International Energy Agency
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World Energy Investment 2017

EXECUTIVE SUMMARY

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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The European Commission also participates in the work of the IEA.

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Total energy investment worldwide was around USD 1.7 trillion in 2016, 12% lower than 2015 in real terms and accounting for 2.2% of global gross domestic product (GDP). A 9% increase in spending on energy efficiency and a 6% increase in electricity networks were more than offset by a continuing drop in investment in upstream oil and gas, which fell by over a quarter, and power generation, down 5%. Falling unit capital costs, especially in upstream oil and gas, and solar photovoltaics (PV), was a key reason for lower investment, though reduced drilling and less fossil fuel-based power capacity also contributed.

The electricity sector edged ahead of the fossil fuel supply sector to become the largest recipient of energy investment in 2016 for the first time ever. Oil and gas represent two-fifths of global energy investment, despite a fall of 38% in capital spending in that sector between 2014 and 2016. As a result, the low-carbon components, including electricity networks, grew their share of total supply-side investment by twelve percentage points to 43% over the same period.

The People's Republic of China (hereafter, "China") remained the largest destination of energy investment, taking 21% of the global total. With a 25% decline in commissioning of new coal-fired power plants, energy investment in China is increasingly driven by low-carbon electricity supply and networks, and energy efficiency. Energy investment in India jumped 7%, cementing its position as the third-largest country behind the United States, owing to a strong government push to modernise and expand India's power system and enhance access to electricity supply. The rapidly growing economies of Southeast Asia together represent over 4% of global energy investment. Despite a sharp decline in oil and gas investment, the share of the United States in global energy investment rose to 16% – still higher than that of Europe, where investment declined 10% – mainly as a result of renewables.

Key trends in energy investment by sector

After a 44% plunge between 2014 and 2016, upstream oil and gas investment has rebounded modestly in 2017. A 53% upswing in US shale investment and resilient spending in large producing regions like the Middle East and the Russia Federation (hereafter, "Russia") has driven nominal upstream investment to bounce back by 6% in 2017 (a 3% increase in real terms). Spending is also rising in Mexico following a very successful offshore bid round in 2017. There are diverging trends for upstream capital costs: at a global level, costs are expected to decline for a third consecutive year in 2017, driven mainly by deflation in the offshore sector, although with only 3% decline, the pace of the plunge has slowed down significantly compared to 2015 and 2016. The rapid ramp up of US shale activities has triggered an increase of US shale costs of 16% in 2017 after having almost halved from 2014-16. The oil and gas industry is undertaking a major transformation in the

way it operates, with an increased focus on activities delivering paybacks in a shorter period of time and the sanctioning of simplified and streamlined projects. The global cost curve has rebased, and a significant component of the cost reduction experienced over the last two years is likely to persist in the foreseeable future.

Global electricity investment edged down by just under 1% to USD 718 billion, with an increase in spending on networks partially offsetting a drop in power generation. Investment in new renewables-based power capacity, at USD 297 billion, remained the largest area of electricity spending, despite falling back by 3%. Renewables investment was 3% lower than five years ago, but capacity additions were 50% higher and expected output from this capacity about 35% higher, thanks to declines in unit costs and technology improvements in solar PV and wind. Investment in coal-fired plants fell sharply, with nearly 20 gigawatts (GW) less commissioned, reflecting concerns about local air pollution and the emergence of overcapacity in some markets, notably China, though investment grew in India. The investment decisions taken in 2016, totalling a mere 40 GW globally, signal a more dramatic slowdown ahead for coal power investment once the current wave of construction comes to an end. Gas-fired power investment remained steady in 2016, but nearly half of it was in North America, the Middle East and North Africa where gas resources are abundant. In Europe, although 4 GW of new capacity came online based on investment decisions made years ago, retirements of gas-power plants exceeded the amount of new capacity that was given the green light for construction. The 10 GW of nuclear power capacity that came on line in 2016 was the highest in over 15 years, but only 3 GW started construction, situated mostly in China, which was 60% lower than the average of the previous decade.

Spending on electricity networks and storage continued its steady rise of the past five years, reaching an all-time high of USD 277 billion in 2016, with 30% of the expansion driven by China's spending in the distribution system. China accounted for 30% of total networks spending. Another 15% went to India and Southeast Asia, where the grid is expanding briskly to accommodate growing demand. In the United States (17% of the total) and Europe (13%), a growing share is going to the replacement of ageing transmission and distribution assets. Overall, the grid is modernising and moving from a pure electricity delivery business to an integrated platform for data and services, enabled by rapid progress in digital information and communications technologies, which grew to over 10% of networks spending. Investment in grid-scale battery-based energy storage is ramping up quickly, having reached over USD 1 billion in 2016.

Investment in energy efficiency expanded once again, despite persistently low energy prices, reaching USD 231 billion in 2016. While Europe was the largest region for this type of spending in 2016, the fastest growth occurred in China, where a strengthening of energy efficiency policies is helping to reduce the energy intensity of the economy, alongside structural changes. Globally, most investment – USD 133 billion – has gone to the buildings sector, which accounts for one-third of total energy demand. While the energy performance standards of equipment and appliances in emerging economies are gradually

tightening, there is still much room for improvement. For example, new air conditioners sold in 2016 will add up to 90 terawatt hours (TWh) of power demand globally and 10 TWh in India alone, exacerbating peak loads. This could have been 40% lower if the highest efficiency standards had been adopted in all countries. In 2016, the numbers of heat pumps sold grew 28% and electric vehicles grew 38%. These technologies improve overall efficiency and if co-ordinated with renewables deployment could help decarbonise space heating and mobility, though so far their impact on oil and gas demand is small. The 750 000 electric vehicles sold in 2016 are expected to reduce transport oil demand by around 0.02%.

Key trends in financing and funding energy investments

More than 90% of energy investment is financed from the balance sheets of investors, suggesting the importance of sustainable industry earnings, which are based on energy markets and policies, in funding the energy sector. This share has barely changed in recent years, though sources of finance are changing in some sectors. While the overall share of project finance, which depends on cash flows for a given asset, remains small, its use in power generation investment – especially renewables – has grown rapidly in the past five years, by 50%, reflecting lower project risk in some emerging economies and the maturation of certain technologies. Newer mechanisms for raising equity and debt, such as green bonds and project bonds, are enabling investors to tap into larger financing pools, especially for refinancing assets and funding investments in smaller-scale projects such as energy efficiency and distributed generation.

The role of state actors in energy investments remains elevated. While the share of public bodies in investment, including state-owned enterprises (SOEs), edged down slightly to 42% in 2016, the level was notably higher than 39% in 2011. This is largely due to the increased role of SOEs in electricity sector investment, notably in China. The share of public bodies in generation investment, at one-third in 2016, has recently begun to moderate while their share in networks investment, at nearly 70%, continues to rise. National oil companies are playing a larger role in upstream oil and gas spending, with their share rising to 44% in 2016 from below 40% before the recent downturn in oil prices. The costs of **go**vernment energy efficiency programmes are equal to almost 15% of energy efficiency spending and, via loans and competitive mechanisms, directly generate private spending that is more than twice this level.

Government policies and new business models are having a profound impact on the way investment in electricity supply is funded. In 2016, 94% of global power generation investment was made by companies operating under fully regulated revenues or regulatory mechanisms to manage the revenue risk associated with variable wholesale market pricing. However, significant changes are occurring in some sectors and markets. Over 35% of utility-scale renewable investment took place in markets where prices for power purchase were set by auctions, contracts with corporate buyers and other competitive mechanisms, up from 28% in 2011. In wholesale markets, funding new thermal generation increasingly

depends on capacity payments or other revenues beyond wholesale markets. While virtually all network investment has a regulated business model, unbundled grid companies accounted for only 40% of grid investment, with the large majority of this funded on the basis of regulated network tariffs, compared with 50% in 2011. Policies that help to reduce the cost of capital and improve the cost-reflectiveness of electricity pricing are especially important in countries such as India and Indonesia where electricity demand is growing rapidly and where utilities face financing constraints.

The downturn in oil prices did not significantly affect the funding of investments by oil and gas companies, though most of them increased leverage significantly. Despite investment cutbacks and better cost discipline, the oil majors increased debt by over USD 100 billion between late 2014 and early 2017. Independent US oil companies, which have a more leveraged business model, initially saw debt costs soar, but the availability and cost of bond financing has improved with a rebound of oil prices since early 2016 and their financial health has improved with efficiency gains. Increased interest in shale assets by large oil companies and financial pressures to reduce debt led to a series of asset sales by independents.

Energy innovation, digitalization and employment

We have tracked USD 65 billion of spending on energy research and development (R&D) worldwide in 2015, based on a bottom-up assessment of spending by public and private bodies. Despite growing recognition of the importance of energy innovation, spending on neither energy technology generally nor clean energy specifically has risen in the past four years. Europe and the United States are the largest spenders, each accounting for over 25% of the total, whereas China is the highest spender on energy R&D as a share of GDP, after overtaking Japan in 2014. Although public and private sources each represent around half of the R&D total, most private R&D is in the oil, gas and thermal power sectors, whereas most public R&D is devoted to clean energy technologies. Important carbon capture and storage projects, largely financed by companies, are starting operation in 2017, but current policies do not support a significant uptick of spending in this decade on these long lead-time projects, as evidenced by the lack of new projects entering construction.

The future role of digital technologies for generating, handling and communicating data has taken centre stage in energy discussions. We estimate that USD 47 billion was spent in 2016 on infrastructure and software directed towards digitalization of the electricity sector to facilitate more flexible network operation, demand management and integration of renewable resources. The oil and gas industry is scaling up its utilisation of digital technologies to improve performance of its operations while keeping costs under control.

It is difficult to justify major energy policy decisions on the basis of their employment impact alone. Our analysis suggests that, in general, technological progress is leading to lower labour intensity across the energy system. For example, a 30% drop in jobs in US oil and gas upstream from its peak level in 2014 to its 2016 trough was accompanied by only a

marginal decrease in production. Productivity improvements are also unfolding for key renewable power generation technologies. A snapshot comparison of different power generation technologies suggests that renewables tend to create more upfront jobs in construction and manufacturing, whereas thermal generation requires more ongoing employment in operations and fuel supply. Combining these activities shows that the employment across the project life cycle resulting from the generation of a new unit of electricity is comparable across technologies. However, the impact on employment of investment in different power generation technologies is likely to be highly region-specific, partly because of the geographical mismatch between fossil fuel production and clean energy deployment as well as due to differences in the international competitiveness of relevant engineering and construction industries. Labour intensity also varies markedly across regions for the same technology. For example, the employment impact of both solar and coal-fired power can vary by 100% or more depending on local conditions.

Implications of energy investment

A 17% decline in global energy investment since 2014 has not yet raised major concerns about near-term energy supply adequacy, which have been eased by excess capacity in global fossil fuel supply and electricity generation in some markets, as well as cost deflation in many parts of the energy sector. But falling investment points to a risk of market tightness and undercapacity at some point down the line. A drop in upstream oil and gas activity and the recent slowdown in the sanctioning of conventional oil fields to its lowest level in more than 70 years may lead to tighter supply in the near future. Given depletion of existing fields, the pace of investment in conventional fields will need to rise to avoid a supply squeeze, even on optimistic assumptions about technology and the impact of climate policies on oil demand. The energy transition has barely begun in several key sectors, such as transport and industry, which will continue to rely heavily on oil, gas and coal for the foreseeable future.

In many cases, it is unclear whether the business models in place are conducive to encouraging adequate investment in flexible electricity assets, raising concerns about electricity security. Continuous investment in flexible assets to ensure system adequacy during periods of peak demand and to help integrate higher shares of wind and solar PV capacity into the system is essential. The bulk of the flexibility that has been introduced so far has come from existing assets, primarily dispatchable capacity (mainly gas-fired plants and hydropower) and transmission interconnections. In 2016, the amount of new flexible generation capacity plus grid-scale storage that was sanctioned worldwide fell to around 130 GW – its lowest level in over a decade, reflecting weaker price signals for investment stemming from ongoing regulatory uncertainty and flawed market designs. For the first time ever, this capacity was virtually matched by the 125 GW of variable renewables capacity (solar PV and wind) commissioned in 2016, whose construction times are generally a lot shorter. The 6% increase in electricity network investments in 2016, with a larger role for digital technologies, supports grid modernisation and the ongoing integration of

variable renewables. However, new policies and regulatory reforms are needed to strengthen market signals for investment in all forms of flexibility.

Although carbon dioxide emissions stagnated in 2016 for the third consecutive year due to protracted investment in energy efficiency, coal-to-gas switching and the cumulative impact of new low carbon generation, the sanctioning of new low-carbon generation has stalled. Even though the contribution of new wind and solar PV to meeting demand has grown by around three-quarters over the past five years, the expected generation from this growth in wind and solar capacity is almost entirely offset by the slowdown in nuclear and hydropower investment decisions, which declined by over half over the same time frame. Investment in new low-carbon generation needs to increase just to keep pace with growth in electricity demand growth, and there is considerable scope for more clean energy innovation spending by governments and, in particular, by the private sector.

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The second annual IEA benchmark analysis of energy investment – the lifeblood of the global energy system – presents diverse findings, with upbeat news in some quarters and bearish indicators in others.

World Energy Investment 2017 provides a critical foundation for decision making by governments, the energy industry and financial institutions.

With analysis of the past year's developments across all fuels and all energy technologies, the report reveals the critical issues confronting energy markets and features the emerging themes for 2017 and beyond. It highlights the ways in which investment decisions taken today are determining how energy supply and demand will unfold tomorrow, complementing the forecasts and projections found in other IEA publications.

This year's edition examines the financial landscape for energy investment and how financing flows are evolving in relation to renewable energy expansion, shorter-cycle oil and gas projects, and innovations in energy efficiency financing.

World Energy Investment 2017 addresses key questions, including:

- Which countries and policies attracted the most energy investment in 2016?
- Investments are growing the fastest in which fuels and technologies?
- How are oil and gas companies reinventing themselves to survive the new technology and price environments in the sector?
- How might energy investment trends affect energy security and climate change mitigation?
- How are business models evolving with the changing availabilities of capital for different energy sources?
- What are governments and the energy sector spending on energy R&D, and who are the biggest spenders?