World Energy Investment 2017: Methodology Annex

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Comments and questions are welcome and should be addressed to:
Economics and Investment Office, International Energy Agency
31-35 rue de la Fédération, 75739 Paris Cedex 15, France
Telephone: (33-1) 40 57 66 16; Email: eio@iea.org

Introduction

The way investment is measured across the energy spectrum varies, largely because of differences in the availability of data and the nature of expenditures. This document explains in greater detail the methodology used to ensure that the estimates are consistent and comparable across sectors in *World Energy Investment 2017 (WEI 2017)*. In most cases, investment is defined as overnight capital expenditures on new assets. For some sectors, such as power generation, this investment is attributed to the year in which a new plant or upgrade of an existing one becomes operational. For other sources, such as upstream oil and gas and liquefied natural gas (LNG) projects, where sufficient capital expenditure data are available, investment reflects the capital spending incurred over time as production from a new source ramps up or to maintain output from an existing asset.

For energy efficiency, the measurement task is more complex and much of the expenditure is by consumers for whom purchases of more efficient goods are not investments *per se*. In *WEI 2017*, as in *WEI 2016* and other recent IEA reports, investment in energy efficiency includes incremental spending by companies, governments and individuals to acquire equipment that consumes less energy than that which they would otherwise have bought. Due to the different possible methodologies available, this estimate of energy efficiency investment is not definitive but is included to provide a comparison with the scale of investment in energy supply. Fossil fuel and power sector investments are those that raise or replace energy supply, while energy efficiency investments are counted as those that reduce energy demand.

Investment estimates are derived from International Energy Agency (IEA) data for energy demand, supply and trade, and estimates of unit capacity costs, analysis of which benefits from extensive interaction with industry. By default, investment data are given in year 2016 US dollars, adjusted using country-level gross domestic product (GDP) deflators and 2016 exchange rates. Unless otherwise stated in *WEI 2017*, all time series and historical comparisons are presented in real dollar terms, adjusted for inflation.

Overall, this approach to investment represents an approximation of real-world practice. In reality, varying time lags and spending patterns characterise the period between the final investment decision and the operation of an energy project. As such, where available, estimates of capital spending and financing activity are also provided to give a more complete picture of the turnover of the energy asset base as well as decisions to commit new capital, for example, to projects that will come online in 2017 or later. While other areas of spending – including operating and maintenance expenditures, research and development, financing costs, mergers and acquisitions or public markets transactions – remain important for energy sector development, and are analysed on a standalone basis, they are not included in the investment calculations of *World Energy Investment 2017*.

Measuring investment in energy efficiency

Defining and measuring investment in energy efficiency is far less straightforward than for investment in energy supply. The IEA defines an energy efficiency investment as the incremental spending to acquire equipment that consumes less energy than would otherwise have been used to provide the service, such as lighting, heating or mobility, had the consumer not bought a more efficient option (i.e. the baseline*).* The additional cost of a more efficient alternative can represent but a small share of the total spending on a particular energy-related good or service. Furthermore, investment and spending is carried out by many millions of households and firms, often without external financing. As much as possible, a bottom-up analysis using sales and investment data on sales of efficient goods is used, as described in the IEA *Energy Efficiency Market Report 2016* (IEA 2016a).

The baselines used to represent the likely alternative investment option, had the more efficient good not be purchased, are specific to each sector and sub-sector (Table 1).

Table Error! Style not defined.**1 Approaches to setting the baselines above which incremental investment in energy efficiency is estimated in different sub-sectors**

Sector	Sub-sector	Baseline
Buildings	Building envelope, HVAC (heating, ventilation, and air conditioning) and controls	Minimum energy performance standards for new construction, incorporated into the baseline with a time lag of several years to reflect adoption of the standard into the value chain.[1] For retrofits of existing buildings, all spending is incremental.
	Appliances and lighting	Minimum energy performance standards, incorporated into the baseline with a time

[1] For example, in *WEI 2017*, we have updated the US estimates to incorporate the International Energy Conservation Codes (IECC) 2009 building codes into the baseline.

		lag of several years
Industry	Energy-intensive industry	Sector average technology efficiency in prior year and no energy management system spending
	Other industry	Sector average technology efficiency in prior year and no energy management system spending
Transport	Light-duty vehicles	Average efficiency of new vehicle sales, per size and power class
	Freight vehicles and other transport	Average intensity of different modes in 2015

Building sector spending for residential and commercial buildings is compiled from published national reports, for example CEE (2017) and spending reports of various public institutions. If not counted elsewhere in the buildings sector estimate, energy efficiency obligations, loans and funds established by policy are considered to be incremental spending. It also draws upon industry sources, in particular Navigant Research Energy Efficient Buildings and construction-sector indices.

For the industry sector and freight transport sectors, the incremental investment is calculated based on the average technology efficiency in a recent base year. The result is modelled on a regional basis and based on the realised level of energy savings in a sector and energy saving cost curves in the World Energy Model (IEA, 2016b). Added to this is published data on investment in industrial energy management systems that improve system-wide efficiencies in manufacturing and heavy industry.

In the light duty vehicles sector, spending is taken to be the additional price of each efficient vehicle (defined as those in the top 25% for fuel economy in their size and power class) sold compared to the average price of vehicles in eight size and eight power classes in each country in that year. Different size and power classes are considered to take into account expressed consumer preferences and to maintain the principle of reduced energy demand for the same level of energy service provided. Underlying data is derived from IHS Polk and supplemented with public data sources, according to the general methodology of the Global Fuel Economy Initiative (GFEI, 2016) as well as Marklines (2017). This price-based approach differs from cost-based approaches that estimate the total cost of the improving efficiency of the car fleet rather than the incremental consumer spending only. Cost-based approaches are commonly used in modelling exercises and aim to quantify the additional costs associated with improved fuel economy in future years, such as those incurred by manufacturers.

Measuring investment in oil, gas, and coal

In line with capital spending in the other energy sectors, the investment estimates for oil, gas and coal represent overnight spending, i.e. the total amount invested in the capacity needed to meet supply in any given year. They are derived from IEA data for demand, supply and trade, plus industry data on investment costs, where available. In the case of upstream oil and gas investment, the announced spending of over 70 leading oil and gas companies representing 75% of global oil and gas production has been surveyed and the results adjusted to correspond to overnight investment to be consistent with the estimates for the downstream sectors. This follows the methodology of the World Energy Model, used to produce the projections in the IEA's annual World Energy Outlook.

The more detailed estimates we present for investment in LNG liquefaction terminals are an exception: they are based on reported annual spending, not overnight spending, for 45 projects that reached final investment decision between 2000 and 2016. Analyses rely on a wide range of publicly available sources. IEA estimates have been made where detailed information is not available, such as disaggregated spending by type of activity and capital spending plans by unlisted companies.[2]

IEA Upstream Investment Cost Index (UICI)

The IEA Upstream Investment Cost Index or UICI is an indicator that the IEA developed to monitor cost trends in the upstream sector. The index measures the annual change of capital costs for exploration and development experienced by operating companies for the entire upstream sector, averaged across all regions and assets. The index is a composite indicator that reflects prices for cement, steel and other construction materials and equipment, as well as the cost of sector specific labour, drilling rigs and oilfield services. The UICI is calculated by weighting the average capital spending of two separate exploration and production indices on the basis of disaggregated historical data for the different key components within these two activities. The index captures the yearly evolution of costs related to the acquisition of seismic data, project management, drilling services and the construction of production facilities, as well as the costs of labour, materials and equipment that are incorporated into charges for drilling, related services and facilities.

IEA Upstream Shale Investment Cost Index (USICI)

The IEA Upstream Shale Investment Cost Index or USICI aims to assess trends in underlying costs incurred directly by operating companies. This index tracks the inflation rate of capital costs associated with the drilling and completion of wells, as well as the construction of required facilities for production across the US shale industry. USICI is built as the weighted

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[2] The LNG investment included in the aggregate investment total for the oil and gas sector is based on overnight spending, however.

average of representative components for each of these key activities, including drilling, completion and field facilities. IEA USICI is therefore a blended indicator that takes into account time evolution of rig rates, cost of fuel, steel and other raw materials, fracking equipment rates, chemicals as well as changes to costs related to a specialised workforce required for the different services.

Measuring investment in electricity and renewables

Unless otherwise noted, the estimates of electricity investment presented in *WEI 2017* correspond to overnight capital spending on new power plants and network assets, or the replacement of old assets; i.e., investment outlays are counted in the year that an asset becomes operational. Thus, the investment for 2016 actually reflects spending carried out previous years too.

Investment estimates reflect IEA analysis on annual capacity additions and unit investment costs, derived in part from surveys with industry, IEA Technology Collaboration Programmes[3], IRENA (2017a) and other organisations. The estimates are shown in 2016 US dollar prices, adjusted using country-level GDP deflators and 2016 exchange rates. Investment does not include operating and maintenance expenditures, financing costs, research and development spending, mergers and acquisitions or debt and equity market transactions.

The methodology is the same as that employed for the IEA medium-term forecasts and long-term scenario analysis in the *World Energy Outlook* and *Energy Technology Perspectives* series. It represents an approximation of real-world practice. In reality, capital outlays on new plants will be spread over the years preceding installation.

Nuclear power presents particular challenges given the long lead times and spending patterns associated with plant development. For new nuclear power plants, investment corresponds to when the unit is connected to the grid, and assumes a construction time of approximately five years before grid connection. The investment in *WEI 2017* assumes overnight costs from IEA/NEA (2010) and IEA/NEA (2015) for plants starting operation in 2016. Investments associated with upgrades and life extensions are difficult to measure and not included in the investment totals in the report.

Investment in electricity networks includes transmission, distribution and grid-scale battery storage. The data corresponds to the overnight capital spending methodology and reflects three key drivers: investment in new infrastructure to accommodate new demand,

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[3] See https://www.iea.org/tcp/ for further details.

investment to replace ageing infrastructure and the investment required to integrate renewables in the power system. Networks investment to accommodate new demand is calculated based on the commissioning of new transmission and distribution lines and on the analysis of data provided by the *NRG Expert Transmission and Distribution Database* (NRG, 2016). The applied unit investment costs are based on past capital expenditures and data from industry surveys. Investment in asset replacement assumes an average lifetime of 40 years for assets already in operation. Unit replacement costs are derived from costs of new infrastructure. Investment costs of transmission and distribution networks required for renewables integration are derived from renewable integration costs based on literature reviews. The analysis of investments in the digitalization of the electricity grid is based on analysis of NRG (2016), BNEF (2016) and MarketsandMarkets (2016). Investment in grid-scale electricity storage is based on the capacity deployment reflected in the *US Department of Energy Global Energy Storage Database* (US DOE, 2017). Investment in pumped-hydro storage, the largest component of global storage investment, is included in the hydropower data of *WEI 2017*.

Finally, data on financing flows and information about investment decisions, where available, are also shown to give a more complete picture of the turnover of the capital stock. For the first time, *WEI 2017* has undertaken an analysis of final investment decisions for power generation, based on awarded equipment contracts from data provided by McCoy Power Reports (2017) (including coal power, gas, power and hydropower) and reported construction starts (nuclear) based on data from the International Atomic Energy Agency, *Power Reactor Information Systems* (PRIS) (2017). These data may not capture smaller projects below 5 MW (below 10 MW for hydropower).

Renewable asset financing data, provided by Clean Energy Pipeline (2017), refers to the commitment of debt and equity capital for new renewables projects. It is a forward looking indicator as it represents the potential value of renewable power that is expected to be commissioned one to four years after financing has been arranged, rather than the actual turnover of the capital stock. Asset financing data covers new projects and are expressed in nominal dollar terms; they exclude hydropower above 50 mega-watts (MW).

Sources of finance

WEI 2017 features new analysis on trends in the sources of finance – the structure of financing arrangements, the types of financial instruments used to directly finance assets and their geographic location – for the energy sector investments presented in the book. The report also analyses the type of ownership, or providers, of capital, using the financial sponsorship of projects as a proxy for the initial ownership of the investment (ownership of an energy asset can change over time through mergers and acquisitions, asset sales and restructuring of assets into new entities, such as joint ventures). The analysis is based on reported data on financial transactions. Given the difficulties in synthesising complex financial data, which are not always complete or transparent, the results should be seen as providing a broad indication of trends.

By financing mechanism

WEI 2017 broadly categorises the sources of finance for new energy assets into balance-sheet financing and project financing. To estimate project-financed investment, reported primary financing data and operational date at project-level are combined to count as investment in a year when the associated project became operational. Only new financing is included, i.e. project finance for refinancing and merger and acquisition are excluded from our analysis. When a project is confirmed ongoing but a reported operational date is unavailable, assumptions about construction times are used. For example, an onshore wind-power project, for which a primary financing transaction occurred in 2014 but the commissioning date is unknown, is counted as investment in 2016, based on an assumption of a two-year construction time. The main data sources for project-level information are IJGlobal (2017), Platts (2017) and BNEF (2017). Balance sheet financing is estimated as the residual of the total investment less the contribution from project finance.

By type of organisation

WEI 2017 analyses the type of organisations that provide funds for energy investments. Using the initial ownership of the investment, it categorises them into three types of organisations: 1. state actors including governments, state-owned enterprises (SOEs) and national oil companies (NOCs); 2. the private sector; and 3. households, communities and autoproducers for self-consumption. Methodologies for estimating the split by type are specific to each sector.

- **Upstream oil and gas:** the ratio of spending by NOCs is calculated based on Rystad (2017) and funds from companies in the private sector are estimated as the residual of the total investment in the sector.
- **Power generation and oil refining:** Reported project-level data were used to identify the majority owner of each project that came online in a given year and match them to the IEA investment data. All investment in residential and commercial-scale solar PV falls into category 3. The main project-data information sources include Platts (2017) and BNEF (2017) for power generation and the Oil and Gas Journal (2017) for refining.
- **LNG liquefaction terminals:** the ownership structure was examined for each of the projects that reached final investment decision since 2000 (see Measuring oil, gas and coal section). Investment estimates by type were then calculated based on reported annual spending, not overnight costs, and allocated according to the stakes held by each type of organisation in a project.
- **For other sectors** (electricity networks, oil and gas transportation, coal mining and infrastructure, and energy efficiency) the share by type of organisation was

estimated based on the analysis of the market structure by country and region for each sector and multiplied with the total investment. For example, all investment in electricity networks in China is counted as state- ownership as the market is dominated by SOEs.

Research and Development

The approach taken is a bottom-up tracking exercise based on publicly reported data. While it is acknowledged that definitions can vary, especially between the public and private sectors in terms of how capitalised assets are included, the numbers are generally taken at face value. No attempts have been made to extrapolate from this dataset to fill known gaps in particular sectors or countries.

The main breakdowns and sources of data are presented in Table 2.

Table Error! Style not defined.**2 Sources for the compliation of energy R&D spending 2012-2015**

Funding type	Region/country	Source
Public	IEA member governments	Data submitted annually to IEA, broken down by technology area. See IEA (2016c)
	China	Statistics Yearbook on Science and Technology Activities of Industrial Enterprises; China Statisitical Yearbook on Science and Technology; Annual company disclosures of listed companies in sectors not separately covered by NBS statistics and their estimated receipt of government funding.
	India	Research budgets of energy-related ministries
	Brazil	CT ENERG, CT PETRO budgets, plus ANEEL project-by-project costs
	Mexico	Data submitted to the IEA
	Indonesia	MEMR Strategic plans
	Russia	Survey data and news coverage
	South Africa	Research budgets of the Department of Energy and SANEDI
State-owned enterprises (with at least 50% government ownership)	Italy and Canada	Data submitted annually to IEA, broken down by technology area. See IEA (2016c)
	China	Statistics Yearbook on Science and Technology Activities of Industrial Enterprises; Annual company disclosures of listed companies in sectors not separately covered by NBS statistics.
	Largest national oil companies	Press reports and adjustments based on annual production statistics
	Other	Reported R&D spending in annual company disclosures, allocated per energy sub-sector according to share of revenue from that activity unless otherwise stated by the company
Private sector	Corporate	Reported R&D spending in annual company disclosures, allocated per energy sub-sector according to share of revenue

		from that activity unless otherwise stated by the company
	China	Statistics Yearbook on Science and Technology Activities of Industrial Enterprises; Annual company disclosures of listed companies in sectors not separately covered by NBS statistics
	Venture capital	Series A, series B and seed funding by technology area from the Cleantech Group i3 database.

Corporate financial reports of over 1 000 companies active in energy sector industry classifications are include in the sample. These classifications include: fossil fuel extraction, transport, conversion and services; electricity generation, including production, equipment manufacture and services; electricity, gas and district heating utilities; electricity and gas networks and smart grids; electric mobility; LEDs; electricity storage; non-electricity renewable energy, including production and equipment manufacture. Company-level R&D by companies that are active in multiple sub-sectors is apportioned to the sub-sectors in line with their disclosed shares of revenue per sub-sector. This is particularly important in the case of companies whose primary sectoral classification is not well-aligned with the full extent of their market and innovation activities.

One notable caveat is that this methodology makes it challenging to capture corporate research into efficient buildings, appliances, vehicles and industry. Such R&D is undertaken within the R&D activities of these other sectors for which energy efficiency cannot be separated from their other research activities. We know that energy research in other sectors is substantial (IEA, 2017). Furthermore, non-listed companies comprise a non-trivial component of total energy R&D spending and these are not captured by our methodology.

Clean energy spending is separated wherever possible to include all technologies (for the public sector and centure capital) and all industry sub-sectors (for the corporate sector) related to: renewables; nuclear; CCS; smart grids; electric mobility; LEDs; electricity storage.

Employment

The direct and indirect employment impact of investment in power generation is assessed on the basis of a broad industry consultation, company disclosures and other publicly available sources including AWEA (2016); EWEA (2012); IRENA (2017b); KPMG (2015); McKinsey Australia (2016); Navigant (2009); NEA/IAEA (2017); Solar Foundation (2017); UKERC (2014); Uria-Martinez, O'Connor and Johnson (2015); US DOE (2017b) and US BLS (2017). For the estimation of indirect employment impact we limit the scope to first-order indirect employment in the supply chain, i.e. we do not consider industries supplying products and services to the primary equipment supplier.

To calculate employment per unit of generation (TWh) per year, the assumptions presented in Table 3 were made. For comparison across the technologies, the job-years estimates per GW of capacity in construction, equipment-manufacturing, operation and maintenance (onsite, offsite and periodical) and fuel supply were annualised over 25 years to derive jobs per TWh of annual electricity production.

The results presented are indicative on a global level. However, it is important to note that employment requirements for different functions can vary significantly by region for a given technology. For example, residential solar PV installations in Germany are among the least labour-intensive (among all solar PV markets), while projects in the United States are among the most intensive, illustrating the impacts that the local policy and functioning of a supply chain can have on project costs and jobs. The number of jobs associated with coal supply in India is far larger than those involved in more efficient mining operations in Australia.

Table 3 Assumptions for estimating jobs/TWh/year by power generation technology

Technology	Size per plant	Load factor	Operating life
Residential solar PV	5.6 kW	16%	25 years
Utility scale solar PV	100 MW	18%	25 years
Onshore wind	30-50 MW	23%	25 years
Hydro (reservoir)	50-100 MW	50%	50 years
Nuclear (advanced light water unit)	1 GW (single unit)	86%	50 years
Gas-fired generation (combined cycle gas turbine)	1 GW (2 units)	34%	25 years
Coal-fired generation (ultra super critical)	1 GW (2 units)	63%	40 years

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