World Energy Investment 2023 Methodology Annex

International Energy Agency

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Introduction

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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 the methodology used to ensure that the estimates are consistent and comparable across sectors in the World Energy Investment 2023 (WEI 2023).

In WEI 2019, the definition of investment changed from the previous editions of WEI where investment was defined as overnight capital expenditure. In WEI 2020 and beyond, investment is again measured as the ongoing capital spending on assets. For some sectors, such as power generation, this investment is spread out evenly from the year in which a new plant or upgrade of an existing one takes a final investment decision (FID), i.e. when a project reaches financial close or begins construction) to the year in which it becomes operational. For other sources, such as upstream oil and gas and liquefied natural gas (LNG) projects, 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 2023, as in other recent IEA reports, investment in energy efficiency includes the incremental spending by companies, governments or individuals to acquire a piece of equipment that is more efficient than the local market average. Due to the different possible methodologies available, this estimate of energy efficiency investment is not definitive but still 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 2022 US dollars, adjusted using country-level gross domestic product (GDP) deflators and 2022 exchange rates. Unless otherwise stated, all time series and historical comparisons are presented in real 2022 US dollar terms, adjusted for inflation.

Overall, this approach to investment represents an approximation of real-world practice and is aligned with the concept of capital expenditure in financial reporting and accounting. In reality, varying time lags and spending patterns characterise the period between the FID and the operation of an energy project. As such, where available, measures of financial performance, financial flows and physical energy changes 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. 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 in IEA investment work, but are not included in the investment calculations of WEI 2023.

Measuring investment in the power sector

The estimates of electricity investment presented in WEI 2023 correspond to annual capital spending on new power plants, battery storage and grid assets, or the replacement of old assets or refurbishments for life extensions. Investment outlays are spread evenly from the year that an asset takes a final investment decision (i.e. it reaches financial close or begins its construction) until the year it becomes operational. Thus, the investment for 2022 reflects spending carried out in assets that will become operational in the future, too. The construction period is estimated from data on reported primary financing transactions, sanctioning dates and operational dates at a project-level by technology and by region in a given year.

Table 1. Sub-sectors and assets included in power sector investment

Sub-Sector	Assets
Fossil-fuel based power generation	Coal-fired power Coal-fired power with CCUS Gas-fired power Gas-fired power with CCUS Oil-fired power
Nuclear power generation	Nuclear power plants (greenfield) Refurbishments and upgrades of existing plants for long-term operations
Renewable power generation	Bioenergy Hydropower Wind (onshore and offshore) Geothermal

Sub-Sector	Assets
	Solar PV (utility-scale, commercial and residential buildings, and off-grid) Concentrated solar power Solar thermal Marine
Electricity grids	Transmission Distribution Public EV chargers
Battery storage	Utility-scale and buildings

Investment estimates reflect IEA analysis on annual capacity additions and unit investment costs, derived in part from surveys with industry, IEA (2022), S&P Global (2023), BNEF (2023a), BNEF (2023b), IRENA (2023), Clean Horizon (2023), Lazard (2023), WoodMacKenzie (2023) and other organisations. The methodology represents an approximation of real-world practice. In reality, capital outlays on new plants also spread over the years preceding installation and capital expenditures are often incurred during the life of a plant, even if this spending does not result in a change to capacity.

Nuclear power presents particular challenges given the long lead times and spending patterns associated with plant development. For new nuclear power plants, spending corresponds to the even allocation from the year in which the unit takes final investment decision to the year in which the unit is connected to the grid. WEI 2023 includes estimates for upgrades to existing nuclear plants to extend lifetime operation. Investment in existing plants is estimated by reviewing plants reaching a 40-year lifetime in a given year and assessing their reported operational plans going forward.

Investment in electricity networks includes transmission and distribution, and spending on digital equipment for the smart monitoring and operation of the grid (e.g. smart meters, automation and public electric vehicles charging stations). The data corresponds to the capital spending methodology and reflects three key drivers: investment in new infrastructure to accommodate new demand (increased connections and consumption), investment to replace ageing infrastructure and investment required to integrate renewables in the power system.

Past investments in transmission and distribution assets and estimates for 2023, where possible, are based in publicly available data from utilities, regulators and other domestic entities. Grids 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 Global Transmission Database (2019). 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 digitalisation of the electricity grid is based on analysis provided by Guidehouse (2022). Electric Vehicle (EV) charging stations investment is based on combining estimates of public and private charger installations with prevailing cost information, based on IEA (2021a). Spending on public EV charging infrastructure is included in the investment of distribution assets, while investment in private EV charging infrastructure is included in end-use.

Additionally, investment in grid-scale battery storage and behind-the-meter storage is based on the capacity deployment reflected in the Clean Horizon Project Database (Clean Horizon, 2023), BNEF (2023a), and the analysis of data from the China Energy Storage Alliance Energy Storage White Paper (CNESA, 2023) as well as WoodMacKenzie (2023). Investment in pumped-hydro storage, the largest component of global storage investment, is included in the hydropower data of WEI 2023. Behind-the-meter storage is derived from BNEF (2023a), CNESA (2023), and WoodMacKenzie (2023).

Finally, data on final investment decisions (FIDs), where available, are also shown to give a more complete picture of the turnover of the capital stock. WEI 2023 has undertaken an analysis of FIDs for power generation based on awarded equipment contracts from data provided by McCoy Power Reports (2023) (including coal power, gas power and hydropower), Clean Energy Pipeline (2023) for renewables except large hydropower, and reported (nuclear) construction starts based on data from the International Atomic Energy Agency, Power Reactor Information Systems (PRIS) (2023) and other sources. These data may not capture projects below 5 MW (below 10 MW for hydropower). However, WEI 2023 has made estimates for investments and FIDs (treated as the same) in small-scale generator sets, based on Global Data (2018) and other publicly available information.

Measuring investment in fuel supply

In line with the other energy sectors, the investment estimates for oil, gas and coal represent capital spending, i.e. the total amount of investment costs incurred 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, global spending estimates are based on the announced spending of close to 90 leading oil and gas companies. The investment activities of these companies, which represent over three-quarters of global oil and gas production, have been surveyed and adjusted to estimate the global spending. For

the oil refining sector, spending estimates are calculated based on project-level information on new refineries and upgrading projects in 108 countries. The investment estimates for the midstream sectors such as oil and gas pipelines and shipping transport were made to correspond to the IEA data for demand, supply and trade for oil and gas products. This follows the new methodology of the World Energy Model (WEM), used to produce the projections in the IEA's annual World Energy Outlook report.

The investment in LNG liquefaction terminals is based on reported or estimated annual spending for nearly 60 projects that reached FID between 2000 through the first quarter of 2023. 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.

The investment for biofuels (including liquid biofuels and biogases) is based on capacity expansion plans for production facilities and assumptions on plant costs. Biofuels investment does not include additional spending on the production and supply of agricultural feedstocks. In this way, the biofuels investment estimate is more comparable to that for downstream fuel supply (e.g. refining and gas processing) activities than to upstream activities.

Historical investment for CCUS is allocated to the sector in which the CO_2 is captured and is classified as clean energy investment. For example the capital expenditures associated with a CCUS project on a power plant are allocated to the power generation sector. With the exception of new plants equipped with CCUS for the production of hydrogen, the estimated costs are based on the incremental costs of the project and equipment for capturing, transporting and storing CO_2. Investments in CO_2 transport and storage infrastructure that is unconnected to an existing CO_2 capture project at the time of construction are allocated to clean energy supply. Investment spending for CCUS is estimated on a project-by-project basis for projects cetegorised as in operation, cancelled or in construction in the IEA CCUS project database using outturn costs of completed projects and known construction times.

Historical investment in hydrogen suppy projects is estimated on a project-by-project basis for projects cetegorised as in operation, cancelled or in construction in the IEA hydrogen project database using regional capital cost curves and construction times.

Net income of the oil and gas industry is calculated from oil and gas production at prevailing oil and gas prices (including subsidies) after operating costs but before taxes; private companies here includes listed and non-listed companies. Distribution of cash spending by the oil and gas industry is based on data from S&P Capital IQ (2022).

Table 2. Sub-sectors and assets included in fuel supply investment

Sub-Sector	Assets
Oil and Gas	Upstream oil Upstream gas Midstream oil (pipelines) Midstream gas (pipelines and LNG) Refining (greenfield) Refining (upgrade and maintenance)
Coal supply	Coal mining Coal transportation
Low-carbon fuels	Biogases Liquid biofuels Hydrogen production

WEI 2023 has undertaken an analysis of asset finance FIDs for clean energy investments made by a subset of oil and gas companies including the Majors (TotalEnergies, BP, Shell, ENI, Chevron, ExxonMobil and Oxy), ADNOC, CNPC (China National Petroleum Corporation), CNOOC, Equinor, Gazprom, Kuwait Petroleum Corporation, Lukoil, Petrobras, Repsol, Rosneft, Saudi Aramco, Sinopec and Sonatrach. The estimated share of total capex in 2022 is based on projects announced through May 2022 and assumes that this pace of investment is maintained through the year. These were gathered from Bloomberg (2022), Bloomberg NEF (2022) and Clean Energy Pipeline (2022) as well as annual reports. The level of clean energy investment is adjusted to company (or subsidiary) relative holdings in the entitiy that made the investment. Total capex spending is estimated from bottom-up analysis of company reporting and Rystad (2022).

Measuring investment in critical minerals supply

Capital expenditure for non-ferrous metal production was used to understand investment trends in the supply of critical minerals that are vital to clean energy technologies. 18 major companies were chosen as a representative list based on their presence in the production of energy transition minerals and the availability of disaggregated information about capital expenditure in companies' annual reports. The estimates for capital spending in exploration activities were gathered from S&P Global (2022).

Production trends for key minerals and metals were assessed using data from USGS (2022) and S&P Global (2022), complemented by additional press research. Future mineral requirements for key minerals and metals were estimated based on (i) clean energy deployment trends under different scenarios,

(ii) sub-technology shares within each technology area (e.g. solar PV module types; EV battery chemistries), (iii) mineral intensity of each sub-technology; and (iv) the pace of mineral intensity improvements, as analysed in the World Energy Outlook 2021.

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 a small share of the total spending on a particular energy-related good or service. Furthermore, spending is typically carried out on the balance sheets of many millions of households and firms, often without external financing. As much as possible, a bottom-up analysis using data on sales of efficient goods is used.

In the buildings sector, the incremental investment for new or renovated buildings is the change in cost for services (design, delivery, installation) and products (lighting, appliances, equipment and materials) that achieve increased energy efficiency performance beyond the investment required for the minimum performance legally allowed. Thus, in principle, the full cost of a renovation that is associated with energy efficiency improvements is included. For building types and products that have legal requirements on the performance of buildings, buildings services or building products, this cost is the incremental spending beyond what is needed to achieve the minimum energy performance standards, energy efficiency regulations or building energy codes. For building types and products that do not have energy requirements, this cost is the incremental spending on energy-efficient services and products beyond what would have otherwise been spent, which in some cases is no spending.

The incremental investment in buildings achieved as a result of a recent improvement in energy efficiency policies is calculated as the difference between the total spending required to achieve the new policy and the total cost required to comply with the previons regulation. The spending for residential and commercial buildings is compiled from published national reports, including those of various government departments, agencies and public institutions. If not counted elsewhere in the buildings sector estimate, energy efficiency obligations, loans and funds established by policy are also considered as incremental spending. The estimate also draws upon industry sources, construction-sector indices and studies of capital cost requirements.

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 (WEM), included in the IEA's annual World Energy Outlook report (IEA, 2022). Added to this is published data on investment in industrial energy management systems that improve system-wide efficiencies in manufacturing and heavy industry.

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

Table 3. Sub-sectors and assets included in end use

Sector	Sub-sector	Assets
Buildings	Energy efficiency	Building materials (envelope and interior) Appliances and lighting HVAC (heating, ventilation, and air conditioning) Smart meters
	Electrification	Heat pumps
	Renewables	Bioenergy Geothermal Solar home systems Other renewables
Industry	Energy efficiency	Industrial energy management systems Fuel efficiency
	Electrification	Electrical efficiency Heat pumps
	Renewables	Bioenergy Geothermal Thermal solar
	Other end uses	Industry CCUS
Transport	Energy efficiency	Road vehicles (passenger light duty vehicles, light commercial vehicles, heavy-freight traffic vehicles, medium-freight traffic vehicles and other road vehicles)
	Other end uses	Road electric and fuel cell vehicles

In the light duty vehicles sector, spending is taken to be the additional price of each efficient vehicle sold (defined as those in the top 25% for fuel economy in their size and power class, according to the Worldwide Harmonised Light Vehicles Test Procedure [WLTP]) 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. Electric light duty vehicles – both battery electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) are included in this exercise with their electricity consumption converted to litres of gasoline equivalent on a WLTP basis. Underlying data is derived from IHS Markit (2022) and supplemented with public data sources and Marklines (2022), according to the general methodology of the Global Fuel Economy Initiative (GFEI, 2019). 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.

Energy financing and funding trends

IEA investment work analyses trends related to financial flows, ownership and the sources of funding and finance – the structure of financing arrangements used to finance assets and their geographic location – for different energy sectors, as well as analysis of these issues from the perspective of companies, banks and investors.

Our analysis also provides an estimate of how the primary sources of finance would evolve over the 2020-2030 decade under different energy pathways. Sources of finance are characterised across four broad parameters:

- type of financing structure (off-balance sheet [project finance] or on-balance sheet [corporate finance]);
- type of provider (private or public);
- type of instrument (according to capital structure - debt or equity);
- origin of provider (international or domestic sources).

The assumptions and analytical approach are included below.

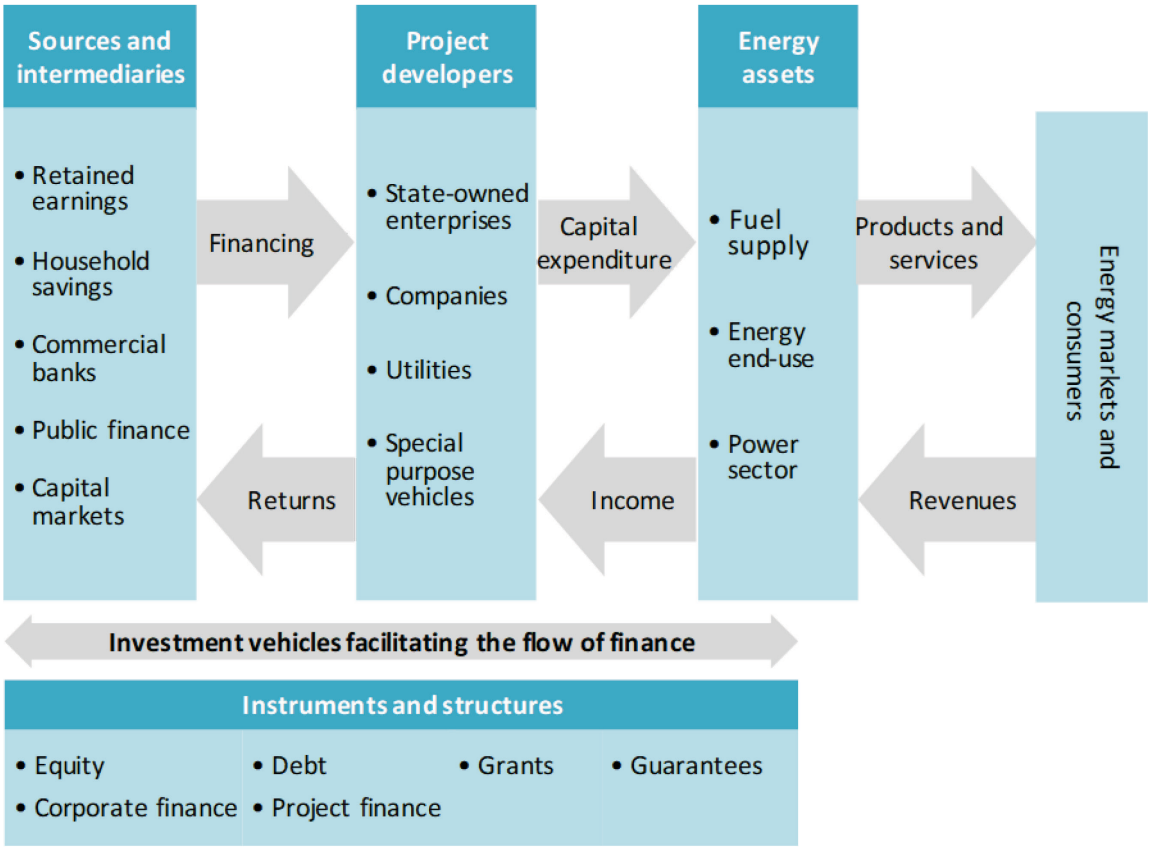
Measuring the sources of finance for investments

Capital spending on energy assets is first disaggregated between balance sheet and project financing, which are carried out by a variety of intermediaries and project developers (Figure 1). The main data sources used to estimate project-financed investment are IJGlobal (2022), the World Bank Public Participation in Infrastructure Database database (2022), Clean Energy Pipeline (2022) and specific transaction announcements. Balance sheet financing is estimated as the residual of total investment less the contribution from project finance.

An analysis of the sources of finance by private and public provider, capital structure (debt and equity sources) and origin of funds (international and domestic) is also carried out. For the project finance portion, this is done on a project-by-project basis – based on the characteristics of the debt providers and equity sponsors – while in the corporate finance portion this is done on a company basis. The latter is based mainly on information from publicly listed-companies, using data from Bloomberg (2022) and Reuters (2022), though also from publicly available data of other non-listed companies (e.g. financial statements, annual reports, etc). For example, to define whether finance is coming from public or private sources, for balance sheet finance the analysis categorises the type of company carrying out spending on its balance sheet as a state-owned enterprise (if a government or government entitiy owns at least 50% of the shares) or private sector actor, while for project finance categorisations are made of the debt providers and equity sponsors.

To translate financing data into investment spending, reported primary financing data, financial close date (proxy of the sanctioned date) and actual or estimated operational date at project-level are combined in a given year. Given the difficulties in synthesising complex data, which are not always complete or transparent, the results should be seen as providing a broad indication of trends.

Figure 1. Financial flows in energy investment



Projecting the sources of finance

The analysis includes an estimation of how the sources of finance would evolve under different energy pathways. Generally, under an energy pathway based on today's policy settings, as in the STEPS, the sources of finance reflect the continuation of recent financing trends across sectors and geographies. With the enhanced policies and measures that deliver the ambitions needed to deliver investments under climate-driven scenarios the outlook for finance shifts, and reflects a better availability of clean energy projects with risk-adjusted returns that attract a wider range of structures and investors; more efficient capital allocation, especially from public sources; and the development of local capacity to invest in clean energy.

Estimates are made through adjusting the ratios of on-balance and off-balance sheet financing, private and public financing, debt and equity, and international and domestic sources based on assumptions made on a sector- and geographical-level. These assumptions include-

- The role of private, international financing and debt generally increases for clean energy under climate-driven scenarios. More ambitious, clear policies – as well as improved regulation – help to improve the investment case for clean energy assets. Under these conditions, perceived risks are seen to be lower and private sector participation would be higher, as well as the willingness to commit higher shares of debt and the ability to raise international finance. In addition, capital from public sources, including public finance institutions (PFIs), is assumed to be more effective in mobilising private finance for new assets and projects.
- Within a given sector (e.g. utility-scale solar PV or wind), the role of private financing is usually smaller in markets at initial stages of deployment compared with more mature markets, and the role of PFI financing is higher. In both types of markets – learning effects, as well as policy and regulatory improvements – have the impact of improving the role of private finance and well as the use of debt over time.
- Specific project risks are also taken into account. For example, the role of PFIs often remain larger in hydropower or geothermal projects compared to wind and solar PV, given higher upfront challenges related to project development. Technologies at a lower level of maturity, such as low-carbon hydrogen and CCUS initially rely more heavily on state-owned enterprises and balance sheet finance, even under climate-driven scenarios.
- For electricity networks, the role of PFI and private capital in transmission and distribution investment increases under climate-driven scenarios, as PFIs become more focused on these assets and as a slightly higher share of private sector participation would be required to mobilise investments.
- Within end use, sector-specific assumptions are also reflected in the sources of finance estimation. In transport, the APS assumes a faster growth in car leasing and auto loan services for efficient, clean transport modes, translating into higher

shares of off-balance sheet and debt financing. In buildings, growth is assumed for off-balance sheet and public financing as energy service companies (ESCOs) become more prominent and as PFIs play an increasing role in financing green buildings.

The role of capital markets

IEA investment work includes analysis on the role of capital markets and institutional investors. With over USD 100 trillion under management, institutional investors – including asset managers, infrastructure funds, insurance companies, pension funds, private equity and venture capital funds and sovereign wealth funds – are a large potential source of finance for the energy sector. Past editions of WEI have noted that 90% of energy investments are financed on a primary basis from the balance sheets of companies and consumers, with a smaller role for project finance (mostly loans from banks).

But such mechanisms also depend on having a robust interconnected system of secondary financial sources and intermediaries and diverse investment vehicles to facilitate flows. Although a number of well-capitalised industry players (e.g. some integrated oil and gas, utility and state-owned companies) are able to make investments from retained earnings alone, there are economic benefits to tapping into wider pools of finance, at a lower cost of capital, and especially in an era of lower interest rates. Moreover, banks often face limits on their lending, particularly with regulatory constraints emerging in recent years, such as Basel III.

Sustainable finance

In the WEI 2023, this analysis includes tracking of sustainable finance trends including the recent dramatic rise of sustainable financial flows, and related regulatory developments, and how this trend relates to energy investment.

For fixed-income, sustainable debt securities – including labelled green bonds, green and sustainable loans and sustainability-linked debt – may provide investors the clearest route to capital allocation for clean energy. They may also be particularly suited for small-scale renewables and efficiency investments, which are difficult for investors to fund directly. These advantages stem from labelling and certification (under frameworks such as Green Bond Principles, and more specific evaluations, e.g. Climate Bonds Standard). Still, frameworks are not always harmonised across markets, and as labelled securities grow beyond green bonds, their impact and uses become more complex to evaluate. These trends are assessed using disclosed data from BNEF (2023) and Refinitiv (2023) with benchmarking against other sources, including Climate Bonds Initiative and issuer reporting.

For equity markets, the WEI 2023 looks the rise of sustainable funds – as defined within quarterly tracking publications by Morningstar (2023) – and ESG practices at institutional investors. Tracking the rise and impact of these practices within equity markets is complex, as it can manifest in a variety of different strategies and projects. Inflows into ESG exchange-traded funds are used as a proxy to demonstrate interest in ESG in equity markets, based on data provided by BNEF (2023). The report also includes an analysis of performance of these funds, based on data provided by Refinitiv (2023). Given that equity markets in emerging market and developing economies are smaller and harder to access, the effect of the rise in sustainable finance in these markets is analysed separately. This analysis is based primarily on analysis of data from Refinitiv (2023), the OECD (2022) and from the three largest index providers, FTSE, MSCI and S&P.

R&D and Technology Innovation

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 reported numbers and their allocations between technology areas are generally taken at face value. Interpolations, estimations and extrapolations are used sparingly.

Government spending

Table 4. Sources for the compilation of public energy R&D spending 2012-2022

Region/Country	Source
IEA member governments, plus Brazil	Data submitted annually to IEA by its members, broken down by technology area and published in the IEA Energy Technology RD&D Budgets database. See IEA (2022a, 2011). The IEA is not able to provide official information on energy technology RD&D for the United States for the period 2016 to 2022 so estimates these years using published data.
China	Statistics Yearbook on Science and Technology Activities of Industrial Enterprises; China Statistical Yearbook on Science and Technology; data submission to the Mission Innovation (MI) Secretariat; energy sector state-owned enterprise annual reports
India	Research budgets of energy-related ministries; data submission to the Mission Innovation (MI) Secretariat; energy sector state-owned enterprise annual reports.
Russia	Energy sector state-owned enterprise annual reports.
Saudi Arabia	Energy sector state-owned enterprise annual reports.
South Africa	Budget reports of the Department of Energy and SANEDI
Early stage and growth-stage venture capital	

Corporate R&D spending

The primary source is reported R&D spending in annual company disclosures extracted from Bloomberg (2023) and supplemented by desk research and quality control for individual large spenders. For WEI 2023, the dataset included spending by 2 315 companies. The data are allocated per energy sub-sector according to share of revenue from that activity unless otherwise stated by the company. The sample at hand includes companies with activities in the following sectors:

- Fossil fuel extraction, transport, conversion and services
- Electricity, gas and district heating utilities, networks, grids and services
- Renewables equipment, generation and services
- Nuclear power equipment, generation and services
- Energy storage and batteries, for vehicle and power grid applications
- Other power equipment and generation, supply and networks
- Automotive and drivetrain components, as well as heavy and long-distance transportation including aviation, trucks, shipping and rail
- Building heating and cooling appliances, cooking, insulation and lighting, as well as construction and materials
- Hydrogen and fuel cells technologies
- Industry including cement, iron and steel, metalworking, and chemicals

R&D budgets of companies that are active in multiple sub-sectors are allocated based on the share of revenue in these sectors (including non-energy sectors), complemented by interviews with major companies and details in corporate annual reports in some cases. These attempts to capture only energy-relevant R&D budgets are 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. Heavy industry and transportation companies are tracked separately from the energy-specific sample and the share of energy within their R&D budgets is not estimated.

One notable caveat is that this methodology indeed makes it challenging to capture corporate research into efficient buildings, appliances and the share of energy in the R&D budgets of industry players. 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. However, 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.

Low-carbon energy technology spending is separated wherever possible to include all technologies (for the public sector and venture capital) and all industry

sub-sectors (for the corporate sector) related to: renewables; nuclear; CCUS; smart grids; electric mobility; LEDs; electricity storage, insulation.

Venture capital

The analysis covers early-stage and growth stage funding for start-ups founded since 1990 as independent entities to develop a product or service that is primarily intended to reduce the cost of a means of energy supply or to improve the environmental impact of providing an energy service. Early stage includes Seed, Series A and B seed funding. Very large deals in these categories – above a value equal to the 90th percentile growth equity deals in that sector and year – are excluded and reclassified as growth-stage investments. Growth stage additionally includes other pre-IPO and pre-acquisition acquisition equity investments. Deals are classified by technology area by the IEA in accordance with IEA energy technology categories and by sector of investor. The primary source is Cleantech Group (2023), supplemented by Crunchbase (2023).

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Glossary

Advanced biofuels:	Sustainable fuels produced from non-food crop feedstocks, which are capable of delivering significant lifecycle greenhouse gas emissions savings compared with fossil fuel alternatives, and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts. This definition differs from the one used for "advanced biofuels" in the US legislation, which is based on a minimum 50% lifecycle greenhouse gas reduction and which, therefore, includes sugar cane ethanol.
Advanced economies:	OECD regional grouping and Bulgaria, Croatia, Cyprus, Malta and Romania.
Asset-backed security:	An asset-backed security (ABS) is an investment security that is backed by a pool of assets, e.g. loans (home, auto, student), leases, credit card debt, royalties, or other financial asset receivables.
Balance sheet finance:	Involves the explicit financing of assets on a company's balance sheet using retained earnings from business activities, including those with regulated revenues, as well as corporate debt and equity issuance in capital markets. To some extent, it measures the degree to which a company self-finances its assets, though balance sheets also serve as intermediaries for raising capital from external sources. The WEI also refers to 'Corporate finance' when describing balance sheet financing.
Blended finance:	A broad category of development finance arrangements that blend relatively small amounts of concessional donor funds into investments, in order to mitigate specific investment risks. This can catalyse important investments that would otherwise be unable to proceed under conventional commercial terms. These arrangements can be structured as debt, equity, risk-sharing or guarantee products. Specific terms of these arrangements, such as interest rates, tenor, security or rank, can vary across scenarios.
Borrowing costs:	Borrowing cost are the costs incurred by a company resulting from the borrowing of funds e.g. interest.
Buildings:	The buildings sector includes energy used in residential, commercial and institutional buildings, and non-specified other. Building energy use includes space heating and cooling, water heating, lighting, appliances and cooking equipment.
Capital costs:	Costs to develop and construct a fixed asset such as a power plant and grid infrastructure or execute a project, excluding financing costs. For power generation assets, capital costs include refurbishment and decommissioning costs.
Capital structure:	Capital structure is the particular combination of debt and equity used by a company to finance its overall operations and growth.
Coal:	Includes both primary coal (including lignite, coking and steam coal) and derived fuels (including patent fuel, brown-coal briquettes, coke-oven coke, gas coke, gas-works gas, coke-oven gas, blast-furnace gas and oxygen steel furnace gas). Peat is also included.
Co-generation:	The combined production of heat and power.

Concessional financing:	Resources extended at terms more favourable than those available in the market. This can be achieved through one or a combination of the following factors: interest rates below those available on the market; maturity, grace period, security, rank or back-weighted repayment profile that would not be accepted/extended by a commercial financial institution; and/or by providing financing to the recipient otherwise not served by commercial financing.
Community choice aggregators (CCAs):	Municipal-level entities that procure bulk power.
Corporate venture capital:	Equity investments in start-ups that are developing a new technology or service by companies whose primary business is not venture capital nor other equity investments. In addition to playing the traditional role of a venture capital investor, corporate venture capital investors often provide support to the start-ups via access to their customer base, R&D laboratories and other corporate resources. Corporate venture capital is used by companies as part of their energy innovation strategies to enter new technology areas or learn about technologies more quickly than developing them in-house.
Current ratio:	Current assets divided by current liabilities.
Debt:	Bonds or loans issued or taken out by a company to finance its growth and operations.
Dispatchable low-carbon power:	Dispatchable low-carbon power refers to technologies whose power output is derived from low-carbon sources and can be readily controlled - increased to maximum rated capacity or decreased to zero - in order to match supply with demand.
Dispatchable power generation:	Refers to technologies whose power output can be readily controlled – increased to maximum rated capacity or decreased to zero – in order to match supply with demand.
District heating:	An insulated network that delivers hot water or steam from co-generation (the combined production of heat and power) or heat-only sources via pipelines to space heating or hot water users in buildings.
Dividend coverage ratio:	The ratio of a company's dividend payout relative to its net income.
Dividend pay-out ratio:	The proportion of a company's net income that is paid out to shareholders in dividends.
Early-stage venture capital:	Generally the first three venture capital fundraising rounds involving external investors in a start-up, referred to as seed, series A and series B. These investments accept a significant share of of technology risk and are a major source of risk capital that support innovation in many clean energy technologies. The values generally increase from up to USD 2 million for a seed round, to USD 10 million or more for a series B round, but can be smaller or much larger.
EBITDA:	Earnings before interest, tax, depreciation and amortization (EBITDA) is a measure of a company's operating performance. EBITDA allows for comparison between companies without needing to take differentiate financial, accounting and tax considerations.
Electrolyser:	Refers to water electrolysers designed for the production of hydrogen via electrolysis using electricity and water inputs.

Emerging market and developing economies (EMDEs):	Unless otherwise specified in the WEI, this group includes all emerging market and developing economies except for OECD member countries Chile, Colombia and Mexico, and may exclude China, as the dynamics of investment in China are quite distinctive and is also a major outward investor in EMDEs.
End use investment:	End use investment includes investment in three categories on the demand side: energy efficiency, end use renewables and other end use.
End use renewable investment:	Capital spending on bioenergy, geothermal and thermal solar, which are directly consumed by residential and service buildings and industry.
Energy efficiency investment:	The incremental spending on new energy-efficient equipment or the full cost of refurbishments that reduce energy use. The intention is to capture spending that leads to reduced energy consumption. Under conventional accounting, part of this is categorised as consumption rather than investment.
Energy Research and development (R&D):	Research and development related to improving the performance or reducing the costs of the production, storage, transportation, distribution and-use of all forms of energy.
Equity:	Common stock, preferred stock, or retained earnings that a company uses to finance its growth and operations.
Free cash flow:	The cash flow available to the company's investors (e.g. shareholders and bondholders) after all operation expenses are paid and investments are made. It is calculated by subtracting capital expenditure from operating cash flow.
Green bank:	A green bank is a public, quasi-public or non-profit entity established specifically to facilitate private investment into domestic low-carbon, climate-resilient infrastructure.
Green bond:	A green bond is a type of fixed-income instrument created to fund projects that have positive environmental and/or climate benefits.
Green mortgage-backed securities (MBS):	A mortgage or loan with the intended purpose to improve existing properties to achieve increased energy efficiency or decreased water usage.
Growth equity:	A type of private equity investment, usually a minority investment, in relatively mature companies that are looking for capital to expand or restructure operations, enter new markets or finance a significant acquisition without a change of control of the business. While it involves less technology risk than early-stage venture capital, it is one of the ways in which energy technology start-ups scale up innovative technologies. It is a strategy of corporate venture capital investing to develop new technologies.
Hydropower:	The energy content of the electricity produced in hydropower plants, assuming 100% efficiency. It excludes output from pumped storage and marine (tide and wave) plants.
Internal rate of return (IRR):	The discount rate that makes the present value of investment cost (cash outflow) equal to that of benefits (cash inflow), whereby making the net present value of the project equal to 0.
Investment:	In WEI 2022, all investment data and projections reflect actual spending across the life cycle of a project, i.e. the capital spent is assigned to the year when it is

	incurred. Investments for oil, gas and coal include production, transformation and transportation; those for the power sector include refurbishments, uprates, new builds and replacements for all fuels and technologies for on-grid, mini-grid and off-grid generation, as well as investment in transmission and distribution, and battery storage. Investment data are presented in real terms in year 2019 US dollars unless otherwise stated. Note that the definition was effective beginning in 2019. Previously, the investment data reflected "overnight investment", i.e. the capital spent is generally assigned to the year production (or trade) is started, rather than the year when it is incurred.
Lead times:	The amount of time from the start of a project to its commissioning. Lead times refer to the time between the final investment decision and the start-up for oil and gas projects and construction time for power generation assets.
Leverage:	Leverage, or gearing, is the relative amount of debt a company uses to raise capital needed to fund its activities.
Light-duty vehicles:	A light-duty vehicle is a road vehicle with at least four wheels and with a kerb weight below 3.5 tonnes. This broadly covers the UN categories of M1 and N1.
Liquidity:	The availability of liquid (cash) assets.
Long-term debt:	Long-term debt, also called non-current liabilities, are a company's financial obligations will mature after a year.
Low-carbon power:	Low-carbon power comes from methods that produce substantially less carbon (or carbon equivalent) emissions than fossil fuel power generations. Low carbon power includes power generation from wind, solar, hydro, nuclear, geothermal, marine, bioenergy, and fossil fuel with CCUS.
Market capitalisation:	Market capitalisation represents to the total value of a company as determined by the stock's present share trading value multiplied by the total number of shares.
Mission Innovation (MI):	A global initiative of over 20 countries to accelerate clean energy innovation. Initiative members aim to double their government and/or state-directed clean energy RD&D investment over five years from 2015 to 2020, among other goals. See the MI website for details.
Mixed feed crackers:	Crackers designed to alter their feedstock mix depending on market conditions.
Mortgage-backed security:	A mortgage-backed security is a sub-type of an asset-backed security that is comprised of a bundle of home loans.
Net debt:	The total debt of a company less its available cash. Net debt compares how much debt a company could pay-off utilizing its liquid assets.
Net Zero Emissions Scenario (NZE)	The Net-Zero Emissions by 2050 Scenario (NZE): An IEA Scenario that shows what is needed for the global energy sector to achieve net-zero CO2 emissions by 2050. It also aims to minimise methane emissions from the energy sector and it contains concrete action on the energy-related United Nations Sustainable Development Goals. The NZE does not rely on action in areas other than the energy sector to achieve net-zero emissions, but with corresponding reductions in emissions from outside the energy sector, it is consistent with limiting the global

	temperature rise to 1.5 °C without a temperature overshoot (with a 50% probability).
Nominal (terms):	Nominal (value or terms) is a financial and economic term that indicates the statistic in question is measured in actual prices that exist at the time. nominal value of any economic statistic means the statistic is measured in terms of actual prices that exist at the time.
Offshore wind:	Refers to electricity produced by wind turbines that are installed in open water, usually in the ocean.
Option-adjusted spread:	An option-adjusted spread is the the calculated spread between a computed index of all bonds in a given rating category and its risk-free counterpart.
Other end use investment:	Capital spending on transport electrification and industry CCUS.
Paris Agreement:	An agreement with the United Nations Framework Convention on Climate Change ratified by almost 190 countries to tackle climate change. It aims to strengthen the global response to keep a global temperature rise this century well below 2 °C above pre-industrial levels. All Parties to the Agreement are required to put forward their best efforts through Nationally Determined Contributions and to strengthen the efforts in the years ahead.
Payback period:	Refers to the period of time required to recover the amount invested in a project from its benefits (cash inflows).
Pooled vehicle:	A pooled (investment) vehicle is a fund created from capital aggregated from many individual investors that are used to secure full payment for investment.
Power generation:	Refers to fuel use in electricity plants, heat plants and combined heat and power (CHP) plants. Both main activity producer plants and small plants that produce fuel for their own use (auto-producers) are included.
Power purchase agreement (PPA):	A power purchase agreement is a legal contract between an electricity generator (provider) and a power purchaser (user).
Project finance:	Involves external lenders – including commercial banks, development banks and infrastructure funds – sharing risks with the sponsor of the project. It can also involve fundraising from the debt capital markets with asset-backed project bonds. They often involve non-recourse or limited-recourse loans where lenders provide funding on a project's future cash flow and have no or limited recourse to liability of the project parent companies.
Property-assessed clean energy (PACE):	A type of financial instrument with the intended use to upgrade energy-efficiency or instal renewable energy sources for commercial, industrial, and private residential properties.
Real (terms):	Real (value or terms) is a financial and economic term that indicates the statistic in questionhas been adjusted to take into account the effect of inflation.
Renewable power:	Power derived from bioenergy, geothermal, hydropower, solar photovoltaic (PV), concentrating solar power (CSP), wind and marine (tide and wave) energy for electricity and heat generation.

Return on Invested Capital (ROIC):	A profitability ratio expressed as operating income adjusted for taxes divided by invested capital. The ratio measures the ability of a company's core business investments to generate profits. For the ROIC/WACC analysis in WEI 2019, invested capital is calculated by subtracting cash and cash equivalent, other long-term assets than property/plant/equipment, good will and intangibles, and current liabilities from total assets.
Revenue:	Revenue is the income a business derives, usually from the sale of goods and services to customers.
Securitisation:	Creating tradeable securities.
Short-term debt:	Short-term debt, also called current liabilities, are a company's financial obligations that are due to be paid within a year.
Stated Policies Scenario (STEPS):	An IEA scenario that reflects the impact of existing policy frameworks and today's announced policy intentions. The aim is to hold up a mirror to the plans of today's policy makers and illustrate their consequences for energy use, emissions and energy security. The aim of the Stated Policies Scenario is to provide a detailed sense of the direction in which existing policy frameworks and today's policy ambitions would take the energy sector out to 2040. Previously known as the New Policies Scenario, it has been renamed in WEO 2019 to underline that it considers only specific policy initiatives that have already been announced.
Sustainable Development Scenario (SDS):	An IEA scenario that outlines a major transformation of the global energy system, showing how the world can change course to deliver on the three main energy-related SDGs simultaneously. SDS shows how the energy sector can achieve the objectives of the UN Sustainable Development Goals (SDGs) most closely related to energy, namely, those goals related to energy access, air pollution emissions and climate change (SDGs 3, 6, 7, and 13). It is aligned with the Paris Agreement's goal holding the increase in the global average temperature to well below 2 °C.
Sustainable debt instruments	Loan instruments or debt structures (e.g guarantee lines, letters of credit) that embed environmental, social and governance related performance indicators, in order to incentivize issuers to achieve progress in non-financial impact areas. There are a variety of sustainability-linked debt instruments: • Green Bonds: A share of proceeds are used to fund green projects • Social Impact Bonds: The rate of the coupon (interest rate) or of the bond repayment itself is linked to the achievement, by the issuer, of pre-agreed social targets (e.g. gender equality) • Sustainability-linked Bonds: The rate of the coupon (interest rate) or of the bond repayment itself is linked to the achievement, by the issuer, of pre-agreed sustainability targets (e.g. GHG reductions) • Transition Bonds: The rate of the coupon (interest rate) or of the bond repayment itself is linked to the achievement, by the issuer, of pre-agreed targets related to the transition (e.g. coal plants closures). The borrower's sustainability performance can be measured against external ratings or equivalent metrics to measure improvements in the borrower's profile.
Tight oil:	Oil produced from shales or other very low permeability formations, using hydraulic fracturing. This is also sometimes referred to as light tight oil. Tight oil includes tight crude oil and condensate production except for the United States, which includes tight crude oil only (US tight condensate volumes are included in natural gas liquids).

Transition bond:	A transition bond is a type of sustainability, fixed-income instrument that is to be used to fund projects to improve environmental performance for fossil-fuel or high-carbon emission projects.
Transport:	Fuels and electricity used in the transport of goods or persons within the national territory irrespective of the economic sector within which the activity occurs. This includes fuel and electricity delivered to vehicles using public roads or for use in rail vehicles; fuel delivered to vessels for domestic navigation; fuel delivered to aircraft for domestic aviation; and energy consumed in the delivery of fuels through pipelines.
Weighted-average cost of capital (WACC):	The weighted average cost of capital is expressed in nominal terms and measures the company's required return on equity and the after-tax cost of debt issuance, weighted according to its capital structure.
Yield company:	Listed equity vehicles holding multiple operational renewable energy projects.

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