RFF REPORT

Global Energy Outlooks Comparison Methods

2018 Update

Richard G. Newell, Stuart Iler,
and Daniel Raimi

APRIL 2018

INTERNATIONAL ENERGY FORUM

RESOURCES FOR THE FUTURE

Global Energy Outlooks Comparison Methods: 2018 Update

Richard G. Newell, Stuart Iler, and Daniel Raimi*

Abstract

We update a harmonization methodology previously developed in 2015 to facilitate comparisons of long-term global energy projections issued by the International Energy Agency, US Energy Information Administration, ExxonMobil, BP, and the Organization of the Petroleum Exporting Countries. We continue to find important differences across outlooks in primary energy units used, assumed energy content of fossil fuels, assumed efficiency of nuclear and renewable electricity conversion from primary energy, categorization of biofuels, and inclusion (or exclusion) of traditional biomass. For example, the US EIA and BP's exclusion of non-marketed traditional biomass yields estimates of global primary energy consumption that are 8 to 13 percent lower than the IEA, ExxonMobil and OPEC, which include these sources. Assumptions about energy content of fossil fuels can vary by more than 10 percent in the data examined here, requiring significant downward adjustment of primary energy consumption estimates for oil and natural gas to make BP and US EIA data comparable to IEA, OPEC, and ExxonMobil. Conventions about primary energy conversion of renewables can alter estimates for these sources, ranging from a 65 percent decrease to a 280 percent increase for particular electricity sources. We also find that there are significant differences in historical data used in these outlooks, even when measured in fuel-specific physical units such as barrels, cubic meters, or tonnes. After taking into account these differences, our harmonization methodology brings estimates within 1.5 percent or less of one another for most fuels in the benchmark year of 2015. We highlight important sources of divergence where organizations producing outlooks may find opportunities to align assumptions and improve datacomparability. Enhancing the comparability of outlooks will improve the quality of the dialogue among stakeholders to the benefit of energy decisionmaking worldwide.

---

* Corresponding author is Richard G. Newell, the President and CEO of Resources for the Future (newell@rff.org); an Adjunct Professor at Duke University's Nicholas School of the Environment; a Research Associate at the National Bureau of Economic Research, Cambridge, MA; and the former Administrator of the US Energy Information Administration. Stuart Iler is a pre-doctoral fellow at Harvard University's Kennedy School of Government (stuartiler@g.harvard.edu). Daniel Raimi is a Senior Research Associate at Resources for the Future (raimi@rff.org) and a Lecturer at the University of Michigan's Gerald R. Ford School of Public Policy.

About Resources for the Future

Resources for the Future (RFF) is an independent, nonprofit research institution in Washington, DC. Its mission is to improve environmental, energy, and natural resource decisions through impartial economic research and policy engagement. RFF is committed to being the most widely trusted source of research insights and policy solutions leading to a healthy environment and a thriving economy.

About the International Energy Forum

The International Energy Forum (IEF) (ief.org) aims to foster greater mutual understanding and awareness of common energy interests among its members. Covering all six continents and accounting for around 90 percent of global supply and demand for oil and gas, the IEF is unique in that it comprises not only consuming and producing countries of the IEA and OPEC, but also Transit States and major players outside of their memberships. The IEF is the neutral facilitator of informal, open, informed and continuing global energy dialogue.

About this Paper

This paper is one of several produced by Resources for the Future in collaboration with the International Energy Forum. The paper updates Newell, R.G. and Iler, S. 2017. Global Energy Outlooks Comparison Methods: 2017 Update. Other papers produced in collaboration with IEF include the background papers for the fourth, fifth, sixth, seventh, and eighth IEA-IEF-OPEC Symposium on Energy Outlooks, and the paper Global Energy Outlook 2015, which compares and synthesizes the results of long-term energy outlooks by IEA, OPEC, US EIA, BP, ExxonMobil, and Shell.

About the Authors

Richard G. Newell is the President and CEO of Resources for the Future (newell@rff.org); an Adjunct Professor at Duke University's Nicholas School of the Environment; and the former Administrator of the US Energy Information Administration. Stuart Iler is a pre-doctoral fellow at Harvard University's Kennedy School of Government (stuartiler@g.harvard.edu). Daniel Raimi is a Senior Research Associate at Resources for the Future (raimi@rff.org) and a Lecturer at the University of Michigan's Gerald R. Ford School of Public Policy.

Contents

1. Introduction

The global energy sector is changing rapidly. Population growth and economic development are driving up world energy demand. At the same time, technological advances are increasing energy efficiency, driving down costs for a variety of technologies, and making more unconventional energy resources economically viable. The results are rapidly changing global trends in energy production, consumption, and trade flows.

Energy outlooks are one way to understand these changes, with a particular eye toward the longer-term future. Each year, multiple long-term energy outlooks, usually projecting 20 to 25 years ahead, are issued by organizations such as the International Energy Agency (IEA), the Organization of the Petroleum Exporting Countries (OPEC), the US Energy Information Administration (US EIA), and international energy companies (e.g., BP, ExxonMobil, Shell). In recent years, other organizations such as the Russian and Chinese Academy of Sciences, new international organizations such as the Gas Exporting Countries Forum, and national oil and gas companies such as the Chinese National Petroleum Company have also issued annual energy outlooks. Each organization makes long-term energy projections using their own model assumptions and historical databases.

Due to the important role these outlooks play in informing decisions by market participants and policymakers, a consistent method of presenting the information from these outlooks can help enable an inclusive and meaningful international energy dialogue. However, each organization uses different methodologies and assumptions, and comparing between and among different outlooks is not at all straightforward. To address this issue, we have developed a methodology to harmonize and compare projections from various outlooks, enabling market participants and policymakers to more clearly evaluate the range of global energy projections.

To illustrate this harmonization process, we use the most recent outlooks available for comparative analysis of energy forecasts, as well as several previously published outlooks to enable the analysis of 2015 data as a common baseline year:

- IEA: World Energy Outlook 2017 (WEO2017), published in November 2017.
- OPEC: World Oil Outlook 2017 (WOO2017), published in November 2017.
- US EIA: International Energy Outlook 2017 (IEO2017), published in September, 2017.
- ExxonMobil: Outlook for Energy 2017, published in December 2016.
- BP: Energy Outlook 2017, published in February 2017.

Each outlook discussed in this paper covers a wide range of topics, ranging from quantitative projections of energy consumption, supply, and carbon dioxide emissions, to qualitative descriptions of technology development. Our purpose is not to hide differences across institutions in their views about the future outlook for the energy system, but rather to control for differences in convention and data sources that in fact obfuscate an accurate assessment of underlying assumptions and judgments about the short-, medium- and long-term in different outlooks.

We focus here on overall primary energy consumption and its key fuel sources—oil and other liquids (including natural gas condensate), natural gas, coal, nuclear, and renewables—and provide a detailed description of our outlook harmonization approach. This paper identifies and addresses the following specific challenges in harmonizing primary energy consumption across different institutional sources:

- Outlooks use different units of primary energy consumption (e.g., qBtu, mtoe, mboe).
- Outlooks use different assumptions for the energy content of fossil fuels.
- Outlooks vary in their assumptions regarding the efficiency of conversion to primary energy of non-combustible energy sources (e.g., nuclear and renewable electric power).
- Outlooks vary in whether they include non-marketed sources of energy, particularly traditional biomass.
- Outlooks vary in their categorization of energy sources (e.g., biofuels, liquids, oil, synthetic gas from coal, and renewables), and whether they include flared gas.
- Outlooks use different historical baseline data.
- Outlooks differ in their regional groupings of countries.

Sections 2, 3, and 4 elaborate on the first four issues mentioned above. Section 5 presents a method for harmonizing world energy consumption among various outlooks and identifies the issue of remaining differences in historical baseline data, using 2015 as a benchmark year. Section 6 discusses differences in geographic groupings, and Section 7 concludes.

2. Primary Energy Unit Conversion and Energy Content Adjustment for Fuels

Most outlooks project energy consumption in three forms: (i) primary energy, (ii) energy use in power generation, and (iii) end-use energy consumption for transport, industry, and residential/commercial buildings (or "other" in the case of BP). Primary energy consumption is a particularly important aggregate measure of long-term trends assessed by various energy outlooks. Primary energy refers to the energy embodied in natural resources prior to any conversion or transformation process for end-use consumption. The level of primary energy consumption and its fuel composition for a country or region is affected by population, economic output and structure, stage of development, indigenous resource availability, and level of energy efficiency. Energy outlooks forecast primary energy consumption by region and by fuel type, but data transformation is necessary to directly compare between most outlooks.

The first challenge of comparing primary energy consumption is the use of different units. Primary energy consumption tends to be reported in a traditional energy unit, such as quadrillion Btu (qBtu) or million tonnes of oil equivalent (mtoe). However, sometimes the primary consumption of a specific fuel is not directly presented, and the comparison of primary energy involves derivation from other energy consumption data.[1] Table 1 displays various units used to report consumption of primary energy and specific fuels across outlooks.

[1] For example, as discussed below, the US EIA does not report primary energy consumption for hydro and other renewables individually. To compare with other outlooks, one has to use data measured in terawatt hours (TWh) and then convert to primary energy. Another example is regional fossil fuel data, which are usually reported in fuel-specifc volume units (e.g., tcf) or mass units (e.g., mbd), rather than in common energy units.

TABLE 1. UNITS OF ENERGY CONSUMPTION USED IN DIFFERENT OUTLOOKS

	IEA	BP	ExxonMobil	US EIA	OPEC
Primary energy units	mtoe	mtoe	qBtu	qBtu	mboed
Fuel/sector-specific units					
Liquids	mbd	mbd[1]	mboed[1]	mbd	mbd
Oil	mbd	mbd	mboed[1]	mbd	mbd
Biofuels	mboed	mboed[1]	mboed[1]	mbd	mbd
Natural gas	bcm	bcfd	bcfd[1]	tcf	mboed
Coal	mtce	btoe[1]	N.A.	short ton	mboed
Electricity	TWh	TWh[1]	TWh	TWh	N.A.

Note: Units are per year unless otherwise noted. mtoe is million metric tonnes of oil equivalent, qBtu is quadrillion British thermal units (Btu), mbd is million barrels per day, mboed is million barrels of oil equivalent per day, bcfd is billion cubic feet per day, tcf is trillion cubic feet, bcm is billion cubic meters, mtce is million tonnes of coal equivalent, btoe is billion metric tonnes of oil equivalent, 1 short ton is equivalent to 0.9072 metric tonnes, and TWh is terawatt hours. N.A. indicates that the source does not provide data in fuel-specific units. [1]Note that for BP and ExxonMobil, these data in mbd, mboed, bcfd, and btoe are only shown visually in figures, rather than in data tables.

As Table 1 shows, each outlook has a standard reporting unit for primary energy consumption. The IEA and BP use mtoe, the US EIA and ExxonMobil use qBtu, and OPEC uses mboed. To compare across outlooks, one needs to place all outlooks in a common unit. For this paper we use qBtu as the benchmark primary energy unit, requiring an appropriate mtoe-to-qBtu conversion factor for the IEA and BP, and mboed-to-qBtu conversion factor for OPEC. According to international convention (see, for example, IEA[2]) energy consumption data in mtoe can be converted into qBtu by multiplying by a factor of 0.03968 qBtu/mtoe. Similarly, OPEC uses a standard conversion factor of 7.33 mboe/mtoe, which is equivalent to 49.8 mtoe/mboed.[3] To transform OPEC's primary energy data from mboed to qBtu, we therefore multiply by 1.976 qBtu/mboed (= 49.8 mtoe/mboed × 0.03968 qBtu/mtoe).

After converting to a common energy unit, considerable difference in baseline data remain due to differences in energy content assumptions made by organizations when converting physical units of fuels (i.e., mbd of oil and other liquids, tcf of natural gas, and mt of coal) to their original energy units. For example, it is our understanding from experts at the US EIA that the principle reason for its significantly higher estimates for liquids and natural gas than IEA is that the US EIA uses the higher heating value (or *gross* calorific value) whereas IEA uses the lower heating value (or *net* calorific value). To address these differences, we derive a set of "energy content adjustment factors" for each organization and for each of the major fuel sources: liquids (Table 2), natural gas (Table 3), and coal (Table 4). Our general approach involves two steps, conducted separately for each organization and for each of the fuels.

---

[2] IEA, *World Energy Outlook 2017* (Paris: OECD/IEA, 2017), p. 740.

[3] Internal communication with OPEC. To convert from mboed to mtoe per year for OPEC, multiply by 365 days per year, and then divide by the standard mtoe-to-mboe conversion factor 7.33. The result is 365 days/year ÷ 7.33 mboe/mtoe = 49.8 mtoe/mboed.

First, we identify energy content assumptions made by each organization. To do so, we obtain two sets of data from each outlook where available—one in energy units (i.e., qBtu, mtoe) and the other in fuel-specific physical units (i.e., mbd of liquids, tcf of natural gas, mt of coal). We derive the implicit average energy content assumptions for each fuel, by organization, by dividing the data in energy units by the data measured in fuel-specific physical units. For the US EIA this results in energy content factors measured in qbtu/mbd for liquids, qBtu/tcf for natural gas, and qbtu/mt for coal. For the IEA and BP this results in energy content factors measured in mtoe/mbd for liquids, mtoe/tcf for natural gas, and mtoe/mt for coal, which we then multiply by 0.03968 qBtu/mtoe to create factors involving only qBtu, which can be directly compared across the three organizations. This yields an energy content factor for each fuel and for each organization, measured in qBtu/mbd of liquids, qBtu/tcf of natural gas, and qBtu/mt of coal. These factors can vary within an outlook across time and regions, but it is not possible for us to calculate a complete set of conversion factors for each outlook, fuel, region, and year. We instead average a near-term and long-term factor to estimate each outlook's energy content assumptions. In practice, these factors vary little over time, and the US EIA confirms that its energy content assumptions do not vary over time.

Second, we derive an energy content adjustment factor for BP and US EIA by dividing the energy content factors for IEA by those of BP and US EIA. This approach has the effect of benchmarking these organizations' estimates so that they are approximately "as if" they had used the average aggregate IEA energy content assumptions for each fuel. We do not adjust OPEC or ExxonMobil data for any differences in energy content assumptions, either because their assumptions are the same as IEA's or due to data limitations.[4]

For example, the conversion process for primary energy consumption of liquids is given in Table 2. Liquids consumption data measured in mbd are given in column (a), in qBtu in column (b), and in mtoe in column (c). Column (d) divides (c) by (a) to create an mtoe/mbd conversion factor. For IEA and BP, column (e) multiplies column (d) by 0.03968 qBtu/mtoe to create a qBtu/mbd conversion factor. For US EIA, column (e) divides (b) by (a) to create a qBtu/mbd conversion factor. Finally, the final row of Table 2 shows the resulting energy content adjustment factors found by dividing the IEA qBtu/mbd factor by the BP and US EIA qBtu/mbd factors. Similarly, we derive energy content adjustment factors for natural gas (Table 3) and coal (Table 4) using the same approach as Table 2.

[4] We do not adjust ExxonMobil data in this manner because their baseline data is based on IEA Annual Statistics Data, and all fuels except oil are directly converted from mtoe to qBTU by multiplying by the standard conversion factor of 0.03968 qBtu/mtoe. For oil, ExxonMobil converts IEA data from kilotonnes to qBtu using its own energy content assumptions for individual petroleum products. However, we were not able to create an energy content adjustment factor for ExxonMobil liquids due to a lack of data in mbd from ExxonMobil. Because OPEC does not present non-liquids energy consumption data in both energy units and fuel-specific physical units, the above approach of deriving energy content factors cannot be used for OPEC data. In addition, in other cases OPEC tends to follow IEA conversion assumptions.

TABLE 2. LIQUIDS ENERGY CONTENT ADJUSTMENT

Source	Year of data	Fuel-specific units	Primary energy units		Implied conversion factors	
		mbd	qBtu	mtoe	mtoe/mbd	qBtu/mbd
		(a)	(b)	(c)	(d)=(c/a)	(e)=(d×0.03968 qBtu/mtoe)
BP[1]	2015	95	-	4,331	45.59	1.809
	2035	110	-	5,022	45.65	1.812
BP avg.					45.62	***1.810***
IEA[2]	2025	102.8	-	4,753	46.24	1.835
	2040	109.1	-	5,030	46.11	1.830
IEA avg.					46.17	***1.832***
						(e)=(b/a)
US EIA[3]	2015	95.3	190.6	-	-	2.000
	2040	112.9	226.0	-	-	2.002
US EIA avg.						***2.001***

Energy content adjustment factors for liquids

US EIA: 0.9156 = 1.832 qBtu/mbd ÷ 2.001 qBtu/mbd

BP: 1.0120 = 1.832 qBtu/mbd ÷ 1.810 qBtu/mbd

Note: All data in the table are consumption data. Dashes indicate the data are not available from a particular source. ExxonMobil's outlook is not included because it does not present data in fuel-specific units (mbd). [1]BP, Energy Outlook to 2035 (London: BP, 2017). [2]IEA, World Energy Outlook 2017 (Paris: OECD/IEA, 2017); liquids consumption sums up oil and biofuels and projected data are from the New Policies Scenario. [3]US EIA, International Energy Outlook 2017 (Washington, DC: US EIA, 2017); projected data are from the Reference Case Scenario.

TABLE 3. NATURAL GAS ENERGY CONTENT ADJUSTMENT

Source	Year of data	Fuel-specific units		Primary energy units		Implied conversion factors	
		bcm	tcf	qBtu	mtoe	mtoe/tcf	qBtu/tcf
			(a)	(b)	(c)	(d=c/a)	(e)=(d×0.03968 qBtu/mtoe)
BP	2015[1]	3,480	122.9[2]	-	3,147	25.60	1.016
	2035[3]	-	169.0	-	4,319	25.55	1.014
BP avg.						25.58	*1.015*
IEA[4]	2000	2,518	88.9	-	2,071	23.29	0.924
	2040	5,304	187.3	-	4,356	23.25	0.923
IEA avg.						23.27	*0.923*
							(e=b/a)
US EIA[5]	2015	-	124.1	128.9	-	-	1.039
	2040	-	177.0	184.0	-	-	1.040
US EIA avg.							*1.039*

Energy content adjustment factors for natural gas

US EIA: 0.8887 = 0.923 qBtu/tcf ÷ 1.039 qBtu/tcf

BP: 0.9099 = 0.923 qBtu/tcf ÷ 1.017 qBtu/tcf

Note: All data in the table are consumption data. Dashes indicate the data are not available from a particular source. ExxonMobil's outlook is not included because it does not present data in fuel-specific units (tcf or bcm). [1]BP, Statistical Review of World Energy 2017 (London: BP, 2017). [2]Data converted from bcm to tcf by multiplying by a standard conversion factor of 0.0353147 tcf per bcm. [3]BP, *Energy Outlook to 2040* (London: BP, 2017); data converted from bcfd to tcf per year by multiplying by 365 days/year and 0.001tcf/bcf. [4]IEA, *World Energy Outlook 2017* (Paris: OECD/IEA, 2017); projected data are from the New Policies Scenario. [5]US EIA, *International Energy Outlook 2017* (Washington, DC: US EIA, 2017); projected data are from the Reference Case Scenario.

TABLE 4. COAL ENERGY CONTENT ADJUSTMENT

Source	Year of data	Fuel-specific units		Primary energy units		Implied conversion factors	
		million short tons	million metric tonnes (mt)	qBtu	mtoe	mtoe/mt	qBtu/mt
			(a)	(b)	(c)	(d)=(c/a)	(e)=(d×0.03968 qBtu/mtoe)
BP[1]	2015	-	7961	-	3887	0.4883	0.01938
	2010	-	7485	-	3633	0.4854	0.01926
BP avg.						0.4868	***0.01932***
IEA	2015[2]	-	7710	-	3837	0.4977	0.01975
	2000[3]	-	4701	-	2311	0.4916	0.01951
IEA avg.						0.4946	***0.01963***
							(e)=(b/a)
US EIA[4]	2015	8525	7734	141.4	-	-	0.01828
	2010	8151	7395	150.3	-	-	0.02033
US EIA avg.							***0.01931***

Energy content adjustment factors for coal

US EIA: 1.0165 = 0.01963 qBtu/mt ÷ 0.01932 qBtu/mt

BP: 1.0160 = 0.01963 qBtu/mt ÷ 0.01931 qBtu/mt

Note: [1]Production data from BP, Statistical Review of World Energy 2017 (London: BP, 2017). [2]Consumption data from IEA, Coal Information 2017 (Paris: OECD/IEA, 2017). [3]Consumption data from IEA, World Energy Outlook 2017 (Paris: OECD/IEA, 2017). [4]Consumption data from US EIA, "World Primary Coal Consumption", International Energy Statistics Database. Accessed February 6, 2018: http://www.eia.gov/beta/international/data/browser/. [5]EIA data converted from short tons to metric tonnes by multiplying by a factor of 0.9072 metric tonnes per short ton. Dashes indicate the data are not available from a particular source.

TABLE 5. ENERGY CONTENT ADJUSTMENT FACTORS FOR LIQUIDS, NATURAL GAS, AND COAL

	Liquids	Natural gas	Coal
US EIA	0.9156	0.8887	1.0165
BP	1.0120	0.9099	1.0160

Table 5 summarizes the resulting energy content adjustment factors for the US EIA and BP for each major fuel. The factors differ moderately across fuels and between the US EIA and BP, and reveal differences in energy content assumptions for each fuel ranging from 1 percent to 11 percent. An implication is that if one does not adjust for differing energy content assumptions, and instead only converts primary energy data based on standard mtoe-to-qBtu conversion factors, this will result in a significant overestimation of liquids and natural gas for the US EIA, and an overestimation of natural gas for BP, when compared to the IEA, OPEC and ExxonMobil. Note that this adjustment is only necessary for fossil fuels, whereas a different approach is necessary for addressing differences in the primary energy content of nuclear and renewable power (see section 3).

Note that determining a single "correct" adjustment factor for each fuel is not currently feasible, as these factors are a summary metric of underlying assumptions about the energy content of different fuels, which vary by region and over time. Controlling fully for these differences would require harmonization of the underlying datasets and energy content assumptions across all the models. Nonetheless, using these more carefully derived energy content adjustment factors resolves a significant amount of the difference that would otherwise exist when comparing estimates across these outlooks.

3. Primary Energy Conversion for Nuclear and Renewable Electricity Generation

3.1. Different Approaches Across Outlooks

It is conceptually straightforward to understand primary energy of fossil fuels and biomass because these combustible fuels have an easily measurable energy content and their upstream physical supply is commonly tracked. In contrast, calculating primary energy for nuclear power and non-biomass renewables such as solar, hydro, wind, and geothermal is more complex because the notion of upstream embodied energy is less well-defined and also not as widely measured. To estimate primary energy for these sources, the standard approach is to identify the amount of electricity generated from the source (i.e., secondary transformed energy), and divide this estimate by an assumed conversion efficiency rate.[5] However, the assumed conversion efficiency assumptions for nuclear and renewable power are not consistent across outlooks (Table 6). We explain the rationale for each outlook's assumptions below.

TABLE 6. PRIMARY ENERGY CONVERSION EFFICIENCY ASSUMPTIONS FOR NUCLEAR AND RENEWABLE POWER

Source	Nuclear	Hydro	Wind/Solar/Other	Geothermal	Biomass
IEA	33%	100%	100%	10%	35%
ExxonMobil	33%	100%	100%	10%	10-40%
OPEC	33%	100%	100%	15%	35%
BP	38%	38%	38%	38%	38%
US EIA	33%	35%	35%	35%	36%

Sources: IEA: World Energy Outlook 2017 (Paris: OECD/IEA, 2017); "Power generation assumptions in the New Policies and 450 Scenarios in the World Energy Outlook 2016," Accessed January 16, 2018. ExxonMobil: Internal communication. OPEC: Internal communication. BP: Statistical Review of World Energy 2017 (London: BP, 2017). US EIA: World Energy Projection System Plus Model Documentation (Washington, DC: US EIA, 2017) and internal communication.

[5] In general, the efficiency rate of a power plant can be calculated by dividing the energy content of the electricity output (i.e., 3412 Btu per kWh) by the energy content of the fuel input. For nuclear and non-combustible renewable power, however, the energy content of the fuel input is not well defined.

IEA, OPEC, and ExxonMobil

The IEA and OPEC make the same conversion efficiency assumptions for nuclear and most renewable electricity source. Because biomass is combustible (like fossil fuels), the two organizations use a conversion efficiency of 35 percent based on an average energy content of biomass. For nuclear power, they divide nuclear electricity generation by an assumed efficiency factor of 33 percent for the steam generator of a typical nuclear power plant; this yields the amount of heat generated in a nuclear reactor, which is taken as the amount of primary nuclear energy. Unlike previous years, the IEA and OPEC take different approaches for geothermal power, which involves the conversion of steam energy into electricity. The IEA has adjusted its conversion efficiency assumption for geothermal from 15 percent to 10 percent, while OPEC has remained at 15 percent. For the remaining renewable power sources—hydro, wind, solar, and other (e.g., tidal)—the two organizations use the "captured energy" approach, which assumes the primary energy content is equal to the energy content of the produced electricity (i.e., 3,412 Btu per kWh). This approach assumes no energy is lost in the conversion process, so the efficiency is 100 percent. ExxonMobil takes the same approach for nuclear and renewables as IEA and OPEC, except that it employs a 10-40 percent conversion efficiency for biomass power. Like previous years, ExxonMobil assumes 10 percent for geothermal, matching this year's IEA assumption.

BP

BP assumes a general conversion efficiency factor of 38 percent (the average for OECD thermal power generation) for electricity generation from nuclear and renewables.[6] This assumption is based on the energy required to generate an equal amount of electricity in a fossil-fueled thermal power plant, known as the "fossil-fuel equivalency" approach.[7]

US EIA

For nuclear power, the US EIA uses the same approach as the IEA, OPEC and ExxonMobil, with a conversion efficiency of roughly 33 percent (although the detailed EIA IEO modeling assumptions vary somewhat by region and over time).[8] The US EIA also uses the same approach as the IEA, OPEC and ExxonMobil for biomass, although the assumed conversion efficiency rate is somewhat higher (36 percent, versus the IEA's assumed 35 percent).[9] For the remaining (non-combustible) renewable power sources (i.e., hydro, wind, solar, geothermal, other) the US EIA uses the "fossil-fuel equivalency" approach (like BP) with an assumed efficiency rate of 35 percent (in contrast to BP's assumption of 38 percent).

---

[6] BP, *Statistical Review of World Energy 2017*, p. 44.

[7] For an overview of alternative approaches to primary energy conversion for non-combustible sources, see IEA, "Frequently Asked Questions", accessed February 13, 2018, at: http://www.iea.org/statistics/resources/questionnaires/faq/.

[8] US EIA, *World Energy Projection System Plus Model Documentation* (Washington, DC: US EIA, 2017), accessed February 13, 2018 at: https://www.eia.gov/outlooks/ieo/weps/documentation/pdf/wepsplus2016_electricitymodule.pdf. We obtained additional model assumptions not included in the report through internal communication with US EIA.

[9] IEA, "Power Generation in the New Policies and 450 Scenarios", accessed February 13, 2018, at: https://www.iea.org/media/weowebsite/energymodel/WEO_2016_PG_Assumptions_NPSand450_Scenario.xlsb.

3.2. Adjusting Nuclear and Renewable Primary Energy for Comparability Across Outlooks

Due to these differences in assumed primary energy conversion efficiency for nuclear and renewables, adjustments must be made to compare projections across outlooks. This requires choosing a benchmark set of assumptions, for which we use the IEA's conversion efficiencies.[10] Notably, OPEC uses identical conversion efficiencies as the IEA for most fuels, with the exception of geothermal, where OPEC assumes 15 percent and the IEA 10 percent conversion efficiency. Similarly, ExxonMobil uses identical conversions to IEA, with the exception of biomass power (10-40 percent for ExxonMobil and 35 percent for the IEA).

To illustrate our harmonization process, consider primary energy consumption from nuclear sources in outlooks from BP and the IEA. BP assumes a nuclear power plant efficiency rate of 38 percent, while the IEA assumes 33 percent. Therefore, the primary nuclear energy consumption figure for BP must be multiplied by 1.15 (0.38/0.33) to be comparable to the primary nuclear energy consumption figure for the IEA. The same approach can be used for BP's outlook for renewable power and the US EIA's outlook for nuclear and renewable power.[11] All multiplicative factors for this purpose are presented later in Table 8.

4. Fuel Categorization

Another challenge arises from different groupings of energy sources across outlooks. While the categorization for coal, natural gas, and nuclear energy is generally consistent, categorizations vary for liquids, oil, biofuels, and renewable energy.

4.1. Liquids, Oil, and Biofuels Categorization

In general, the term "liquids" usually includes biofuels, whereas "oil" does not. Liquid biofuels refers mainly to bioethanol and biodiesel. The US EIA and BP include biofuels in the liquids category, along with crude oil, natural gas liquids, refined petroleum products and liquids derived from other hydrocarbon sources (e.g., gas-to-liquids and coal-to-liquids). In contrast, the IEA and ExxonMobil distinguish biofuels from "oil", with the IEA including them in the "bioenergy" category and ExxonMobil treating them as part of the "other renewables" category. For OPEC, biofuels are included in the "biomass" category in the primary energy projection table of WOO2017 (Table 2.2), but included in the liquids category in tables and figures describing liquids supply projections. This different treatment of biofuels can make cross-outlook comparison of estimates for liquids, oil, and renewables challenging.

In addition, biodiesel and bioethanol have different energy content per unit volume than petroleum-based diesel and gasoline. BP estimates that the energy content of 1 barrel of

[10] Note that, due to data limitations, we apply these assumptions on a global scale even though they may vary somewhat from region to region within outlooks.

[11] This approach requires obtaining the necessary data on the individual renewable power sources (i.e., hydro, wind, solar, geothermal, and other), in qBtu, from the US EIA. A somewhat different approach is needed to convert the US EIA figures on renewable power when using the standard published data because at this time the US EIA only publishes net electricity generation (in TWh) rather than primary energy for each renewable source. To benchmark these figures with the IEA estimates, one would convert EIA's estimates of net generation in TWh to qBtu (by multiplying by 0.003412 qBtu/TWh) and then divide by IEA's conversion efficiency assumptions for each renewable source.

ethanol is equivalent to 0.58 barrels of oil equivalent, and 1 barrel of biodiesel is equivalent to 0.86 barrels of oil.[12] To make biofuels comparable to other liquids fuels in terms of their ability to meet transport demand, biofuels are usually measured in *energy-equivalent* volumetric units (i.e., mboed), as shown in Table 1, and the mbd-to-qBtu conversion factor for liquids derived from Table 2 can apply. One should be aware that the amount of biofuels expressed in energy-equivalent terms is smaller than that in pure volumetric terms. For example, when the IEA WEO2017 estimates global biofuels production of 1.7 mbd in 2016, the volume of physical production was actually roughly 2.3 mbd.[13]

4.2. Renewables Categorization and Non-Marketed Energy

Comparisons of renewable energy consumption present another challenge, particularly the treatment of non-marketed renewable energy sources. The US EIA and BP only include marketed renewables in their projections, while the IEA, OPEC, and ExxonMobil include non-marketed energy (i.e., traditional biomass). In addition, BP excludes any renewable energy that is consumed directly in the form of heat. For example, if biomass or waste is used in a combined heat and power plant, BP only includes the power generated, not the heat. These different approaches result in large gaps in renewable energy consumption estimates among those outlooks, particularly related to traditional biomass.

In 2015, for example, non-marketed renewable energy totaled about 51 qBtu and comprised about 9 percent of global primary energy consumption and 65 to 68 percent of all renewable primary energy in the IEA, OPEC and ExxonMobil estimates (see Table 9). The scale of energy consumption from non-marketed sources can lead to misleading comparisons across outlooks in categories including renewable energy consumption, total global energy consumption, and the shares of different energy sources in total energy. For example, for 2015 this difference resulted in overall global energy consumption for the IEA, OPEC and ExxonMobil that is about 11 percent higher than US EIA and BP. Similarly, the total renewable share in IEA, OPEC and ExxonMobil estimates is 13 percent, whereas US EIA and BP estimates range from 4 to 5 percent. This is almost entirely attributable to the inclusion/exclusion of non-marketed energy, particularly non-marketed traditional biomass.

Renewables groupings also vary between outlooks, and re-categorization is necessary to enable direct comparison. Table 7 displays the different categories for which primary energy consumption of various renewable energy sources are reported in the outlooks. Because of the wide variation in the treatment of non-hydro renewables, we aggregate these sources into a single category to compare across outlooks.

As shown in Table 7, the US EIA's IEO2017 uses a single "Other" category to report primary energy consumption for all renewable power sources, including hydro, wind, solar, geothermal, biomass, and waste. To derive the US EIA's primary energy consumption estimate for each renewable source, one must convert the amount of electricity generated from that source (in TWh) to its primary energy equivalent, as described in section 3.2. Finally, as we note above, biofuels are treated differently across outlooks. To make data comparable across outlooks, we subtract biofuels from "bioenergy", "biomass" and "other renewables" for the IEA, OPEC and ExxonMobil, respectively, and add these biofuels to liquids, alongside oil.

---

[12] BP Statistical Review of World Energy 2017, p. 48.

[13] Energy equivalent volumes from IEA *World Energy Outlook 2017*, Table 4.1; physical volumes from IEA, *Oil 2017*, Annex Table 1.

TABLE 7. RENEWABLE ENERGY CATEGORIES IN DIFFERENT INTERNATIONAL ENERGY OUTLOOKS

Outlook	Renewable energy categories
BP	Hydro; Other renewables (incl. wind, geothermal, solar, and biomass/waste).
ExxonMobil	Biomass/waste (incl. non-marketed traditional biomass); Hydro; Other renewables (incl. biofuels). For electricity generation (in qBtu) renewable categories are: hydro, wind, and other renewables.
IEA	Hydro; Bioenergy (incl. non-marketed traditional biomass and biofuels); Other renewables. For electricity generation (in TWh) renewable categories are: hydro, bioenergy, wind, geothermal, solar PV, CSP, and marine.
OPEC	Hydro; Biomass (incl. non-marketed traditional biomass and biofuels); Other renewables (incl. wind, solar PV, solar thermal, and geothermal).
US EIA	Renewables included in “Other” for primary energy. For electricity generation (in TWh) renewable categories are: hydro, wind, geothermal, solar, and other (incl. biomass, waste, and tide/wave/ocean).

5. Outlook Harmonization and Historical Data Differences

In this section, we describe a method for using the information provided above to harmonize outlook estimates of world primary energy consumption. We apply this methodology to 2015 data below, but note that it could be applied to any common projection year.

First, convert all primary energy consumption data to qBtu using the standard conversion factors of 0.03968 qBtu/mtoe (for IEA and BP) and 1.976 qBtu/mboed (for OPEC).

Second, adjust BP and US EIA fossil fuel data for differences in energy content assumptions by multiplying by the energy content adjustment factors found in Table 5.

Third, for individual US EIA renewables categories, calculate estimates in qBtu by multiplying data in TWh by 0.003412 qBtu/TWh.

Fourth, use the IEA’s conversion efficiency assumptions to benchmark primary energy consumption of nuclear and renewable energy. Based on the conversion efficiency assumptions collected in Table 6, we can calculate a multiplicative factor by fuel for each outlook as shown by Table 8.

Fifth, adjust data to yield a uniform definition of liquids (incl. biofuels) and non-hydro renewables (excl. biofuels). In our approach, we subtract biofuels from renewables in the IEA and ExxonMobil outlook, and add biofuels to the liquids category. The results are then comparable to the liquids data in the US EIA and BP’s outlooks. Table 9 and Figure 1 display the results of this methodology. Notably, ExxonMobil’s data are not transformed (with the exception of moving biofuels into the “liquids” category). This is due to three factors: ExxonMobil’s energy consumption data are presented in qBtu, most of its conversion efficiency assumptions are the same as the IEA’s (our benchmark), and data for categories such as biomass conversion efficiency are insufficient for us to make detailed estimates.

TABLE 8. MULTIPLICATIVE FACTORS FOR EACH FUEL SOURCE TO CONVERT PRIMARY ENERGY IN OTHER OUTLOOKS TO IEA'S PRIMARY ENERGY CONVERSION EFFICIENCY ASSUMPTIONS

	BP	US EIA	ExxonMobil	OPEC	IEA (benchmark)
Nuclear	1.15	1	1	1	1
Hydro	0.38	0.35	1	1	1
Wind/Solar/Other	0.38	0.35	1	1	1
Geothermal	3.80	3.50	1	1.50	1
Biomass	1.09	1.03	1[2]	1	1
Non-hydro average	0.51[1]	N.A.	N.A.	N.A.	N.A.

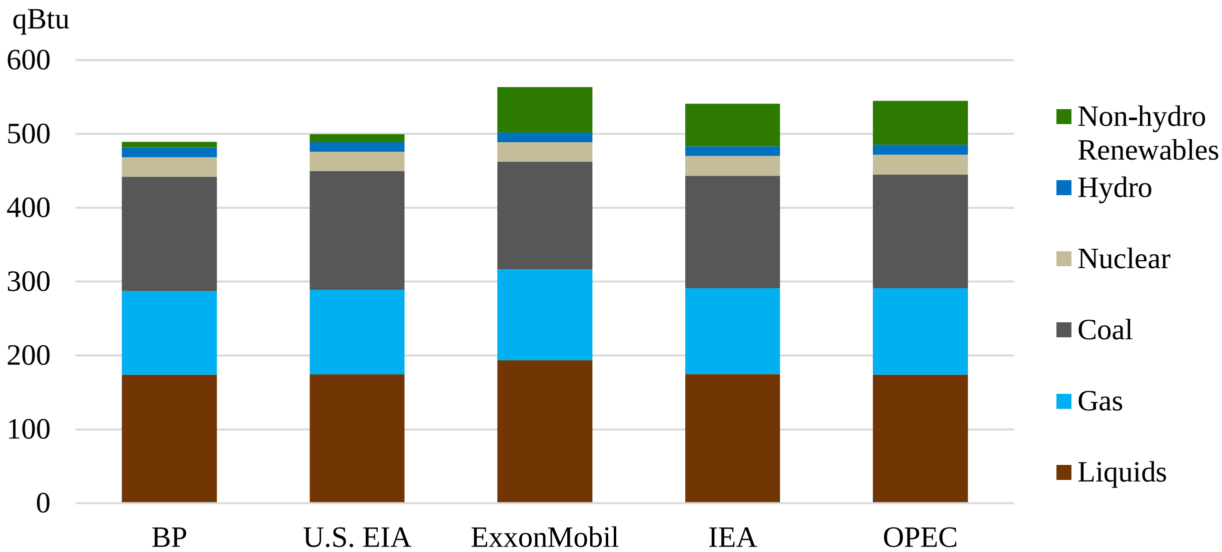
Note: N.A. indicates the conversion is not applicable. [1]This factor is found by dividing BP's assumed primary energy conversion efficiency of 38 percent by an assumed average 75 percent non-hydro conversion efficiency for IEA (which we computed based on the global share of each non-hydro power source in total non-hydro power). [2]Note that although ExxonMobil uses a range of conversion efficiencies of 10 to 40 percent for biomass power, whereas IEA uses a 35 percent, we do not adjust due to a lack of data.

TABLE 9. COMPARISON OF OUTLOOK PRIMARY ENERGY CONSUMPTION DATA IN 2015 (QBTU)

	IEA	ExxonMobil	OPEC	BP	US EIA
Liquids	175	193	174	174	175
Oil (excl. biofuels)	172	190	171	171	171
Biofuels	3.0	3.5	3.2	3.0	3.0
Gas	117	124	117	113	115
Coal	152	145	154	155	161
Nuclear	27	27	27	27	26
Hydro	13	13	13	13	13
Non-hydro renewables (incl. non-marketed)	58	61	60	-	-
Non-hydro renewables (marketed only)	-	-	-	7	11
Total renewables (incl. non-marketed)	71	75	73	-	-
Total renewables (marketed only)	-	-	-	21	24
Total energy excl. non-hydro renewables	483	502	485	482	489
Total primary energy[1]	541	564	545	489	500

Note: Totals or subtotals may not sum due to rounding. [1]IEA, ExxonMobil, and OPEC totals are larger because they include non-marketed renewables, whereas US EIA and BP do not, as described in section 4.2. Dashes indicate the data are not available from a particular source.

FIGURE 1. HARMONIZED OUTLOOK PRIMARY ENERGY CONSUMPTION IN 2015

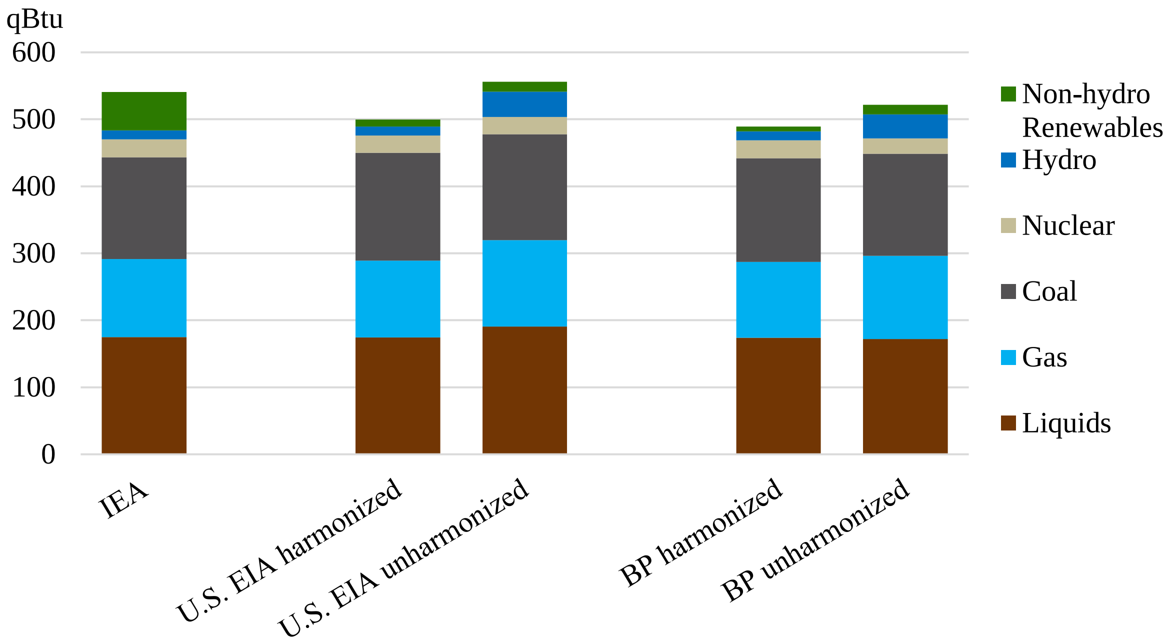


Note: IEA, ExxonMobil and OPEC include non-marketed renewables, whereas BP and the US EIA do not.

To understand the significance of the differences arising from this standardization process, it is useful to examine how the data appear in both harmonized and unharmonized form. Because the most substantial adjustments occur for BP and the US EIA, Figure 2 presents pre- and post-harmonization data for global primary energy consumption in 2015. The figure highlights the large differences arising from different assumptions across these outlooks, with US EIA data adjusted by 56 qBtu and BP data adjusted by 32 qBtu. For reference, total primary energy consumption in Central and South America in 2015 was roughly 30 qBtu.

Although the harmonization process adjusts for a significant amount of divergence, it does not eliminate all discrepancies in historical consumption data. In particular, the divergence in fossil fuels consumption estimates is not negligible for some outlooks. For example, ExxonMobil has substantially higher estimates for oil and natural gas consumption, and a significantly lower estimate for coal consumption than the IEA. It is our understanding from experts at ExxonMobil that the differences exist for three primary reasons: (1) ExxonMobil includes flared gas in natural gas totals, whereas IEA omits flared gas; (2) ExxonMobil includes synthetic gas from coal in natural gas totals, whereas IEA includes it in coal totals; and (3) ExxonMobil and IEA may use different energy content assumptions for liquids, which we cannot control for due to a lack of data. Other differences include the US EIA's relatively high estimate for coal and BP's lower estimate for natural gas. For renewables, ExxonMobil and OPEC show high estimates for non-hydro renewables, although the differences are not large in absolute terms.

FIGURE 2. HARMONIZED AND UNHARMONIZED PRIMARY ENERGY CONSUMPTION IN 2015



Due primarily to their exclusion of non-marketed renewables, BP and the US EIA have far lower total consumption estimates than the IEA, OPEC and ExxonMobil. After accounting for the exclusion of non-marketed renewables, the divergence from the IEA across outlooks in total primary energy consumption is 1.2 percent or less for OPEC, BP, and the US EIA. The difference between ExxonMobil and the IEA is larger, totaling 3.9 percent when excluding non-marketed renewables, and 4.2 percent for total primary energy. These discrepancies may be attributable to limitations in our conversion process, unidentified differences in definitions of energy categories, or other factors such as variances in original consumption data used by each organization Table 10 shows the percentage differences in 2015 primary energy consumption data relative to the IEA.

To understand whether the differences shown in Table 10 are attributable to inadequacies in our conversion methodology or to discrepancies in historical statistics, we also collected energy consumption data in physical units from these organizations, presented in Table 11. These data are either drawn directly from the outlooks or from other publications or databases from the same organizations. ExxonMobil and OPEC are not included in Table 11 because they do not present data in fuel-specific units.

TABLE 10. 2015 PRIMARY ENERGY CONSUMPTION DATA RELATIVE TO IEA

	BP/IEA	ExxonMobil/IEA	EIA/IEA	OPEC/IEA
Liquids	-0.4%	10.7%	-0.1%	-0.3%
Oil (excl. biofuels)	-0.4%	10.6%	-0.1%	-0.5%
Biofuels	-0.9%	15.4%	1.0%	5.9%
Gas	-2.9%	6.0%	-1.7%	0.3%
Coal	1.7%	-4.5%	5.6%	1.2%
Nuclear	0.1%	-0.3%	-2.3%	0.2%
Hydro	1.5%	-0.2%	-1.0%	1.3%
Non-hydro renewables (incl. non-marketed)	-	6.9%	-	3.7%
Non-hydro renewables (marketed only)	-	-	-	-
Total renewables (incl. non-marketed)	-	5.5%	-	3.2%
Total renewables (marketed only)	-	-	-	-
Total energy excl. non-hydro renewables	-0.3%	3.9%	1.2%	0.4%
Total primary energy	-9.5%	4.2%	-7.6%	0.7%

Note: Dashes indicate the data are not available from a particular source.

TABLE 11. FUEL-BY-FUEL COMPARISON OF ENERGY CONSUMPTION DATA IN 2015 (IN FUEL-SPECIFIC UNITS)

	BP[1]	US EIA[2]	IEA
Liquids (mbd)	95	95	94[3]
Oil (excl. biofuels) (mbd)	94	94	93[3]
Biofuels (mboed)	1.5	1.5	1.6[3]
Gas (tcf)	123	124	125[4]
Coal (mt)	-	-	7,710[5]
Nuclear (TWh)	2,575	2,510	2,571[3]
Hydro (TWh)	3,903	3,850	3,888[3]

Note: Units are per year unless otherwise noted. [1]BP, *"BP Statistical Review of World Energy June 2017"* (London: BP, 2017); [2]US EIA, *"International Energy Outlook 2017"* (Washington D.C: US EIA, 2017); [3]IEA, "World Energy Outlook 2017" (Paris: OECD/IEA, 2017); [4]IEA, *Natural Gas Information 2017* (Paris: OECD/IEA, 2017). [5]IEA, *Coal Information 2017* (Paris: OECD/IEA, 2017). Dashes indicate the data are not available from a particular source.

Table 12 presents percentage differences relative to IEA data based on the fuel-specific data shown in Table 11. This table illustrates the scale of discrepancies in Table 10 attributable to fuel-specific historical data, as opposed to other uncontrolled-for differences in energy content or energy conversion.

Subtracting the results in Table 12 from Table 10 leads us to Table 13, which shows the gap in primary energy consumption remaining after controlling for differences in historical data and conversion efficiency assumptions. Note that the remaining gap is quite small for most energy sources. For biofuels the larger difference is easily attributable to rounding errors due to the relatively small absolute magnitude of biofuels. There is also a greater than one percent difference in oil, and a modest difference for natural gas. It is not clear how much of these historical data differences across institutions persist in their future projections, which are built in part on a historical baseline.

TABLE 12. 2015 HISTORICAL DATA IN FUEL-SPECIFIC UNITS RELATIVE TO IEA

	BP/IEA	US EIA/IEA
Liquids	0.8%	1.1%
Oil (excl. biofuels)	1.0%	1.2%
Biofuels	-7.7%	-5.4%
Gas	-2.1%	-1.1%
Coal	-	-
Nuclear	0.2%	-2.4%
Hydro	0.4%	-1.0%

Note: Dashes indicate the data are not available from a particular source.

TABLE 13. REMAINING DIFFERENCES IN 2015 ENERGY CONSUMPTION AFTER CONTROLLING FOR DIFFERENCES IN HISTORICAL DATA AND PRIMARY ENERGY CONVERSION EFFICIENCY ASSUMPTIONS

	BP/IEA	US EIA/IEA
Liquids	-1.2%	-1.2%
Oil (excl. biofuels)	-1.4%	-1.4%
Biofuels	6.8%	6.4%
Gas	-0.8%	-0.6%
Coal	-	-
Nuclear	0.0%	0.1%
Hydro	1.1%	0.0%

Note: Dashes indicate the data are not available from a particular source.

6. Country Details and Groupings Across Outlooks

In addition to comparing energy consumption at a global level, insights can be gleaned from regional comparisons across outlooks. A challenge that arises, however, is that outlooks differ in the categorization of countries into regional groupings. Table 14 shows how outlooks vary in their choices for such regional groupings.

All outlooks present data for the Organization of Economic Cooperation and Development (OECD) and non-OECD nations. For other regional categories, however, groupings vary across energy outlooks. We examined the regional definitions for each outlook, and found that regional data can be regrouped into five broad geographic areas: Americas, Europe, Asia & Oceania, Africa and Middle East. While the definitions for Africa and Middle East are fairly consistent across outlooks, further harmonization is necessary to create comparable groupings for the Americas, Europe, and Asia & Oceania. The US EIA and OPEC distinguish OECD nations within geographic areas, while BP, ExxonMobil, and—as of 2017—the IEA do not distinguish between OECD nations and non-OECD nations in each geographic region. Note that OPEC's WOO has a specific regional category for OPEC member countries and excludes these countries from their geographic areas. As a result, OPEC's data for Latin America, Middle East and Africa are not typically comparable with other outlooks. However, OPEC has disaggregated its member countries into geographical regions in OPEC long-term liquids demand projections, allowing for more direct comparison with the IEA. Below we summarize variation between the regional classification systems of BP, ExxonMobil, the US EIA, and the IEA.

Americas

The IEA, BP, ExxonMobil divide the continent into “North America” and “Central/South America” (or “Latin America”). The difference between “North America” and “OECD Americas” (used by OPEC and the US EIA) is that the former excludes Chile and the latter includes it. “OECD Americas” contains four countries: the United States, Canada, Mexico and Chile.

Europe

Outlooks use a variety of terms to describe modestly different geographical groupings across Europe. Most outlooks include Russia and its neighboring states into groups such as the Commonwealth of Independent States (BP), Russia/Caspian (ExxonMobil), and Eurasia (IEA and OPEC), while the US EIA groups together Non-OECD Europe and Eurasia. For continental Europe, BP, ExxonMobil, and the IEA include a comprehensive “Europe” category for all European nations, while BP and the IEA also include a category for the European Union. The US EIA and OPEC group include a “OECD Europe” category.

Asia and Oceania

BP, ExxonMobil, and the IEA include all Asian and Oceania countries in one “Asia/Pacific” category, including both OECD and Non-OECD nations. BP and the IEA also respectively include “Other Emerging Asia” and “Southeast Asia” categories. The US EIA and OPEC group Asian nations according to OECD status.

Specific Countries

At the national level, only three countries are presented in all five outlooks: the United States, China, and India. Russia is detailed in four outlooks, while Brazil is included in three. Japan and Canada are presented individually in two outlooks.

TABLE 14. REGIONAL GROUPINGS AND COUNTRY DETAIL ACROSS OUTLOOKS

Region	BP	ExxonMobil	IEA	US EIA	OPEC
OECD / Non-OECD	OECD Non-OECD	OECD Non-OECD	OECD Non-OECD	OECD Non-OECD	OECD
Americas	N. America S. and C. America[1]	N. America Latin America	N. America C. and S. America	OECD Americas Non-OECD Americas	OECD America Latin America
Europe	Europe	Europe	Europe	OECD Europe[3]	OECD Europe
	European Union	Russia/Caspian	European Union	Non-OECD Europe and Eurasia	Eurasia
	Commonwealth of Independent States[2]		Eurasia		Other Eurasia
Asia and Oceania	Asia Pacific Other Emerging Asia	Asia/Pacific	Asia Pacific Southeast Asia	OECD Asia Non-OECD Asia	OECD Asia Oceania Other Asia
Africa	Africa	Africa	Africa	Africa	Middle East and Africa
Middle East	Middle East	Middle East	Middle East	Middle East	
					OPEC nations

Country Detail	BP	ExxonMobil	IEA	US EIA	OPEC
	United States[1]	United States	United States	United States	United States
	China	China	China[4]	China	China
	India	India	India	India	India
	Russia	Russia/Caspian	Russia	Russia	Russia
	Brazil		Brazil	Brazil	
			Japan	Japan	
			South Africa		
				Mexico and Chile	Mexico and Chile
				Australia and New Zealand	Australia
				Canada	Canada
				South Korea	

Notes: [1]BP excludes Puerto Rico from the US and includes it in Central/S. America. [2]Data for the Former Soviet Union are only provided for total consumption and production (with no breakdown by fuel or sector). [3]The US EIA includes Israel in OECD Europe for statistical purpose. [4]The IEA includes Hong Kong in China, while the other outlooks separately count Hong Kong.

7. Conclusion

Energy industry experts, policymakers, and a range of other stakeholders make decisions and plan for the future based on the information and analysis provided by energy outlooks produced by a number of government and private institutions. However, outlooks vary in a number of important methodological aspects, and comparing between outlooks is not straightforward. Without a way to clearly compare one outlook to the next, decision-makers may not understand the range of possibilities envisioned by different short-, medium- and long-term projections, or the assumptions that underpin those projections. This paper lays out a method for more accurate comparison of several major long-term energy outlooks, not to bury important differences in views about the future, but rather to control for varied conventions and historical data that mask true differences between the outlooks.

We find that there are important differences across outlooks in the assumed energy content of fossil fuels, the assumed efficiency of nuclear and renewable electricity conversion from primary energy, the categorization of biofuels, and the inclusion (or exclusion) of traditional biomass. The exclusion of non-marketed traditional biomass from US EIA and BP estimates, for instance, yields estimates of global primary energy consumption that are 8 to 13 percent lower than for the IEA, OPEC and ExxonMobil, which include these sources. Assumptions about energy content of fossil fuels can vary by more than 10 percent in the data examined here, requiring significant downward adjustment of primary energy consumption estimates for oil and natural gas to make BP and US EIA data comparable to IEA, OPEC, and ExxonMobil. Conventions about primary energy conversion of renewables can alter primary energy estimates for these sources ranging from a 65 percent decrease to a 280 percent increase for particular power sources.

After harmonizing these conventions to the extent practicable, we find that at a global level ExxonMobil baseline estimates for liquids and—to a lesser extent—natural gas are substantially higher than other outlooks, and its estimate for coal is atypically low: the differences are primarily due to evolving historical data, the inclusion of flared gas and synthetic gas from coal in natural gas totals, and different energy content assumptions for liquids. The US EIA's estimate for coal is relatively high, whereas BP's estimate for natural gas is on the low side. ExxonMobil's estimate for non-hydro renewables is also atypically high, and the US EIA's estimate for nuclear is atypically low, although these differences are not large in absolute terms. We also find that there are differences of up to four percent in historical data used in these outlooks, and that after we take additional account of these differences in historical data, our harmonization methodology brings estimates within 1.5 percent or less of one another for most fuels in the 2015 benchmark year we examine.

We conclude that undertaking a harmonization process like we describe is necessary in order to provide a more accurate benchmark for comparing results across outlooks, particularly when examining estimates of primary energy consumption (e.g., qBtu, mtoe). Estimates measured in fuel-specific units (e.g., mbd, tcf, TWh) are less subject to these concerns, but are still subject to historical data differences. Our identification of important sources of divergence in convention and historical data also highlights areas where institutions that produce outlooks may find opportunities for the identification of common assumptions and data improvement, to the benefit of energy dialogue and energy decision making worldwide

Glossary

Abbreviations and Acronyms

IEA	International Energy Agency
US EIA	US Energy Information Administration
OPEC	Organization of the Petroleum Exporting Countries
WEO	World Energy Outlook (IEA)
IEO	International Energy Outlook (US EIA)
GDP	Gross Domestic Product

Units

qBtu	quadrillion British thermal units
mtoe	million metric tonnes of oil equivalent
mbd	million barrels per day
mboed	million barrels of oil equivalent per day
bcfd	billion cubic feet per day
tcf	trillion cubic feet
bcm	billion cubic meters
mt	million metric tonnes of coal
TWh	terawatt-hours