Incorporating International Petroleum Reserves and Resource Estimates into Projections of Production

U.S. Energy Information Administration

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This paper is released to encourage discussion and critical comment. The analysis and conclusions expressed here are those of the authors and not necessarily those of the U. S. Energy Information Administration.

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Introduction

The Energy Information Administration (EIA) receives periodic requests for our assessment of international oil reserves estimates and explanations of how our long-term oil production projections link to them. EIA recognizes the need for reliable international reserves estimates that reflect a uniform application of consistent standards for reserves reporting. Unfortunately, the diversity and complexity of the existing reserves estimates and varied application of reporting standards across countries present significant barriers to meaningful representation of international reserves estimates. Because existing reserves estimates and their associated terminology can be quite confusing, EIA strives to ensure that its long-term oil production projections are supported by careful assessment of the best reserves – and resource – information available to us.

Analyses of specific oil field production profiles and decline rates – and related graphical representations of future production from different distinct resource categories – have been developed by other organizations using energy data and analytical resources of the company IHS. EIA periodically purchases access to the IHS database to update our near-term projections and resource assumptions, but budget limitations preclude buying continuous access and we do not currently have an active subscription. Given the 25-year horizon of EIA's oil production and consumption scenarios, the reserves data and projections available from such sources must also be supplemented with estimates of geologically expected resources that are not directly associated with discovered fields. Provision must also be made for future technological advancement leading to enhanced resource accessibility.

The following discussion provides information on our assessment methodology, comparable long-term outlooks' approaches to resource uncertainties, production decline rates, resource terminology, and the available estimates.

EIA's Assessment Approach

The future of world oil supply and demand is inherently uncertain. Recognizing that a multitude of different oil market conditions are possible in both the near and distant future, EIA develops a variety of projection scenarios covering a wide range of possible future market balances and supply and demand environments. While we don't label any one of our cases as "most likely" or "most accurate," we do ensure that each case is internally consistent and supported by oil resource estimates. EIA's sources and use of oil resource estimates are similar to that of several well-respected and comparable efforts,

including long-term projections developed by IHS Cambridge Energy Research Associates (CERA) and the International Energy Agency (IEA).

EIA's, CERA's and IEA's projections all recognize that some resources that have yet to be discovered and/or classified as proved reserves will be developed and brought online to satisfy a significant portion of future oil demand, especially during the latter part of a 20- to 25-year projection period. Existing producing fields and known projects under development together provide the inventory of productive capacity from which world oil markets will be primarily supplied in the near term. Known projects alone provide a measure of current development activity and investment by producers. Long-term projections incorporate the understanding that producers will continue to identify and develop as-yet unknown fields and pursue additions to reserves through exploration of new basins and types of resources, extensions of existing fields, and the application of improved or new technology to increase recovery factors in mature areas.

EIA reviews known projects and their completion status to develop a fairly detailed view of the production capacity that will be available to supply oil over the near-term – roughly the next three to five years. Major upstream oil investment projects typically take several years to plan and execute, with a gestation period ranging from three years to ten years or more. However, we do not limit our projections of oil supply over a longer period of time to currently known resources or projects, since future projects that are as yet unknown will also contribute to supply. Production projections over a longer time interval must be based on an assessment of estimated resources, field production profiles and declines, supply economics, anticipated product demand, and investment conditions in each country where oil resources are located. The methodology that underlies our long-term international liquids production projections is summarized in the section entitled "Liquids production modeling approach" on pages 27-29 of the *International Energy Outlook 2010* (*IEO2010*) (see the attached documents at the end of this discussion paper).

At EIA's April 2009 annual energy conference, EIA hosted a roundtable discussion of future oil production focused on "known but yet to be developed" and "yet to be found" resources. One of the charts presented (**Figure 1**) showed future production from existing projects and known projects under development, which together must be relied upon for most near-term production. While the chart deliberately omitted EIA's projections of additional projects and investments needed to meet demand in each of our projection cases over a longer time horizon, in order to allow the conference panel to openly discuss multiple scenarios and possibilities, this should not be misconstrued as suggesting that the consumption path depicted in the chart is infeasible or unsupported by economic resources. The white area labeled "Unidentified Projects" (located between future production from existing and identified supply projects and the projected consumption of liquids) reflects resources converted to production in EIA's *Annual Energy*

Outlook 2009 (*AEO2009*) Reference case that are referred to as "known but yet to be developed" and "yet to be found" resources in the IEA's "*World Energy Outlook 2010 (WEO2010)"* (**Figure 2**) and as "fields under appraisal" and "yet to find resources" in CERA's long-term outlook.

Focusing on the first three to five years of the "World's Liquid Fuel Supply" graph in "Announced Projects Typically Meet Majority of Production Replacement and Growth Needs During Next Three Years" (**Figure 3**), the yellow and red areas represent expected future production volumes derived from projects that are known to be planned or under development. The known projects do not include all planned projects because many mid-size and small projects are not mentioned in the news or trade press. The gaps between the shaded areas and the three AEO2009 price case demand lines represent the volumes of oil production that would need to be provided by presently unknown, perhaps presently unplanned, projects or fields yet to be found. Over time the gaps are typically filled in as additional information becomes public. Sometimes a gap is even temporarily "over filled" as production exceeds consumption and the resulting excess production is put into storage. The gap does not represent an expected production shortfall, rather it logically reflects lack of firm information about the future because investment decisions are less certain and more flexible the further out in the future they are.

In the *IEO2010*, "World Liquids Production" (**Figure 4**) depicts the source regions of liquids production that we expect will satisfy demand in the Reference Case. Because EIA does not currently have an active subscription to the proprietary IHS database of supply projects, an update of the "World's Liquid Fuels Supply" graphic has not been issued. "Comparing the recent world outlooks from EIA (IEO) and IEA (WEO)" (**Figure 5**) provides an apples-to-apples comparison of three EIA and three IEA scenarios. EIA is precluded from disseminating the relevant CERA projections[1] under the terms of its contract with CERA.

Rate of Decline of Existing Production

The rate at which existing production is expected to decline is a very significant factor in assessing what volumes of resources will need to be developed in the future to meet projected liquids demand. At any given time some fields are just beginning to produce, some are maintaining their production rates, and others are declining. EIA used a 4.5 percent global annual average decline rate for all fields in the *AEO2009*. This rate was estimated by CERA based on its assessment of IHS data for the production profiles of over

[1] IHS CERA, Private Report "Pausing for Breath: Liquids Production Capacity to 2030" Parts 1 and 2, published respectively in October and November 2009, and Special Report "The Future of Global Oil Supply: Understanding the Building Blocks" published in November 2009.

800 of the worlds' oil fields.[2] In ongoing EIA modeling efforts existing projects decline at a rate that is specific to each project.

The need for new projects and their ability to meet demand at a given price are heavily determined by the decline in existing production. As CERA's research indicated, a field's production profile and decline rate are shaped by a variety of factors including "the field size, [physical characteristics of the] reservoir, technology, investment patterns, and government decisions." A change in any one of these factors could change the production profile designed by the company or country governing the field's development. For example, a field's decline can be slowed by application of new production technology, the discovery and development of a new reservoir in the field, or a change in the market that makes further investment in the field economically viable.

Reservoir characteristics are much less likely to drive rapid or dramatic changes in a given field's expected production and decline rate profiles than are so-called "above ground" factors, ranging from economics to technology to politics. Due to the significance these factors have for the world's future oil supply and their exposure to unanticipated changes, no responsible analyst would claim to precisely predict future global oil production. EIA's assessment of future production possibilities are therefore based on scenarios structured on a specified set of aboveground factors from which EIA can develop projections of what resources might be economically developed in a given timeframe, taking account of timelines for development of oil projects as well as supporting infrastructure (e.g. pipeline systems and terminals). Taken together, the scenarios depict a range (although not an all-inclusive one) of possible future world oil markets and country production profiles.

Estimates of Resources and Reserves

EIA's country-level resource estimates are identical across all scenarios, which are presented as alternative oil price cases with differing resultant demand paths and supply mixes. All of the supply mixes are based on EIA's published proved reserves estimates and the U.S. Geological Survey's (USGS) World Petroleum Assessment 2000 estimate of both undiscovered conventional resources and the growth of known conventional resources.

Unfortunately, the estimation and reporting of resources and reserves (which are a small subset of resources; see the McKelvey classification scheme of **Figure 6**) is far from standardized or transparent internationally. Estimates of resources and reserves are functions of the knowledge of physical quantities originally in place, the availability of technology to convert the in-place resources to producible reserves, the economic

[2] CERA's research and findings were published in "Finding the Critical Numbers" in September 2007.

feasibility of producing them, and the uncertainties associated with these factors. All of these factors can and do change over time. Unfortunately, "resources" and "reserves" are often ambiguously or incorrectly used terms. The Society of Petroleum Engineers (SPE) (see attached document SPE 2005, *Comparison of Selected Reserves and Resource Classifications and Associated Definitions*) and Securities and Exchange Commission (SEC) convention for describing confidence in reserves estimates (not yet used internationally by all estimators) is as follows:

- "proved" reserves have the highest probability of eventual production (when properly estimated, a recovery probability of 90 percent or more, often referred to as a P90 or a "1P" estimate)
- "probable" reserves are the next most likely to be producible
- "possible" reserves have the lowest probability of eventual production
- the sum of "proved" + "probable" reserves yields a median, P50 or "2P" estimate of reserves with a recovery probability of 50 percent
- the sum of "proved" + "probable" + "possible" reserves yields a higher volume P10 or "3P" estimate with a recovery probability of 10 percent or less.

It is important to remember that the three reserves classes – proved, probable and possible – encompass "discovered commercial" resources. Reserves are a subset of resources.

> "All systems define major resource categories that can be mapped directly to the SPE categories: undiscovered (prospective resources), discovered unrecoverable, discovered sub-commercial (contingent resources) and discovered commercial (reserves)." – SPE 2005, *Comparison of Selected Reserves and Resource Classifications and Associated Definitions*, page 3. (see attached document)

The P90, P50, and P10 terminology applies to estimated volumes at three particular confidence levels distributed along a continuous probability distribution of estimated volumes, whereas the 1P, 2P 3P notation is typically used in business settings when discussing discrete estimates of reserves irrespective of how they were estimated. The McKelvey box diagram developed in the early 1970's stylistically captures both the geologic certainty and the economic feasibility of oil resources and reserves (**Figure 6**).

EIA is able to construct a rather thorough and well-informed assessment of the United States' oil resources owing to the resource assessment efforts of the USGS and the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), as well as EIA's own estimation of United States proved reserves. That, however, is not the case outside of U.S. borders. With no universally applicable reporting requirements, the measurement and classification of oil reserves and resources still varies by country, and not all of the world's reserves are being developed by the publicly-traded companies that

are held to SEC reporting standards. As noted in IEA's *World Energy Outlook 2008* (*WEO2008*) "there is no internationally agreed benchmark or legal standard as to how much proof is needed to demonstrate the existence of a discovery, nor about the assumptions to be used to determine whether discovered oil can be produced profitably." IEA also noted that progress on developing a set of universal rules is hampered by the different existing standards in each country.

The attached SPE paper addresses the variety of reporting standards internationally as well as SPE's efforts to harmonize and cross reference these standards. The National Petroleum Council's (NPC) 2007 report "Facing the Hard Truths about Energy" (see "Helpful Links" below) provides a further discussion of the variation in reserves reporting standards across countries. While EIA supports efforts to develop a universal system and standardized regulations for reserves reporting, we do not have the resources, access, or mandate to independently verify the resources or reserves reported by other nations. To put the level of effort in context, EIA has about 10 employees dedicated to gathering and analyzing oil and natural gas reserves and resources for the United States--where EIA has authority to require reporting of proved reserves and publicly traded companies are subject to SEC rules. In support of previous research on field reserves growth and recovery, EIA has in the past used IHS's EDIN database on oil and gas fields' reserves reporting history. This database is the only source of information of which we are aware that provides proved, probable, and possible reserves estimates by field for countries outside the United States.

As of 2007, only seven percent of the world's proved reserves were owned by firms subject to SEC reporting requirements, and well over ninety percent of the world's proved reserves were held by countries that limit or prohibit others' access to their resources. That, in turn, impacts the reporting and validation of reserves estimates. Sovereignty issues and secrecy surrounding reserves estimates severely limit the sources available for estimate verification. As more attention is given to the reliability and accuracy of international reserves estimates, it is possible other nations will eventually be more willing to share reserves data with EIA, USGS, and SPE through the Joint Oil Data Initiative (JODI)[3].

Even the IHS database of historic and current reserves estimates is heavily populated by estimates either taken directly from or derived from government sources (about one-sixth and two-thirds of the estimates, respectively). The IHS database also provides some estimates from field operators (about one-eighth of the estimates) and from

[3] JODI is an international effort to improve the availability and reliability of monthly oil production and consumption data. It was conceived by Ministers at the seventh International Energy Forum (April 2001) and launched by six international organizations – Asia-Pacific Economic Cooperation (APEC), Eurostat, IEA, Latin American Energy Organization (OLADE), Organization of the Petroleum Exporting Countries (OPEC) and United Nations Statistics Division (UNSD) – and their member countries.

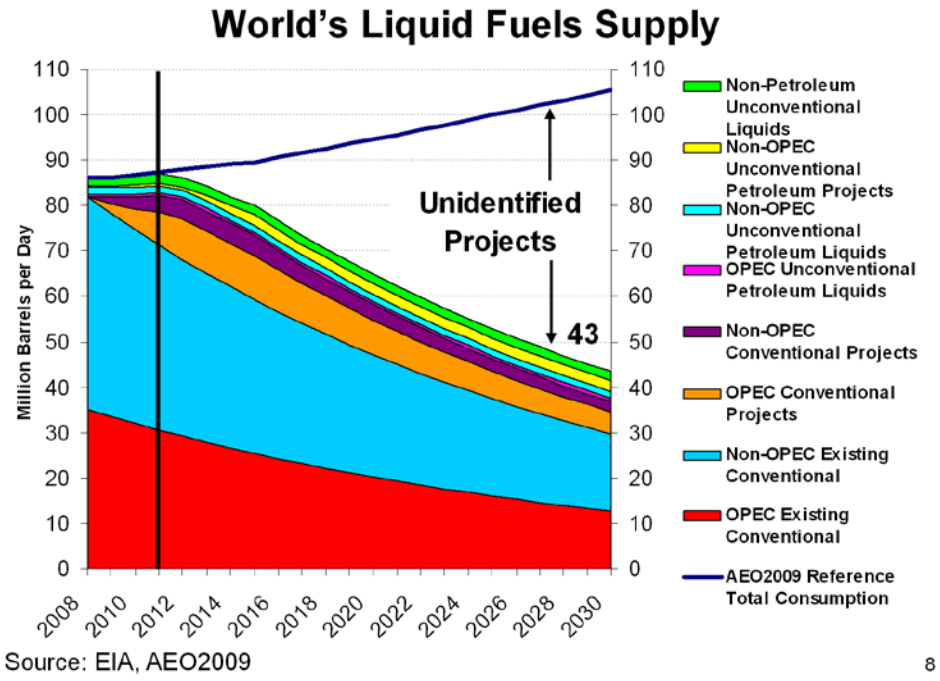
miscellaneous sources (less than one-tenth of the estimates). While the IHS database does not necessarily contain estimates for every field in every country, it does generally have enough field-level information to provide insight on an individual country's reserves estimates.

Notwithstanding its limitations, the USGS relied on the IHS database to support its World Petroleum Assessment 2000 (see "Estimates of Ultimately Recoverable Resources from Conventional Global Oil and Natural Gas Liquids", **Figure 7**). EIA has also used the IHS database to research probable reserves and initial-in-place (IIP) estimates in the past.

IIP is the total of all expected recoverable and unrecoverable resources, sometimes also referred to as original-oil-in-place (OOIP). Current estimates of global IIP range from 14 to 24 trillion barrels. Comparatively, the world has produced about 1.1 trillion barrels of petroleum as of 2010. The smaller IIP estimates often do not include all types of petroleum; for example, source rocks and oil shales are sometimes omitted. The most thoroughly documented IIP estimates point to over 20 trillion barrels of oil. The table of IIP estimates provided (**Figure 8**) is for a base case scenario with the data divided into six categories of petroleum and four regions. What portion of the remaining 14 to 24 trillion barrels of IIP petroleum will be produced in the future will depend on technology, economics and policy.

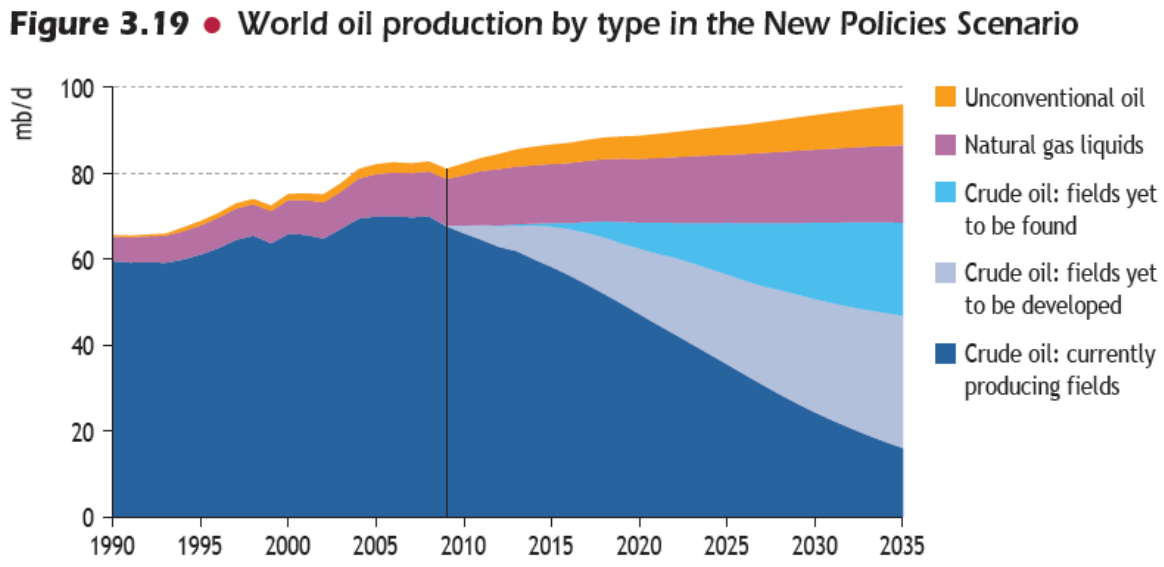
Cited Figures

Figure 1



(Source: EIA Energy Conference, April 7, 2009)

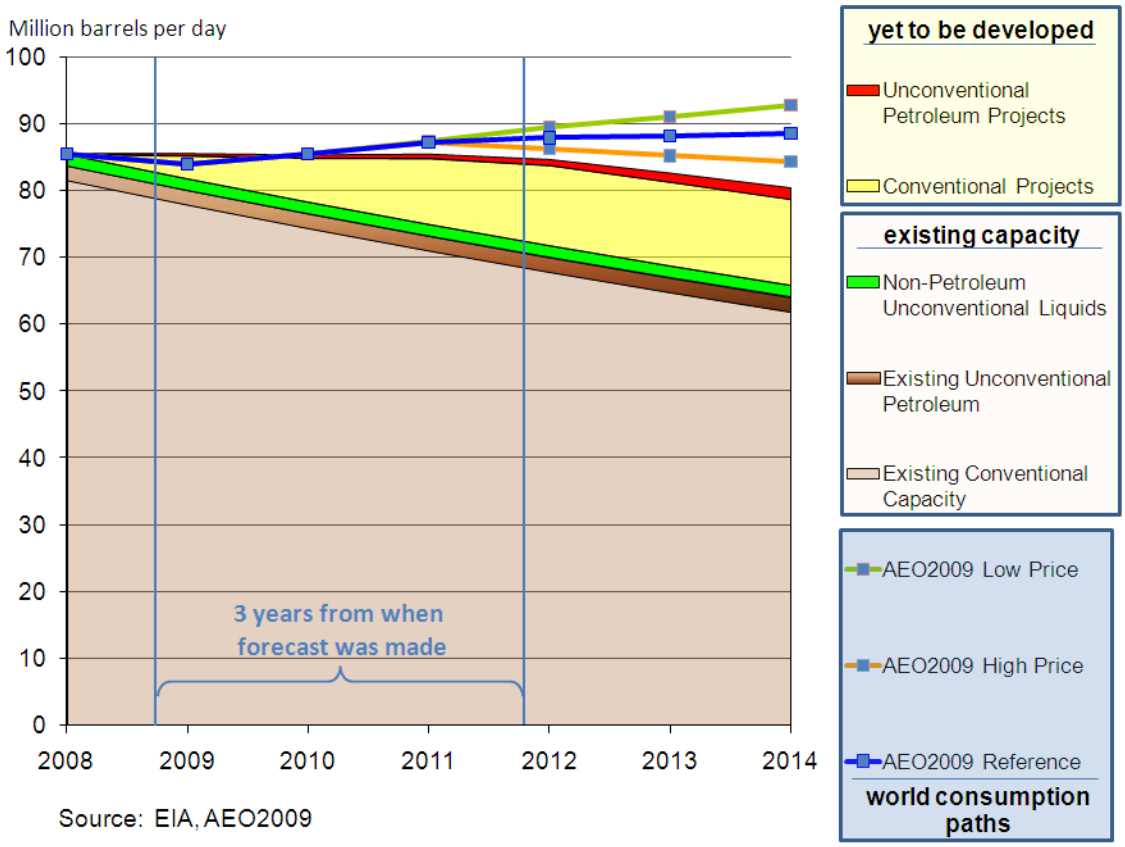
Figure 2



(Source: IEA World Energy Outlook 2010, page 122, Figure 3.19)

Figure3

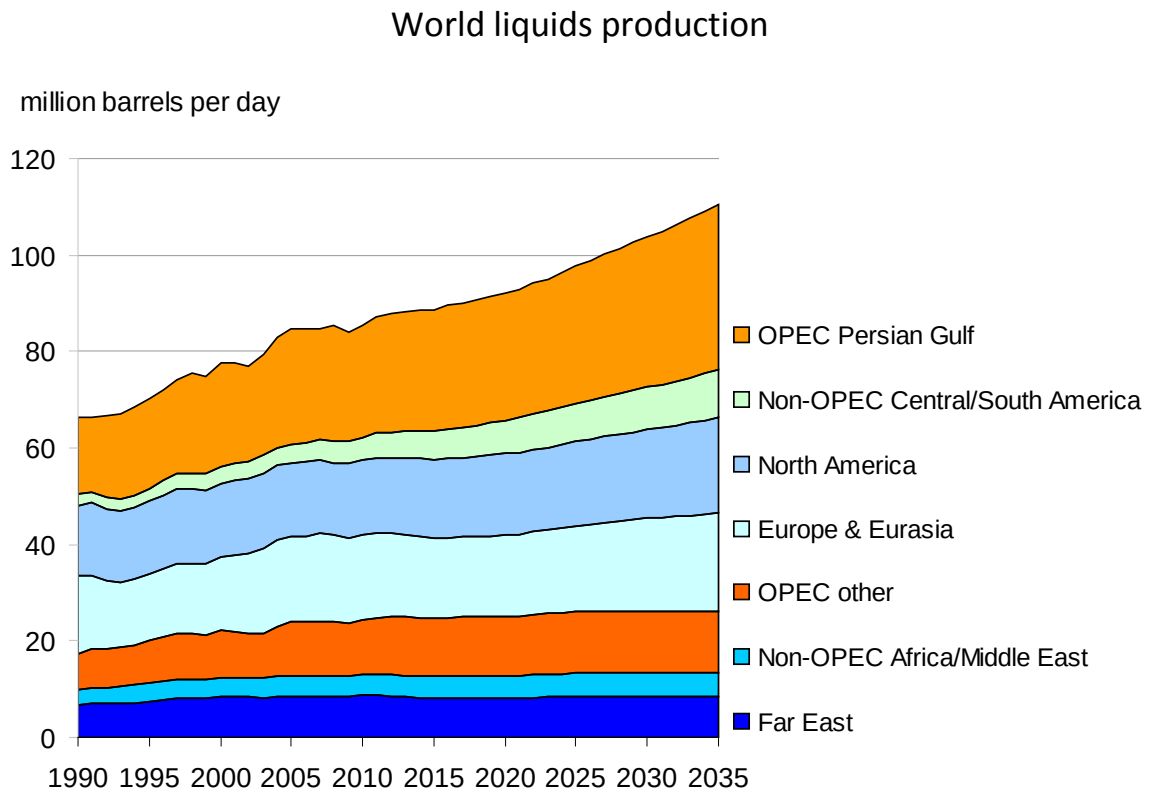
Announced projects (yellow and red areas) typically meet majority of production replacement and growth needs during next three years



Notes:

- This analysis was done in late 2008 / early 2009 for the AEO2009. It shows that as of October 1, 2008 announced projects were expected to meet almost all replacement and new production volumes for the following three years through September 2011.
- Brown areas show petroleum production capacity declining at 4.5 percent
- Green area is non petroleum production (not changing here)
- **YELLOW** area shows announced projects as scheduled to come online
- **RED** area is for unconventional productions (oil sands mainly)
- LINES = world demand trajectories
- Area between RED area and the three AEO2009 world consumption paths include smaller projects not tracked (because of limited data) and projects not yet identified.

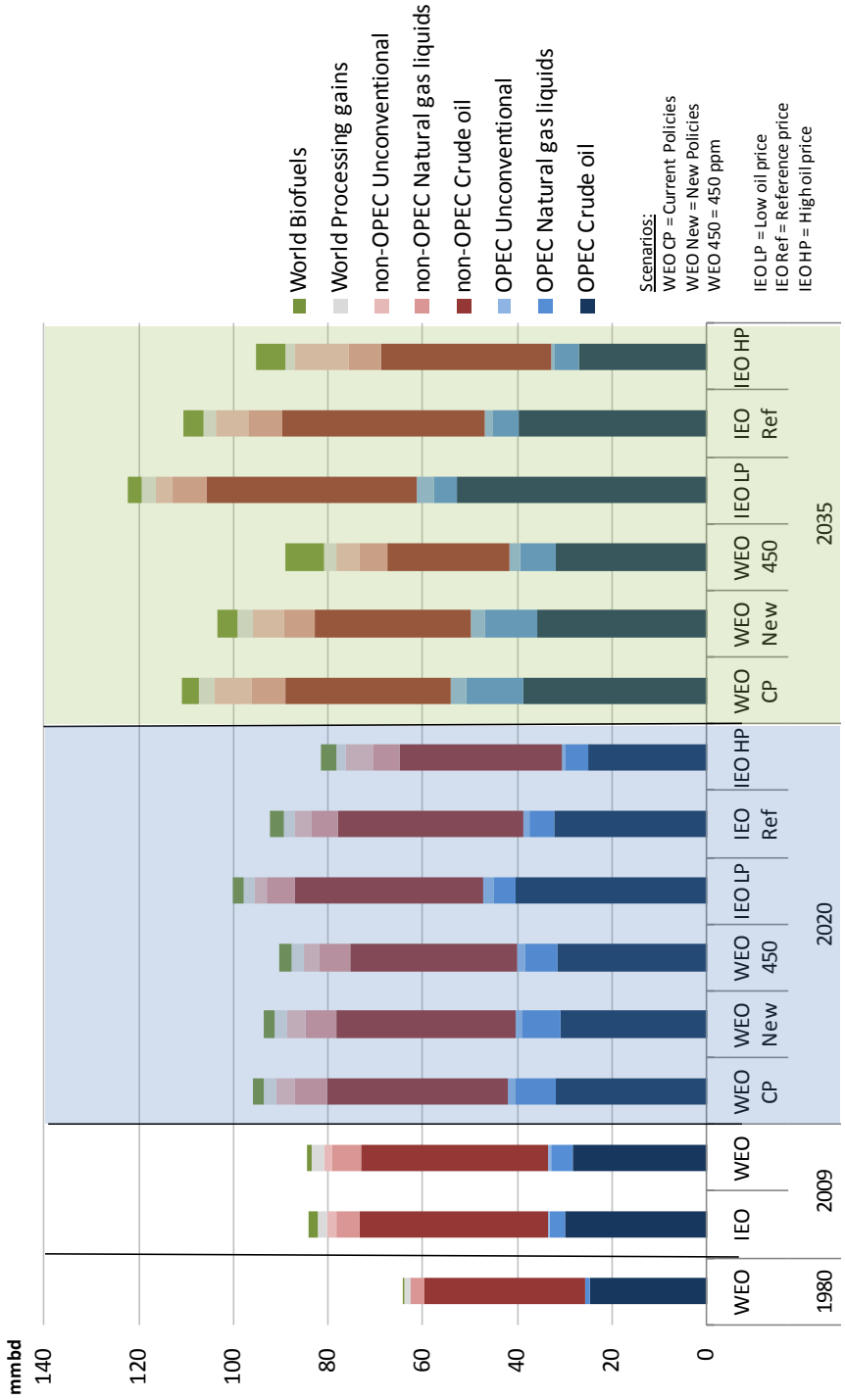
Figure 4



Source: EIA IEO 2010 (July 2010)

Figure 5

Comparing the recent world outlooks from EIA (IEO) and IEA (WEO)



Sources: WEO2010 table 3.3 and IEO2010

Figure 6

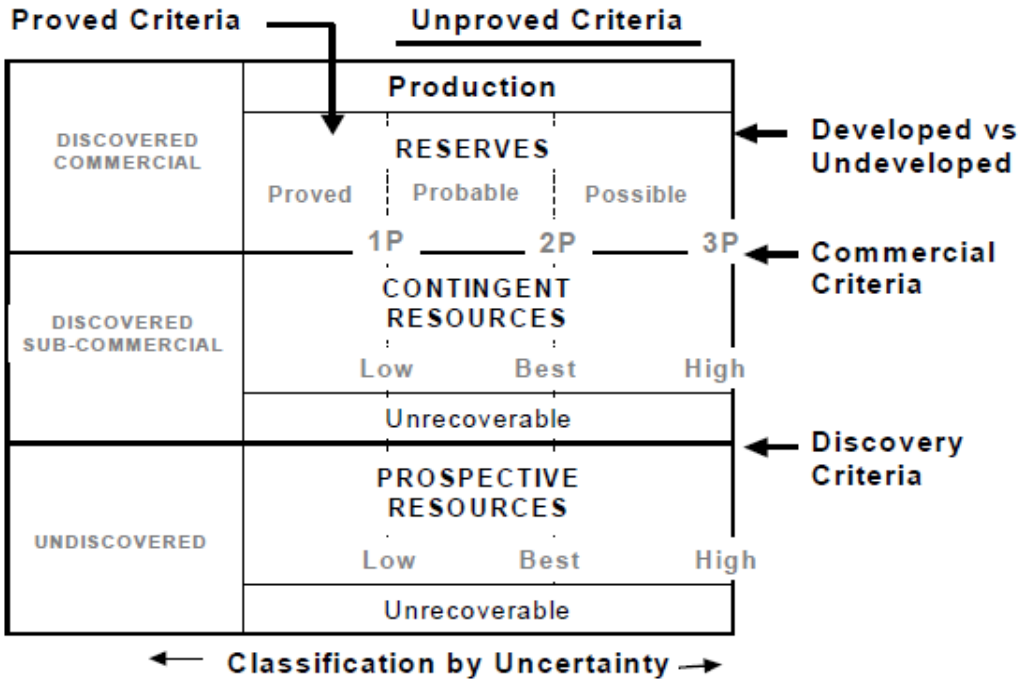
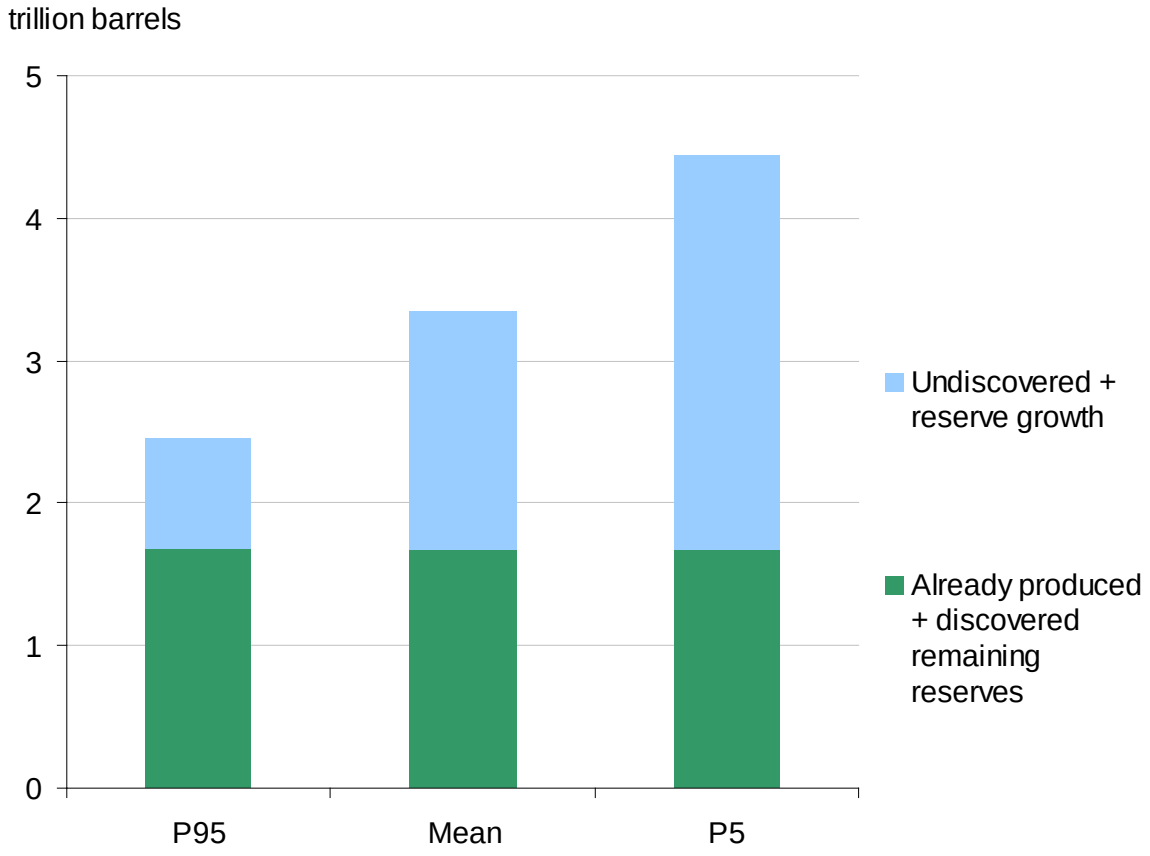


Figure 3: Decision Points in Resource Classification

Source: SPE 2005 Comparison of Selected Reserves and Resource Classifications and Associated Definitions, Figure 3, page 25

Figure 7

Estimates of ultimately recoverable resources from conventional global oil and natural gas liquids



Note: P95 represents a 95 percent chance that the resource size will equal or exceed the estimate, while P5 indicates a 5 percent chance that the probability will equal or exceed the estimate.

(Source: USGS World Petroleum Assessment 2000, Table 1)

Figure 8

Global Initial-in-Place estimate for petroleum liquids

(trillion barrels)	Mid. East OPEC	Other OPEC	United States	Other Non-OPEC
Conv. Crude and Condensate	2.6	2.6	0.9	2.9
Natural Gas Plant Liquids	0.3	0.3	0.2	0.4
Extra Heavy Crude (<10º API)	0.0	2.3	0.0	0.0
Bitumen	0.0	0.0	0.0	2.4
Oil Shale	0.0	0.0	2.1	0.7
Source Rock	0.9	0.9	0.3	1.0
Total Liquids	**3.8**	**6.0**	**3.4**	**7.4**

Note: Estimates of global IIP for petroleum liquids vary from 14 to 24 trillion barrels. This table shows 20.6 trillion barrels.

Sources: I.H.S. Energy, World Energy Council, USGS, Nehring Associates, EIA analysis April 2008

Helpful Links

U.S. Energy Information Administration
http://www.eia.gov

U.S. Energy Information Administration, *International Energy Outlook 2010*
http://www.eia.gov/oiaf/ieo/index.html

Society of Petroleum Engineers, reserves and resources information
http://www.spe.org/industry/reserves/

Society of Petroleum Engineers, "Comparison of Selected Reserves and Resource Classifications and Associated Definitions" (see pages 23 & 29 in particular)
http://www.spe.org/industry/reserves/docs/OGR_Mapping_Final_Report.pdf

National Petroleum Council, 2007 report *Facing the Hard Truths about Energy*
http://www.npchardtruthsreport.org/download.php

National Petroleum Council, Hard Truths report, Chapter 2 (see page 96)
http://downloadcenter.connectlive.com/events/npc071807/pdf-downloads/NPC-Hard_Truths-Ch2-Supply.pdf

International Energy Agency, *World Energy Outlook 2008* (see Chapters 9-15)
http://www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2056

USGS *World Petroleum Assessment 2000*
http://energy.cr.usgs.gov/WEcont/WEToC.pdf

Joint Oil Data Initiative (JODI)
http://www.jodidata.org/

Attached Documents

EIA *IEO2010* "Liquids production modeling approach," pages 27-29

SPE 2005 report "Comparison of Selected Reserves and Resource Classifications and Associated Definitions"