

Executive Summary

- **2°C world sees oil demand peak in 2020:** In a scenario consistent with limiting climate change to 2°C (its “450 Scenario”), the International Energy Agency (IEA) projects that global demand for oil will grow modestly through 2020 and then begin declining by 1% per year through at least 2035 (with 2035 demand roughly 15%, or 13 million barrels per day (MBDP), lower than 2013 demand). Looking out to 2050, a 2°C scenario sees oil use decline to roughly 50 MBDP.
- **Demand projections of oil majors not focused on a 2°C future:** We survey projections and scenarios from Shell, BP, and ExxonMobil and find that no modeling of future oil demand in a 2°C-constrained world. The result is that projected 2035 oil demand is on average 28 MBDP (i.e. 36%) higher than in the IEA’s 450 Scenario; the corporate projections we survey are, however, roughly aligned with future oil demand in the IEA’s central (or “New Policies”) scenario, which assumes less vigorous action to control climate change (e.g. considerably lower future prices on CO₂ emissions than in the 450 Scenario).
- **Risk to projects with a supply cost over \$80/bbl:** We combine demand projections with supply curves for global oil production to identify key supply cost thresholds at which projects may become vulnerable to future reductions in oil demand and oil prices. We find significant demand/price risks for projects with a Breakeven Oil Price (BEOP) over \$80/bbl (and especially those with a BEOP over \$100/bbl). Conversely, under present conditions we find minimal risk for projects with a BEOP below \$60/bbl. A major uncertainty in this area is how OPEC - which controls a majority of sub-\$60/bbl oil production – would respond to a structural decline in oil demand.
- **Downside risks from transport efficiency and fuel-switching:** In addition to implementation of economy-wide CO₂ targets (as in the IEA’s 450 Scenario), we find key downside risks to future oil demand/prices to include lower-than-expected economic growth in Asia, rapid deployment of fuel-efficient cars and electric vehicles, substitution of natural gas for oil, and curtailment of oil consumption subsidies. If realized, these trends may negate potential oil demand growth even absent compelling near-term action to address climate change.

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Oil Demand: Comparing Projections and Examining Risks

To complement our recent report on carbon asset risk in the oil industry (Carbon Supply Cost Curves – Evaluating Financial Risk to Oil Capital Expenditures), this note compares projections of future oil demand under “business-as-usual” and carbon-constrained scenarios from a variety of sources.

In contrast to industry outlooks that generally project continued growth in global oil demand through 2040, we find that vigorous action to address climate change is likely to begin reducing oil demand by 2020. By lowering future oil prices, such a structural decline in demand may threaten the profitability of new projects with supply costs above \$80-100/bbl

In addition to implementation of prices on CO₂ emissions, we find significant downside risks to future oil demand to include slower-than-expected economic growth in China and other Asian economies, rapid deployment of more fuel-efficient cars/trucks and electric vehicles, substitution of natural gas and renewable energy sources for oil, limits on vehicular air pollution in developing countries, and curtailment of subsidies for fossil fuel consumption (which totaled \$200+ billion globally in 2012). To manage carbon asset risk in their portfolios, investors should engage with oil companies to advocate for incorporating such risks into their long-term demand projections and business planning.

Analysts

CTI:
Reid Capalino

ETA:
Paul Spedding
Mark Fulton

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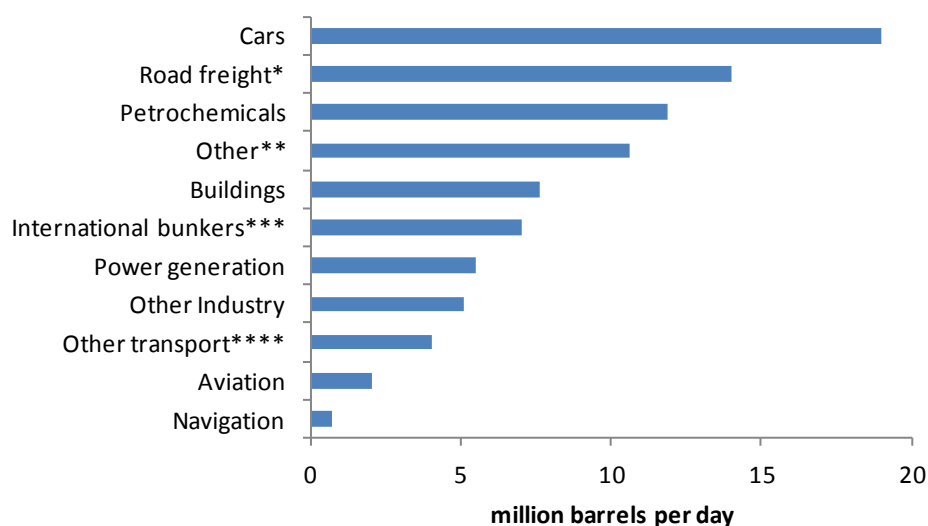
Contents

| | |
|---|----|
| 1. Introduction..... | 3 |
| 2. Projections of future oil demand..... | 4 |
| 3. Downside risks to future oil demand and oil prices | 16 |
| 4. Supply costs of marginal oil production under different oil demand scenarios | 31 |
| Appendix A - Details on IEA Scenarios..... | 40 |
| Appendix B - Components of oil supply and demand in IEA Scenarios..... | 41 |

1. Introduction

Oil use is pervasive in the world economy - chiefly as a fuel for transport, but also as feedstock for petrochemical production, a source of heat for buildings, and, in some regions, even a fuel for power generation. Oil demand has grown from 76.3 million barrels per day (MBPD) in 2000 to 91.4 MBPD in 2013 (for a compound annual growth rate, or CAGR, of 1.4%).¹ The most recent available data has oil as the source of 31% of global primary energy demand and 36% of global carbon dioxide (CO₂) emissions.² If the world is to control future climate change within responsible levels (i.e. the widely-cited 2 degrees Celsius, or 2°C, limit), the trajectory of future oil demand will figure centrally in this challenge.

Figure 1 Oil demand by sector, 2012 (million barrels per day)



Source: IEA, ETA analysis 2014

*Includes light-commercial vehicles and freight trucks. **Includes agriculture, transformation, and non-energy use (mainly bitumen and lubricants).

International marine and aviation bunkers (note that total for "Aviation" refers only to domestic aviation). *Includes road, rail, pipeline, and non-specified transport.

¹ 2000 data from International Energy Agency (IEA), *World Energy Outlook 2013 (WEO 2013)*, Paris: OECD/IEA, 2013, 505 <http://www.worldenergyoutlook.org/publications/weo-2013/IEA>. 2013 data from IEA, *Oil Market Report*, April 11, 2014, 4, <http://omrpublic.iea.org/currentissues/fullpub.pdf>.

² Data is for 2011 from IEA, *WEO 2013*, "Annex A - Tables for Scenario Projections", 573-574.

2. Projections of future oil demand

This study focuses on long-term projections of future oil demand from the International Energy Agency (IEA). In its annual *World Energy Outlook* publications - probably the most widely cited source of global energy projections - the IEA examines global energy trends through 2035 under three different scenarios:³

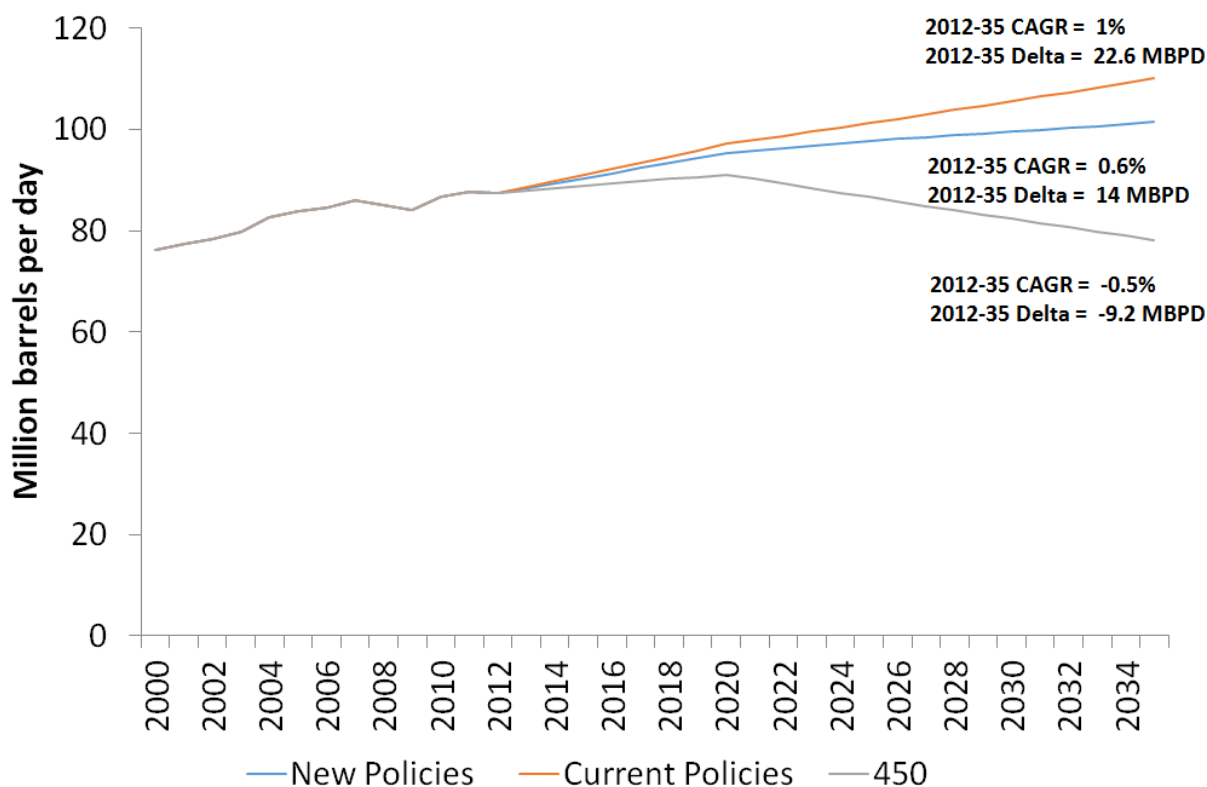
- **Current Policies Scenario:** this scenario assumes only the implementation of government policies and measures that had been enacted by mid-2013.
- **New Policies Scenario:** this scenario takes into account "broad policy commitments and plans that have already been implemented to address energy-related challenges as well as those that have been announced, even where the specific measures to implement these commitments have yet to be introduced. It assumes only cautious implementation of current commitments and plans."
- **450 Scenario:** this scenario "sets out an energy pathway that is consistent with a 50% chance of meeting the goal of limiting the increase in average global temperature to 2 degrees C compared with pre-industrial levels." For the years prior to 2020, the 450 Scenario assumes "more vigorous policy action to implement fully the Cancun Agreements than is assumed in the New Policies Scenario"; for the years after 2020, OECD countries and other major economies "are assumed to set economy-wide emissions targets for 2035 and beyond to ensure collectively an emissions trajectory consistent with stabilization of greenhouse-gas concentrations at 450 parts per million."

The figure below illustrates the IEA's long-term projections for global oil demand under these three different scenarios.⁴ Given our interest in risks to oil production as a result of a global energy transition, in this study we focus on the New Policies Scenario and 450 Scenario.

³ IEA, *WEO 2013*, 645.

⁴ The IEA decomposes its estimate of overall oil demand into eight different sub-estimates for various oil products (e.g. ethane, gasoline, diesel, etc.). For detail on these estimates (as well as the IEA classification of the different liquid fuels that go into the overall oil supply), see Appendix B.

Figure 2 Oil demand in IEA scenarios – 2035 demand of 101 MBPD (New Policies) vs. 78 MBPD (450)



Calculations of 2012-2035 Delta (i.e. absolute change) and CAGR assume original WEO 2013 value for 2012 world oil demand of 87.4 MBPD (rather than the IEA's more recent 2012 estimate of 90.1 MBPD). Source: IEA, ETA analysis 2014

Oil demand trends in IEA New Policies and 450 Scenarios

Several high-level conclusions emerge from the figure above:

- In New Policies Scenario, demand grows but at a modest rate:* The IEA's central scenario sees oil demand grow (particularly in the years prior to 2020), but at an overall CAGR less than half that of the 2000-2013 period. Asian countries account for two-thirds of the gross demand increase, with China overtaking the US as the world's largest oil market around 2030; efficiency policies and fuel-switching in OECD countries play leading roles in curtailing post-2020 demand growth (for more detail on the regional and sector-level trends in the IEA New Policies Scenario see Box 1.1 below).
- "New Policies" shows significant impact on demand growth:* Note that 2035 oil demand in the New Policies Scenario is more than 8 MBPD lower than in the Current Policies Scenario. This illustrates the significant impact that implementation of energy policy commitments (e.g. vehicle fuel efficiency standards) is projected to have on curbing growth in oil demand (a topic we return to at the end of this note).
- Projected climate policy impact on oil demand strongest post-2020:* Through 2020, oil demand continues to grow in both the New Policies and 450 Scenarios. In the 450 Scenario, however, 2020

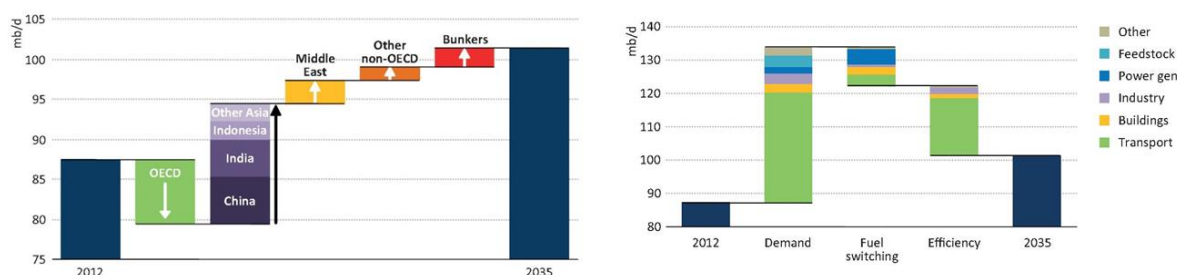
represents peak demand, after which oil demand begins to decline by an average of 1% year (as opposed to continuing to grow at a slower rate). Through 2035, a shift in the oil demand trajectory of the New Policies Scenario to that of the 450 Scenario reduces required cumulative oil production by ~8% (note that if these demand trajectories were to continue through 2050, the difference in required oil production would grow substantially).

Box 1.1 Drivers of oil demand and demand destruction in the IEA New Policies Scenario

The two figures below illustrate the key region and sector dimensions of demand growth (and demand destruction) in the IEA New Policies Scenario.

- *Engine of oil demand growth shifts to Asia:* Through 2035, Asian countries (principally China, India, and Indonesia) account for two-thirds of the projected gross demand increase. Demand in China alone rises by 6 MBPD as that nation overtakes the US as the world's largest oil market around 2030 (by which point, ironically, China's demand growth has slowed notably from its pre-2020 level). Declining demand in OECD countries is owing to a combination of greater efficiency and more widespread fuel-switching (discussed below).

Figure 3 Transport and petrochemicals in Asia and Middle East drive growth in oil demand Figure



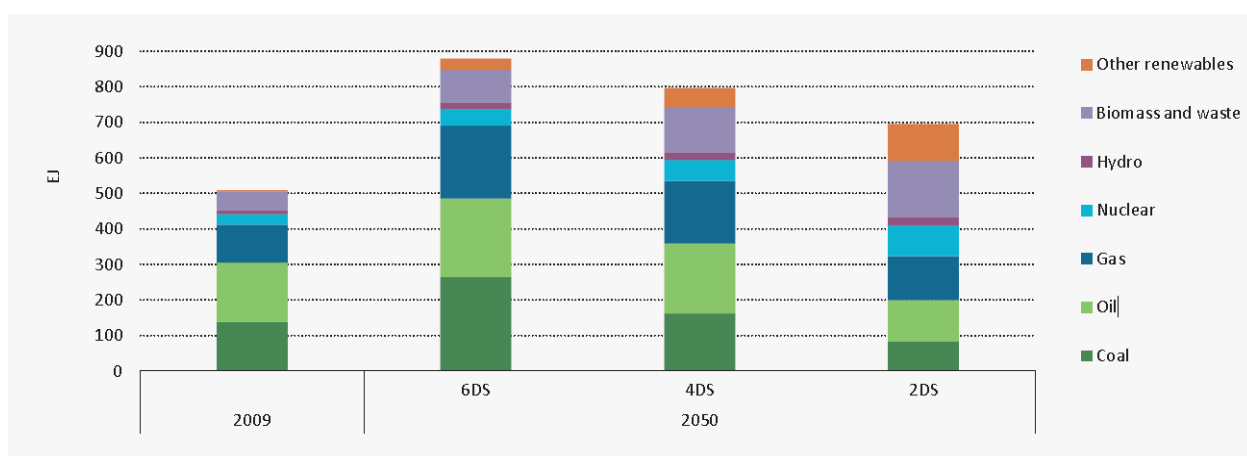
Data for IEA New Policies Scenario, 2012-2035. Source: IEA

- *More oil for transport and petrochemicals, less for power and buildings:* 85% of net growth in oil demand (i.e. +12.1 MBPD arises in the transport sector), chiefly owing to more road freight and passenger vehicles in China, India, and other non-OECD countries. Industrial use of oil also increases (by +3.8 MBPD, nearly all of this in the form of feedstock for petrochemical production) while gross demand increases in buildings and power generation (i.e. expected to occur with rising incomes and populations) are overwhelmed by a combination of efficiency increases and fuel-switching.
- *Efficiency and fuel-switching offset 32 MBPD by 2035:* The combined impact of efficiency increases and fuel-switching lowers the 2012-2035 net increase in global oil demand by 21 MBPD relative to the Current Policies Scenario (a net increase of 14 MBPD between 2012 and 2035). Efficiency improvements account for 65% of these savings and relate overwhelmingly to more efficient cars (and, to some extent, trucks). Savings due to fuel-switching occur due to penetration of biofuels/natural gas vehicles/electric vehicles in the transport sector and a combination of natural gas and renewables in the power generation and buildings sectors.

Looking out to 2050: the IEA 2DS Scenarios

Our companion report, *Carbon Supply Cost Curves: Evaluating Financial Risk to Oil Capital Expenditures*,⁵ considers the impact of carbon constraints on the oil sector through 2050. As this date exceeds the timeframe of published results for the IEA World Energy Outlook scenarios (which go only until 2035), we look also to two other IEA scenarios - the 4DS and 2DS scenarios - which closely resemble the New Policies and 450 Scenarios (through 2035) but extend all the way until 2050.⁶ The figure below shows projected 2050 global energy supply by fuel source in the 6DS, 4DS, and 2DS scenarios (with the 6DS resembling the Current Policies Scenario through 2035).

Figure 4 Total primary energy supply in the IEA 6DS, 4DS, and 2DS scenarios, 2009-2050 (Exejoules)



* For reference, we convert from EJ to MBPD at a rate of 1 EJ = 0.48 MBPD of oil. Source: IEA

In the 4DS, the 2050 global oil supply is roughly 95 MBPD (i.e. roughly halfway between current global demand and projected 2035 demand in the New Policies Scenario). The projected slight decline in oil use from 2035 to 2050 reflects demand-destruction due to rising efficiency beginning to overwhelm increasing demand from economic and population growth in non-OECD countries. For example, in the 4DS, adoption of higher fuel-economy standards across all major economies (including those in Asia) increases the average fuel-economy of passenger light-duty vehicles by 30% over 2009.⁷

More interestingly, in the 2DS oil use in 2050 declines to roughly 50 MBPD - an absolute decline of 37.4 MBPD relative to 2012 (assuming the IEA *WEO 2013* estimate for 2012 demand) that is the result of oil use from 2012-2050 declining at a CAGR of 1.5%. This 40%+ reduction in overall oil use is the result of extensive displacement of oil from the transport sector. The 2DS sees substantial increases in fuel efficiency (as described above) but also major penetration of electric vehicles, hydrogen-powered vehicles, and biofuels.

⁵ Carbon Tracker Initiative and Energy Transition Advisors, *Carbon Supply Cost Curves: Evaluating Financial Risk to Oil Capital Expenditures*, May 2014, <http://www.carbontracker.org>.

⁶ IEA, *Energy Technology Perspectives 2012: Pathways to a Clean Energy System*, (Paris: OECD/IEA, 2012), 8, 31, <http://www.iea.org/Textbase/npsum/ETP2012SUM.pdf> Note that, through 2035, the 4DS and 2DS Scenarios closely resemble the New Policies and 450 Scenarios.

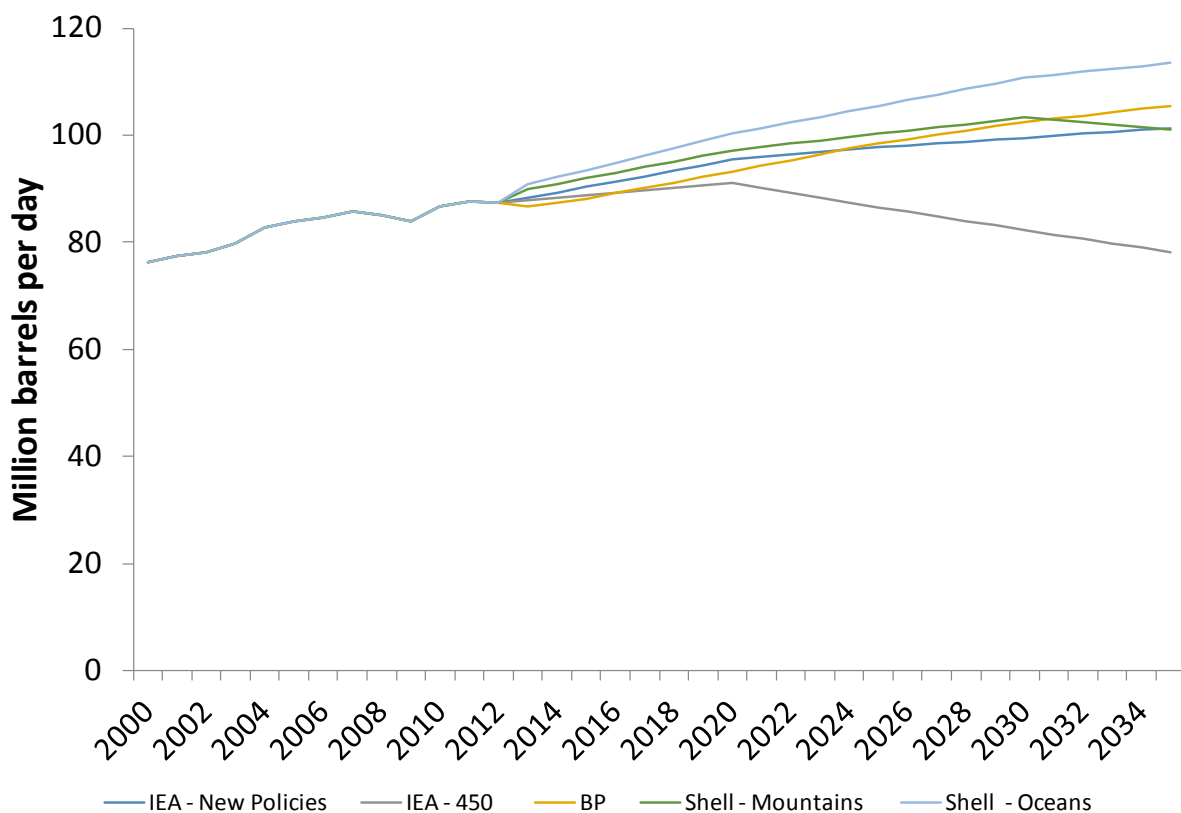
⁷ IEA, *Energy Technology Perspectives 2012*, 36.

The IEA notes, however, that such changes will require "a revolution in vehicle propulsion systems, particularly the electrification of LDVs (light-duty vehicles)"⁸ - a topic that the electric vehicle section of our "Downside Risks" chapter discusses in more detail.

Comparing IEA oil projections with those from global oil majors

The figure compares demand projections from the IEA New Policies and 450 Scenarios with projections from Shell⁹ and BP.¹⁰

Figure 5 IEA demand projections vs. oil majors



*Data for oil majors converted from million tons of oil equivalent to million barrels per day using the IEA's product specific conversion factors. * For simplicity of reading, data shown from 2000-2012 is just from IEA numbers. Historic number from other sources slightly different due to differences in definitions and methodologies. For exact figures on 2012-2035 projected oil demand increase, see Table 7 below. Source: IEA, company reports, ETA analysis 2014.

⁸ IEA, *Energy Technology Perspectives 2012*, 39.

⁹ Shell, *New Lens Scenarios: A shift in perspective for a world in transition*, March 2013, http://s01.static-shell.com/content/dam/shell-new/local/corporate/Scenarios/Downloads/Scenarios_newdoc.pdf

¹⁰ BP, *BP Energy Outlook 2035*, January 2014, http://www.bp.com/content/dam/bp/pdf/Energy-economics/Energy-Outlook/Energy_Outlook_2035_booklet.pdf

Since methodological differences (i.e. in defining oil as part of the "total liquids supply"¹¹) complicate comparing the *level* of projected oil demand from different sources (i.e. 100 MBPD in 2030), the table below compares projections of 2012-2035 growth in oil demand (in both absolute and relative terms) from the IEA, BP, Shell, ExxonMobil¹² and the Organization of the Petroleum Exporting Countries (OPEC).¹³

Table 1 Projected change in oil demand under different scenarios, 2012-2035 (absolute change in MBPD, growth rate in CAGR)

| | Absolute change (MBPD)* | CAGR |
|----------------------------|--------------------------------|-------------|
| IEA - New Policies | 14.0 | 0.6% |
| IEA - 450 | -9.2 | -0.5% |
| BP | 18.1 | 0.8% |
| ExxonMobil | 20.2 | 0.8% |
| Shell - Mountains scenario | 13.7 | 0.6% |
| Shell - Oceans scenario | 26.1 | 1.1% |
| OPEC | 19.6 | 0.9% |

* Data for oil majors converted from million tons of oil equivalent to million barrels per day using the IEA' assumed mix of product specific conversion factors.
** Compound Annual Growth Rate. **Source:** IEA, BP, ExxonMobil, Shell, OPEC

The projections in the table and chart above assume differing rates of population/economic growth, energy efficiency trends, penetration of alternative fuels, and (in the case of the IEA) presence/absence of committed policies to reduce CO₂ emissions. Surveying the projections, several tentative conclusions emerge:

- *Oil majors and OPEC more bullish on demand growth than the IEA:* With the exception of Shell's "Mountains" scenario (in which "stability is the highest prize" and "those at the top... unlock resources steadily and cautiously, not solely dictated by immediate market forces"), projections from the three oil majors and OPEC show greater demand growth than does the IEA New Policies Scenario. Relative to the IEA New Policies Scenario, the difference in projected growth for 2012-2035 ranges from 4.1 MBPD for BP to 12.1 MBPD for Shell's "Oceans" scenario (in which "strong economic growth and stagnant policy development lend greater influence to market forces").
- *All projections show demand growth moderating:* The previous point notwithstanding, all projections show the average annual rate of demand growth declining below the 2000-2013 historic rate of 1.4%.

¹¹ For more detail on the IEA classification of the liquid fuels supply, see Appendix B.

¹² Exxon Mobil, *The Outlook for Energy: A View to 2040*, 2014, http://www.bp.com/content/dam/bp/pdf/Energy-economics/Energy-Outlook/Energy_Outlook_2035_booklet.pdf

¹³ Organization of the Petroleum Exporting Countries, 2013 World Oil Outlook, 2013, OPEC Secretariat, http://www.opec.org/opec_web/static_files_project/media/downloads/publications/WOO_2013.pdf

- *None of the industry forecasts align with oil demand in the IEA 450 Scenario:* Looking at 2012-2035 industry/OPEC projections relative to the IEA 450 Scenario, in 2035 an additional 27-29 MBPD of oil production are required in order to meet expected future demand.¹⁴

Impact of carbon prices on future oil demand - rising but limited

As oil is currently the source of 36% of global CO₂ emissions, policies that impose a price on those emissions, such as carbon taxes and carbon cap-and-trade systems, have the potential to reduce demand for oil.¹⁵ The spread of carbon pricing around the world will make carbon pricing a more material force in oil markets over the coming years and decades. The World Bank estimates that 40 national and 20 sub-national jurisdictions (across both developed and developing countries) - representing 21% of the total of 50 GtCO₂e that are emitted globally each year - already have or are considering implementing an explicit price on carbon.¹⁶ Since these mechanisms usually do not cover all domestic emissions, however, the effective coverage is reduced to around 7% of global emissions. Broadening carbon pricing programs in developed countries and enacting planned initiatives in major emerging economies (such as China, Brazil and others), however, could put an effective carbon price on nearly half of global CO₂ emissions.

Even while becoming more material, however, existing and proposed carbon pricing policies are unlikely to affect demand for oil to the same extent that they will affect demand for coal. The reasons for this relate to both the sectors covered under carbon pricing programs and the level of carbon price likely to result from such programs. With respect to coverage, existing and proposed carbon pricing policies focus heavily on emissions from power generation and industry, which currently account for roughly 25% of global oil demand (a share that is projected to decrease); conversely, emissions from the transport sector (currently 54% of global oil demand, and projected to increase) are likely to be covered under very few programs.¹⁷ With respect to price levels, noting that transport accounts for the majority of oil demand, the level of carbon price needed to reduce demand for oil in this sector varies considerably across regions and alternative technologies/modes of transport.

Sector coverage of carbon pricing programs - emphasis on power and industry, not transport

The table below illustrates the IEA's assumed CO₂ prices in selected regions for the New Policies and 450 Scenarios. Across both scenarios, the transport sector is subject to a carbon price in only three countries - China, New Zealand, and the European Union (which applies a carbon price only to aviation). From 2020-2035 total transport oil demand affected by such programs is projected to be less than 15% of overall

¹⁴ The 27-29 MBPD figure includes an average of the two Shell scenarios. In general, note that the misalignment mentioned above is largely a modeling *choice* rather than a result of the modeling per se.

¹⁵ For example, using the US EPA's energy forecasting model, a 2008 US study found that a carbon price of \$14/ton CO₂ (in 2005 dollars) would from 2010-2030 reduce average US demand for petroleum liquids by 3.9% (or 1 MBPD). Robert Shapiro, Nam Pham, and Arun Malik, "Addressing Climate Change Without Impairing the U.S. Economy: The Economics and Environmental Science of Combining a Carbon-Based Tax and Tax Relief," The U.S. Climate Task Force, June 2008, <http://www.sonecon.com/docs/studies/CarbonTaxReport-RobertShapiro-2008.pdf>

¹⁶ World Bank, *Mapping Carbon Pricing Initiatives: Developments and Prospects 2013*, Carbon Finance at the World Bank, May 2013, http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/06/26/000356161_20130626122256/Rendere d/PDF/ACS48840WP0P140ial0use0only09000ACS.pdf

¹⁷ IEA, *WEO 2013*, 511.

transport-related oil demand.¹⁸ Note, however, that many of the countries in the table below (especially those in the European Union) already levy taxes on transport fuels such as gasoline and diesel, sometimes at quite high levels.¹⁹ Such taxes have a variety of goals other than reducing CO₂ emissions (i.e. reducing local air pollution, reducing traffic congestion, etc.); that said, including even a portion of such taxes would increase to well above 15% the percentage of transport-related oil demand subject to some form of corrective tax.

Table 2 CO₂ price assumptions in selected regions (2012\$/ton CO₂)

| | Region | Sectors | 2020 | 2030 | 2035 |
|---------------------------|---------------------------------------|----------------------------|------|------|------|
| Current Policies Scenario | EU | Power, industry & aviation | 15 | 25 | 30 |
| | New Zealand* | All** | 15 | 25 | 30 |
| | Korea | Power & industry | 15 | 25 | 30 |
| New Policies Scenario | EU | Power, industry & aviation | 20 | 33 | 40 |
| | New Zealand | All* | 20 | 33 | 40 |
| | Korea | Power & industry | 20 | 33 | 40 |
| | China | All | 10 | 24 | 30 |
| | South Africa | Power & industry | 8 | 15 | 20 |
| 450 Scenario | US & Canada | Power & industry | 20 | 95 | 125 |
| | EU | Power, industry & aviation | 35 | 95 | 125 |
| | Japan | Power & industry | 20 | 95 | 125 |
| | Korea | Power & industry | 35 | 95 | 125 |
| | New Zealand | All | 35 | 95 | 125 |
| | China, Russia, Brazil, & South Africa | Power & industry*** | 10 | 70 | 100 |

*Excludes IEA estimates for Australia, which recently passed legislation to eliminate its carbon pricing policy. **Agriculture is not assumed to be in New Zealand's Emissions Trading Scheme. *** All sectors in China. Note: In the IEA New Policies Scenario, a shadow price for CO₂ in the power sector is assumed to be adopted as of 2015 in the US, Canada, and Japan (starting at \$15/ton CO₂ and rising to \$35/ton CO₂ in 2035). Source: IEA, ETA analysis 2014

Using the above assumptions, the table below estimates the share of global oil demand that is subject to a carbon price in the IEA New Policies and 450 Scenarios, as well as the weighted average carbon price across the assumed carbon price regimes (in terms of both \$/ton CO₂ and \$/bbl of oil).²⁰ The weak coverage of the transport sector means the share of 2020-2035 global oil demand subject to a carbon price ranges from 18.5% in the New Policies Scenario to 22% in the 450 Scenario. Moreover, achieving this level of coverage depends critically on the implementation of a carbon pricing policy in China; excluding China reduces the

¹⁸ ETA calculation based on IEA data.

¹⁹ JEL article

²⁰ Note that because these estimates exclude carbon prices for several smaller countries and provinces (e.g. Finland, Switzerland, British Columbia) that are not included in the table above the actual share of world oil demand covered in the IEA scenarios will be slightly higher than the figures in the table below.

effective coverage of global oil demand to only 4% in the New Policies Scenario and 7% in the 450 Scenario. With only one-fifth of future global oil demand subject to a carbon price even in the most ambitious case, it becomes difficult for carbon prices to exert significant influence on the trajectory of future global oil demand.

Table 3 Implications of CO₂ price assumptions for oil markets in selected regions of IEA New Policies and 450 scenarios

| | Share of world oil demand covered by CO ₂ price, 2020-2035* (%) | | Weighted average CO ₂ price (2012\$/ton CO ₂) | | Potential impact on price of oil (\$/bbl)** | |
|--------------|--|------------------|--|-------------|---|-------------|
| | <i>with China</i> | <i>w/o China</i> | <i>2020</i> | <i>2035</i> | <i>2020</i> | <i>2035</i> |
| New Policies | 18.5 | 4.0 | 12.0 | 32.0 | 5.7 | 15.1 |
| 450 | 22 | 7.0 | 17.0 | 107 | 7.5 | 5.03 |

*Includes only selected CO₂ price regimes as detailed in Table 2 above. **Assumes lifecycle CO₂ emissions of 0.47 tons/bbl. Note that in practice the impact of a carbon price on the actual market price of oil will depend on the relative price-elasticity of supply and demand. Source: IEA, ETA analysis 2014

Level of carbon prices

Recognizing that the share of global oil demand subject to a carbon price is likely to rise in the years ahead (but remain fairly limited), the second determinant of the impact on oil demand concerns the level of the carbon prices imposed. Taking a weighted average across the selected regions, for the New Policies Scenario the table above calculates a weighted average carbon price of \$12/ton CO₂ in 2020 rising to \$32/ton CO₂ in 2035; in the 450 Scenario, the weighted average price is \$17/ton CO₂ in the 450 Scenario rising to \$107/ton CO₂ in 2035. Note that even the lower end of this range (\$12/ton CO₂ in 2020) would mark an increase over the current CO₂ price in carbon trading regimes such as the European Union ETS or the US Regional Greenhouse Gas Initiative.²¹ Translated into \$/bbl terms, carbon prices reach the equivalent of \$15-50/bbl by 2035 (assuming use of a lifecycle CO₂ conversion factor). The IEA's assumption of rising carbon prices are one reason why, from 2011-2035, oil demand in the power sector declines at an annual rate of 2.7% in the New Policies Scenario and 4.5% in the 450 Scenario. Similarly, carbon prices are a contributor to the projection of flat to modestly declining industrial demand for oil (depending on the scenario).

Assuming that future carbon prices were extended to the transport sector, the far high level of long-term prices assumed in the 450 Scenario (relative to the New Policies Scenario) would benefit a wider range of low-carbon transport alternatives. In discussing the impacts of carbon prices on the transport sector, the Intergovernmental Panel on Climate Change (IPCC) has emphasized the promising near-term economics of "efficiency improvement for light-duty vehicles, long-haul heavy duty-vehicles, and ships," which (depending on the region) are often cost-effective now with a very low or even no price on carbon emissions.²² Certain other low-carbon alternatives, however, such as "electric vehicles, aircraft, and possibly high-speed rail,"

²¹ Prices cited for May 2 2013. <https://www.pointcarbon.com/news/euets/> and http://www.rggi.org/docs/Auctions/23/Auction_23_Market_Monitor_Report.pdf

²² IPCC, *IPCC Fifth Assessment Report - Climate Change 2014: Mitigation of Climate Change*, "Chapter 8 – Transport", http://report.mitigation2014.org/drafts/final-draft-postplenary/ipcc_wg3_ar5_final-draft_postplenary_chapter8.pdf

with current technology may require a carbon price of more than \$100/tCO₂.²³ Reasons for this include "the high investment costs needed to build low-emissions transport systems, the slow turnover of stock and infrastructure, and the limited impact of a carbon price on petroleum fuels already heavily taxed"²⁴ (as discussed below, there is also the issue of "the limited impact of a carbon price on petroleum fuels" already heavily *subsidized*). Hence, over the medium and long term a scenario of significantly reduced transport-related oil demand is likely to require a combination of combining carbon prices, heightened fuel efficiency or low-carbon transport standards, and declining technology costs for many low-carbon alternatives.

Carbon pricing assumptions of oil companies

As commercial entities, oil companies must account for existing and proposed carbon prices as an added cost of doing business. Accordingly, many have begun to do so. A recent CDP survey identified nine oil companies that currently claim to incorporate a carbon price into their planning and investment decisions.²⁵ CDP notes that use of such internal or "shadow" carbon prices can "help identify revenue opportunities, risks, and as an incentive to drive maximum energy efficiencies to reduce costs and guide capital investment decisions." Its 2013 report showed nine oil companies to apply internal carbon prices of \$8-46/ton CO₂ (with the date of the assumed price varying across regions and companies).

From the perspective of an oil company, assuming a carbon price has two major implications. One relates to additional direct costs that may be borne by the company as a result of carbon emissions related to the exploration, development, production, refining, or transportation of oil. The other relates to how implementation of carbon prices may affect future demand for (and price of) their products. Regrettably, public information about the exact ways in which oil companies are using internal carbon prices remains limited.

Project costs

With respect to additional project costs, several oil companies have been leaders in using internal carbon prices to make their businesses more energy efficient. BP first introduced an internal carbon price (along with business unit goals for emissions reductions) in the late 1990s.²⁶ The 2013 CDP reports includes excerpts from BP, Conoco Phillips, and Chevron all attesting to the use of carbon prices to achieve a similar purpose. Though necessary and commendable, use of carbon prices to analyze the "incremental emissions profile" of a project is a limited application, as in general 90%+ of the emissions related to a barrel of oil relate to its *combustion* rather than its production, refining, and transport. For example, if applied only to "non-combustion" CO₂ emissions, a \$40/ton CO₂ carbon price would likely raise projects costs by only ~\$2/bbl.

²³ IPCC, "Chapter 8 –Transport." As discussed below, however, options such as electric vehicles have the potential for significant declines in technology costs.

²⁴ IPCC, "Chapter 8 –Transport."

²⁵ CDP, "Use of internal carbon price by companies as an incentive and strategic planning tool: a Review of Findings from CDP 2013 disclosure," December 2013, <https://www.cdp.net/CDPResults/companies-carbon-pricing-2013.pdf>

²⁶ Reinhardt, Forest L., and Mikell Hyman. "Global Climate Change and BP." Harvard Business School Case 708-026, October 2007. (Revised October 2009.) <http://www.hbs.edu/faculty/Pages/item.aspx?num=34984>



Future energy demand

The more interesting question is whether and how oil companies are incorporating CO₂ prices into their long-term projections of future energy demand and future energy prices. On this front, surveying the long-term projections of several large oil companies suggests the following conclusion: oil companies are beginning to account for future prices but are doing so in a way very much in line with the IEA New Policies (or Current Policies) scenario, rather than with the more ambitious 450 Scenario. For example, in the context of discussing drivers of lower coal demand, Statoil's recent energy outlook acknowledges the influence of "gradually tougher climate and other environmental policies, combined with higher carbon prices;"²⁷ overall, however, the "future of energy and climate policies, and their impact on energy markets" is "another key uncertainty."²⁸ Shell's recent energy outlook has a decidedly mixed view on future carbon pricing; of the two scenarios that has a lower emissions profile (the "Mountains" scenario), "electricity prices begin to reflect an implicit price for emissions, while explicit carbon dioxide pricing remains patchy and at a low level overall", resulting in global emissions significantly above a 2C pathway.²⁹

ExxonMobil CO₂ Proxy Cost

More detailed disclosure of CO₂ assumptions comes from ExxonMobil. As described in its energy outlook and recent report to stakeholders, ExxonMobil uses a "proxy cost of carbon", which "seeks to reflect all types of actions and policies that governments may take over the Outlook period relating to the exploration, development, production, transportation or use of carbon-based fuels."³⁰ ExxonMobil explains this proxy cost as an "effort to quantify what we believe government policies over the Outlook period could cost to our investment opportunities."³¹ The map below illustrates ExxonMobil's assumed proxy cost of carbon by region in 2040. Though Exxon discloses that in some regions the proxy cost reaches as high as \$80/tCO₂, overall the figures are roughly in line with the 2035 assumptions of the IEA New Policies Scenario.

²⁷ Statoil, "Energy Perspectives: Long-term macro and market outlook," June 2013, 29, <http://tinyurl.com/lt4myul>

²⁸ Statoil, 8.

²⁹ Shell, 24.

³⁰ ExxonMobil, *Energy and Carbon - Managing the Risks, 2014*, 17, <http://tinyurl.com/pa7dbz8>

³¹ ExxonMobil, *Energy and Carbon*, 18.



Figure 6 ExxonMobil assumed CO₂ prices in 2040 (2012\$/tCO₂)

CO₂ "proxy" cost

Assumed cost of CO₂ emissions associated with public policies in 2040 in 2012 dollars



Source: ExxonMobil 2014 Outlook for Energy

As for the possibility of carbon price levels more in line with the IEA's 450 Scenario, ExxonMobil describes such a scenario as "highly unlikely" and therefore unnecessary to incorporate into planning assumptions. In explaining this decision, Exxon contends that governments "will carefully balance the risk of climate change against other pressing social needs... including the need for accessible, reliable and affordable energy" and that an "artificial capping of carbon-based fuels" to levels consistent with a low-carbon scenario is "highly unlikely."³²

³² ExxonMobil, *Energy and Carbon - Managing the Risks*, 18.

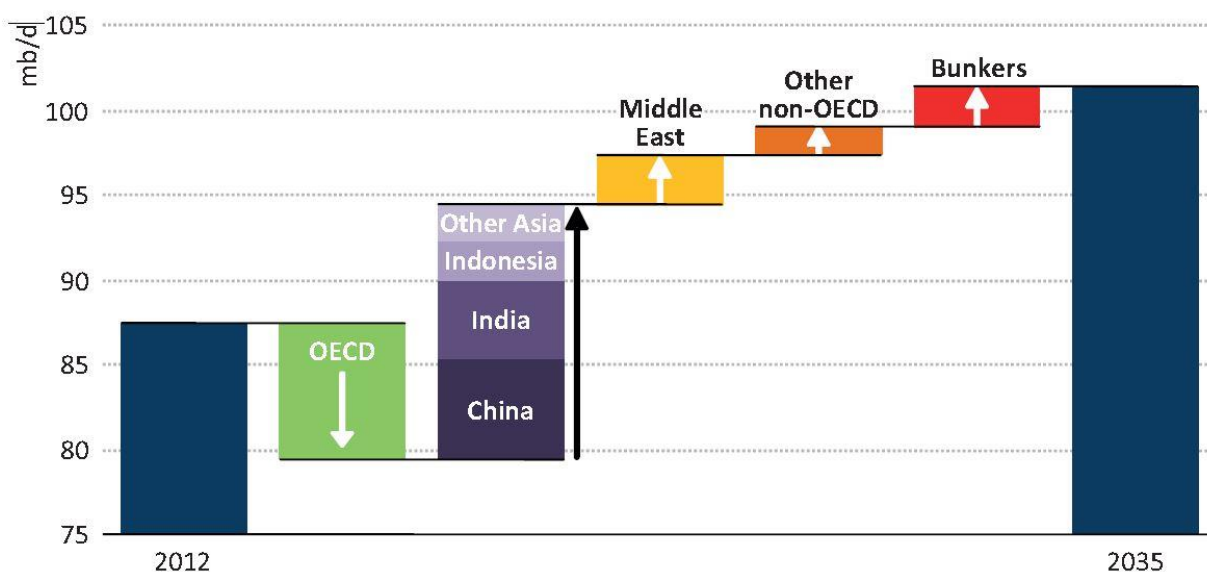
3. Downside risks to future oil demand and oil prices

The above discussion largely ignores the potential for downside risks to oil demand (and hence price) beyond those contained in the IEA scenarios. Such developments, however, may materially affect future oil demand and/or oil prices, and hence move the source of marginal supply farther down the supply cost curve (particularly with respect to non-OPEC supplies). The paragraphs below review some key potential uncertainties, including slower economic growth in emerging markets (especially China), and greater-than-expected efficiency and fuel switching.³³

Will China and other emerging market economies grow as quickly as expected?

Emerging economies, mostly in Asia and specifically China, are the drivers of growth in global oil demand. Since the end of 2007, oil demand for non-OECD countries has increased by more than 8 MBPD while demand for OECD countries has fallen by roughly 4 MBPD.³⁴ Through 2035 the IEA New Policies Scenario sees non-OECD Asia (principally China, India, and Indonesia) accounting for nearly two-thirds of the gross increase in global oil demand (~15 MBPD). 6 MBPD of this comes from China alone, which is projected to surpass the US as the world's largest oil consumer by 2035.

Figure 7 IEA New Policies Scenario – China and other non-OECD Asian countries drive growth in oil demand



Source: IEA

³³ In addition to trends related to demand, note that there is also downside risk to oil prices based on greater than expected growth in oil supply, particularly from low-cost OPEC production. See IEA, *WEO 2013*, 490-493.

³⁴ Steven Kopits, "Oil and economic growth: a supply-constrained view," presentation to Columbia University Center on Global Energy Policy, 11 February 2014, 24, <http://tinyurl.com/mhkju2k>.

The IEA acknowledges, however, that its projections of future energy demand are “highly sensitive to assumptions about the rates and patterns of GDP growth.”³⁵ This is particularly the case for China, where currently growth in energy consumption tends to proceed in lock-step with growth in per-capita income.³⁶ Given recent evidence on what the International Monetary Fund (IMF) describes as “China’s systemic importance in emerging markets growth,” assumptions about China’s future rate of economic growth have implications for future energy demand throughout emerging economies.³⁷ Across all three of its scenarios in WEO 2013, the IEA assumes that China’s economy will continue to grow at an average annual rate of 8% through 2020, with the rate of average annual growth decelerating below 6% from 2020-2035; the projections for non-OECD Asia as a whole are slightly lower, with an average annual growth rate of 5.8% through 2020. These projections are broadly similar to those of mainstream economic forecasters such as the IMF (which projects China’s growth rate to be 7.5% in 2014 and 7.3% in 2015).

Table 4 Selected assumptions on CAGR of real GDP growth in IEA New Policies Scenario, 1990-2035 (%)

| | 1990-2011 | 2011-2015 | 2011-2020 | 2011-2035 |
|----------------|-------------|------------|------------|------------|
| OECD | 2.2 | 1.9 | 2.2 | 2.1 |
| European Union | 1.8 | 0.7 | 1.3 | 1.6 |
| Non-OECD | 5.0 | 5.6 | 5.8 | 4.8 |
| Asia | 7.5 | 6.8 | 7.1 | 5.6 |
| China | 10.0 | 8.0 | 8.1 | 5.7 |
| India | 6.5 | 5.7 | 6.5 | 6.3 |
| ASEAN* | 5.0 | 5.5 | 5.5 | 4.6 |
| World | 3.3 | 3.6 | 4.0 | 3.6 |

*Association of Southeast Asian Nations (10 member states). Note: Calculation based on GDP expressed in year-2012 dollars in purchasing power parity terms.
Source: IEA analysis based on data from the IMF, OECD, Economist Intelligence Unit and World Bank databases; ETA analysis 2014

There are, however, notable downside risks that could significantly diminish China’s near-term growth prospects. *Some commentators have argued that rebalancing China’s economy toward greater consumption – and meeting the target for personal income growth set at the recent National People’s Congress - requires*

³⁵ IEA, *WEO 2013*, 38.

³⁶ IMF, *World Economic Outlook 2014: Recovery Strengthens, Remains Uneven*, 2014, 125, <http://www.imf.org/external/Pubs/ft/weo/2014/01/>. In technical terms, the IMF notes that “income elasticity of energy consumption is close to one at current levels of income per capita in China (as it was earlier in other fast-growing Asian economies)” whereas “advanced economies can sustain GDP growth with little if any increase in energy consumption.”

³⁷ The IMF (*World Economic Outlook 2014*, 125-126) notes that “A 1 percentage point rise in China’s growth... increases other emerging market economies’ growth by about 0.1 percentage point on impact. The positive effect tends to build over time as emerging markets’ terms of trade get a further boost, highlighting China’s relevance for global commodity markets.” The IMF also notes, however, that “emerging market economies’ diversification toward China has also exposed them to adverse shocks from China’s growth. Specifically, China’s recent slowdown provided an additional setback to their growth: of the 2 percentage point shortfall in emerging market economies’ quarterly (year-over-year) growth in 2012–13 relative to 2010–11, China accounted for ½ percentage point” (i.e. 25%).” From the perspective of impacts on oil demand, however, one should note that energy demand in some of these other emerging economies is less sensitive to GDP trends than is the case in China.

an annual GDP growth rate of “only” 3-4%³⁸ (i.e. half the IEA’s assumed growth rate through 2020). More generally, the IEA observes that China’s period of sustained high growth has seen “a build-up of risks within China’s economy, including reliance on export-led growth, weaknesses in the financial sector (both within and outside the formal banking sector) and local government finances, and concerns about the affordability of property in China.”³⁹ In the same vein, though concluding overall that “the likelihood of a hard landing in China after overinvestment and a credit boom continues to be small”, the IMF detects increasing risks due to “asset-quality-related balance sheet problems in the financial sector.” Should a build-up of these risks eventually overwhelm the government’s capability for corrective intervention, the IMF notes that “spillovers to the rest of the world, including through commodity prices, could be significant.”⁴⁰

The IMF explores the medium-term consequences for world oil markets from a protracted slowdown in the growth of China and other emerging markets.⁴¹ Even coupled with a scenario of a faster-than-expected recovery of the US economy, slower-than-expected growth in China and other emerging markets still reduces the assumed real price of oil in 2018 to 8% below the average 2013 price (i.e. to \$95/bbl, in 2012 dollars). A 2018 price of \$95/bbl would be 15% below the projected 2020 oil price in the IEA New Policies Scenario. Moreover, bear in mind that this results from a scenario of relatively modest (albeit prolonged) deceleration of growth in China and other emerging markets. *Note also that the growth rate for China in the IMF’s downside risks scenario is still substantially above the 3-4% annual growth rate cited above as the same analysts’ estimate of an appropriate medium-term target for Chinese growth. Taking the IMF estimates and recent history as a guide,⁴² a reduction in China’s growth of this magnitude could put sustained, downward pressure on oil prices, perhaps back to the \$80 level where OPEC is likely to defend prices due to fiscal concerns.*

³⁸ Micahel Pettis, “China is going to slow down but it can handle it,” *Financial Times*, July 28, 2013, <http://www.borrelliwalsh.com/files/publications/408/408China%20is%20going%20to%20slow%20down%20but%20it%20can%20handle%20it%20-%20FT.pdf>. See also Craig Mackenzie, “Could China’s carbon emissions peak sooner than expected?”, October 14 2013, <http://www.rtcc.org/2013/10/11/could-chinas-carbon-emissions-peak-sooner-than-expected>.

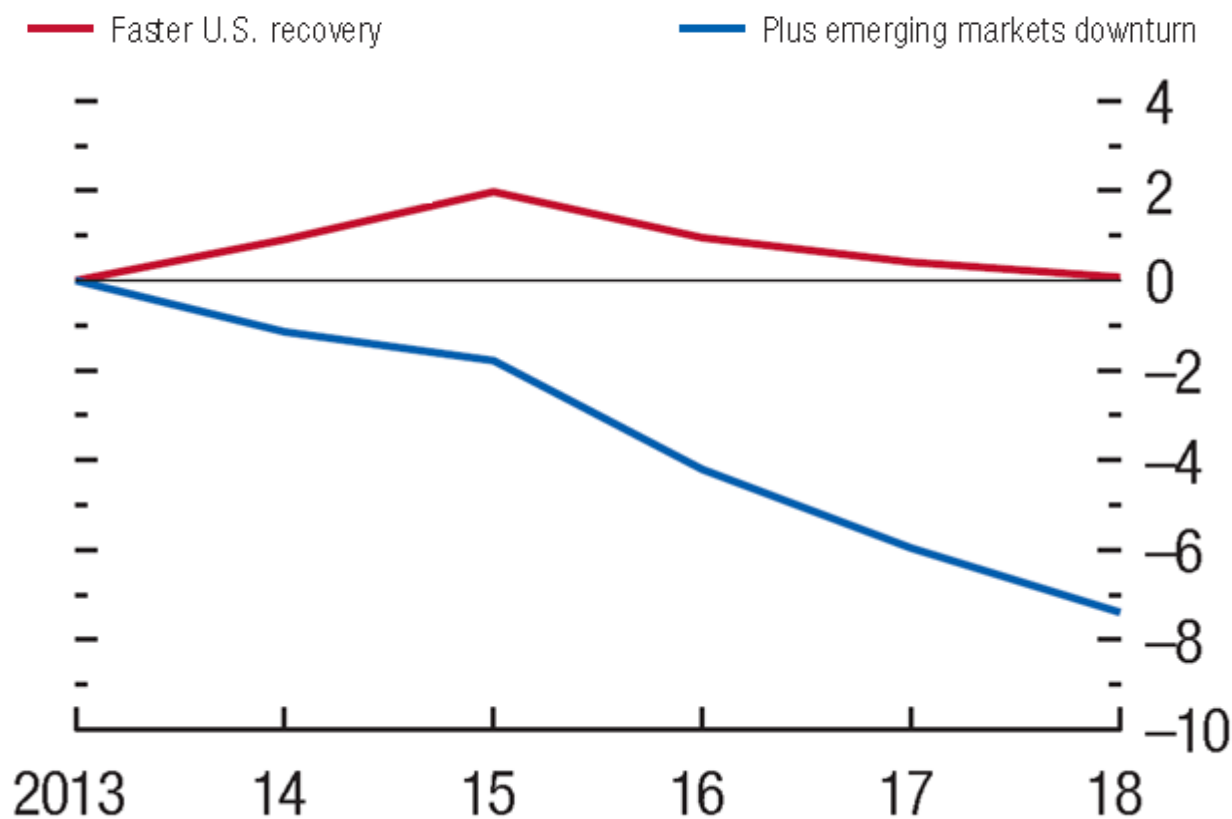
³⁹ IEA, *WEO 2013*, Box 1.2, 39.

⁴⁰ IMF, *World Economic Outlook 2014*, 17.

⁴¹ IMF, *World Economic Outlook 2014*, 18. The downside risks explored in the scenario relate to a downward adjustment in investment as a result of a combination of (1) higher-than-expected costs of capital due to the change in the external environment, (2) recent downward revisions to expectations of growth in partner countries, and (3) a correction of some past overinvestment. In this scenario real GDP growth declines relative to a baseline by nearly 1 percentage point per year in China and 0.6 percentage point in most other emerging markets.

⁴² In 2008-2009 a 3 MBPD drop in demand caused the price of Brent crude to fall from \$97/bbl to \$62/bbl, and during 2009 to go as low as \$40/bbl. BP Statistical Review of World Energy June 2013, “Oil: spot crude prices, 2013,” <http://www.bp.com/statisticalreview>.

Figure 8 Impact on real oil price (%) from combination of a faster recovery in the United States and slower growth in emerging markets (percent deviation from baseline IMF projection)



Source: IMF G20MOD simulations

Ultimately the future growth trajectory of China and other emerging economies is somewhat uncertain, depending on many variables including the likelihood that China’s leaders will enact policies to constrain rapid credit growth, correct financial distortions in the economy, and adopt more market-focused exchange rates. Policy action in other emerging economies to create a more sustainable pattern of economic growth is similarly both uncertain and highly significant. The above analysis, however, highlights the risks to realization of strong growth in non-OECD economies and oil demand in scenarios such as the IEA New Policies Scenario. In the IEA New Policies Scenario, demand for oil continues to grow through 2035, and there is no substantial decline in the rate of demand growth until after 2020. *Protracted slower economic growth in emerging markets could cause the rate of demand growth to flatten within this decade (i.e. before stronger efficiency mandates and other policy actions begin to curb demand growth post-2020).*

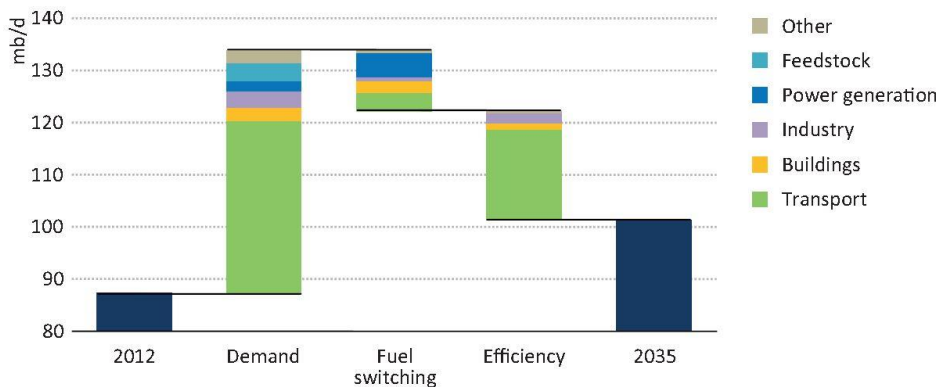
Road transport - efficiency, EVs, air pollution control measures threaten demand growth

Road transport accounts for a larger share of global oil demand than any other activity. As oil-based fuels still supply 95% of the energy for road transport (roughly the same percentage as in 1971), in 2012 global oil demand was 19 MBPD for passenger light-duty vehicles (PLDVs) and 14 MBPD for road freight (i.e. light-commercial vehicles and commercial trucks); the combined oil demand across these two sub-sectors amounted to 38% of total global oil demand.⁴³ Through 2035 the IEA New Policies Scenario projects oil demand for road transport (PLDVs and road freight) to grow by 8 MBPD, an amount equivalent to 57% of the projected net increase in oil demand across all sectors from 2012-2035.

Will increases in road transport efficiency exceed IEA expectations?

Assumptions about increasing efficiency of road transport (particularly for PLDVs), however, make the New Policies Scenario projected increase in transport oil demand notably lower than it would be without such efficiency improvements. The figure below illustrates that in the New Policies Scenario, improvements in transport efficiency (across all forms of transport) reduce projected 2035 global oil demand by roughly 19 MBPD (relative to what demand would be without such efficiency improvements).

Figure 9 IEA New Policies Scenario - improvements in transport efficiency decrease 2035 demand by ~19 MBPD



Source: IEA

The bulk of these savings relate to road transport and reflect the impact of new fuel-efficiency and CO₂-efficiency mandates in the US, Europe, and elsewhere.

⁴³ IEA, *WEO 2013*, 510-514.

Table 5 Transport efficiency in US and EU may displace 4 MBPD by 2035

| Standard(s) | Timeline | Estimated Oil Demand Impact |
|---|-------------------------|---|
| US GHG for light-duty vehicles US fuel-economy for light-duty vehicles | 2012-2016 2017-2025 | 2 MBPD by 2025 (combined) |
| US GHG for heavy-duty vehicles US fuel-economy for heavy-duty vehicles | 2014-2018 2018-2025* | 0.4 MBPD by 2025, 0.5 MBPD by 2035 Potential for additional 0.8 MBPD by 2035 |
| EU GHG for light-duty vehicles | 2020 | 0.54 MBPD by 2030 |

*Phase 2 standards for heavy-duty fuel-economy (for 2018 onwards) to be announced sometime in 2014. Estimate here based on work from the American Council for an Energy-Efficient Economy (ACEEE) using the US Department of Energy's 2012 Vision Model. **Source:** US EPA/DOT, ACEEE, European Commission

Other analyses, however, project the potential for improvements in transport efficiency to be significantly greater than in the IEA New Policies Scenario. *Whereas in the New Policies Scenario the average PLDV on the road in 2035 consumes roughly 30% less fuel than today, a 2012 HSBC report estimated that (on a demand-weighted basis) "a 40% improvement in mileage per gallon is achievable by 2020."*⁴⁴ HSBC note that fuel savings as a result of such an efficiency improvement could amount to 6-7 MBPD (one one-third of 2012 road transport demand). HSBC justify this projection by arguing that existing automobile technology can deliver annual improvements in efficiency greater than the 1.7% observed for 2008-2011.⁴⁵ In the same vein, a 2012 Citi analysis predicts the average fuel economy of PLDVs to increase by 3-4% annually.⁴⁶ Should efficiency of PLDVs increase on this more rapid trajectory, the IEA's projected 3 MBPD increase in oil demand for PLDVs through 2035 becomes far less likely to occur. Inasmuch as the increasing efficiency of passenger vehicles carries over to road freight - which in many non-OECD countries may take some time to occur⁴⁷ - the potential demand impacts become even more significant.

⁴⁴ HSBC Global Research, "Oil & carbon revisited - Value at risk from 'unburnable' reserves," January 25 2013. Part of this difference in the IEA number, however, is due to the relatively greater share of the 2035 car fleet that will be in non-OECD countries that (relative to OECD countries) tend to have lower fuel-efficiency standards.

⁴⁵ Global Fuel Economy Initiative, "International Comparison of light-duty vehicle fuel-economy and related characteristics," Working Paper 5/10, 2011, http://www.globalfueleconomy.org/Documents/Publications/wp5_ia_fuel_Economy_report.pdf.

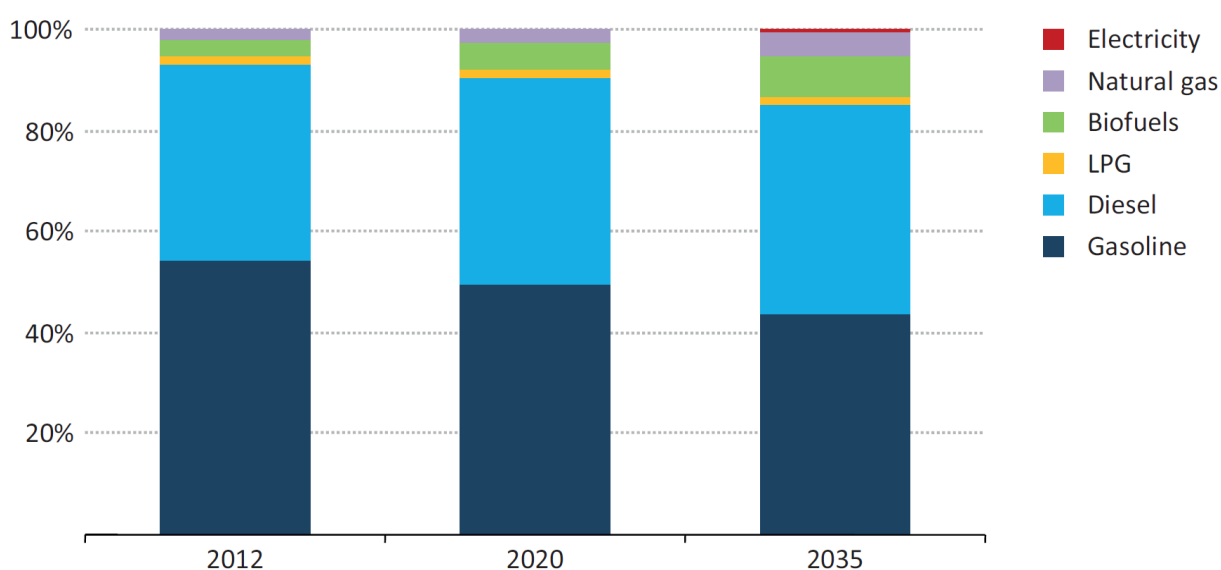
⁴⁶ Citi ("Global Oil Demand Growth - The End is Nigh," 26 March 2013) point to (1) greater focus on fuel efficiency in China and other large non-OECD nations; and (2) proliferating fuel economy standards that, in some cases, require annual fuel economy improvements as high as 4.7%

⁴⁷ For example, Citi (6) forecast the fuel economy of the global heavy-duty truck fleet to increase by only 1-2% annually.

Will demand for electric vehicles exceed IEA projections?

With the exception of the IEA 450 Scenario, all of the demand projections reviewed above assume minimal penetration of non-oil based fuels and technologies into the transport sector. For example, the figure below illustrates that in the IEA New Policies Scenario by 2035 the combination of biofuels, natural gas, and electricity still supply less than 20% of the energy for road transport; as a result, 2035 oil demand displacement from these three transport alternatives appears material - 8.5 million barrels of oil equivalent per day (MBOEPD), up from 3 MBOEPD in 2012 - but manageable.

Figure 10 Fuel mix in road-transport energy demand in IEA New Policies Scenario



Source: IEA. Note: Shares for oil products are calculated on a volumetric basis; the contributions of other fuels are shown as equivalent volumes of the oil product that they displace.

Note in particular in the IEA New Policies Scenario the cautious projections for deployment of electric vehicles (EVs), meaning plug-in hybrid electric vehicles (PHEVs) and battery-electric vehicles, or (BEVs).⁴⁸ In 2012 the global EV market had sales of 100,000 vehicles⁴⁹; in the New Policies Scenario annual EV sales are projected to grow at a 22% CAGR through 2020 (resulting in 2020 sales of 500,000 vehicles⁵⁰) and less than a 15% CAGR from 2020-2035 (resulting in 2035 sales of less than 4 million vehicles). As a result, in the New Policies Scenario EVs account for minimal savings in oil use - 0.035 MBPD in 2020 and ~0.235 MBPD in 2035. In contrast, the 450 Scenario sees significantly more rapid uptake of EVs, with projected oil savings reach 1.5 MBOEPD by 2035.⁵¹

The IEA qualifies its EV projections by noting that "projecting the expansion of the EV market is extremely difficult" and that "a large improvement in the performance of batteries and a big fall in their cost could lead

⁴⁸ The IEA projections discussed here do not include hybrid electric vehicles, or HEVs.

⁴⁹ IEA, *WEO 2013*, 520.

⁵⁰ Comparing with what the IEA calculates as aggregate national 2020 targets for EV sales of 7 million.

⁵¹ IEA, *WEO 2013*, 521.

to rapid take-off-in demand.⁵² It is therefore unsurprising that some private forecasters expect EV sales to grow significantly more quickly than in the IEA Scenarios (particularly since in 2013 global EV sales doubled relative to 2012)⁵³. For example, Navigant Research recently forecast that by 2020 annual light-duty EV sales (PHEVs and BEVs) will reach roughly 3 million vehicles.⁵⁴ 3 million in annual EV sales would be 6X projected 2020 sales in the New Policies Scenario and 3X implied⁵⁵ projected sales in the 450 Scenario. Among the assumptions driving Navigant's more bullish forecast on future EV deployment are increasing vehicle availability, a 26% decline in battery pack costs for PHEVs by 2020 (battery costs accounting for as much as 50% of total PHEV costs), and improved vehicle range and performance of BEVs. Efforts of developing countries to curb local air pollution (a topic discussed below) have also been providing a boost to EV sales.⁵⁶

Table 6 Global electric vehicle sales (plug-in hybrid and battery electric vehicles), 2012 and 2020E

| | 2012 | 2020E |
|-------------------|---------|-------------|
| IEA New Policies | 100,000 | 500,000 |
| IEA 450 | 100,000 | ~1,100,000* |
| Navigant Research | 100,000 | ~3,000,000 |

*Estimated from IEA data based on 0.035 MBPD of oil savings due to EVs in 2020. Source: IEA, Navigant Research, ETA analysis 2014

Navigant's projections have EV sales growing at a 31% CAGR from 2013 through 2020 (from 2012-2020 this would be roughly a 55% CAGR); should this rate of increase continue beyond their forecast period, by the mid-2020s oil savings attributable to EVs would exceed 1 MBPD. Should this rate of increase continue all the way until 2035 (a substantial *if*), oil savings attributable to EVs would reach 13 MBPD. As the IEA notes, projecting long-term demand for an emerging technology is very challenging. Recent trends, however, suggest that potential for oil demand displacement due to EV adoption may be significantly stronger than expected.

In China, measures to fight air pollution may reduce 2035 gasoline demand by 1 MBPD

Projections of increased oil demand for personal transport in non-OECD countries reflect the surge in personal vehicle ownership in these countries. Without question, over the coming decades China and other emerging economies are likely to add hundreds of millions of new cars. With respect to future oil demand, however, it matters significantly exactly how many hundreds of millions of new cars will be added. The IEA

⁵² IEA, *WEO 2013*, 521.

⁵³ EV Obsession, "World Electrified Vehicle Sales (2013 Report)," Feb 10 2014, <http://evobsession.com/world-electrified-vehicle-sales-2013/>.

⁵⁴ Navigant Research, "Electric Vehicle Market Forecasts - Global forecasts for light-duty hybrid, plug-in hybrid, and battery electric vehicles: 2013-2020," 2Q 2013, <http://www.navigantresearch.com/wp-assets/uploads/2013/06/EVMF-13-Executive-Summary.pdf>.

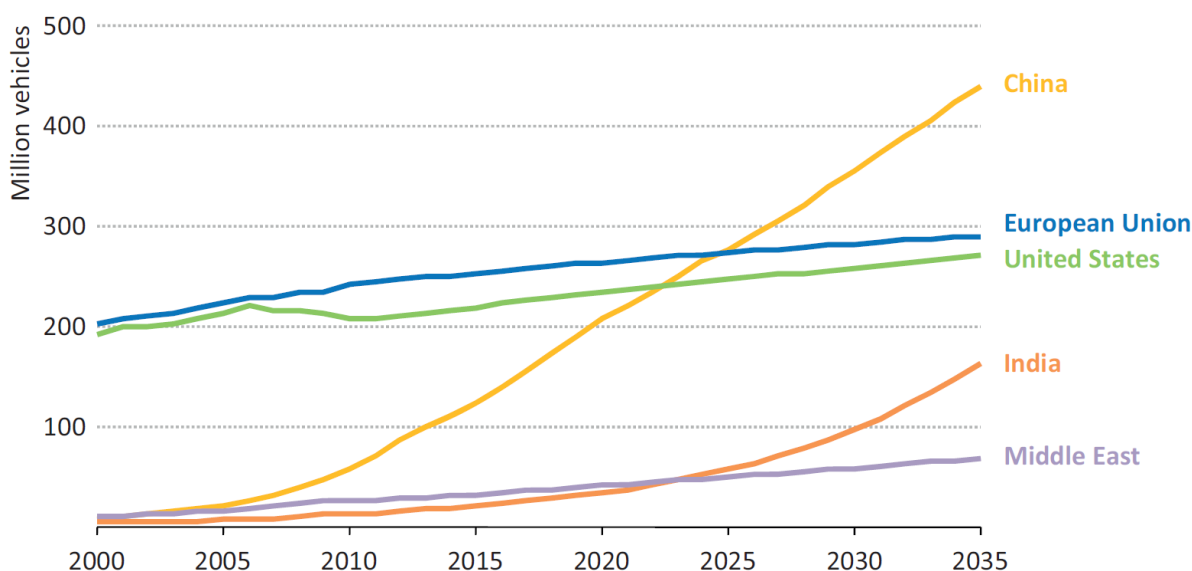
⁵⁵ Implied based on 0.073 MBOEPD in 2020 oil savings.

⁵⁶ "Electric-vehicle production worldwide forecast to surge 67% in 2014", Los Angeles Times, Feb 4 2014, reports that "the city of Beijing is limiting sales of new cars while also deploying 20,000 EVs in 2014, and a total of 170,000 EVs by 2017." <http://articles.latimes.com/2014/feb/04/autos/la-fi-hy-autos-electric-vehicle-global-production-forecast-2014-20140204>

notes that, other things equal, a 1% decline in the annual growth rate of personal light-duty vehicle sales in non-OECD countries (relative to the assumed rate of 4.3%) will reduce 2035 oil demand by 2.7 MBPD.⁵⁷

Measures to curb air pollution in China and other emerging economies present significant downside risk to the IEA's projected rate of new car additions in these countries. Note that of the 14 MBPD projected increase in global oil demand through 2035 under the IEA New Policies Scenario, nearly 3 MBPD of this involves an increase in gasoline demand from China. Rising gasoline demand in China is the result of the IEA projecting a nearly 5X increase in China's fleet of personal cars (i.e. personal light-duty vehicles), from roughly 90 million in 2013 to roughly 430 million in 2035. This projection matches the ambition of several influential leaders in China's automobile sector, who have argued for a national target of 400 million cars by 2030.⁵⁸

Figure 11 Projected growth in personal light-duty vehicle fleet in IEA's New Policies Scenario



Source: IEA.

Analysts from Deutsche Bank, however, argue that increasing China's car fleet to 400+ million vehicles poses a severe danger to China's air quality and public health. In a March 2013 note, Deutsche Bank analysts focused in on the problem of particulate matter (PM2.5)⁵⁹ emissions in China, of which 20% come from cars.⁶⁰ PM2.5 emissions are linked to increased prevalence of asthma and bronchitis, as well as an increase in the death rate from cardiovascular disease and respiratory ailments.⁶¹ The World Health Organization's recommended limit for PM2.5 concentration is 25 parts per million; China's average levels are already 3X the

⁵⁷ IEA, *WEO 2013*, 514.

⁵⁸ Deutsche Bank Markets Research, "China Strategy Special Report: Big bang measures to fight air pollution," February 28 2013.

⁵⁹ This refers to particulate matter less than 2.5 micrometers in diameter, which is believed to pose the greatest health risk because it penetrates deeply into lungs.

⁶⁰ Deutsche Bank Markets Research, 10.

⁶¹ US EPA, "PM 2.5: Objectives and History," <http://www.epa.gov/region4/sesd/pm25/p2.html>.

WHO limit, and in some places (e.g. Beijing in mid-January 2013) have reached 36X the WHO limit (i.e. 900 ppm).⁶² Absent serious reform, DB analysts estimate by 2025 China's average PM2.5 limits will be 10X the WHO limit (i.e. 125+ ppm).

DB outlines a plan to reduce PM2.5 emissions within China to a safe level by 2030 (i.e. to 35 ppm, just above the WHO limit).⁶³ *Aside from reducing emissions from coal plants, the single most important source of PM2.5 emissions reduction (19% of the overall reduction) comes from the transport sector. A large part of this involves reducing China's 2030 target for passenger vehicles from the current 400 million to 250 million.* This would imply curbing annual growth in annual car ownership from a level of 20% (over the past five years) to a level of 4-5% for 2013-2030. Extrapolating this trend beyond 2035 (and reducing the annual growth rate from 2030-2035 to 3%), this implies a 2035 personal vehicle fleet of 290 million cars, versus 430 million in the IEA New Policies Scenario). To achieve this lower growth trajectory, the DB analysts advocate policies such as greater investment in subway and rail and using car a plate auction system to raise the costs of private car ownership.⁶⁴

With respect to the implications for oil demand, the lower growth trajectory for growth in car ownership alone could reduce Chinese oil demand by 1 MBPD by 2035. Note that this likely understates the full demand impact of reducing PM2.5 emissions since, in addition to reduced car ownership, the DB plan also proposes (1) a 1% annual average increase in fuel efficiency and; (2) strong incentives to promote adoption of EVs and NGVs. In other words, not only fewer cars (hence fewer miles driven), but also less gasoline consumed per miles driven, and a reduced share of cars that burn gasoline. Taking such changes into account would increase the reduction in oil demand.

Table 7 Reducing car ownership in line with a PM2.5 control scenario reduces 2035 oil demand by 1 MBPD - increase in car fleet and gasoline use by scenario, 2012-2035

| | PLDV* Fleet 2012 | PLDV Fleet 2035 | Gasoline Use Increase 2012-2035 (MBPD) |
|----------------------------------|---------------------|--------------------|---|
| IEA New Policies Scenario | 90 | 430 | 3 |
| PM2.5 Pollution Control Scenario | 90 | 290 | 2 |

* Passenger light-duty vehicle. Source: IEA, Deutsche Bank, ETA analysis 2014

⁶² Deutsche Bank Markets Research, 102.

⁶³ From 2015-2030 the DB plan sees China's average PM2.5 fall by more than half (i.e. 72.7 to 35 ppm) – implying a significant reduction in annual PM2.5 emissions. Conversely, under the IEA's 2012 New Policies Scenario (comparable data for 2013 has not been released), annual PM2.5 emissions (thousand tons/year) in China over this period decline, but only by 21% - a trend that is not consistent with reducing China's average PM2.5 concentration by more than half. International Institute for Applied Systems Analysis, "Emissions of Air Pollutants for the World Energy Outlook 2012 Scenarios – Draft Final Report," June 2 2012, 24
http://www.worldenergyoutlook.org/media/weowebiste/energymodel/documentation/IIASA_WEO2012_air_pollution.pdf

⁶⁴ The analysts note that "in Singapore, the additional cost of owning a private car (including the price of car license plate, import duty, registration fees, etc.) is about 400% of the original car price. In comparison, fees and taxes on car ownership in Beijing are about 38% of the original car prices. This is one of the reasons why car penetration rate in Beijing is now 1.5x of that in Singapore, even though Beijing's per capita income is only 1/8th of the latter." Deutsche Bank Markets Research, 37.

Beyond China - India and South Asia

Though notable, 1 MBPD is still only 7% of the projected increase in 2012-2035 oil demand under the IEA New Policies Scenario. The potential for measures to curb air pollution to affect oil demand, however, extends far beyond China. *For example, under the New Policies Scenario by 2035* India is projected to add ~150 million new cars, with the result being an additional 1 MBPD of gasoline demand.⁶⁵ A recent air-sampling study, however, found PM2.5 levels in New Dehli to be twice as high as those in Beijing (and trending upward),⁶⁶ this in a country that already has the world's highest death rate from chronic respiratory diseases and more deaths from asthma than any other nation.⁶⁷

More generally, a more recent analysis by Yale University researchers identified seven of the 10 countries with the worst air pollution exposures in the world to be in South Asia.⁶⁸ Many of these same countries, however, account for a large share of the projected 7.7 MBPD in 2035 gasoline use from "other" economies in the IEA New Policies Scenario.⁶⁹ Moving from personal to commercial transport and looking across the entire non-OECD region (i.e. including India and China), the IEA projects 7 MBPD of increased demand for diesel through 2035.⁷⁰

The bottom line is that much of the IEA's projected increase in oil consumption for transport is set to occur in countries that already are grappling with severe air pollution and public health challenges. Inasmuch as the above case study on China is any indication, reducing pollution levels within these countries to acceptable levels may require curbing growth in personal and commercial vehicles (hence consumption of gasoline and diesel) significantly below projections of the IEA New Policies Scenario. This suggests that the cumulative impact of measures to fight air pollution in developing countries could amount to several MBPD by 2035.

⁶⁵ IEA, *WEO 2013*, 513.

⁶⁶ Gardiner Harris, "Beijing's Bad Air Would be Step up for Smoggy Dehli," *New York Times*, Jan 25, 2014, http://www.nytimes.com/2014/01/26/world/asia/beijings-air-would-be-step-up-for-smoggy-delhi.html?_r=0

⁶⁷ World Health Organization, "Mortality: Chronic respiratory diseases, deaths per 100,000 – Data by Country," <http://apps.who.int/gho/data/node.main.A866?lang=en>

⁶⁸ Yale Center for Law and Environmental Policy, "2014 Environmental Performance Index: Air Quality," <http://www.epi.yale.edu/our-methods/air-quality>

⁶⁹ This means countries other than the US, Europe, Middle East, India, and China.

⁷⁰ IEA, *WEO 2013*, Figure 15.19.

Expanded fuel-switching: natural gas, solar

Figure 10 above illustrates that in the IEA New Policies Scenario, fuel-switching (chiefly in the transport and power sectors) reduces 2035 demand by almost 12 MBPD, relative to what demand would be without such fuel-switching. Continued declines in the cost of alternative fuels and technologies, however, may increase the scale and speed at which such substitution can occur. The paragraphs below review recent analyses of the oil-substitution potential of natural gas and solar.

Mortality: Chronic respiratory diseases, deaths per 100,000

Data by country

Oil-to-gas switching potential of 4.9 MBPD by 2020, 13.6 MBPD by 2025

The combination of increasing shale gas production and expanded trade in liquefied natural gas (LNG) is broadening the opportunities to use natural gas as a replacement for oil. Citi analysts note attractive oil-to-gas switching opportunities in "bunker fuel for ships, Natural Gas Vehicles (NGVs) replacing primarily gasoline-powered Light Duty Vehicles (LDVs), heavy duty trucks both in and ex-US, power generation, petrochemicals and various industrial processes."⁷¹ Moreover, in each of these sectors actual oil-to-gas switching has been accelerating as of late. Surveying the substitution potential across all sectors (using what they deem to be "fairly conservative assumptions"), Citi analysts note a potential impact of 2.3-4.9 MBPD by 2020 and 5.5-13.6 MBPD by 2025.⁷² Combined with increasing efficiency of road transport (discussed above), Citi argue that oil-to-gas substitution may limit 2015-2020 oil demand growth to 0.4 MBPD or less (versus a 2015-2020 increase of ~5 MBPD in the IEA New Policies Scenario).

Table 8 Potential natural gas substitution for oil, 2012-2025 (MBPD)

| | Low | Low | High | High |
|-----------------------------|-------------|-------------|-------------|-------------|
| Sector | 2020 | 2025 | 2020 | 2025 |
| Shipping | 0.1 | 0.6 | 0.3 | 1.6 |
| Natural Gas Vehicles | 0.7 | 1.4 | 1.5 | 4.0 |
| US trucks | 0.2 | 0.5 | 0.6 | 1.0 |
| Global trucks (ex US) | 0.1 | 0.5 | 0.3 | 1.0 |
| Power generation | 0.7 | 1.0 | 1.0 | 2.0 |
| Petrochemicals | 0.3 | 1.0 | 0.7 | 2.0 |
| Other | 0.2 | 0.5 | 0.5 | 2.0 |
| Total | 2.3 | 5.5 | 4.9 | 13.6 |
| % global oil demand* | 2.0 | 5.8 | 5.0 | 13.8 |

*Oil demand estimates from IEA New Policies Scenario. **Source:** Citi research, IEA, ETA analysis 2014

⁷¹ Citi, 2.

⁷² Citi, 2.

Declining solar costs may hasten decline of oil use in the power sector

Currently 6% of oil global oil demand is used for power generation (5.5 MBPD in 2012), a share that the IEA New Policies Scenario projects to drop below 3% by 2035 (i.e. to 2.7 MBPD). A recent note from Bernstein Research, however, argues that the falling cost of solar energy may hasten this decline. Focusing on the costs of utility-scale solar in developing economies with a strong solar resource (which they justify as representative of "the growth markets for global energy today"), Bernstein find \$/MMBtu cost of solar to be below that of oil or of Asian LNG.⁷³ The authors argue that this cost advantage will accelerate the use of solar to replace off-grid kerosene, diesel, and crude oil as a fuel for power generation.⁷⁴

There are limits to the ability to replace oil with solar as a fuel for power generation, owing both to the variability of solar and (in some countries) to heavy subsidies for oil consumption (discussed below). That said, as with electric vehicles, the declining costs of solar have the potential to accelerate near-term substitution away from oil.

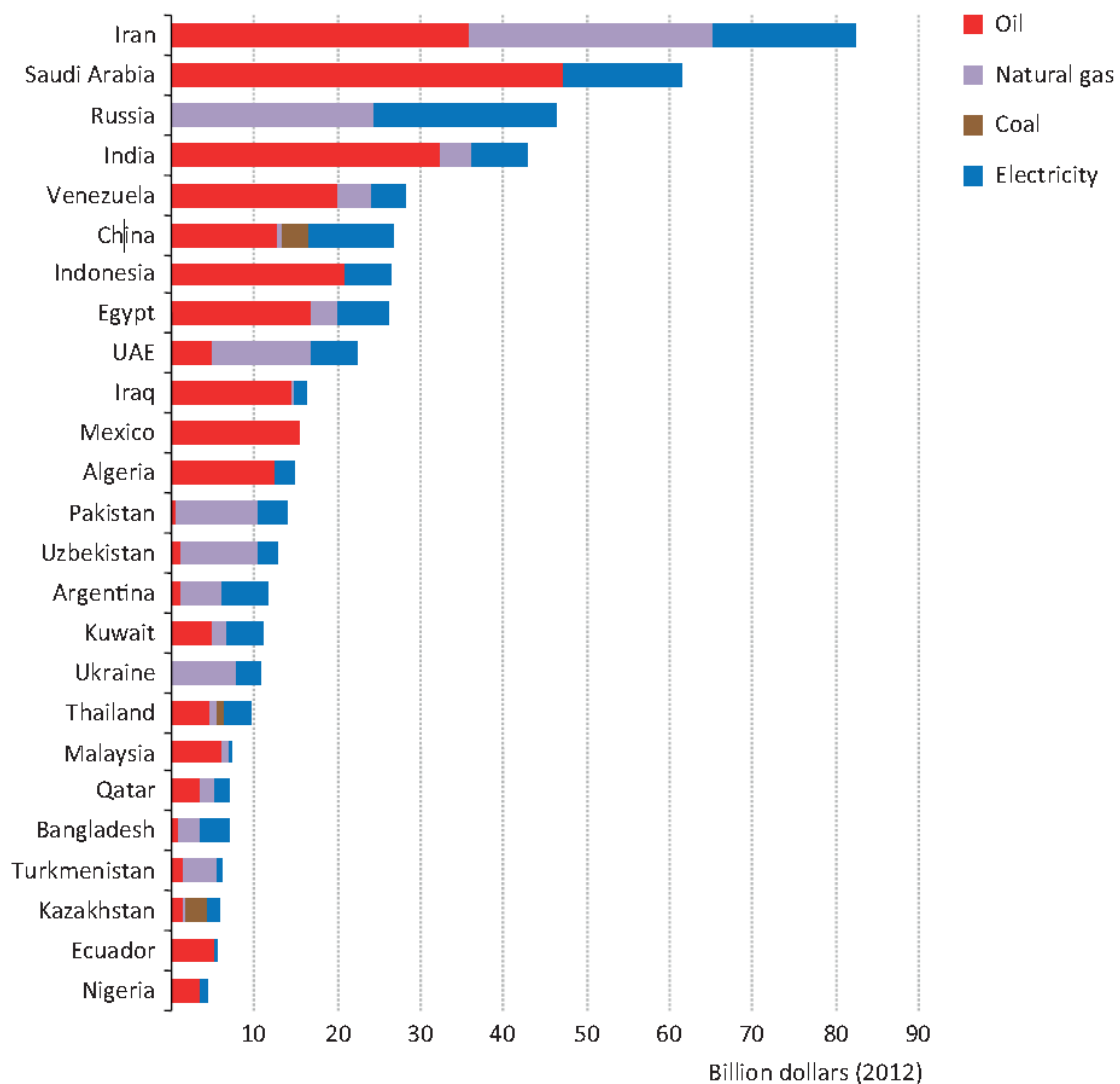
⁷³ Bernstein Research, "Welcome to the Terrordome," April 10 2014.

⁷⁴ The authors further argue that recognition of the long-term vulnerability of oil demand (first in power generation, later in transport) will cause a surge in oil production that puts downward pressure on oil prices over the medium term.

Progress in reducing oil subsidies increases likelihood of future demand reductions

Note that each of the trends outlined above will be more likely to occur to the extent that countries of the world follow through on commitments to reduce subsidies for oil consumption. For 2012, the IEA estimates global subsidies for oil products to be \$277 billion (including both production and consumption subsidies).⁷⁵ Oil consumption subsidies comprise 75% of this total and are concentrated in oil-exporting countries of the Middle East and North Africa, as well as oil-importing countries of developing Asia. For example, the IEA estimates that in 2012 countries in the Middle East subsidized oil consumption to the tune of \$112 billion (or 13% of oil-export revenues).⁷⁶

Figure 12 Economic value of fossil-fuel consumption subsidies by fuel for top 25 countries, 2012



Source: IEA

⁷⁵ IEA, *WEO 2013*, 94. For reference, the IEA estimates 2012 global subsidies to renewable energy were \$101 billion (*WEO 2013*, 25).

⁷⁶ IEA, *WEO 2013*, 506.

Such subsidies can severely distort the economics of oil consumption, with negative economic and environmental consequences. For example, the IEA notes that:

- "At the extremely low gasoline prices prevailing in Saudi Arabia today, an investment in a more efficient car (consuming half the gasoline per 100 kilometres (km) of the average car on Saudi Arabia's roads today) would pay back only after almost twenty years"⁷⁷
- Oil supplies the fuel for one-third of power generation in the Middle East (2 MBPD), at an unsubsidized cost (given world oil prices above \$100/bbl) of nearly \$200/Megawatt-hour (i.e. nearly 4X the Middle East's cost of natural gas combined-cycle plants, 2X the cost onshore wind, and 1.3X cost of Solar PV).⁷⁸

Oil consumption subsidies are particularly relevant given that high-subsidy nations in the Middle East and developing Asia account for nearly all of the growth in oil demand in the IEA New Policies Scenario through 2035. Projections in this scenario incorporate partial phase-outs of subsidies for oil (as well as subsidies for coal, natural gas, and electricity), and the IEA notes encouraging recent initiatives in Indonesia, India, and China (along with more tentative efforts at reform in Iran and Saudi Arabia). Such reform efforts reflect implementation of commitments made in recent policymaking forums such as the 2012 Rio+20 conference and the 2009 G-20/Asia Pacific Cooperation Forum Pittsburgh Summit. Inasmuch as such reform efforts gather momentum, the likelihood of future oil demand coming in below current projections will increase considerably.

⁷⁷ IEA, *WEO 2013*, 507.

⁷⁸ IEA, *WEO 2013*, 508.

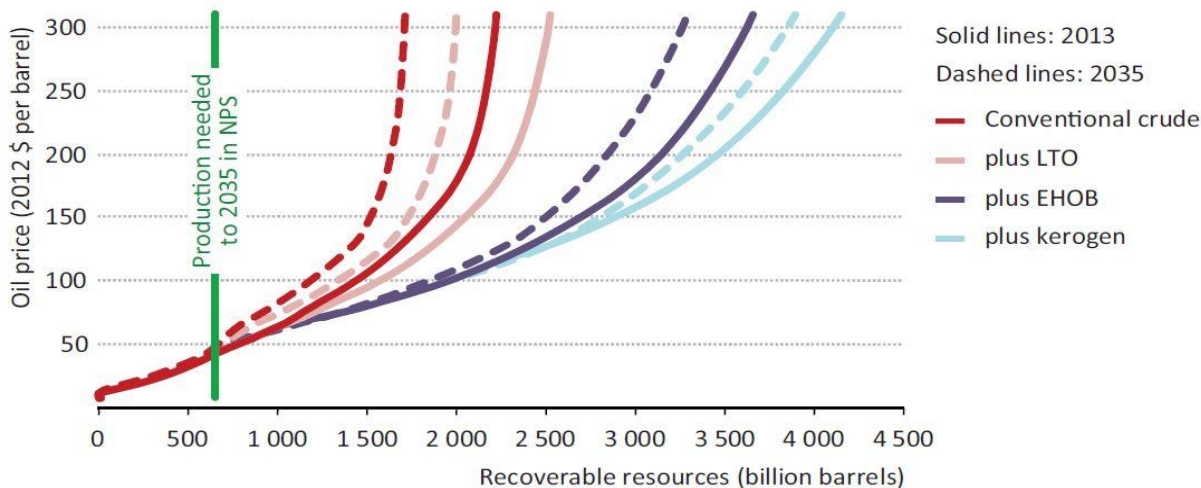
4. Supply costs of marginal oil production under different oil demand scenarios

To determine the risk to global oil basins under a climate-constrained future, it is necessary to compare the demand projections above with estimates of global oil supply curves. Such an analysis demonstrates which portions of the global oil supply curve could become uneconomic under different demand scenarios (for more on this topic, see our companion *Carbon Supply Cost Curves* report.⁷⁹ As a metric of supply costs we focus on Breakeven Oil Price (BEOP), which our data provider (Rystad Energy) defines as the Brent-equivalent oil price that – considering all future cash flows (i.e. costs, revenues, government take - is needed to deliver an asset-level net present value (NPV) of zero assuming a 10% discount rate.⁸⁰ The paragraphs below emphasize some key BEOP points on the oil supply curve under different demand scenarios.

Key supply cost #1: \$50/bbl - BEOP of marginal production from world oil supply under IEA New Policies Scenario 2035 demand projection

Excluding natural gas liquids and a variety of ancillary oil sources (i.e. gas-to-liquids, coal-to-liquids, and additives), meeting the level of projected oil demand in the IEA New Policies Scenario will require 640 billion barrels of cumulative production between now and 2035.⁸¹ Comparing production needs with global oil supply curves can give an indication of the supply cost of the marginal barrel of oil necessary to meet future demand. The figure below suggests that under the New Policies Scenario, the marginal barrel needed to meet oil demand through 2035 would be commercial at \$50/bbl. Assuming no supply constraints, \$50/bbl can be thought of as the long-run price needed to provide the marginal barrel of oil through 2035.

Figure 13 World supply cost curves for 2013 and 2035 in the IEA New Policies Scenario



The supply curves are cumulative, i.e. the “plus LTO” line includes conventional crude and LTO (light tight oil - see Appendix A); the “plus EHOB” includes conventional crude, LTO and EHOB (extra heavy oil and bitumen), and so on. The vertical green line indicates 2013-2035 required production. **Source:** IEA.

⁷⁹ Carbon Tracker Initiative and Energy Transition Advisors, *Carbon Supply Cost Curves*.

⁸⁰ Rystad Energy, "Breakeven prices in UCube - breakeven price calculated at an asset level," *UCube Technical Presentation 2014*, 2014, 23.

⁸¹ IEA, *WEO 2013*, 455.

In practice, however, the marginal long-run supply cost through 2035 is likely to be far above \$50/bbl. The chief reason for this is that the "world supply cost curves" approach does not allow for producers that may curtail production at prices well above the theoretical breakeven prices. Especially important in this regard are the actions of the 12 countries that comprise the Organization of Petroleum Exporting Countries (OPEC), a topic discussed in more detail below.

Role of OPEC in world oil markets

As the source of 73% of the world's current proved oil reserves⁸², the 12 member states of the Organization of Petroleum Exporting Countries (OPEC)⁸³ wield significant influence in global oil markets. OPEC nations coordinate their oil production activities around annual quotas intended to keep world oil prices within agreed-upon levels.⁸⁴ Even with quota-restricted supply, however, OPEC nations remain a dominant source of world oil production. The table below illustrates that through 2050 OPEC is projected to supply 38% of global oil production⁸⁵; moreover, given that member states control the lion's share of the world's low-cost conventional crude oil, OPEC is projected to supply 55% of production with a breakeven oil price of \$0-60/bbl (see Table 6 below).

Table 9 Oil production total and in the \$0-60/bbl breakeven oil price, 2014-2050 (MBPD)

| | Total Oil Production | Oil Production \$0-60/bbl |
|------------|----------------------|------------------------------|
| OPEC | 38 | 29 |
| % OPEC | 38% | 55% |
| non-OPEC | 61 | 24 |
| % non-OPEC | 62% | 45% |

Source: Rystad Energy, ETA analysis 2014

Note, however, that OPEC target levels for world oil prices are thought to be well above the marginal costs of production in OPEC nations. Partly this is because the dominant producers within OPEC are national companies such that are fully-owned by their national governments (e.g. Saudi Aramco, National Iranian Oil

⁸² BP, *BP Statistical Review of World Energy*, June 2013, p. 6. Includes gas condensate and natural gas liquids (NGLs) as well as crude oil. BP defines proved reserves of oil as "generally taken to be those quantities that geological and engineering information indicates with reasonable certainty can be recovered in the future from known reservoirs under existing economic and operating conditions."

⁸³ OPEC members include Saudi Arabia, Iran, Iraq, Kuwait, Qatar, the United Arab Emirates, Nigeria, Angola, Algeria, Libya, Venezuela, and Ecuador.

⁸⁴ Such quotas enable OPEC to use its spare production capacity - currently estimated at 2-4 MBPD, with a medium-term goal of 8 MBPD - to increase or decrease supply in response to changing economic conditions. OPEC, "OPEC Upstream Capacity in the Medium Term", *OPEC World Oil Outlook 2011*, http://www.opec.org/opec_web/en/data_graphs/645.htm. Goldman Sachs, *380 Projects to Change the World: From Resource Constraint to Infrastructure Constraint*, April 12, 2013, 17.

⁸⁵ In the IEA New Policies Scenario through 2035, OPEC nations increase their cumulative share of global oil production from 43% to 46%. IEA, *WEO 2013*, 488-489.

Company, Qatar Petroleum, PDVSA, etc.); these governments depend on oil exports to supply the overwhelming majority of government revenues. This has led analysts to coin the term "OPEC fiscal breakeven price," meaning the oil price necessary to balance revenues and expenditures OPEC governments (given current spending commitments). For 2013 one study estimate the output-weighted fiscal breakeven price of OPEC nations to be \$105/bbl.⁸⁶

The fiscal needs and coordinated production decisions of OPEC countries are a key reason why, for a given demand scenario, market oil prices may be above the breakeven price of marginal supply.⁸⁷ Still, given the variance in required fiscal breakeven prices across OPEC - from \$58/bbl in Qatar to \$144/bbl in Iran - there is considerable uncertainty about how OPEC would respond to a structural decline in oil demand as would occur in a carbon-constrained world.⁸⁸ Should individual OPEC nations seek to stabilize government revenues by pressing for higher production quotas, the wedge between market oil prices and costs of marginal supply may diminish (thereby exposing higher-cost producers within and outside OPEC to potentially significant downside).

⁸⁶ APICORP (Arab Petroleum Investments Corporation), 2013, "Modeling OPEC Fiscal Break-Even Oil Prices: New Findings and Policy Insights", *Economic Commentary*, Vol. 8, No. 8-9, APICORP research

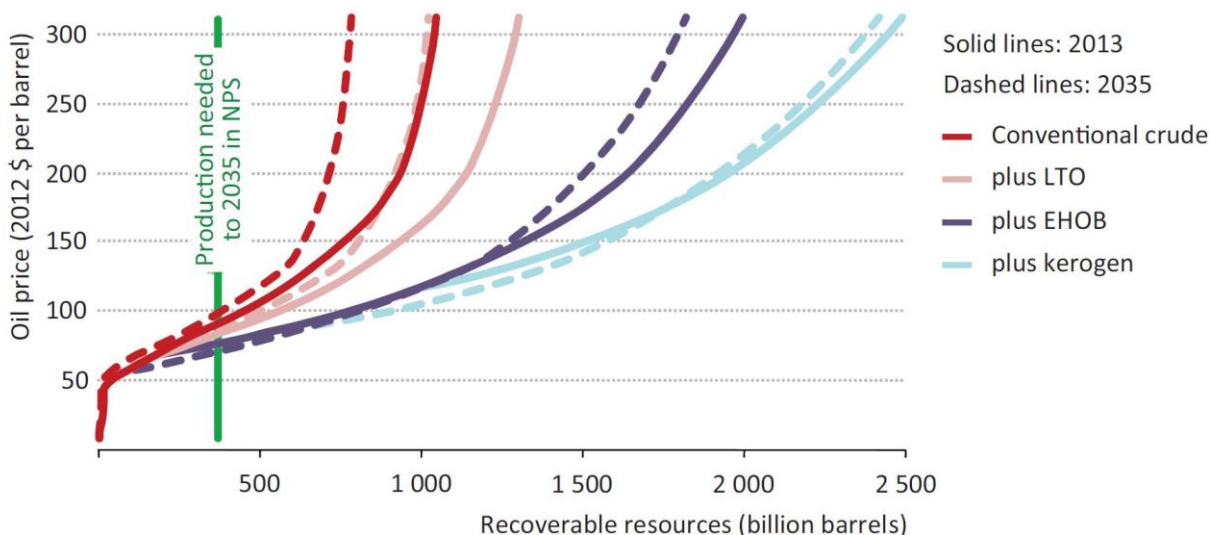
⁸⁷ IEA, *WEO 2013*, 455-456. For example, the IEA cites the fiscal needs of OPEC countries as a key reason to doubt the likelihood of its "Low Oil-Price Case" (in which an additional 5-6 MBPD of oil supply, chiefly from OPEC, causes the 2020-2035 world oil price to stabilize at \$80/bbl in real terms - roughly the production cost of marginal supply - instead of increasing to \$128/bbl as in the New Policies Scenario). IEA, *WEO 2013*, 490-493.

⁸⁸ Note that the IEA's "Low Oil-Price Case" – discussed in the note above - assumes the same demand trajectory as the New Policies Scenario.

Key supply cost #2: \$80-90/bbl - BEOP of marginal non-OPEC production under IEA New Policies Scenario demand projection

To gain a more accurate perspective on future long-run marginal supply costs, it is necessary to look at the ~60% of cumulative production (i.e. 380 billion barrels) that the IEA New Policies Scenario projects to come from non-OPEC sources. Note that long-run non-OPEC supply curves for the most part *begin* at around \$50/bbl, and intersect with required cumulative production through 2035 at \$80-90/bbl. Hence, assuming that OPEC defends oil prices as described in Box 1.2 above, the long-run marginal cost of oil will be set by non-OPEC costs. Looking at new and existing projects, it appears that oil demand through 2035 can be met from non-OPEC oil resources with a long-run marginal supply cost of \$80-90/bbl.

Figure 14 Non-OPEC supply cost curves for 2013 and 2035 in the NPS



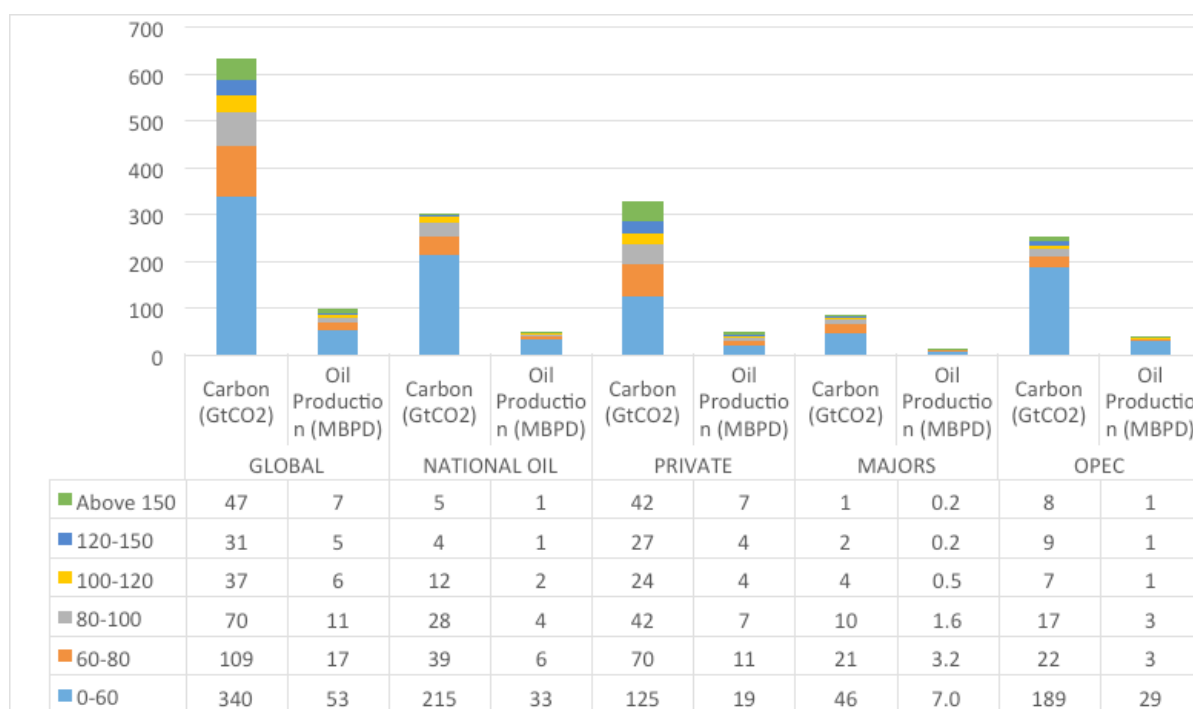
The supply curves are cumulative, i.e. the “plus LTO” line includes conventional crude and LTO (light tight oil);⁸⁹ the “plus EHOB” includes conventional crude, LTO and EHOB (extra heavy oil and bitumen), and so on. The vertical green line indicates 2013-2035 required production. **Source:** IEA.

⁸⁹ Various categories of oil supply in this IEA figure are different from those we use in our companion *Carbon Supply Cost Curves* report. Here “light tight oil” contains elements of what we term “tight liquids” as well as elements of what we term “shale oil”; “kerogen” is included in the category we term “shale oil”; “extra heavy oil and bitumen” combines our categories of “extra heavy oil” and “oil sands.”

Key supply cost #3: \$60/bbl – BEOP of marginal production with 360 GTCO₂ 2050 carbon budget

In our companion report on *Carbon Supply Cost Curves*, we simulate a low-carbon future by assuming a 2050 carbon budget for oil of 360 GTCO₂, which is equivalent to roughly ~766 billion barrels of required cumulative oil production (or average daily production of 56-57 MBPD).⁹⁰ Using data from Rystad Energy’s UCube upstream oil and gas database⁹¹ to construct a global oil supply curve, we find that – including all potential OPEC production – essentially all of this carbon can be supplied from production with a break-even price of \$60/bbl or less (Table 6 below). Hence \$60/bbl becomes a key threshold supply cost, as production within this range will be needed even in a 2°C climate-constrained world.⁹²

Table 10 Potential carbon (GTCO₂) and oil (MBPD) production by BEOP level, 2014-2050



Source: Rystad A/S, ETA analysis 2014

*Breakeven oil price, i.e. price that generates a lifecycle project NPV of zero assuming a 10% discount rate.

**“National Oil” companies refers to partly or fully state-owned companies, whereas “private” companies have no formal degree of state ownership.

*** “Majors” are a sub-category of the “private” category and include - ExxonMobil, BP, Royal Dutch Shell, Chevron, Total, ConocoPhillips and Eni).

⁹⁰Carbon Tracker Initiative and Energy Transition Advisors, *Carbon Supply Cost Curves*, 27-28. Given a 2°C 2050 carbon budget for all fossil fuels of 900 GTCO₂, we approximate an “oil-specific” carbon budget of 360 GTCO₂ to be 40% of the overall fossil fuel budget (roughly consistent with its current share of global fossil fuel-related CO₂ emissions, which in 2011 the IEA reported as 36% - IEA, *WEO 2013*, Annex A - Tables for Scenario Projections, 574).

⁹¹ Rystad Energy, “UCube,” describes UCube as a “complete and integrated field-by-field database, including reserves, production profiles, financial figures, ownership and other key parameters for all oil and gas fields, discoveries and exploration licenses globally.” <http://www.rystadenergy.com/Databases/UCube>

⁹² Applying a somewhat different methodology from that of our *Carbon Supply Cost Curves* report, Rystad concluded that the most expensive field necessary to meet its 2050 oil-specific carbon budget (of 358 GTCO₂) had a BEOP of \$72/bbl - suggesting that, in a 2°C world, currently non-producing fields with breakeven costs above \$72/bbl are unlikely to be developed (Rystad Energy, *Petroleum Production under the 2 degree scenario (2DS)*, July 2013, 26).

Long-term oil price projections, marginal supply costs versus actual market prices

The supply costs (i.e. break-even prices) calculated above illustrate the cost of production for the marginal barrel of oil supply under a given demand scenario. Note, however, that break-even prices of marginal production do not necessarily determine the prevailing market oil price. In the New Policies Scenario the average IEA crude oil import price (a proxy for international oil prices) moves steadily upward to reach \$113/bbl by 2020 and \$128/bbl by 2035 (both figures in year-2012 dollars).⁹³ Relative to the New Policies Scenario, the 450 Scenario sees reduced demand for oil and hence a reduced call on costlier non-OPEC production; the result is that oil price hits a ceiling of \$110/bbl in 2020 and then gradually declines to \$100/bbl in 2035. Overall, oil prices average \$111/bbl in the 450 Scenario versus \$122.5/bbl in the New Policies Scenario (both figures in year-2012 dollars). Note that these values are above the \$80-90/bbl marginal supply cost for non-OPEC supply in the New Policies Scenario.

Table 11 Oil prices in the IEA New Policies and 450 Scenarios, 2011-2035 (2012\$/bbl)

| | 2011 | 2020 | 2030 | 2035 | Average |
|--------------|------|------|-------|------|---------|
| New Policies | 110 | 113 | 126.5 | 128 | 122.5 |
| 450 | | 110 | 107 | 100 | 111 |

Source: IEA WEO and Redrawing Energy and Climate Map

Since the New Policies and 450 Scenarios projections go only until 2035 (whereas the timeframe our companion Carbon Supply Cost Curves report extends to 2050), we reproduce another set of IEA projections for its 4DS and 2DS scenarios (which extend to 2050, but lack the detailed published results by region and sector).⁹⁴ In the 2DS scenario by 2050 the oil price drops to \$91/bbl (in 2012 dollars); in the 4DS scenario declines to \$124/bbl by 2050.

Table 12 Oil prices in the IEA 2DS and 4DS Projections, 2011-2050 (2012\$/bbl)

| | 2011* | 2020 | 2030 | 2050 | Average |
|-----|-------|------|------|------|---------|
| 4DS | 110 | 114 | 123 | 124 | 121 |
| 2DS | | 102 | 102 | 91 | 100 |

*For consistency with table above 2011 price shown is actual 2011 price, rather than the predicted price (which was substantially lower). Source: IEA ETP 2012.

⁹³ IEA, *WEO 2013*, 45.

⁹⁴ IEA, *Energy Technology Perspectives 2012: Pathways to a Clean Energy System*, (Paris: OECD/IEA, 2012), 8, 31, <http://www.iea.org/Textbase/npsum/ETP2012SUM.pdf> Note that, through 2035, the 4DS and 2DS Scenarios closely resemble the New Policies and 450 Scenarios.

As discussed below, the reasons for this wedge between market prices and resource supply costs include:

- *Curtailment of supply by OPEC producers:* For discussion of this, see the “Role of OPEC in world oil markets” section above.
- *Provision for technical and geopolitical risks risk (i.e. a \$15/bbl “contingency”):* In our companion *Carbon Supply Cost Curves* report, we discuss the industry use of a “contingency” (which we estimate at a flat \$15/bbl) to provide some spread between a project’s breakeven price and the actual market oil price.⁹⁵ Typically, oil companies require an oil price for budget purposes that is above that needed for commerciality. So, if an oil development had a breakeven price of \$80/bbl, the oil company would not sanction development unless its expected oil price was well above this level. This contingency is meant to serve as a buffer against unforeseen risks and volatility in prices and costs. This is particularly relevant since the future average crude import prices in the IEA Scenarios – i.e. \$128/bbl in 2035 in the New Policies Scenario – are calculated with a risk-free discount rate.⁹⁶
- *Constraints on increasing non-OPEC supplies:* Even leaving aside intentional restrictions of supply by OPEC and standard provision for risk, the oil industry faces challenges in rapidly increasing production to meet growing demand including, (1) the long lead times required for projects to come online (with, for example, the largest deepwater projects now having a seven-year time span between discovery and project sanction)⁹⁷; (2) shortages of skilled personnel (particularly to execute ultra-deepwater, oil sands, and other complex unconventional projects), which are compounded by the oil industry’s generally cautious hiring practices;⁹⁸ and (3) geopolitical instability. The IEA argues that such constraints, rather than economics, constitute the major barrier to expansion of global oil supplies. This means that the oil price may be above the cost of the marginal barrel, “limiting demand to a level that can reasonably be expected to be supplied, given expected limitations in both OPEC and non-OPEC countries.”⁹⁹

It is worth noting that estimating future oil prices is a blend of science and gut feel which explains why those from different bodies can differ so materially. We would also note that, as used by industry, many oil price “forecasts” are actually planning assumptions. By this we mean they are prices that oil companies and economic forecasters use to assess company financial projections or economic outlooks, not what they actually think the oil price will necessarily be. But even if the oil price is an assumption rather than a projection or forecast, it can still influence development decisions if it is driving decisions regarding capital allocation. For example, a company using an \$80/bbl planning assumption (which many international majors

⁹⁵ Carbon Tracker Initiative and Energy Transition Advisors, *Carbon Supply Cost Curves*, 8. We draw the \$15/bbl as industry convention from Rystad Energy, *Petroleum Production under the 2 degree scenario (2DS)*, July 2013, 26.

⁹⁶ IEA, *WEO 2013*, 455-456. For comparison, IEA oil supply costs (and Rystad Energy UCube analyses) assume a uniform 10% discount rate. In their project analyses, Goldman Sachs assume a discount rate that varies from 11-15% depending on the country (Goldman Sachs, *380 Projects*, 131).

⁹⁷ Goldman Sachs, *380 Projects*, 23.

⁹⁸ IEA, *WEO 2013*, 455-456, 500

⁹⁹ IEA, *WEO 2013*, 456.



do) would not go ahead with a project that needed \$100/bbl even if the market price was \$120/bbl. For example, as of Q42013 Shell tested the economic performance of long-term projects against price ranges of \$70-110/bbl for Brent crude oil.¹⁰⁰ This is below the IEA's range despite Shell's scenarios showing a long-term growth rate for oil demand either equal to or nearly twice that of the IEA's New Policies Scenario.

The takeaway from the above discussion is that, due to both industry dynamics and the presence of risk, over long time periods the average supply cost for marginal production is likely to be below average market oil prices. This finding is highly relevant to the analysis in our companion Carbon Supply Cost Curves report.

¹⁰⁰ Shell 2013 Annual Report, "Crude Oil and Natural Gas Prices," 16 http://reports.shell.com/annual-report/2013/servicepages/downloads/files/entire_shell_ar13.pdf

Relating future oil demand estimates to key BEOP levels on oil supply curves

We now move on to assess the price bands that are likely to determine which projects are likely to be viable in a low-carbon world. Looking at the key BEOP levels above, key break-even prices levels above, we believe that the global oil supply curve falls into five "breakeven price bands."

- *OPEC produces (\$0-60/bbl)*: Including all potential OPEC supply, production with a BEOP below \$60/bbl can supply nearly all required oil through 2050 assuming a 2°C "oil-specific" carbon budget 360 GtCO₂ (and all required oil through at least 2035 in the IEA New Policies Scenario). This is the scenario where OPEC does not constrain production to protect prices.
- *OPEC defends market share (\$60-80/bbl)*: This is the price level where much future *non*-OPEC production becomes economic. Excluding the \$15/bbl contingency we mention above, this is therefore the area to which prices would need to fall to curtail new investment outside OPEC. Such a price would imply that OPEC had decided to abandon its policy of defending price and moved to defending market share (as it has done previously, for example in 1986)
- *Today (above \$80/bbl up to \$100/bbl)*: This is the planning level that most major oil companies use to assess developments. The top end of this band is close to the current long-term price of oil and as a result developing projects with BEOPs near \$100/bbl may be seen as risky. By this we mean that projects in this band, especially towards the \$100/bbl end, could prove uneconomic, especially under a low-oil demand scenario.
- *High demand future (\$100-120/bbl)*: As this band is at or above the long term price of oil, projects in this band must be considered marginal in our view. As the band is above most companies' planning assumptions, projects in this band are unlikely to be developed except for strategic reasons.
- *High-price future (\$120-150/bbl)*: This band is above most industry assumptions and forecasts and would only appear possible if demand growth proved to be extremely robust or, more likely, if we saw a supply shock such as the 1979 Iranian revolution or the 1973 OPEC embargo. Even if prices rose to these levels, we suspect that oil companies will be reluctant to commit to developments unless conditions were seen to be sustainable. As a result, projects in this band are likely to be seen by companies themselves as uneconomic.

Appendix A - Details on IEA Scenarios

Table 13 Cross-cutting policy assumptions by scenario for selected regions

| | Current Policies Scenario | New Policies Scenario | 450 Scenario |
|---------------------------|---|---|--|
| OECD | | | <ul style="list-style-type: none"> Staggered introduction of CO₂ prices in all countries. \$100 billion financing provided to non-OECD countries by 2020. |
| United States | <ul style="list-style-type: none"> State-level renewable portfolio standards (RPS) that include the option of using energy efficiency as a means of compliance. Regional Greenhouse Gas Initiative (RGGI): mandatory cap-and-trade scheme covering fossil-fuel power plants in nine northeast states including recycling of revenues for energy efficiency and renewable energy investments. State-wide cap-and-trade scheme in California with binding commitments. | | <ul style="list-style-type: none"> 17% reduction in greenhouse-gas (GHG) emissions by 2020 compared with 2005. CO₂ pricing implemented from 2020. |
| Japan [†] | | | <ul style="list-style-type: none"> 25% reduction in GHG emissions by 2020 compared with 1990. CO₂ pricing implemented from 2020. |
| European Union | <ul style="list-style-type: none"> EU-level target to reduce GHG emissions by 20% in 2020, relative to 1990. EU Emissions Trading System. Renewables to reach a share of 20% in energy demand in 2020. | <ul style="list-style-type: none"> Partial implementation of the EU-level target to reduce primary energy consumption by 20% in 2020: <ul style="list-style-type: none"> Partial implementation of the EU Energy Efficiency Directive. National Energy Efficiency Action Plans. | <ul style="list-style-type: none"> 30% reduction in GHG emissions by 2020 compared with 1990. Emissions Trading System strengthened in line with the 2050 roadmap. Full implementation of the EU Energy Efficiency Directive. |
| Australia and New Zealand | <ul style="list-style-type: none"> Australia: Clean Energy Future Package - carbon prices through taxes/emissions trading scheme as of mid-2015. New Zealand: emissions trading scheme from 2010. | <ul style="list-style-type: none"> Australia: 5% reduction in GHG emissions by 2020 compared with 2000. New Zealand: 10% cut in GHG emissions by 2020 compared with 1990. | <ul style="list-style-type: none"> Australia: 25% reduction in GHG emissions by 2020 compared with 2000. New Zealand: 20% reduction in GHG emissions by 2020 compared with 1990. |
| Korea | <ul style="list-style-type: none"> Cap-and-trade scheme from 2015 (CO₂ emissions reductions of 4% by 2020 compared with 2005). | <ul style="list-style-type: none"> 30% reduction in GHG emissions by 2020 compared with business-as-usual. | <ul style="list-style-type: none"> 30% reduction in GHG emissions by 2020 compared with business-as-usual. Higher CO₂ prices. |

[†]Japan is reviewing its basic policies on energy and climate change, some of which are expected to be announced by the end of 2013. Source: IEA

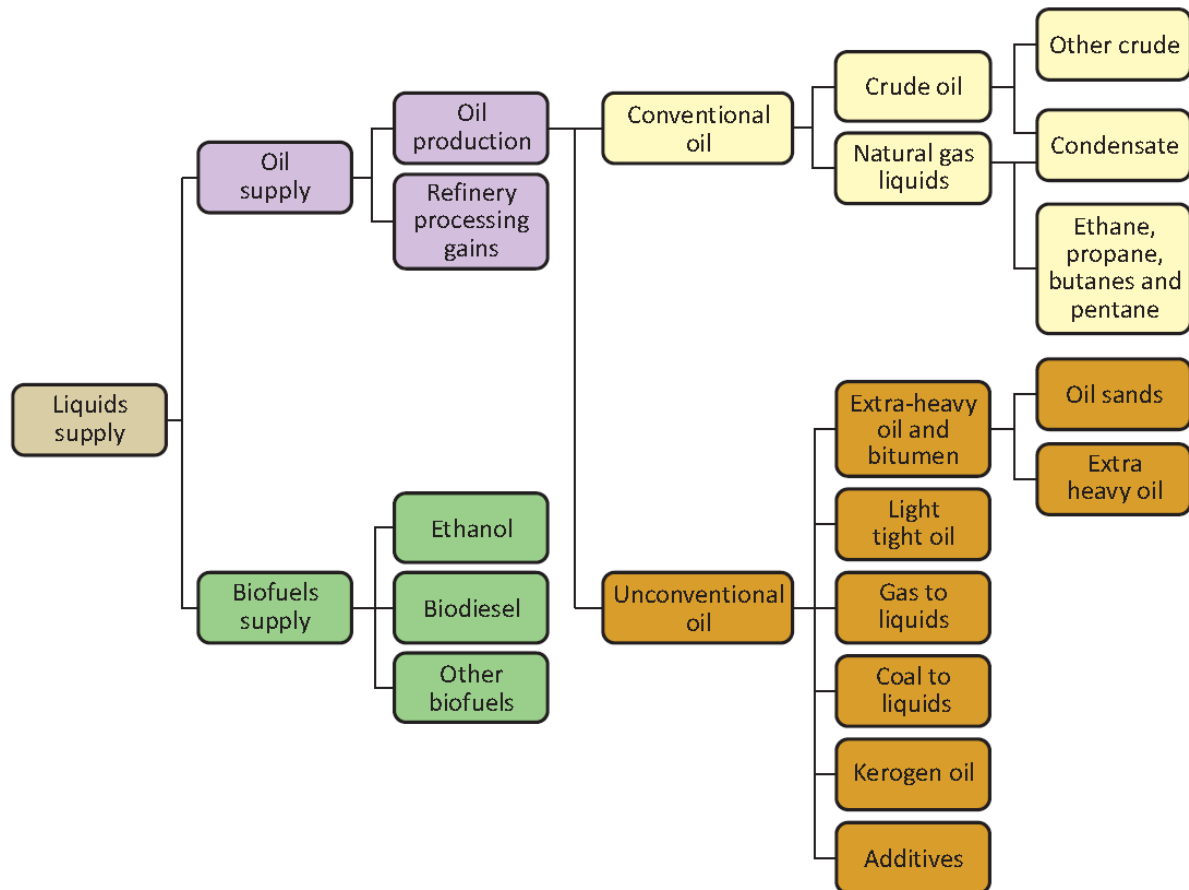
Table 14 Cross-cutting policy assumptions by scenario for selected regions

| | Current Policies Scenario | New Policies Scenario | 450 Scenario |
|----------|--|---|---|
| Non-OECD | <ul style="list-style-type: none"> Fossil-fuel subsidies are phased out in countries that already have policies in place to do so. | <ul style="list-style-type: none"> Fossil-fuel subsidies are phased out within the next ten years in all net-importing countries and in net-exporting countries where specific policies have already been announced. | <ul style="list-style-type: none"> Finance for domestic mitigation. Fossil-fuel subsidies are phased out within the next ten years in all net-importer and in net-exporters by 2035.* |
| Russia | <ul style="list-style-type: none"> Gradual real increases in residential gas and electricity prices (1% per year) and in gas prices in industry (1.5% per year). Implementation of 2009 energy efficiency legislation. | <ul style="list-style-type: none"> 15% reduction in GHG emissions by 2020 compared with 1990. 2% per year real rise in residential gas and electricity prices. Industrial gas prices reach export prices (minus taxes and transport) in 2020. Partial implementation of the 2010 energy efficiency state programme. | <ul style="list-style-type: none"> 25% reduction in GHG emissions by 2020, compared with 1990. Quicker rise in residential gas and electricity prices. CO₂ pricing from 2020. More support for nuclear and renewables. Full implementation of the 2010 energy efficiency state programme. |
| China | <ul style="list-style-type: none"> Implementation of measures in the 12th Five-Year Plan, including 17% cut in CO₂ intensity by 2015 and 16% reduction in energy intensity by 2015 compared with 2010. | <ul style="list-style-type: none"> 40% reduction in CO₂ intensity compared with 2005 by 2020. CO₂ pricing from 2020. Share of 15% of non-fossil fuel in total supply by 2020. Energy price reform including more frequent adjustments in oil product prices and increase in natural gas price by 15% for non-residential users. | <ul style="list-style-type: none"> 45% reduction in CO₂ intensity by 2020 compared with 2005; higher CO₂ pricing. Reduction of local air pollutants between 2010 and 2015 (reduction of 8% for sulphur dioxide, 10% for nitrogen oxides). |
| India | <ul style="list-style-type: none"> Trading of renewable energy certificates. National solar mission and national mission on enhanced energy efficiency. 11th Five-Year Plan (2007-2012). | <ul style="list-style-type: none"> 20% reduction in CO₂ intensity by 2020 compared with 2005. | <ul style="list-style-type: none"> 25% reduction in CO₂ intensity by 2020 compared with 2005. |
| Brazil | <ul style="list-style-type: none"> Implementation of National Energy Efficiency Plan. | <ul style="list-style-type: none"> 36% reduction in GHG emissions by 2020 compared with business-as-usual. Strengthened implementation of National Energy Efficiency Plan. | <ul style="list-style-type: none"> 39% reduction in GHG emissions by 2020 compared with business-as-usual. CO₂ pricing from 2020. |

*Except the Middle East where subsidy rates are assumed to decline to a maximum of 20% by 2035. Note: Pricing of CO₂ emissions is either by an emissions trading scheme (ETS) or taxes. Source: IEA

Appendix B - Components of oil supply and demand in IEA Scenarios

Figure 15 IEA classification of liquid fuels



Source: IEA

Table 15 Main sources and uses of oil products, 2012

| Product | Main sources | Main sectors | World demand | |
|----------------|---|--|--------------|--------------|
| | | | mb/d | % of total |
| Ethane | NGL fractionation | Petrochemical feedstock | 2.4 | 2.8 |
| LPG | NGL fractionation, condensate splitters, petroleum refineries | Petrochemical feedstock, buildings, road transport | 7.6 | 8.7 |
| Naphtha | Condensate splitters, Petroleum refineries | Petrochemical feedstock, gasoline blending | 5.7 | 6.5 |
| Gasoline | Petroleum refineries | Road transport | 20.8 | 23.8 |
| Kerosene | Petroleum refineries | Aviation fuel, buildings | 6.3 | 7.3 |
| Diesel | Petroleum refineries | Road transport, bunkers, buildings, industry, power generation | 26.0 | 29.7 |
| Fuel oil | Petroleum refineries | Bunkers, industry, power generation | 8.3 | 9.5 |
| Other products | Petroleum refineries | Non-energy use, refinery own use, power generation | 10.2 | 11.7 |
| Total | | | 87.4 | 100.0 |

Notes: Diesel excludes biodiesel (made from biomass feedstocks), but includes coal- and gas-to-liquids (CTL and GTL) diesel. Gasoline excludes ethanol, but includes additives and CTL GTL gasoline. **Source:** IEA WEO 2013

Table 16 World primary oil demand by product in the New Policies Scenario, 2012-2035 (MBPD)

| | 2000 | 2012 | 2020 | 2035 | 2012-2035 | |
|----------------|-------------|-------------|-------------|--------------|-------------|-------------|
| | | | | | Delta | CAAGR* |
| Ethane | 1.7 | 2.4 | 3.2 | 3.3 | 0.9 | 1.3% |
| LPG | 5.9 | 7.6 | 8.6 | 9.2 | 1.6 | 0.8% |
| Naphtha | 4.3 | 5.7 | 6.3 | 7.5 | 1.8 | 1.2% |
| Gasoline | 18.7 | 20.8 | 22.1 | 22.7 | 1.9 | 0.4% |
| Kerosene | 6.5 | 6.3 | 7.0 | 8.2 | 1.9 | 1.1% |
| Diesel/gasoil | 20.2 | 26.0 | 29.2 | 31.4 | 5.4 | 0.8% |
| Heavy fuel oil | 8.7 | 8.3 | 7.8 | 7.4 | -0.9 | -0.5% |
| Other products | 10.2 | 10.2 | 11.3 | 11.6 | 1.4 | 0.5% |
| Total | 76.3 | 87.4 | 95.4 | 101.4 | 14.0 | 0.6% |

* Compound average annual growth rate. Notes: Naphtha includes only petrochemical feedstock use. Naphtha used as a gasoline blending component is included in gasoline. **Source:** IEA WEO 2013

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