The IEA World Energy Outlook

A critical review 2000-2020

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About the authors

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All conclusions and any errors that remain are the author's own.

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The WEO's energy blind spots

The International Energy Agency (IEA) is widely considered to be an authoritative source of energy data and analysis. Its World Energy Outlook (WEO) influences and shapes expectations of how the global energy landscape will evolve over coming decades and is a frequent input into policy and industry decisions. However, the WEO has also been the subject of criticism, particularly over its projection of renewable energy growth, and of its portrayal of the potential to cut greenhouse gas emissions to limit global warming.

By examining WEOs dating back to 2000, this comprehensive analysis surfaces the assumptions, biases and blind spots that have led the IEA, in its annual WEO reports, to overestimate the expected role of fossil fuels, nuclear power and carbon capture and storage (CCS) in the global energy system and to underestimate the growth of renewable energy. This extends beyond the IEA's well-known and longstanding underestimation of solar PV growth; some sources, such as offshore wind, were not included until they were already contributing significantly to electricity supply.

This retrospective analysis of WEOs over several years shows a pattern of more optimistic assumptions for fossil fuels and the technologies that will enable fossil fuels – particularly CCS – as well as painting an overly optimistic picture of nuclear energy capacity. WEO scenarios exhibit signs of a consistent bias towards describing future pathways – including those with specific climate constraints – that create minimum disruption to the incumbent fossil fuel industry.

The analysis found that:

- **Coal and natural gas production levels were more accurately predicted by the 'climate-constrained scenarios'** in much of the past decade than by the "central" scenarios, despite a lack of concerted climate policy. These climate-constrained scenarios (450S, later named Sustainable Development Scenario) assume more aggressive action to respond to climate change than under central scenarios (the New Policies Scenario, later named Stated Policies Scenario).
- **Nuclear energy capacity has been consistently overstated**, with Japan's fleet, mostly mothballed since the 2011 Fukushima disaster, included in capacity figures. As recently as 2016, the WEO's central scenario anticipated 450GW of capacity in 2020, considerably above the 375GW seen.
- Many **key assumptions driving WEO projections are obscured** by both changes in methodology between annual additions and by aggregation of key categories. In particular, projections of the contribution of CCS technology to emissions reductions are flattered by their inclusion with industrial energy efficiency.
- The expected role of **CCS in 2020 was halved from its peak and pushed 20 years into the future**. The technology would be fundamental to continuing use of coal and natural gas in power generation in a carbon-constrained world.
- Early **WEO central scenarios dramatically underestimated the growth of wind power** – with the WEO's 2020 assumption reached 15 years early – while offshore wind was only recognised as a major power generating technology in its own right in 2019.
- The **WEO consistently low-balled the contribution of solar power**. Its projection in 2002 for total solar photovoltaic capacity – of 18GW – was equal to installations made in just one year, 2007, just five years later.
- Although this paper doesn't systematically analyse the IEA's non-WEO publications, it can be observed that the **consistent under-estimation of renewables growth in the WEO contrasts with projections from other IEA series** or departments that were solely focused on those technologies, which tended to be more accurate.

At a time when so much of humanity's fate rests on the speed with which greenhouse gas emissions are cut, it is imperative that the IEA provide a balanced approach to energy technologies.

Assumptions about energy technologies are a key input into all long-term energy scenarios. Greater transparency about the assumptions going into the WEO would allow its attributes to be better understood by users and modellers.

We hope that this report will inform analysis and decisions both within the WEO team, and among those who use and wish to better understand this highly influential scenario series.

Introduction

The International Energy Agency (IEA) plays a key role in the world's energy systems. Its own description places it "at the heart of global dialogue on energy, providing authoritative analysis, data, policy recommendations". Its mission is to "shape a secure and sustainable energy future for all".[1]

Since its founding in 1973 as an agency of the OECD, the IEA has broadened its activities from its original focus on oil to the entire energy complex and has a role in many critical international climate initiatives. It has been a high-profile advocate for clean energy stimulus measures in response to the COVID pandemic.[2] Leading commentators have suggested it should adopt a formal role as an authority to help manage the international effort to reach net zero carbon emissions.[3]

However the IEA and its flagship series, the World Energy Outlook (WEO), have come under considerable criticism in recent years. Published each year, the WEO aims to "provide critical analysis and insights on trends in energy demand and supply, and what they mean for energy security, environmental protection and economic development."

In particular, the scenarios that the WEO presents have come under growing scrutiny by researchers for their assumptions about renewable energy penetration, the continuing role of fossil fuel and nuclear generation, and about technologies such as carbon capture and storage (CCS).

This report reviews the history and evolution of the IEA, introduces the WEO scenarios, considers its projection of various energy technologies, and summarises its involvement in various climate and energy initiatives. Its goal is to trigger discussion of the methodologies that underpin the WEO's scenarios and of how these scenarios are used in real-world policy and investment decisions.

Box 1: The IEA's scenarios

In its forward-looking analysis, the WEO typically presents three different scenarios, although the names of these have changed over time, as have their functions within the WEO.

Baseline or "business as usual" scenarios: Assuming no change to existing, implemented energy policy

Its baseline **Current Policies Scenario** considers how energy markets would evolve if governments made no changes to existing policies and measures. This was known as the Reference or Reference Case Scenario prior to 2010. In this report, we refer to these as "baseline" or "business as usual" scenarios.

"Central scenarios": Assuming that announced policies will be implemented

The **Stated Policies Scenario**, previously known as the **New Policies Scenario**, considers how current policy ambitions would affect the energy sector: in addition to existing policies, it takes into account policies that have already been announced but are not yet implemented. The New Policies Scenario was introduced in WEO 2010 and was designated as the central scenario from WEO 2011. In this report, we refer to these as central scenarios. However prior to 2011, the central WEO scenario was the "Reference scenario", or what is now called the Current Policies Scenario.

"Climate scenarios": Assuming future policies will constrain emissions to meet a specified warming level

The **Sustainable Development Scenario** maps out how to meet sustainable energy goals in full, aligned with the Paris Agreement and holding the rise in global temperatures to well below 2°C, and meeting objectives relating to universal energy access and cleaner air. Earlier iterations of this scenario include the **450 Scenario** and the **Alternative Policy Scenario**. We refer to these as climate (or climate-constrained) scenarios.

For more detail, see the Appendix on page 24.

Brief history of the IEA

The IEA was founded in 1974 by Western oil-consuming countries in reaction to the oil embargo implemented by the Arab members of the Organization of Petroleum-Exporting Countries (OPEC).[4] Rapidly increasing oil prices forced the founders to act quickly and they chose to establish the IEA under an existing organisation, the Organization for Economic Cooperation and Development (OECD). The IEA's primary task was to manage a system of oil stocks that could be jointly deployed in case of another sudden oil supply shortfall.[5]

In the years since, the global energy context has changed considerably, and the IEA has sought to adapt its role and mandate accordingly. Only five years after it was founded, the then acting head of the IEA Ulf Lantzke wrote in *Foreign Affairs* that the "experience in 1979 alone has lowered expectations of future OPEC oil production and reinforced the trend to a slowing down of nuclear energy capacity. Hence, it now appears that world coal production must at least triple by the end of this century (2000) if we are to have adequate energy supplies to accommodate even moderate levels of economic growth."[6] Lantzke suggested that, by that date, 700 million tonnes of coal per year would be needed to meet demand. The actual production in 2000 was around 4,600 million tonnes, with Europe alone producing 778 million tonnes.[7]

Growing concern about climate change in the 1990s, marked by the creation of the UN Framework Convention on Climate Change (UNFCCC) in 1992, led to rising demand from various stakeholders for the IEA to focus more on energy decarbonisation strategies. However, the appetite within the IEA to shift attention from fossil and nuclear energies towards renewable energy remained limited.

To balance the IEA position, renewable energy advocates promoted the idea of a global renewable energy agency. In 2009, the International Renewable Energy Agency (IRENA) was created, initially with German government funding, and with 75 countries signing the founding contract in Bonn. As of the end of 2019, IRENA was supported by 183 countries, with another 23 countries in the process of formal accession.[8]

IRENA's creation was a "serious blow to the IEA"[9] which likely contributed to its increasing focus on renewables and climate change[10]. In 2015, the IEA's Ministerial Meeting approved a new modernisation strategy, with three pillars.[11] It proposed that the IEA:

- Strengthen and broaden the IEA's commitment to energy security beyond oil, to natural gas and electricity;
- Deepen the IEA's engagement with major emerging economies; and
- Provide a greater focus on clean energy technology, including energy efficiency.

The phrase "renewable energy" was not to be found in the new strategy. However, in April 2019 – 10 years after IRENA was established – the IEA and IRENA signed a memorandum of understanding in Berlin to cooperate on international energy issues.[12]

Box 2: Historical scope of this analysis, and the definition of "2020 expected" numbers in figures

Historical scope of qualitative and quantitative WEO analysis:

The review conducted for the research includes the WEO editions from 2000 through 2019. However due to changes to the WEO methodology introduced in 2008, most charts featured in this report focus on WEO scenarios published between 2010 and 2019. Some other years are omitted due to changes in WEO energy categories. The most recent years (2017 to 2019) cannot be included because the WEO ceased making 2020 projections after 2016.

2020 energy numbers exclude COVID-19 impacts:

We compare projections found in past WEO editions to actual expected levels for 2020, as estimated by the author. The COVID crisis means these numbers will in reality be somewhat different. We use the phrase "expected 2020 figure" throughout to indicate these recent estimates and differentiate them from both the "projected" 2020 numbers shown in the past WEOs, and the COVID-affected numbers, which are not referred to in this paper.

The IEA's WEO scenarios

The IEA describes the World Energy Outlook as its flagship publication; the "gold standard in long-term energy analysis".[13] The first IEA World Energy Outlook was published in 1977[14] and has been published annually since 1998. The WEO scenarios are produced using the World Energy Model (WEM), which has been developed by the IEA over more than two decades.

An introduction to scenarios

Scenarios are "what if" analyses, not forecasts. An energy model – a specific computer tool – uses a set of input parameters and assumptions in order to map out what could happen in the energy sector in response to the implementation of certain policies, or under various different cost scenarios and/or technological developments.

An energy scenario therefore shows what might happen under clearly defined assumptions – it is not a prediction. This is arguably a necessary approach, since making definite forecasts of such complex systems as the global energy market is impossible given that it includes, among many things, assumptions regarding human behaviour and innovation.[15]

The role and influence of the WEO

IEA scenarios play an important role in the energy policy debate and are therefore more influential than most other scenarios.[16] According to the organisation itself, WEO scenarios are used by both the public and the private sector as frameworks for policy, planning and investment decision-making.[17] The IEA also stresses that its WEO scenarios are not forecasts but are merely intended to demonstrate how markets could evolve under certain conditions.[18] The foreword of the WEO 2015 states: "The reason that we look into the future is to trigger key policy changes in the present." However, the WEO central scenarios "are widely used as a baseline case for future energy planning, at least in the short to medium term"[19] and the IEA is known for its influence on other models and modellers, and having a "strong discursive power amongst energy agencies[20]. Given their influence, there exists a need for realistic assumptions which reflect current market developments in fuel costs and across the entire technology range of energy-consuming technologies (e.g. electrical appliances, vehicles, buildings) or energy conversion technologies (e.g. power plants or heating systems).

Key criticisms of the WEO scenarios

Although much of the IEA's data is well regarded, and the organisation is a key partner in many climate-related initiatives (see section 2.3), its WEO scenarios have come under increasing criticism in recent years on the grounds that they undermine efforts to decarbonise the global energy system.

The criticisms can be summarised as follows:

- The WEO tends to underestimate the growth of renewable energy, particularly in its central scenarios;
- It fails to correctly constrain emissions in the climate scenarios to align with objectives spelled out by climate science;
- The labelling and presentation of the scenarios creates a normative perception around the higher emissions scenarios; and
- These shortcomings mean that the scenarios are used to justify continued fossil fuel production.

The first two criticisms can be read in the context of the World Energy Model methodology. One analysis of the WEM found weak interconnection between demand and supply modules of the model, and a lack of forward-looking cost optimisation processes for suppliers or consumers.[21]

The analysis concludes that the WEM is not "a computable economic equilibrium model", but "rather a comprehensive and detailed system of loosely connected simulation models, drawing on broad insights from geology, technology, economics and political science". It also notes that "the flexibility of economic behaviour is effectively contained and that the relations of the modelling system are not sufficiently responsive to shifts and shocks in technology, preferences, policies and prices," and that the WEO itself "largely is a product of historical trends and developments, combined with a rich set of exogenous assumptions and coefficients for the evolution of technology, prices and policies".

An analysis of the previous WEOs can shed light on how these assumptions have been manifested and it shows that, consistently, the WEO has underestimated the penetration of renewables into the global energy system.

IEA WEO: A review of the past decade of projections

The following sections document different scenario results of past WEO editions and compare them with real-world developments in 2019 and with estimates of full-year 2020 numbers, as expected early in the year (prior to COVID-related changes in energy and emissions). It is based on a literature review of similar analyses, as well as the author's own analysis.

Projection of coal production volumes

Coal production in 2020 envisaged by past WEOs changed significantly between different annual editions. It is important to note that its climate-constrained scenarios were more successful at predicting actual 2020 (ex-COVID) coal production than the central scenarios.

Central scenarios 2013-2016: The 2013 and 2014 projections for 2020 were significantly higher than 2020 actual/expected. The IEA began to revise its estimates down in 2015 after China's 13th Five Year Plan, covering 2016-2020, indicated a slowing in overall coal demand.

Climate-constrained scenarios 2013-2016: These scenarios all projected that 2020 production would be the same as in the year of publication. They have been closer to the expected 2020 number than the central scenarios.

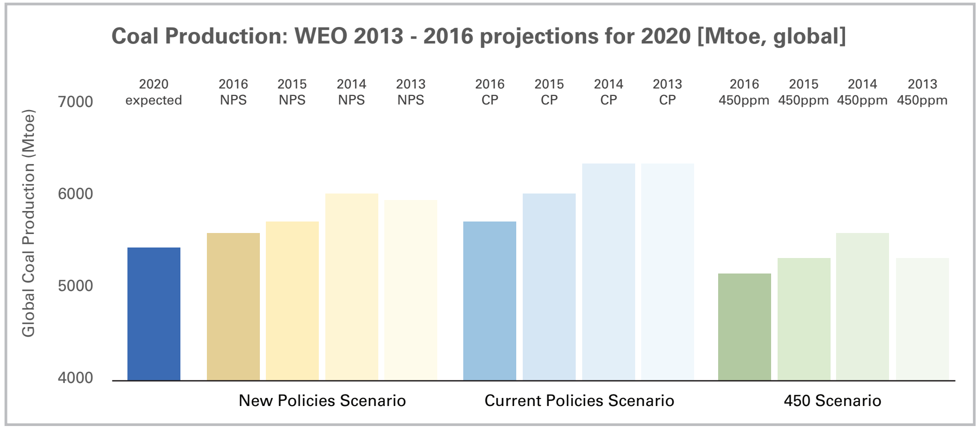

Figure 1: Projected total coal production in (Mtoe) from WEO 2000 to WEO 2019 versus expected real value for 2020. No 2020 values are published in WEOs 2017-2019. See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

Projection of gas production volumes

The WEO view of natural gas production in 2020 has also, as with that of coal, changed significantly over the years. The gas production projections are also similar to coal production in that the climate-constrained scenarios were more successful in predicting actual 2020 (ex-COVID) gas production than the central scenarios.

Central scenarios 2013-2016: All central scenarios in these years projected that natural gas production in 2020 would be the same as in the year of publication.

Current Policies Scenarios all overestimated gas production.

Climate-Constrained Scenarios (450S) 2013-2016: All years assumed only a very small decrease from climate constraints – of about 5% relative to central policy scenarios.

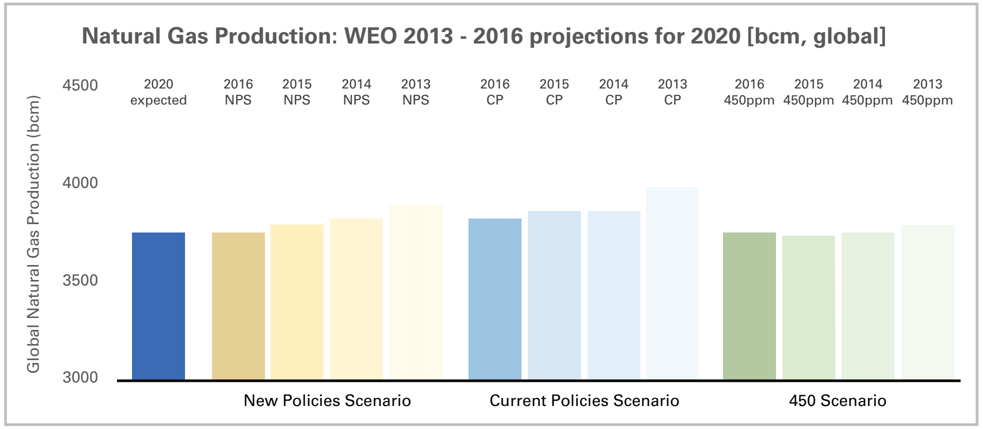

Figure 2: Projected global gas production in (bcm) from WEO 2000 to WEO 2019 versus expected real value for 2020. No 2020 values are published in WEOs 2019-2017. See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

Projection of oil production volumes

The level of oil production projected for 2020 changed little in the period analysed here. Central scenarios for 2020 were fairly close to the actual projected demand (pre-COVID) for 2020 and were extremely close to the production for the year in which the scenario was published. Climate-constrained scenarios were somewhat lower, while the "no policy" scenarios were somewhat higher.

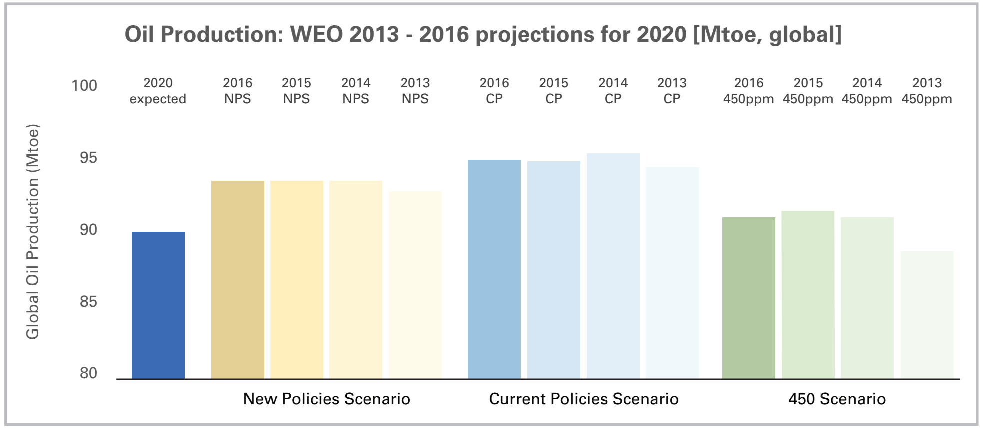

Figure 3: Projected total oil production in (Mtoe) from WEO 2000 to WEO 2019 versus estimated real value for 2020. No 2020 values are published in WEOs 2017-2019. See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

The most detailed review regarding both the historical and IEA-projected oil production volume and price has been done by Wachtmeister et al.[22] The main results are summarised in Figure 4. They indicate that the IEA's estimates for future crude oil prices (the lower group of lines) was less successful than its projections of production levels (higher group of lines).

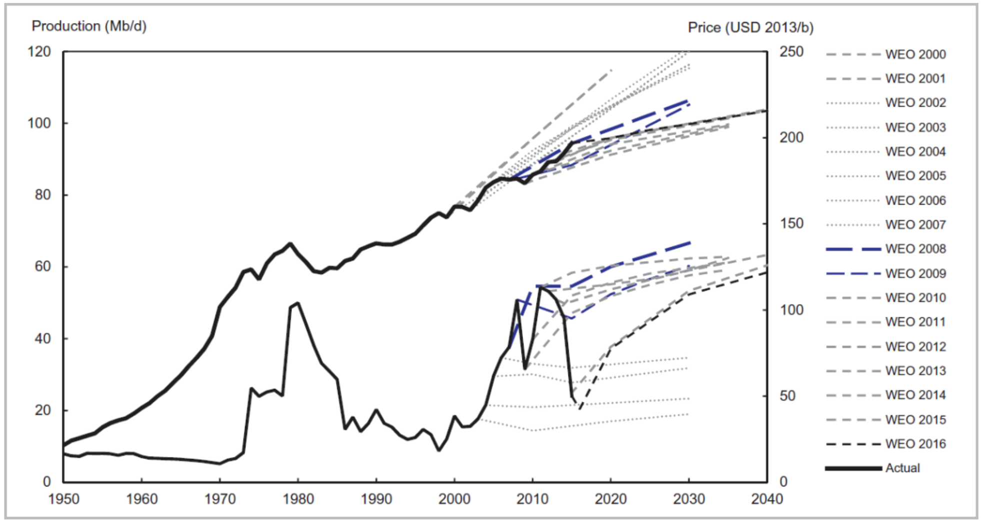

Figure 4: Historical world oil production and price from 1950 to 2015 and projections for world oil supply and oil prices from central scenarios of WEO 2000 to 2016 (Wachtmeister 2018).

Power generation projections

The projection of global power plant capacities for the most important power plant types are analysed below. Here, we do not analyse different scenarios, but instead compare the real installed capacity in 2020 with projections under the New Policy Scenario of all WEOs since 1994.

- Not all publications contain figures for every technology; for this reason, some years are not shown.
- Detailed regional analysis was not possible because regional breakdowns changed between different WEO editions, with the exceptions of China, India and OECD Europe, which remain similar.

Projection of coal power generation

WEOs published between 2000 and 2004 did not anticipate the rapid rise of coal capacity in China, which is not part of the OECD and is therefore only an associate member of the IEA. In 2008, China operated 37% of the world coal power plants, which rapidly increased to 47% by 2017. Between 2008 and 2017, China added 418GW of coal capacity – almost twice as much as Europe's existing coal-fired capacity – constituting 75% of all new-build coal power plants globally.

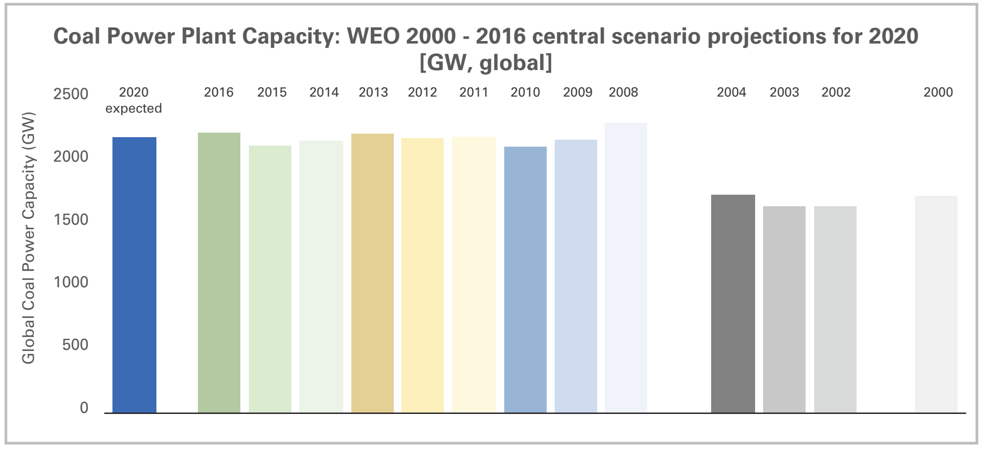

Figure 5a: Projected global coal power plants in total installed capacity (GW) from WEO 2000 to WEO 2019 versus estimated real value for 2020. Presented are central scenarios only (Reference scenario or New Policies Scenario). No 2020 values are published in WEOs 2017-2019. See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

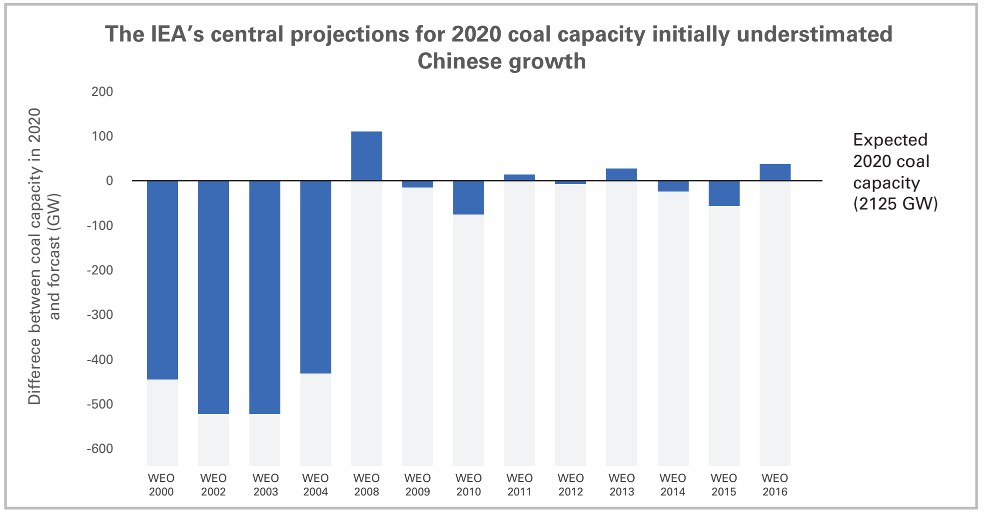

Figure 5b: The difference between projected global coal power plants in total installed capacity (GW) from WEO 2000 to WEO 2019 versus estimated real value for 2020. Presented are central scenarios only (Reference scenario or New Policies Scenario). No 2020 values are published in WEOs 2017-2019. See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

India – also not an IEA member country – added 140GW of new coal power plants, which represents nearly all the remaining 25% of the global coal power plant increase. All other countries have either not built any new coal-fired plants or have shut down more capacity than they have added to the grid. In fully liberalised power markets – such as those in North America and Europe – new coal power plants are not economically competitive.

Projection of gas power generation

Early projections (New Policy Scenario) in WEO 2000 to WEO 2004 estimated almost exactly the gas power plant capacity for 2020 (approximately 1,800GW). The estimate was increased between 2008 and 2010, heading back towards the WEO 2000 level by 2012 and remaining there until the time of writing this analysis.

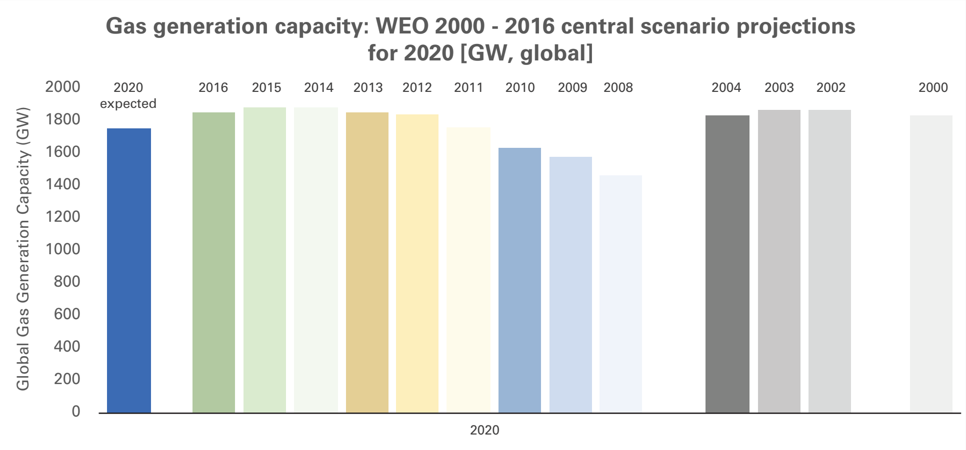

Figure 6a: Projected global gas power plants in total installed capacity (GW) from WEO 2000 to WEO 2019 versus estimated real value for 2020. Presented are central scenarios only (Reference scenario or New Policies Scenario). No 2020 values are published in WEOs 2017-2019. See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

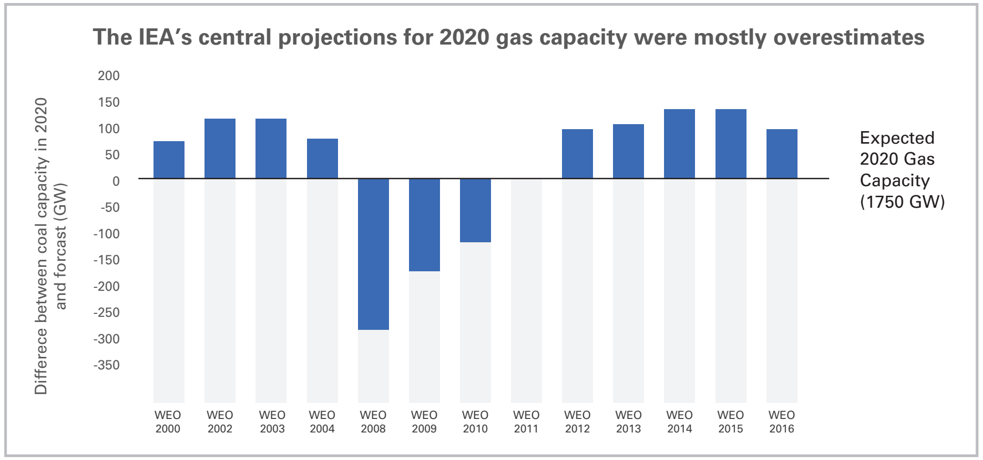

Figure 6b: The difference between global gas power plants in total installed capacity (GW) from WEO 2000 to WEO 2019 versus estimated real value for 2020. No 2020 values are published in WEOs 2017-2019. Presented are central scenarios only (Reference or New Policies Scenario). See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

The IEA has been active in promoting an increasing role for gas – especially unconventional gas mainly from the USA – in the power sector. Hence the upwards correction of the estimated 2020 gas power plant capacity from 1,461GW in WEO 2008 (its lowest ever estimate for 2020) to 1,845GW in WEO 2012. First estimations for 2020 project a total global installed gas power plant capacity of 1,629GW – a capacity projected in WEO 2011. In 2012, the IEA declared the "Golden Age of Gas" and developed "Golden Rules" for its facilitation.[21]

Projections of CCS uptake

- **CCS plays a key role in the IEA's assumptions about how emissions will be cut in the "climate constrained" scenarios since 2007. However the scale has changed dramatically over the years.**
- **The installed capacity in 2030 of coal power plants with CCS in the 450 Scenario in WEO 2010 was calculated at around 400GW – or a third of all coal power plants – but in WEO 2019 this coal CCS capacity in 2050 was estimated at 215GW. The expectations have been halved and postponed by 20 years.**
- **Charting the changes in CCS projections over the years was not possible, as the WEO's method of accounting for and categorising CCS has changed so frequently.**

Carbon capture and storage (CCS) technology was first introduced as a technical option to reduce energy-related carbon emissions in WEO 2000. The parameters and references have changed each year, obscuring both the actual calculated potential of CCS in the climate-constrained scenarios in most years, and making it impossible to precisely track how this estimate has changed in each WEO iteration.

The WEO in 2000 noted that: "all power-generation alternatives fired by fossil fuels can in principle be combined with techniques that capture CO2 from exhaust gases and store it in ocean depths or geological formations."[22] It added that existing CCS technologies require extra energy, reducing the overall efficiency of generation and adding costs, and argued that "various processes for CO_2 separation are currently under intensive research and, with a breakthrough in cost reduction, CO_2 sequestration may be able to reduce emissions from power generation in many markets, especially with strict GHG regulations and/or tax schemes in place." Given the costs and uncertainty involved, the IEA did not include CCS in its Alternative Scenario, an early version of its climate-constrained scenario.

The following five WEO editions (2001 to 2005) discussed CCS technology and the status of its research and development.

In WEO 2006, CCS had still not been included in the Alternative Scenario. However, it introduced an additional scenario: the Beyond Alternative Policy Scenario (BAPS). Here, CCS technology was still seen as a distant prospect. A technical feature set out the possibilities for CCS, noting its continued high cost, limited operational experience, and the minimal impact that the 11 planned large-scale projects would have on emissions over the next decade.

It stated that: "Recent IEA analysis shows that CCS could play a significant role by 2050 in limiting CO_2 emissions from coal-fired power plants in rapidly growing economies with large coal reserves [...] This potential will be exploited only if at least ten large-scale integrated coal-fired power plants with CCS are demonstrated and commercialised within the next decade."[23] The 2006 report's Beyond Alternative Policy Scenario quantified the CCS potential in power generation by 2030 at 2Gt CO^2 and industry at up to 1Gt CO_2. This latter figure included an unspecified volume of reductions from energy efficiency measures as well (see orange bar in Figure 7).

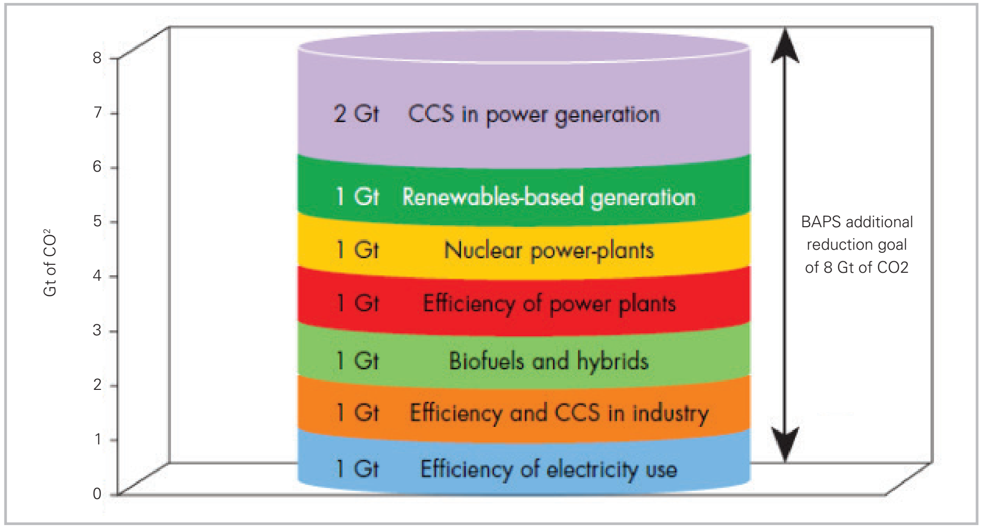

Figure 7: WEO 2006, chapter 10, figure 10.1: Reduction in energy-Related CO2 emissions in the BAPS case compared with the alternative policy option

In 2007, seven years after CCS was first discussed in the IEA's World Energy Outlooks, this technology was included in the Alternative Policy Scenario (which became the 450 Scenario in 2009). Hopes were high in the 2007 edition, which described "Clean coal technology, notably CCS, [as] one of the most promising routes for mitigating emissions in the longer term – especially in China, India and the United States, where coal use is growing fastest". It added: "CCS could reconcile continued coal burning with the need to cut emissions in the longer term – if the technology can be demonstrated on a large scale and if adequate incentives to invest are put in place."[24]

Between 2007 and 2019, CCS was part of the Alternative Policy Scenario, renamed the 450 Scenario in 2009. The actual amount of CCS in regard to installed capacity (GW) and overall calculated carbon reduction potential (in Gt CO_2) was presented in continuously changing contexts: sometimes CO_2 savings were given in comparison to the Current Policy Scenario; in others, they were compared to the New Policy Scenario. The actual CO_2 savings were often presented accumulated with other measures, such as industrial energy efficiency or nuclear, and mostly only as a percentage of the relative savings. However, the actual role of CCS in total CO_2 savings remained very modest and only a minority of all fossil fuel power plants in 2030 were assumed to have CCS technology installed.

Since 2016, expectations have been continuously revised downwards. In WEO 2016 and WEO 2017, the calculated CO_2 abatement for CCS technology was not presented as a single parameter, but instead combined with nuclear and/or renewable hydrogen for the first time. In WEO 2018, the term was changed to Carbon Capture Utilisation and Storage (CCUS), with "utilisation" referring to the use of CO_2 for enhanced oil or gas recovery. Here, the captured CO_2 is pumped into oil or gas wells to force the remaining fossil fuel resource out and increase the utilisation rate of those wells.[25] Such utilisation adds economic benefits to the costly technology.

Furthermore, CCUS is now presented with hydrogen production and/or biomass CCS (BECCS) to achieve negative emissions. WEO 2019 still includes CCS as one technology within the Sustainable Development Scenario (the renamed 450 Scenario) – with a total CO_2 capture of 0.7 Gt by 2030 and 2.8 Gt by 2050. In the context of 2018 energy-related CO_2 emissions of 33.1 Gt CO_2, this represents a range of just 2.1%-8.5% – at most 31 days of that year's CO_2 emissions. The overall amount of CCS-related carbon emissions therefore has not changed significantly since the first publication of the BAPS scenario in WEO – but it has been pushed back by 20 years.

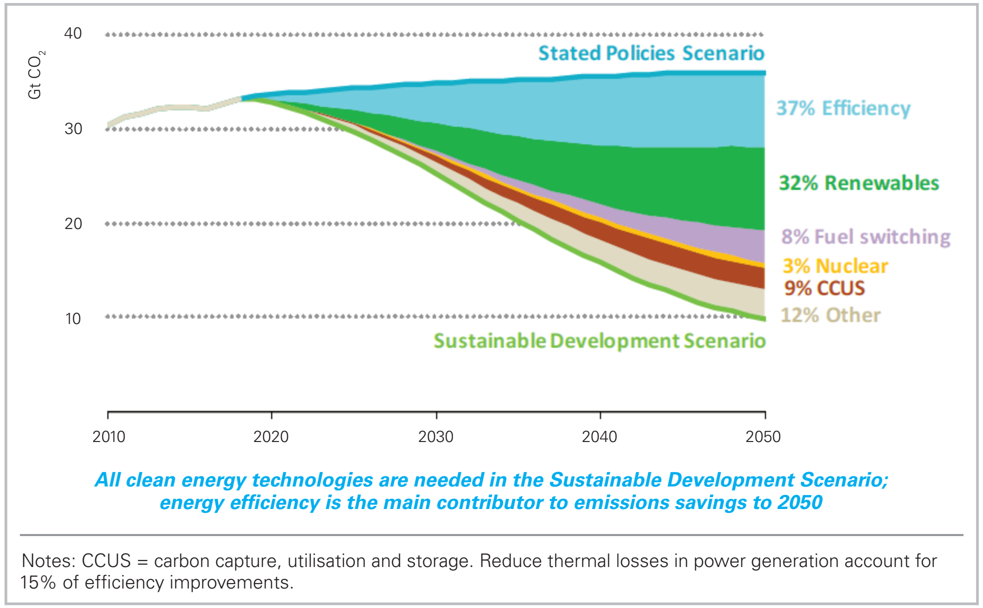

Figure 8: WEO 2019, chapter 2, figure 2.16: CO2 emissions reductions by measure in the Sustainable Development Scenario relative to the Stated Policies Scenario

	NP	CP	450	NP	CP	450	NP	CP	450	NP	CP	450
[Gt CO_2]	2020	2020	2020	2030	2030	2030	2035	2035	2035	2040	2040	2040
WEO 2010	33.7	35.4	31.9	35.1	40	24.9	35.4	42.6	21.7	na	na	na
WEO 2011	34.4	36.1	31.9	35.7	40.7	24.8	34.4	36.1	21.6	na	na	na
WEO 2012	34.6	36.3	31.4	34.6	41.2	24.9	37	44.1	22.1	na	na	na
WEO 2013	34.6	36	31.7	36.5	40.8	24.7	37.2	43.1	21.6	na	na	na
WEO 2014	34.2	35.5	32.5	36.3	40.8	25.4	37.2	na	na	38	45.9	19.3
WEO 2015	33	34.2	31.4	34.8	39.2	24.9	35.8	na	na	36.7	44.1	18.8
WEO 2016	32.8	33.7	31.3	34.5	38.6	25.2	35.5	na	na	36.3	43.7	18.4
WEO 2017	na	na	na	34.3	37.8	25.1	34.9	na	na	35.7	42.7	18.3
WEO 2018	na	na	na	34.6	37.7	25.5	35.2	na	na	35.9	42.5	17.6
WEO 2019	na	na	na	34.9	37.4	25.2	35.2	na	na	35.6	41.3	15.8

Table 1: Energy related CO2 emissions in three IEA scenarios between WEO 2010 and WEO 2019

Projection of wind power generation

Early projections for wind power capacity published in the WEO since 2000 underestimated the potential for wind power generation significantly. The 2002 WEO projected total global wind power capacity of 55GW by the year 2020, while that capacity was achieved only three years later. The WEO 2004 almost doubled the estimation for 2020 to 97GW under its central New Policies Scenario. Again, the actual development was much faster; global wind capacity passed 97GW in 2009.

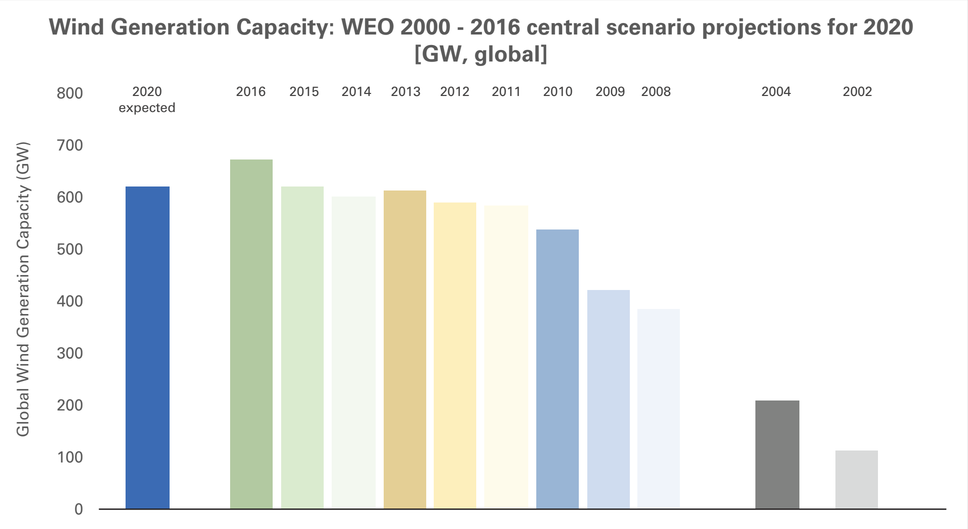

Figure 9a: Projected global wind power plants in total installed capacity (GW) from WEO 2000 to WEO 2019 versus estimated real value for 2020. No 2020 values are available for WEO 2017-2019. Presented are central scenarios only (Reference scenario or New Policies Scenario). See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

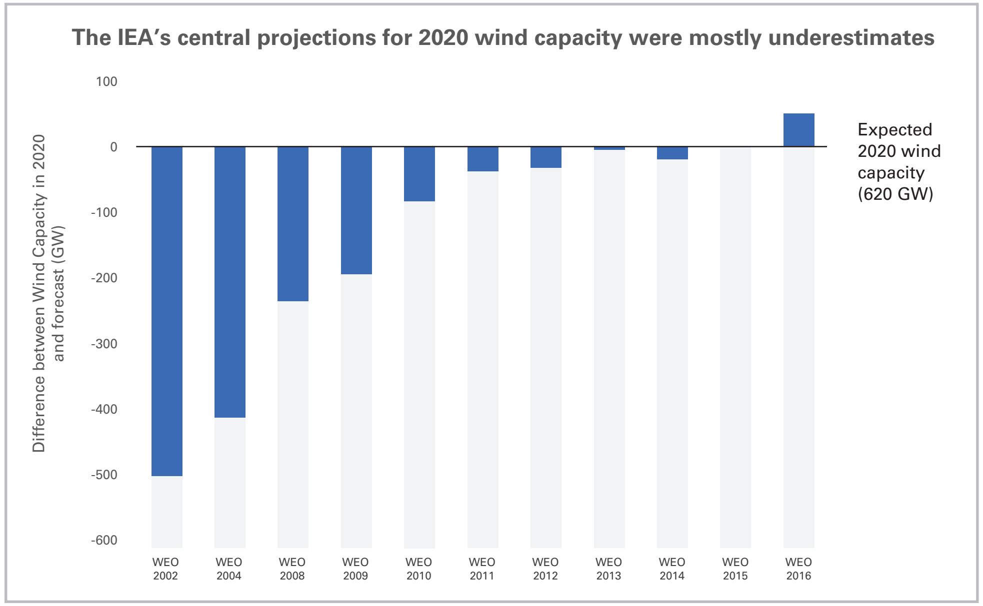

Figure 9b: Difference between projected global wind power installed capacity (GW) from WEO 2000 to WEO 2019, and the estimated real value for 2020. No 2020 values are available for WEO 2017-2019. Presented are central scenarios only (Reference scenario or New Policies Scenario). See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

The IEA increased its projections for wind power in the New Policies Scenario every year between 2005 and 2015 to catch up with actual market developments. While the IEA Wind Technology Collaboration Programme (IEA Wind TCP) – an international co-operation that shares information and research activities to advance wind energy research – was founded in 1977,[26] the WEO projections did not reflect the actual dynamic of this young market. The wind industry became increasingly engaged with the process of IEA projections and, largely due to the efforts of the newly founded Global Wind Energy Council in 2007, WEO projections began to increasingly reflect wind industry realities.

In 2019, the IEA recognised offshore wind technology as one of the major power generation technologies and published the Offshore Wind Energy Outlook 2019.[27] This was regarded as a breakthrough by the wind industry. It remains to be seen to what extent offshore wind will be integrated into the WEO as an important carbon-neutral power generation technology and what role this technology will have in future IEA scenarios compared with CCS and nuclear.

Projection of photovoltaic power generation

Today, solar photovoltaics (PV) is among the cheapest power generation technologies. In October 2017 – after solar PV had become the fastest growing power generating technology globally – the IEA wrote that "what we are witnessing is the birth of a new era in solar PV. We expect that solar PV capacity growth will be higher than any other renewable technology through 2022."[28]

However, in the first two decades of the development of solar PV, the IEA did not foresee any important role in the power sector for this technology. It only began distinguishing between solar PV and concentrating solar power (CSP) from WEO 2010 onwards. A detailed analysis of IEA projections, with a focus on solar PV, was published in 2015 by Metayer, Breyer and Fell.[29] The authors found that: "The projection for 2020 reported by WEO 2010 had been already achieved in 2012, eight years in advance and two years after the publication, which clearly documents the projection inefficiency of the WEO in the early 2010s. At that time, PV had already become a major source for new power capacity investments. (...) Already in 2010, PV installations represented more than 6% of total global power plant capacities and more than five times more than the new nuclear capacities of that year. Therefore, it had been more than overdue to include solar PV as its own category and a further indication that the WEO had been very slow in accepting the real role of PV."

Solar Generation Capacity: WEO2000 - 2016 central scenario projections for 2020 [GW, global]

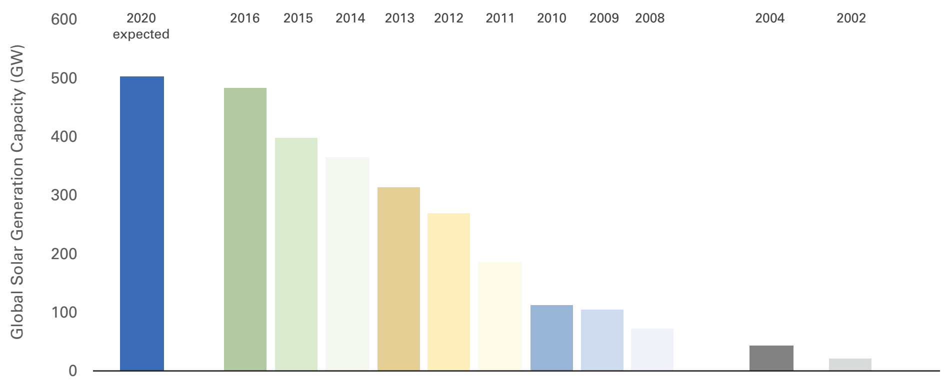

Figure 10a: Projected global photovoltaic powerplants in total installed capacity (GW) from WEO 2000 to WEO 2016 versus estimated real value for 2020. No 2020 values are available for WEO 2017-2019. Presented are central scenarios only (Reference scenario or New Policies Scenarios). See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

The IEA's central projections for 2020 Solar PV capacity were all underestimates

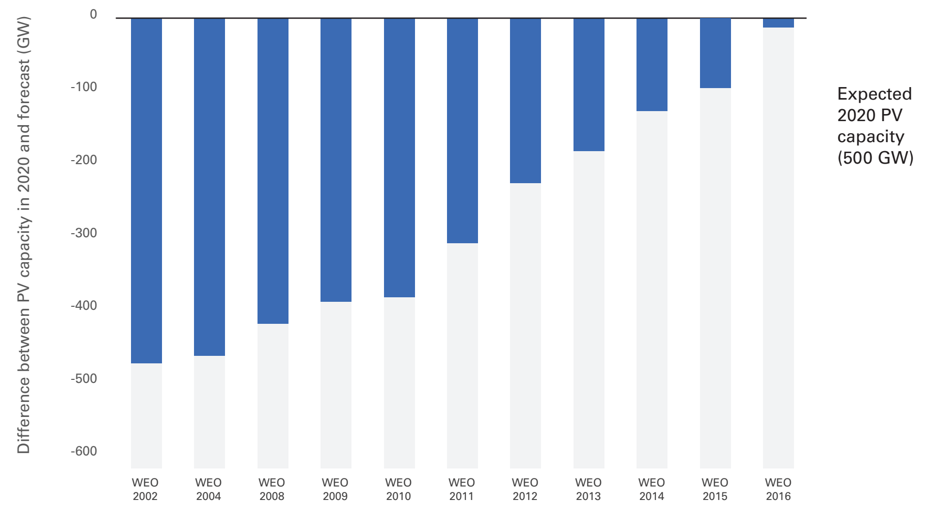

Figure 10b: Difference between projections for total PV installed capacity (GW) from WEO 2000 to WEO 2016, versus estimated real capacity in 2020. No 2020 values are available for WEO 2017-2019. Presented are central scenarios only (Reference scenario or New Policies Scenarios). See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

Figure 10a and 10b show projections of global solar PV capacity from WEO 2000 to WEO 2016 (New Policies Scenario) versus estimated actual capacity in 2020. The global projection for 2020 in the WEO 2002 was a total of 18GW – equal to just one year's capacity addition, in 2007, five years after publication. The extreme discrepancy between IEA's PV projections and the real development in the solar industry continued for another decade.

Figure 11 shows that the IEA projected the actual global capacity installed each year of the respective WEO publication as the maximum market volume for the following years: In 2011, The global annual solar PV market installed 31.8GW – the annual market projection (under the New Policies Scenario) of the WEOs from 2011 until 2013 was between 25-30GW. In 2015, global PV capacity additions equalled 46.9GW – WEO 2015 estimated an annual market until 2020 of 45-50GW. In 2016, the market installed 74GW.

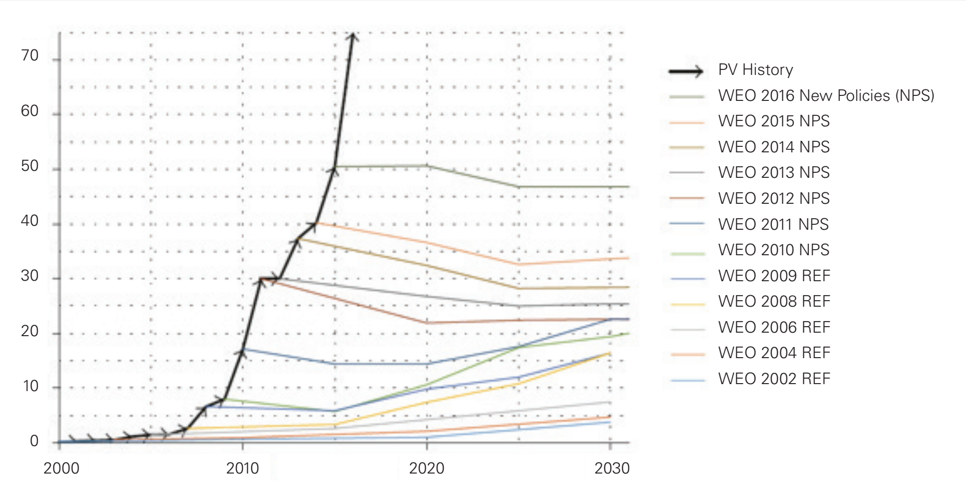

Figure 11: Reality versus IEA predictions: annual PV additions. In gigawatt peak. Data from IEA WEO 2002-2016 NPS and REF scenarios (Hoekstra et. al. 2017) [30]

Projection of nuclear power generation

Global nuclear capacity is quite stable at around 400GW. However, the IEA does not consider all phased-out and/or long-term shut down reactors when updating its installed capacity figures. Thus, the global total capacity of nuclear provided in WEO publications is higher than the actual available nuclear capacity for the power sector. Around 2010, the IEA predicted a "nuclear renaissance" which did not materialise due to significant cost overruns and substantial technical problems, as well as the Fukushima nuclear catastrophe in March 2011.

Japan – one of the largest nuclear power plant operators globally with 48.8GW of capacity across 54 reactors – shut down all its nuclear plants after Fukushima. However, the IEA still includes these in its capacity figures. Years later, only five nuclear power plants have been restarted with a total capacity 9GW.[31] While it is unlikely that the remaining 40GW will be restarted, the WEO continues to list reactors which were forced to shut down almost a decade ago as "installed capacity".

China is the only country which has added a considerable amount of new nuclear capacity. Between 2008 and 2017, it added 28GW, while the total global installed capacity provided in the WEO for 2017 was 412GW – 21GW more than in 2008. As of early 2020, Germany has retired 15 of its 21 reactors, and the remaining six will be shut down by 2022.[32] Its total capacity fell from 23.6GW in 2000 to 9GW in early 2020.[33] New power plants are unable to compete in liberalised electricity markets and require vast subsidies.[34]

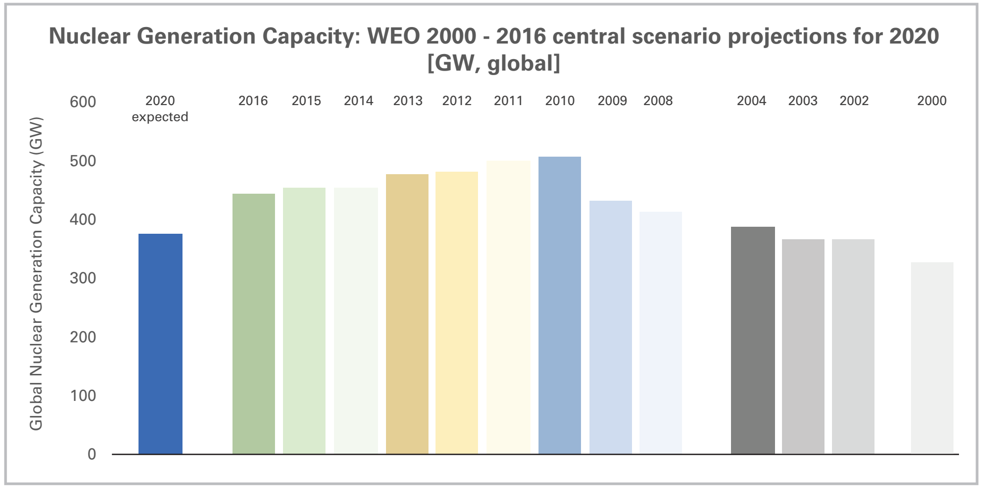

Figure 12: Projected global nuclear power plants in total installed capacity (GW) from WEO 2000 to WEO 2019 versus estimated real value for 2020. No 2020 values are published in WEOs 2017-2019. Presented are central scenarios only (Reference scenario or New Policies Scenario). See Box 1 for descriptions of scenarios, and Box 2 for further explanatory notes.

The IEA elsewhere

The IEA's role in climate change research and fora

The IEA is undoubtedly one of the most important – perhaps the most important – institutions producing energy data and analysis globally. It contributes to a number of international initiatives researching and addressing climate change, and is a key source of data on energy emissions.

The IEA and the UNFCCC

The IEA WEO plays an important role in the UNFCCC process around the global climate negotiations and supplies data as well as scenarios for possible decarbonisation pathways.[35]

The IEA and the IPCC

In 1990, the First Assessment Report from the Intergovernmental Panel on Climate Change (IPCC) was published, and a global and national greenhouse gas inventory statistic was established. The IEA has been cooperating with the IPCC since 1991 and, over time, IEA experts have contributed to setting out international methodologies, such as the various editions of the IPCC Guidelines for GHG inventories and have taken part in the GHG review process of the UNFCCC.[36] In December 2017, the IEA and the IPCC held a two-day expert meeting in which both organisations agreed to widen their cooperation and to work together in capacity-building to develop energy-related national statistical systems in developing countries. Furthermore, the IEA and IPCC want to broaden their work on data, which encompasses contributions on scenario work to the IPCC report on 1.5 degrees as a key input to the Talanoa Dialogue, the collective stock-taking process undertaken in 2018 to assess progress towards the Paris Agreement's long-term goals.[37]

The IEA and the SDGs

The IEA is the "lead custodian agency" for Sustainable Development Goal 7.2 on renewable energy and 7.3 on energy efficiency. It is also a custodian of SDG target 12.c, which aims to rationalise inefficient fossil-fuel subsidies that encourage wasteful consumption.[38]

Global Energy and CO2 Status Report

Since 2001, the IEA has collected and published global energy-related carbon emissions data, a vital data source for the global climate discussion (EDGAR/IEA 2017).[39]

Other climate and energy transition initiatives

The IEA is formally involved in other processes and initiatives, such as:

- The Clean Energy Ministerial, a high-level forum hosted by the IEA;
- The Clean Energy Transitions Programme;
- The Electric Vehicle Initiative;
- Energy Efficiency in Emerging Economies;
- EU4Energy;
- The Global Commission for Urgent Action on Energy Efficiency; and
- The Technology Collaboration programme for solar PV, wind and other technologies.

The IEA's non-WEO reports

The IEA publishes a vast number of reports, analysis and scenarios besides the WEO series, including:

- Energy Technology Perspectives, which describe emerging 'clean' energy technologies, including all renewable power and heating technologies, fossil fuel technologies including carbon capture and storage, nuclear energy and a whole range of energy efficiency measures and industry processes. The first edition was published in 2006.[40]
- Oil, gas and coal industry outlooks, which report in great details on the development of the respective industries and which offer a five-year outlook.
- The Tracking Clean Energy Processes reports, which assess the status of 45 energy technologies and sectors and provide recommendations on how they can get 'on track' with the Sustainable Development Scenario.[41] The interactive website shows with colour codes (green – on track; yellow – more efforts needed; red – not on track) the actual developments in comparison to the Sustainable Development Scenario.

In addition, various special country reports are published every year.

While it is beyond the scope of this paper to provide a comprehensive comparison between the WEO and other IEA publications, below is one example of divergence on numeric projections and on messaging.

Divergence between the Medium-Term Renewable Energy Market Report and the WEO on Solar PV

The Medium-Term Renewable Energy Market (MTREM) Report – published between 2011 and 2018 – was the first IEA publication dedicated to projecting global renewable energy developments. In contrast to the WEO and Energy Technology Perspectives, the MTREM reports were conducted in close cooperation with the renewable energy industry.

A comparison between solar PV projections made in the 2015 MTREM and the 2015 WEO shows a clear divergence between the two. The MTREM 2015 projected 429GW for solar PV for 2020 under its "accelerated case". For the WEO published in the same year, even its most aggressive climate scenario, the 450 Scenario, only projected 420GW in 2020, while the Current Policies pegged the number at 361GW, and the New Policies Scenario at 397GW.

Appendix 1: The World Energy Model's methodology

The World Energy Model

The World Energy Outlook methodology has changed substantially since the first edition of the WEO was published in 1977. For this analysis, we reviewed WEOs from 1994 until 2019, as earlier editions were not available. This section also draws on a literature review of scientific journals.

The WEO scenarios are produced using the World Energy Model (WEM), which has been developed by the IEA over more than two decades. The WEM is a long-term energy model consisting of three main modules: final energy consumption (covering residential, services, agriculture, industry, transport and non-energy use); energy transformation, including power generation and heat, refinery and other transformation; and energy supply. Outputs from the model include energy flows by fuel, investment needs and costs, CO2 emissions and end-user pricing.[42]

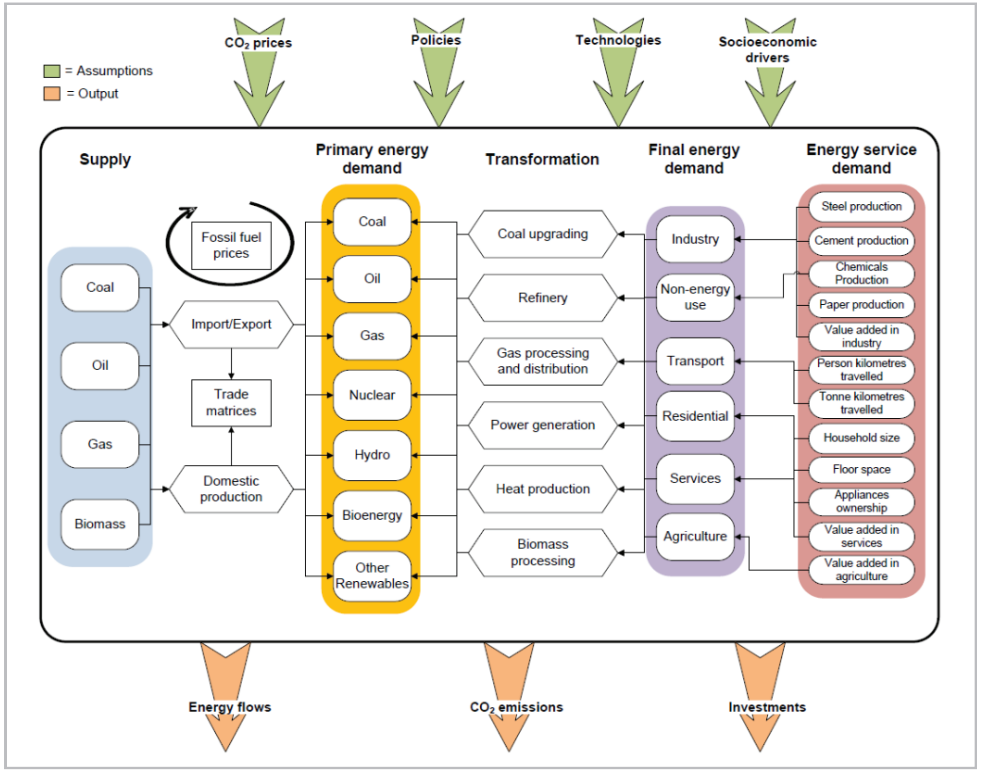

Figure 13: World Energy Model overview – Source IEA-WEM 2019

The starting point for energy supply and demand projections and price information is derived from databases – mainly of the IEA – from IEA's member countries and aggregated global energy data. The WEM divides the world into 25 regions, 12 of which are countries, and the remaining 13 are groups of countries. The horizon of projections is typically over 25–30 years, and exogenous assumptions include forecasts for economic growth, population growth, technological progress and policy developments.[45]

Key exogenous assumptions driving the model are economic growth and demographics.[46] Furthermore, costs of CO2 emissions, plans and measures for energy and climate policies, technological progress by industry and region are exogenous assumptions which define and influence the output significantly. Crude oil and natural gas prices are also exogenous, whereas end-user prices for a range of energy products are determined by the model.

The WEM output includes supply of and demand for different energy carriers, costs and investments, end-user prices and energy-related greenhouse gas emissions. To summarise, the WEM presents itself as a large-scale data-intensive simulation model for the global energy system. Three main modules cover final energy consumption, energy conversion/transformation and energy supply. In terms of methodology, the WEM combines insights from engineering with energy accounting and energy economics.[47]

The three WEO scenarios

Different assumptions are used to calculate various scenarios within the WEM. Input data such as current energy demand, existing power plants and current fuel prices and assumptions for future development, such as the oil price and costs of power plant installation e.g. solar photovoltaic or coal power plants, are required to compute energy scenarios with any energy model.

Those exogenous inputs are key and define to a large extent the outcome of the model. For example, in 2004, the installation of solar photovoltaic power plants cost $9,000 per kilowatt on average,[48] while gas power plants costs were at $1,000 per kW. The overall electricity production costs at that time were $0.40 per kilowatt hour (kWh) for solar and $0.05 per kWh for gas power plants. The assumption that solar PV installation costs will not decline over the next decade would result in either very high electricity costs in a solar-dominated scenario – which would be seen as unfavourable – or would prevent the increase of solar in any scenario at all. Therefore, assumptions on cost and technology development define to a large extent the outcome of a scenario.

WEOs of the past decade calculate three scenarios – the names of which have changed over time:

A. ***No Policy Changes:*** The Business-As-Usual (BAU) scenario, also called the Reference case or – later on – the Current Policies Scenario, assumes that energy policies of the modelled region(s) will not change. "To illustrate the outcome of our current course, if unchanged, the Current Policies Scenario embodies the effects of only those government policies and measures that had been enacted or adopted by mid-2019. The scenario is designed to offer a baseline picture of how global energy markets would evolve without any new policy intervention."[49]

B. ***Implementing announced policies:*** The New Policy Scenario (NPS) – which was renamed the Stated Policies Scenario in the WEO 2019 – "takes into account the policies and implementing measures affecting energy markets that had been adopted as of mid-2019, together with relevant policy proposals, even though specific measures needed to put them into effect have yet to be fully developed. The Stated Policies Scenario assumes only cautious implementation of current commitments and plans. This is done in view of the many institutional, political and economic obstacles which exist, as well as, in some cases, a lack of detail in announced intentions and about how they will be implemented. For example, the GHG- and energy-related components of the Nationally Determined Contributions (NDCs) pledged under the Paris Agreement are incorporated. Where the energy policy landscape has continued to evolve since the NDCs were announced, the NPS has been updated, becoming more ambitious in terms of GHG emissions reductions in some countries and less ambitious in others. But we take a generally cautious view in the Stated Policies Scenario of the extent and timing of which policy proposals will be implemented".[50]

C. ***Significant policy changes or "climate constrained" scenarios:*** These scenarios illustrate the IEA's view of the energy future under the most ambitious climate policies. Initially titled "Alternative Policy Scenario", it was renamed the "450 Scenario" in 2009, a scenario that held atmospheric emissions of greenhouse gases to below a ceiling of 450 parts per million (considered to give a reasonable chance of limiting global warming to below 2°C above pre-industrial levels). However, this scenario does not lead to a total decarbonisation of the energy sector. It was replaced in 2017 with the Sustainable Development Scenario which aimed to integrate some of the Sustainable Development Goals that relate to air quality and access to modern energy.[51]

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