ANALYTICAL FRAMEWORK

This is the sixth edition of the *Market Report Series - Renewables 2017* (here and after referred to as "*Renewables 2017"*), formerly called the *Medium Term Renewable Energy Market Report* (*MTRMR*). This report forecasts renewable energy developments within the electricity, heat and transport sectors. Renewable electricity focuses on eight technologies – hydropower, bioenergy for power, onshore wind, offshore wind, solar photovoltaic (PV), electricity from concentrated solar power (CSP), geothermal and ocean power. The renewable transport section provides production forecasts for transport biofuels, including ethanol, biodiesel, advanced biofuels and for the first time: renewable electricity consumption in electric vehicles (EVs). Final energy use of renewable sources for heat focuses on modern bioenergy (excluding traditional biomass), geothermal and solar thermal technologies. Additionally, heat pumps are covered.

Baseline data

As a relatively young and rapidly evolving market, monitoring 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-estimated in government reporting. Identifying the renewable portion from multi-fuel applications, such as in the co-firing of biomass with fossil fuels or municipal waste generation, also remains problematic. Moreover, the increased geographic spread of renewable deployment, particularly within areas outside the Organisation for Economic Co-operation and Development (OECD), creates the challenge of tracking developments in less transparent markets (NB please see the "Glossary" at the end of the book for definitions of how geographic regions are defined).

This report aims to provide a review of renewable energy trends over time, both historically (2016 and prior) and over the forecast period (2017 – 2022). Official International Energy Agency (IEA) statistics provide the basis for much of the historical data, though data coverage is limited in some cases, particularly for 2016 data. Therefore, this report's historical data are determined by consulting multiple sources, including official IEA statistics (IEA, 2017b; IEA, 2017c), work by IEA Technology Collaboration Programmes (IEA TCPs), reporting by industry associations and consultancies, and direct contact with governments and industry. These sources are indicated in the relevant sections of this document. As such, historical data points, including 2016, may reflect estimates that are subject to revision. Except where noted, prices and costs are expressed in real, 2016 United States dollars.

Renewable electricity outlook:

Given the local nature of renewable development, the approach begins with bottom up country-level analysis of each renewable electricity technology in major markets. Forecasts stem from both quantitative and qualitative analysis of the characteristics and emerging trends in each market. For key markets, country-level examinations start with an assessment of the prevailing renewable project pipeline, which is established using various country-level sources as well as the renewable energy projects database of Bloomberg New Energy Finance (BNEF, 2016). This pipeline is analysed in the context of a country's power demand outlook, power generation situation, grid and system integration issues, current policy environment and the economic attractiveness of renewable deployment.

For some countries, e.g. emerging markets, power demand growth acts as a driver for renewable generation; for others, e.g. more mature markets, demand growth (or lack thereof) can act as a neutral variable or even a constraint on development. Therefore renewable power forecasts are made within the context of the entire power sector. Total power demand and generation forecasts for major markets are based on expectations for real gross domestic product (GDP) and are continuously updated when new historical data is available. Assumptions for GDP growth stem from the International Monetary Fund's (IMF's) *World Economic Outlook*, released in April 2017. This exercise is done in close co-ordination with other IEA medium-term reports, in particular *Gas 2017* (IEA, 2017a) and *Coal 2017* (IEA, forthcoming a). From this analysis, an assessment for major markets is made as to whether the power grid can absorb the forecasted generation mix and variability.

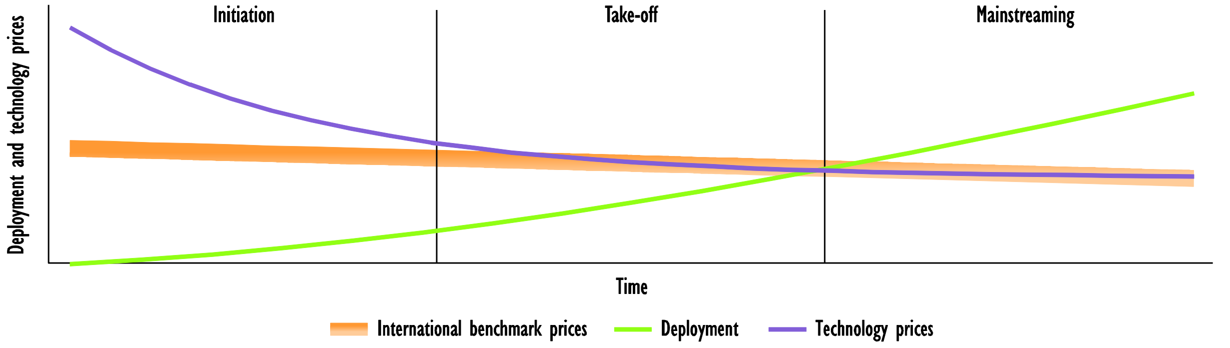
An evaluation of the prevailing policy framework, including announced policies as of September 2017, is a key determinant of the main case forecast. Both the overall enabling environment and the design and implementation of renewable policies are important. The enabling environment includes cross-cutting enablers that can support, or hinder, the successful implementation of policies and the creation of an attractive investment climate, based on five categories (described in more detail in IEA, 2015):

- regulatory and institutional factors
- financial and economic factors
- technical, infrastructure and innovation factors
- social factors
- environmental factors.

Moreover, countries go through different phases of renewable development as deployment grows and costs and prices reduce and converge with international norms: Inception, Take-off and Mainstreaming (IEA, 2011). The policy priorities between the phases differ: initially, a very secure investment climate is needed to encourage early investors, and an appropriate regulatory framework must be put in place; once deployment takes off, the emphasis shifts to encouraging cost reduction and to managing support costs; in the mainstreaming phase, physical and market integration become the key challenges (Figure 5.1). The position of a given market within this journey and the effectiveness of its policy design and implementation in meeting associated priorities significantly impact the trajectory and sustainability of renewable deployment going forward.

Aside from policy, *Renewables 2017* looks at economic attractiveness and power system integration as deployment factors. Attractiveness assessments stem from few variables, including levelised costs of electricity (LCOE), policy incentives, economic resource potentials, macroeconomic developments and the market design of the power system. For many countries the potential exists for policy improvements or non-economic barrier changes over the medium term.

Figure AF.1 The renewable policy journey and changing policy priorities



Initiation phase	Take-off phase	Mainstreaming phase
• The first examples of the technology deployment under commercial terms • **Secure support needed to encourage early investors.** • Local supply chain absent. • Define regulatory framework e.g. permitting procedures may be unclear or lengthy.	• The market starts to grow rapidly. • **Policy priority is to encourage costs to converge with international benchmarks.** • Manage total support costs remain within the expected envelope. • Refine regulatory procedures.	• The annual market has reached a significant scale. • The supply chain is well established. • Generation prices are consistent with international norms and approach fossil-based alternatives. • **Technical and market integration becomes key issues.**

Source: IEA (2015), *Enabling Renewable Energy and Energy Efficiency Technologies: Opportunities in Eastern Europe, Caucasus, Central Asia, Southern and Eastern Mediterranean*.

Based on IEA analysis for each of the key regions and markets, *main case* forecasts are made for renewable electricity capacity by source through 2022. Generation forecasts 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. The resulting country-level capacity and generation forecasts can be found in the online data appendix of the report.

This report includes *accelerated case* projections for renewable capacity to illustrate how certain market and policy enhancements could impact renewable deployment. The aim of the accelerated case is to show how addressing some of the challenges outlined in the main case forecast could result in higher renewable capacity growth over the medium term. A number of country-specific developments, as described within each regional outlook, would need to occur to achieve this result. Given uncertainties over such enhancements occurring in concert, the accelerated case is represented by a range and is indicative of the potential upside for annual renewable deployment over the medium term.

In this report, hydropower generation data include output from pumped storage plants due to the difficulty in separating the capacity and generation for mixed plants (plants that generate electricity from both natural water inflows and pumping). Electricity output from pumped storage is not considered primary power generation in the IEA Energy Balances (IEA, 2017c) because the inputs of electricity used to pump the water have already been accounted for under the primary energy source (e.g. coal, wind, solar PV). As such, electricity output from pumped storage is typically excluded from power generation data and treated separately in other analysis. However, because this report forecasts hydropower generation from capacity that cannot always be separated into such discrete parts as in generation, all electricity from pumped storage plants is included. No such attempt to account for only the renewable portion of the pumped generation is made in this report.

Renewable heat outlook:

Analysis of renewable heat consumption is made using data for the direct use of modern biomass (traditional use of biomass is excluded from the analysis), solar thermal and geothermal heat sources. In addition, indirect use of renewables for heat is included from two sources:

- Commercial heat, i.e. heat produced centrally and distributed through district heating networks;
- Renewable electricity for heat. This is based on estimates for the amount of electricity used for heat and the share of renewables in electricity generation.

The renewable heat sections analyse historical trends of the final energy consumption of renewables for heat and presents projections for 2015-22 as output by the industry and building modules of the World Energy Model (WEM) under the New Policies Scenario in the forthcoming IEA *World Energy Outlook 2017* (IEA, forthcoming b). The WEM is a large-scale simulation tool that models global energy demand on the basis of a set of assumptions which are explained in detail in the IEA, 2017d. The New Policies Scenario takes into account the policies and implementing measures affecting energy markets that had been adopted as of mid-2017, together with relevant policy proposals, even though specific measures needed to put them into effect have yet to be fully developed. Generally speaking, projections for final renewable energy consumption are made based on future heat demand and the available technology options to meet it in the context of the policy framework as outlined by the New Policies Scenario.

Renewable transport outlook:

To maintain the focus on renewable energy markets, where discussing market developments for bioenergy and conventional transport biofuels, no wider assessment of sustainability considerations or related benefits e.g. rural development, for these is included. The conventional biofuel supply analysis is based on a capacity-driven model. The core of the model is a plant-level database. Given their small and fragmented nature, biofuels plants are difficult to track. The industry also remains volatile, with company exits and consolidations. Still, biofuels capacity can quickly change in response to market conditions. Future production is modelled on installed capacity and utilisation factors in a given country, which is based on historic trends and expected economic, fuel demand and policy developments.

This year’s report, *Renewables 2017*, estimates the amount of renewable electricity consumed by EVs, a segment comprised of two- and three wheelers, cars, and buses. The methodology used for this exercise is outlined in Box 3.4 within Chapter 3 of the report. One of the key assumptions of this analysis is how the electricity consumed by EVs is allocated to renewable sources. This analysis assumes that renewable electricity consumption in EVs is proportional to the share of renewable electricity generation in electricity supply on a country basis. This assumption is based on the principle of allocating the final energy consumption of a secondary energy source (electricity) to it primary source (renewables) based on the shares in gross production. This convention is in line with the renewable energy statistical accounting frameworks established by the Sustainable Energy For All *Global Tracking Framework* (SE4ALL, 2013; SE4ALL, 2015) and the European Commission Renewable Energy Directive 2009/28/ED (European Commission, 2009). These approaches have been developed because real-world observed data on the primary energy source of the electricity consumed at the point of the final end-user does not exist. This is, in part, due to the complexity of physical flows along the electricity supply chain such as trade, transmission and distribution losses, and the increasing use self-consumption and storage. Therefore, for the purposes of *Renewables 2017*, this simplified methodology was chosen to ensure comparability and repeatability at the global level based on the best available comprehensive data.

Renewable Energy Technology Trends and Costs

The technology chapter features analysis on technology trends and costs. For technology trends, the section characterises recent market developments and in some cases provides an outlook for specific market development through 2022. Key markets driving the trend, along with drivers and barriers, are identified. Technology costs trends are assessed based on industry and manufacturing developments and recent technology cost developments, including discussion of LCOEs. The primary assumptions used to display the ranges for the main LCOE graphs are listed in the table at the end of this document.

All investment data presented, unless otherwise noted, are derived from the IEA analysis on renewable electricity capacity additions and unit investment costs, historical and forecasted. Investment is defined as overnight capital expenditures on new renewable power plants or the replacement of old plants. When a renewable technology comes to the end of its *technical* lifetime, for the purpose of this report, it is assumed that it is replaced or refurbished with an equal amount of capacity at a reduced cost.

Table AF.1 Economic and technical lifetime assumptions in *Renewables 2017* (years)

Technology	Economic lifetime	Technical lifetime
Hydropower	35	70
Solar PV buildings	20	25
Solar PV utility	20	25
STE/CSP	25	30
Onshore wind	25	30
Offshore wind	25	30
Geothermal	35	50
Bioenergy	20-25	40
Ocean	20	20

Table AF.2 Central assumptions for global LCOE ranges by technology in 2016

	Typical system costs (USD 2016/kW)	Full-load hours	Annual O&M (% of system cost)	Discount rate (% real)	Economic lifetime
Bioenergy					
Dedicated biomass electricity	800-4 500	7 000	2.5-6.5	7-8	20
Hydropower					
Large plants	1 300-2 500	2 200-6 600	2.5	8-12	35
Small plants	2 000-3 500	2 200-6 600	2.5	8-12	35
Geothermal					
Flash plants	2 100-5 000	7 450	2.5	8-9	35
Binary plants	1 600-6 700	7 450	2.5	8-9	35
Offshore wind					
China	3 300-3 800	2 950	3.5	8-9	25
Germany	4 200-4 900	3 850	3.5	7-8	25
United Kingdom	4 300-5 000	3 850	3.5	8-9	25
Onshore wind					
China	1 050-1 300	1 900	1.5	6.5-7.5	25
Germany	1 650-1 850	2 000	1.5	3-4	25
Japan	2 100-2 400	2 200	1.5	6-7	25
United States	1 600-1 900	2 950	1.5	6-7	25
PV – utility					
China	1 050-1 300	1 500	1.0	6-7	20
Germany	1 000-1 200	1 050	1.0	2.5-3.5	20
Japan	1 750-2 350	1 075	1.0	2.5	20
United States	1 800-2 400	1 450	1.0	7-8	20
PV – commercial					
China	1 200-1 450	1 050	1.0	6.5-7.5	20
Germany	1 200-1 500	1 050	1.0	4.5-5.0	20
Japan	2 200-2 600	1 075	1.0	2.5	20
United States	2 800 -3 400	1 300	1.0	8.5-9.5	20
PV – residential					
China	1 350-1 650	1 050	1.0	6.5-7	20
Germany	1 450-1 800	1 050	1.0	2.5	20
Japan	2 700-3 000	1 075	1.0	1.5-2.0	20
United States	3 800-4 200	1 300	1.0	9-10	20
STE (6-hour storage)					
South Africa	5 100	3 250	1.0	10.5-11.0	25
United States	7 500	3 370	1.0	8	25

Notes: Typical system cost assumptions refer to the time of commissioning of the project kW = kilowatts; O&M = operation and maintenance. Assumptions for construction time: bioenergy – 3 years, large hydro – 5 years, small hydro – 3 years, geothermal – 3 years, offshore wind – 3 years, onshore wind – 2 years, solar PV – 1 year, STE – 2 years. A more in-depth overview of investment costs and LCOE values for a range of bioenergy systems is provided within the 'Bioenergy for power section'.

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