
• Tackle non-economic barriers.	**Examples**
• Administrative	Large number of permits needed.
• Regulatory	Stop-and-go policy approach.
• Infrastructure	Weak power grids.
• Public acceptance	"Not in my backyard" behaviour.
• Environmental	Unclear impacts of new technologies.
• Address system integration issues.	

Source: IEA *Deploying Renewables 2011*.

Box 1 Defining the analytical framework for the *Medium-Term Renewable Energy Market Report* (continued)

For many countries the potential exists for policy improvements or non-economic barrier changes over the medium term. As such, country sections analyse possible forecast changes in an *enhanced case*, where market-specific challenges – *e.g.* pertaining to policy, grids or attractiveness – are overcome.

Outlooks for technology and financing guide the global picture

The key market assessments plus estimates for other countries in the world under the *baseline case* are judged against the supply abilities of global technology and financial markets. In these sections, *MRMR* focuses on identifying bottlenecks that could pose risks to the country-level forecast.

The technology chapter features several forms of analysis. First, it describes system properties of different renewable technologies, elaborates on their advantages and challenges, and makes judgement on their further exploitable potential. Second, the section characterises market developments by technology since 2005. Third, the chapter provides an outlook for market development through 2017. It consolidates, by technology, the country-level forecasts, identifies the key markets for each technology and addresses potential deployment barriers that lie ahead. For wind and solar PV, the report attempts to characterise the supply ability of global manufacturing capacity in those sectors.

The analysis of global financing reports on recent developments in renewable electricity investment, using data from Bloomberg New Energy Finance. It then discusses key trends over the medium term from a top-down perspective, identifying the impacts of policy on investments and the degree to which the availability and cost of financing may enable or hinder renewable energy development.