A NATIONAL STRATEGY FOR ENERGY SECURITY

THE INNOVATION REVOLUTION

MAY 2016

ENERGY SECURITY LEADERSHIP COUNCIL

A PROJECT OF

Securing America's Future Energy

A NATIONAL STRATEGY FOR ENERGY SECURITY

The Innovation Revolution

MAY 2016

ENERGY SECURITY LEADERSHIP COUNCIL

a project of

Securing America's Future Energy

Table of Contents

Energy Security Leadership Council

COUNCIL CO-CHAIRS

Frederick W. Smith
Chairman, President & CEO, FedEx Corporation

General James Conway, U.S. Marine Corps (Ret.)
34th Commandant, U.S. Marine Corps

CHAIRMAN EMERITUS

General P.X. Kelley, U.S. Marine Corps (Ret.)
28th Commandant, U.S. Marine Corps

COUNCIL MEMBERS

Peter Ackerman
Managing Director, Rockport Capital, Inc.

Admiral Dennis C. Blair, U.S. Navy (Ret.)
Former Director of National Intelligence and Commander in Chief, U.S. Pacific Command

General Bryan "Doug" Brown, U.S. Army (Ret.)
Former Commander, U.S. Special Operations Command

General Richard A. Cody, U.S. Army (Ret.)
Former Vice Chief of Staff, U.S. Army

Sam Gilliland
Former CEO, Sabre Holdings

Adam M. Goldstein
President and COO, Royal Caribbean International

General Michael W. Hagee, U.S. Marine Corps (Ret.)
33rd Commandant, U.S. Marine Corps

General John W. Handy, U.S. Air Force (Ret.)
Former Commander, U.S. Transportation Command and Air Mobility Command

Admiral John C. Harvey, U.S. Navy (Ret.)
Former Commander, U.S. Fleet Forces Command

Maurice R. Greenberg
Chairman & CEO, C.V. Starr & Co., Inc.

Admiral Gregory G. Johnson, U.S. Navy (Ret.)
Former Commander, U.S. Naval Forces, Europe

Mark Joseph
CEO and Vice Chairman, Transdev North America

Admiral Timothy J. Keating, U.S. Navy (Ret.)
Former Commander, U.S. Pacific Command

Herbert D. Kelleher
Founder & Chairman Emeritus, Southwest Airlines Co.

John F. Lehman
Former Secretary of the U.S. Navy

General David D. McKiernan, U.S. Army (Ret.)
Former Commander, International Security Assistance Force (ISAF), Afghanistan

General Duncan J. McNabb, U.S. Air Force (Ret.)
Former Commander, U.S. Transportation Command

General T. Michael Moseley, U.S. Air Force (Ret.)
Former Chief of Staff, U.S. Air Force

Nirmal Mulye
Founder & Chairman, Nostrum Group

General Michael E. Ryan, U.S. Air Force (Ret.)
16th Chief of Staff, U.S. Air Force

David Schwarz
Founder, President and CEO, David M. Schwarz Architects

Eric S. Schwartz
Former Co-CEO, Goldman Sachs Asset Management

Eric Silagy
President and CEO, Florida Power & Light Company

Jeffrey C. Sprecher
Chairman and CEO, Intercontinental Exchange (ICE), Inc. and Chairman, New York Stock Exchange

Paul H. Stebbins
Chairman Emeritus, World Fuel Services Corporation

David P. Steiner
CEO, Waste Management, Inc.

Michael T. Strianese
President, CEO and Director, L3 Communications Holding, Inc.

General Charles F. Wald, U.S. Air Force (Ret.)
Former Deputy Commander, U.S. European Command

Josh S. Weston
Honorary Chairman, Automatic Data Processing, Inc.

Statement of Purpose

The Energy Security Leadership Council ("Council") believes that America's energy security can be fundamentally strengthened through a combination of major reductions in oil consumption, increases in domestic energy production, and reforms to energy-related regulations. Most importantly, we must transform our transportation sector so that oil is no longer its primary fuel. The Council's recommendations reflect the realities of global energy interdependence and the promise of American resources and technological ingenuity. Taken together, the portfolio of proposed recommendations constitutes a path forward that recognizes both the continued risks to our nation posed by dependence on oil and the available solutions. The Council's mission is to secure the support of a bipartisan coalition committed to making the necessary hard choices and sustaining efforts to implement meaningful solutions.

Letter to the President, the Congress, and the American People

The past decade has been one of historic change in the American energy economy. Yet, one fact remains unaltered: American mobility continues to depend almost entirely on oil. Petroleum is the engine of our economy, enabling the movement of goods, our daily commutes, and essential emergency services. While oil has facilitated the rise of the modern era, our over reliance on it creates tremendous energy security vulnerabilities because the price of this critical commodity is subject to manipulations by national oil companies that actively hinder the kind of regular, transparent price discovery needed for markets to function properly. Such manipulations constrain U.S. foreign policymaking, affect the flexibility and activities of the military, and threaten economic growth and fiscal stability. Although the global oil market remains oversupplied and fuel is cheap at the moment, the end-state of this manipulation will predictably be followed by an all-too-familiar price spike.

Our dependence on oil endures and therefore our focus on solutions should not be distracted. Successfully addressing the enormous challenge that oil dependence poses to our nation requires a multi-faceted approach that emphasizes substantially decreasing the oil intensity of the U.S. economy and expanding domestic transportation energy production. This strategy includes efforts not only to increase the efficiency of our cars and trucks, but also to spur far greater diversity in transportation fuels. Achieving this transition is an immense and urgent challenge.

The recommendations presented by the Energy Security Leadership Council ("Council") in this report are designed around one clear goal: to safeguard the security of the United States by reducing our dependence on oil in a manipulated global marketplace. This is the enduring mission of the Council.

The Council has issued three major recommendation reports since 2006. Through constantly evolving political, geopolitical, and economic circumstances, in addition to dynamic changes in domestic and global energy, the core message remains the same: American oil dependence must be addressed through innovative policies that take advantage of domestic production while driving greater vehicle efficiency and the adoption of oil alternatives in the U.S. transportation sector.

Today, OPEC is working to undermine the American shale industry. At the same time, the Middle East region, where so much of the world's oil is concentrated, is becoming more unstable—seemingly by the day. Mitigating these threats is a core part of the Council's approach. Despite such threats, revolutionary innovations are occurring across a variety of related industries and products, resulting in more efficient drilling and important technological progress in advanced fuels and autonomous vehicles in particular.

This year's publication, *A National Strategy for Energy Security: The Innovation Revolution*, offers a comprehensive set of policy recommendations designed to position the American transportation sector for a timely and significant shift away from petroleum fuels. This will be achieved through policies designed to accelerate adoption of technologies—including autonomous vehicle technologies—that enable a new era of American mobility, powered by domestically abundant, readily available resources. These policies include strengthening research and development programs, expanding deployment activities at the local and national levels, and removing or reforming regulatory barriers. The Council also includes recommendations targeted at safely increasing domestic oil and natural gas production in addition to recommendations that seek to eliminate or counter the market manipulation and power of the OPEC cartel through a variety of legal, regulatory, and market mechanisms.

The Council recognizes that market-designed and market-driven approaches are the preferred method for overcoming economic challenges. But given the importance of oil to our economy and the power that foreign governments wield over oil production levels, engagement by the U.S. government is warranted. Put simply, only government action can address a problem that is the creation of foreign governments. That said, the Council also recognizes that federal policies are inherently imperfect and require keen vigilance to ensure they do not overreach nor cause unanticipated negative consequences. The policy recommendations described in this report should be reviewed regularly (and revised when necessary) to ensure they are achieving their intended impact on improving our nation's security.

The United States currently finds itself in an exceptional position of strength in its ability to influence both the domestic and international energy landscapes. We should act on this moment, securing real, lasting change while we are most capable. We urge policymakers and the next president to seize this opportunity to advance a new national agenda around strengthening American oil security, countering oil market manipulations, and ensuring our nation remains on a path toward sustained prosperity.

James T. Conway, U.S. Marine Corps (Ret.)
34th Commandant,
U.S. Marine Corps

Frederick W. Smith
Chairman, President & CEO,
FedEx Corporation

Summary for Policymakers

Rarely in history has Americans' perception of the nation's energy security oscillated as wildly as it has over the past decade. In 2008, amid a historic oil supply crunch and record run-up in global oil prices, U.S. spending on oil reached nearly 6 percent of GDP, a level historically associated with recession.[1] The nation, heavily dependent on fuel purchased from overseas, sent a record $388 billion abroad for oil, accounting for well over half of the country's trade deficit. And with no alternatives to oil in transportation, American households saw their spending on gasoline double in a few short years, draining thousands of dollars from the typical family's disposable income.

While the ensuing global recession—triggered in part by high oil prices—offered temporary relief at the pump, geopolitical instability and a host of other factors led to the nearly immediate return of near-record oil prices beginning in 2010. High and volatile oil prices would act as a consistent drag on American economic growth for much of the period immediately following the recession, from 2010 to 2014. Yet quietly, in the background, a revolution was underway.

After decades of decline and stagnation, the American oil industry did what great American industries do: they invented and engineered a turnaround of historic proportions. Driven by the rapid expansion of the domestic shale industry, U.S. field production of liquid fuels surged by 55 percent from 2010 to 2014, reaching all-time highs.[2] The shale industry created 220,000 direct American jobs in just five years and supported hundreds of thousands more, all while investing nearly a trillion dollars throughout the domestic supply chain.[3] From Pennsylvania and Ohio to North Dakota and Texas, shale increased economic growth, employment, and government revenues.

Meanwhile, U.S. oil policy took important steps forward. New fuel-economy regulations enacted in 2011 and 2012 promised to cut American dependence on oil through 2025 by as much as 3 million barrels per day (mbd), leading to sharply declining oil intensity which fundamentally means that we could generate more GDP using less oil. Investments in advanced battery manufacturing and support for plug-in electric vehicles (PEVs) and other advanced technology mobility sparked a nascent industry, with dozens of models available to U.S. consumers in showrooms around the country. American consumers were opting for more efficient vehicles and driving fewer miles.

Measurable progress began to surface: U.S. oil import levels plummeted from a record 60 percent of supplies in 2005 to just 26 percent in 2014, keeping hundreds of billions of dollars of American wealth at home, where it could be productively deployed.[4] Oil spending as a share of GDP returned to less dangerous levels. Household spending on oil pulled back from historic highs.

1 SAFE analysis based on data from Department of Commerce, Bureau of Economic Analysis, and EIA, State Energy Data System.
2 EIA, *Petroleum Supply Monthly*, February 2016.
3 Capital spending from John England, Gregory Bean, and Anshu Mittal, "Following the Capital Trail in Oil and Gas," Deloitte University Press; and jobs data from U.S. Department of Labor, Industry Employment at a Glance and reflects the change from January 2010 to December 2014 in employment in Oil and Gas Extraction and Oil and Gas Support Activities.
4 Production and import data from EIA, *Petroleum Supply Monthly*, February 2016.

If the previous five years were the age of the American energy security renaissance, 2015 was the year of OPEC. Driven largely by surging American oil production, the global oil market entered a period of significant oversupply in which OPEC market share was shrinking, and global oil prices were declining. For the national governments that comprise OPEC, whose budgets and economies depend overwhelmingly on export revenues from state-run national oil enterprises, these dynamics were an existential threat. Following a tumultuous meeting of the cartel in November 2014, Saudi Arabia and its allies in the Gulf region embarked on a deliberate strategy of global price war designed to rebalance the market on terms more favorable to global oil producers—and more predatory to global oil consumers.

In the months that followed, global oil prices collapsed at an incredible pace, shedding 40 percent of their value in just two months. Despite falling prices, Saudi Arabia took the extraordinary step of sharply increasing its production in order to put additional pressure on markets. After averaging $100/bbl from 2011 to 2014, prices averaged $52/bbl in 2015 and are expected to average just $34/bbl in 2016.[5]

In normal market conditions, low oil prices are an unalloyed benefit for the U.S. economy. Indeed, U.S. households in 2015 enjoyed a roughly $94.6 billion reduction in oil spending, a cut on par with the 2011 payroll tax cut, which totaled $108 billion.[6] But in the transformed domestic energy landscape, low prices present the economy with complex tradeoffs, stimulating consumption while undermining a key growth sector—the domestic oil industry. Perhaps more importantly, today's rapid and severe plunge in oil prices are transitory, and simply reflect Saudi Arabia's strategy to wrest control of the global oil market back from the competitive forces that led to this moment, and to restore the cartel's ability to more effectively manipulate markets for its own gain.

The Saudi strategy appears to be working. In sharp contrast to the robust growth it enjoyed from 2011 to 2014, relatively high cost U.S. oil production has plateaued and begun to decline at an increasingly rapid rate. The U.S. oil and gas industry has shed more than 150,000 jobs in just 18 months and cut capital spending to its lowest level in a decade.[7] Meanwhile, investment in capital-intensive oil supplies around the world, including deepwater resources and Canadian oil sands, has declined by more than $225 billion, leading analysts to warn of an impending supply crunch by the end of the decade.[8]

As dramatic as the supply-side impacts have been, developments on the demand side have arguably been more concerning. After improving by 12 percent between 2011 and 2014, the efficiency of cars and trucks sold in the United States has actually declined slightly over the past year, creating a difficult environment for the federal government's upcoming review of new standards.[9] Americans purchased pickup trucks and sport-utility vehicles at a record pace in 2015, and gasoline demand returned to levels last seen in 2007. Growth in the sales of vehicles powered by electricity and natural gas have stalled.[10]

On its current trajectory, the net effect of these trends will be a substantially tighter oil market by 2020. The International Energy Agency has warned that a global shortfall in oil supplies will emerge in 2018 and average roughly 1 mbd from 2019 to 2021, steadily eroding the glut in supplies that built up over the past two years.[11] While shale production would likely fill a portion of this gap, investment in much higher-cost supplies will ultimately be needed to fill the hole, which will take time. In short, the low prices of today are already cementing the higher prices of tomorrow.

5 EIA, *Short-Term Energy Outlook*, February 2016. Quoted prices are Brent crude oil spot.
6 SAFE analysis based on data from Bureau of Economic Analysis.
7 SAFE analysis based on data from Department of Labor and Barclays Global Upstream Survey.
8 SAFE analysis based on data from Barclays Global Upstream Survey, January 2016; and see, e.g., UBS, "Major Projects Database Update: Trouble Down the Line," February 2, 2016.
9 Michal Sivak and Brandon Schoettle, University of Michigan, Transportation Research Institute.
10 SAFE analysis based on data from Hybridcars.com.
11 IEA, *Medium-Term Oil Market Report* 2016.

Oil Price Volatility

Volatility is an ever-present condition of oil markets and devastates consumers and producers. Rapid fluctuations in oil prices—both upwards and downwards—wreak havoc on the U.S. economy. Price shocks also lead to geopolitical instability and reorder U.S. foreign policy priorities. These market gyrations have historically contributed to deep recessions and distorted investment decisions, causing severe supply and demand imbalances and damaging the economic and national security interests of the United States.

Economic Shocks

Oil has been an economically and geostrategically important commodity for more than a century, but U.S. vulnerability to price shocks did not reach acute levels until 1973 when a group of oil-rich states deliberately cut production in what became known as the Arab Oil Embargo. The consequent quadrupling of prices profoundly shaped the economic and political landscape for the rest of the decade. GDP contracted between November 1973 and March 1975, and unemployment reached 9 percent.[12] The economic situation worsened in 1979 when the Iranian Revolution resulted in the peak loss of 5.6 mbd of Iran's oil output, which was exacerbated by a series of supply cuts by other OPEC nations.[13]

The price spike of the mid-2000s engendered a similar economic tailspin. Between 2007 and 2008, oil prices increased to $147 per barrel, when volatility—a measure of how much prices have moved up and down—grew to an astonishing 120 percent (Figure 1).[14] The record high price helped contribute to the Great Recession.[15] Prices then dropped dramatically due to weakened demand before rebounding rapidly after the Great Recession, and in fact annual averages between 2011 and 2014 were similar to 2008.[16] Total U.S. spending on oil averaged approximately $880 billion per year (more than 5 percent of U.S. GDP) and households spent more than $2,600 per year during the period.[17]

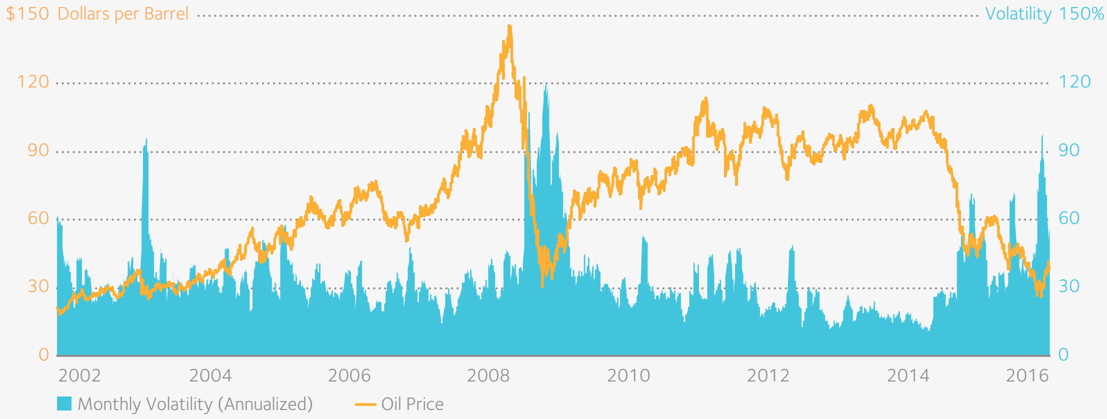
Distorted Investment

Price volatility creates a highly uncertain investment climate. When Saudi Arabia increased production in the mid-1980s, sending oil prices plummeting to $10 per barrel, global upstream oil spending declined approximately 30 percent between 1985 and 1986 and did not reach 1985 levels again until the early 1990s.[18] Likewise, spending declined approximately 17 percent between 2014 and 2015, and is being estimated to fall a further 11 percent in 2016.[19] In the United States, spending is being affected more severely than elsewhere, and could decline by approximately $100 billion (or more than 50 percent) between 2014 and 2016.[20] In 2015, there were more than 40 oil industry bankruptcies, with more expected in 2016.[21] This decline in upstream spending has also led to some 140,000 workers losing their jobs.[22] These elements are sustaining recessionary conditions in areas of the country, and laying the groundwork for future supply shortages.

12 National Bureau of Economic Research, "US Business Cycle Expansions and Contractions"; and Bureau of Economic Analysis.
13 IEA, *IEA Response System for Oil Supply Emergencies*, 2012, at 11.
14 EIA; and SAFE analysis based on data from EIA.
15 See, e.g., James D. Hamilton, "Oil prices and the economic recession of 2007-08," June 16, 2009.
16 EIA, Real Prices Viewer.
17 SAFE analysis based on data from EIA and Bureau of Economic Analysis.
18 SAFE analysis based on data from Barclays Global Survey.
19 Id.
20 Id.
21 Navigant Consulting, *Oil and Gas Market Notes: 2016 State of Play*, March 2016, at 1.
22 Bureau of Labor Statistics; and see, e.g., John Kemp, "U.S. Oil, Gas Industry Sheds 100,000 Jobs in Slump," February 4, 2016.

FIGURE 1

Oil Price Volatility



Source: SAFE analysis based on data from EIA

Stymied Innovation

American presidents since Richard Nixon have pledged to end the nation's oil dependence. These calls especially resonate with voters when gasoline prices overwhelm household budgets. However, memories are short, and political pressure abates when prices recede. For example, fuel economy standards implemented in 1975 improved the average mileage of cars and light trucks by nearly 70 percent between 1975 and 1987.[23] No further improvement was made for more than two decades as prices remained relatively low until the mid-2000s.[24]

Since oil prices collapsed in late 2014, sales of more efficient vehicles have fallen, with U.S. sales-weighted new vehicle fuel economy ratings stagnating at 2014 levels around 25.2 miles per gallon following steady increases of roughly 1 mile per gallon per year since 2008.[25] Simultaneously, sales of plug-in electric vehicles declined year-over-year for the first time ever in 2015, following rapid percentage gains since commercial introduction in 2011.[26] Since preferences of American motorists frequently hinge on short-term gasoline prices, non-market interventions—in some cases by foreign governments strongly incented to undermine competing fuel technologies—creates price volatility that undermines private sector innovation and affects consumer behavior.

Compromised National Security

The extreme economic importance of oil—and thus of preventing oil price volatility—creates national security challenges and undermines the United States' ability to conduct effective foreign policy. Notably, more than 50 percent of daily oil supplies transit through seven major chokepoints in often unstable regions, most notably the Middle East.[27] The U.S. military is forced to accept the burden of protecting these maritime supply routes and vulnerable energy infrastructure across the globe at a cost of between $67.5 billion and $83 billion annually, plus an additional $8 billion in military operations (2009 Dollars).[28] Moreover, the United States has participated in numerous conflicts in the Middle East in particular, while also being confronted with terrorism—often funded by oil revenues.

23 EPA, Light-Duty Automotive Technology and Fuel Economy Trends: 1975 – 2015," December 2015.
24 Id.
25 SAFE analysis based on data from Michal Sivak and Brandon Schoettle, University of Michigan, Transportation Research Institute.
26 SAFE analysis based on data from Hybridcars.com.
27 See, e.g., EIA, "World Oil Transit Chokepoints", November 10, 2014, at 2.
28 RAND Corporation, "Imported Oil and U.S. National Security," 2009, at 74.

America's Enduring Energy Security Challenge

The idea that the United States could achieve independence from the global oil market has rarely been shown to be so fundamentally misguided. In truth, the American economy has scarcely ever been more exposed to the vagaries of the global oil market than it is in mid-2016. At its core, the American energy security problem remains one of overwhelming dependence. Oil remains America's vital fuel, accounting for 35 percent of total primary energy consumption, a share larger than any other energy source. But that measure alone understates its importance because petroleum fuels today account for 92 percent of the energy consumed in transportation—a share essentially unchanged since the advent of the automobile—and there is virtually no ability to switch to other fuels for transportation, especially in the short term at any meaningful scale. This reliance has made oil the lifeblood of the U.S. economy, and access to reliable, affordable supplies continues to be an urgent priority of supreme national interest.

Contrary to many observers' expectations, the U.S. shale industry has in some ways deepened the country's exposure to the global oil market and the anti-competitive forces that drive it by adding significant supply-side risks to the equation. Just as high oil prices have historically undermined economic growth by weakening consumers, low oil prices now undermine the economy by damaging the oil industry. The capital and labor dislocations that have occurred in recent months have played an important role in undermining economic growth. Today, as ever, the problem is not high prices or low prices; the problem is volatile and unpredictable prices.

Taken as a whole, this outsized exposure should be deeply concerning to policymakers. While U.S. shale has clearly added a new dynamic to the market, the long-term trends in oil do not point toward a fundamental shift in three key dynamics that have driven 40 years of U.S. oil policy:

There is no free market for oil: While oil is traded in open and liquid markets, the oil market as whole is far removed from any free market ideal. OPEC represents only one significant breakdown in normal market structure. As of 2015, despite a massive increase in U.S. reserves from shale, state-run enterprises in countries from Russia and the former Soviet Union to the Middle East and North Africa controlled more than 90 percent of global oil reserves. These governments, which are often home to the world's least expensive oil supplies, make upstream investment decisions based on a complex and opaque mix of factors, including competing social and military spending needs.

As a result, production from national oil companies typically lags resources by a wide margin. For example, the national oil companies (NOCs) within OPEC controlled nearly three-fourths of global proved oil reserves at the end of 2014, yet accounted for only 40 percent of global liquid fuels production. If resources within OPEC were among the world's most expensive, this dynamic would be unremarkable from an economic perspective. Instead, the opposite is true: oil reserves within OPEC are widely known to be among the world's least expensive and most easily accessible from a geological perspective. The decades-long, persistent disconnect between production of these inexpensive resources and their prominence in the global resource base therefore largely reflects anti-competitive behavior. The net economic effect of this behavior is also significant. According to the World Bank, oil rents—the difference between the value of crude oil production at world prices and total costs of production—equaled 3 percent of GDP in 2013.

Major oil producers are prone to instability: Rising levels of instability in the Middle East now directly threaten more than 40 percent of the world's oil production capacity. As a direct result of their market-share strategy, Saudi Arabia and its fellow Arab Gulf states have found themselves in an increasingly precarious position. The collapse in oil revenues suffered since 2014 has hollowed out national budgets even as spending on social and military programs is soaring. Gross public debt in Saudi Arabia, just 2 percent of GDP in 2015, is set to reach 20 percent in 2016, and once mammoth foreign exchange reserves currently provide just a 5-year fiscal buffer.[29] In neighboring Iraq, the government is

29 IMF, *Regional Economic Outlook, Middle East and Central Asia,* October 2015.

running annual deficits near 100 percent of revenue, threating the state's ability to adequately fund its increasingly intense and expensive conflict against the Islamic State.[30]

The story is similar or worse in numerous national oil producers throughout the Middle East and former Soviet Union, whose rigid, export-dependent economies are ill-equipped to weather this storm. Indeed, for OPEC members to benefit from their strategy, they must survive it. In the event that some do not, history suggests that the collapse in these countries' oil industries will be severe, long-lasting, and inflict significant damage on the global economy.

Oil prices are highly volatile: Today's oil market is among the most volatile in recent history, with uncertainty reaching levels last experienced at the height of the global financial crisis.[31] This uncertainty makes it extremely difficult for businesses to plan and consumers to invest. Fuel-intensive industries such as airlines and shipping companies are forced to make sub-optimal investments in capital and logistics, and the automotive industry in particular is often left facing stranded capital assets as sharp jolts in prices affect consumer preferences in real time.

Moreover, evidence suggests that the current oil market structure may be particularly prone to damaging levels of volatility, including oil price spikes. In large part, this is because of the sharp drawdown of spare capacity, especially in Saudi Arabia—the traditional repository of global spare capacity. Spare capacity is oil production that can be brought online in a matter of weeks. Today, this spare capacity rests in global inventories, which have swelled by as much as 500 million barrels compared to normal levels. But in the event of a crisis, inventories would be drawn down relatively quickly, after which the current market has no immediate, alternative source of supply outside of government strategic stockpiles.

A National Strategy for Energy Security

America needs a strategy for energy security that rests on a set of core fundamental principles. First, the overriding goal of policy must be to increase fuel diversity in transportation. Creating and sustaining competition to oil is the most direct and effective way to guarantee the nation's energy security in the decades to come. Second, in light of the evolving nature of the American energy economy and the enduring threat of anti-competitive dynamics in oil markets, policymakers should prioritize policies that can offer a measure of protection to the domestic oil and gas industry. In part, this can be accomplished by expanding the range of resources available to the industry. But the federal government should explore more direct approaches, including steps that challenge the legal, institutional, and market structures that allow OPEC to operate as a cartel.

Finally, and perhaps most importantly, policymakers should ensure that the country is well-prepared to support the development and deployment of new technologies that could radically transform our economy and society. For the first time in more than 100 years, the automotive industry is on the verge of introducing a technological advancement that has the potential to improve both social and personal utility. Autonomous vehicles and intelligent transportation systems could radically transform everything from the ways in which we power our vehicles and design our cities to the costs of moving people, goods, and services throughout the economy. Policy must be flexible and nimble to allow the nation to maximize the benefits of autonomy while minimizing the risks.

Americans awakened to the profound risks of energy *insecurity* in the waning days of 1973, when several Arab members of OPEC announced an embargo of oil shipments to the United States in retaliation for our support of Israel in the Yom Kippur War. In a matter of months, OPEC engineered an unprecedented spike in global oil prices that triggered one of the most severe U.S. recessions of the 20th century. Just four short years later, the Iranian revolution and onset of the Iran-Iraq War triggered another price spike of even greater magnitude and an additional severe recession.

30 Loveday Morris, "Iraq is Broke. Add that to the List of Worries," Washington Post, March 5, 2016.
31 EIA, *Short-Term Energy Outlook*, March 2016.

In response to those events, American policymakers took action. Legislation signed into law in 1975 created the nation's first fuel efficiency standards and the Strategic Petroleum Reserve. And steps taken in 1978 dramatically curtailed the use of oil in the electric power sector. These steps made important progress in reducing the economy's exposure to high oil prices. Yet in the decades that followed, U.S. policymakers took precious few steps to maintain this progress, and even took steps backward in many regards. By the time the oil price spike of 2007-08 arrived, the country found itself unprepared.

Too often, America's exposure to the risks of oil dependence has been measured by consumers and policymakers as a function of the price of oil at a specific point in time or our level of reliance on foreign suppliers. The result has been long periods of inaction and inattention after each crisis, which simply leaves the country dangerously exposed for the inevitable next crisis. The risk of such complacence today is high. Low oil prices have reduced the sense of urgency shared throughout the country as recently as 2014. Yet just as it has been so many times before, the oil market is in the midst of a cycle. We must be better prepared when the tide once again turns.

VISION

A Path to 50 by '40

Vision

Oil is central to the history of modern transportation. In the United States, oil provides 92 percent of energy that powers the transportation sector: nearly every car, truck, plane, and ship responsible for moving Americans and their goods. This overt dependence on oil creates vulnerabilities with potentially drastic consequences for the American economy and national security.

Two spikes in the price of oil served as bookends to the Great Recession that began in 2008, and amplified already widespread economic damage. Yet this was far from the first time oil was able to exert its massive influence over the U.S. economy. In 1973, an embargo by Arab member states of the Organization of the Petroleum Exporting Countries (OPEC) prompted supply shortages that drove the price of oil from $3 per barrel (bbl) to almost $12/bbl in a matter of months.[1] This supply squeeze and the subsequent four-fold increase in the cost of oil prompted a lengthy recession, spurring U.S. policymakers to create the country's first fuel efficiency standards designed to reduce reliance on the volatile global oil market.

Total U.S. spending on oil as a share of GDP reached six percent in 2008, just like in the mid-1970s.

While increasing the efficiency of existing vehicle technologies is a noble and worthwhile goal that has helped insulate the U.S. economy from the negative effects of higher oil prices in particular, it is only a partial solution, doing little to free U.S. transportation from its overall reliance on oil. Since the embargo more than 40 years ago, oil use in the transportation sector has declined by only 3 percentage points, to little real effect on American energy security—total U.S. spending on oil as a share of GDP reached six percent in 2008, just like in the mid-1970s.[2] More crises will undoubtedly occur in the future. To be truly secure from oil shocks, greater competition through diversification of energy fuels powering U.S. transportation is required. Preferably, these fuels should be domestically sourced, relatively stable in price, readily available, and used in transportation applications.

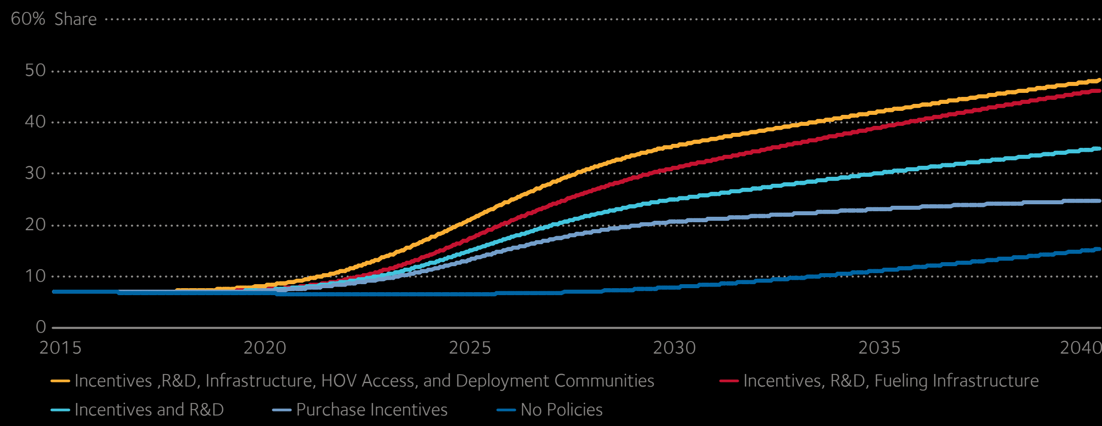
It is clear the United States must reduce its dependence on oil, starting with the transportation sector, which is responsible for an overwhelming majority of American consumption. Current projections suggest little more than incremental shifts toward increased fuel diversity in the sector—from 92 percent oil today to 88 percent by 2040. In the absence of government policy, volatile global oil prices undermine progress towards a transportation system powered by a more diverse set of fuels. Given the urgency of the problem, a more ambitious approach is warranted.

Achieving greater energy security will require that the United States employ a fuel mix in its transportation sector that is far less dependent on oil. Significantly reducing the amount of oil required by the sector will carry with it positive economic and national security outcomes, insulating the American economy from the often-volatile global oil market and granting greatly increased leverage to U.S. foreign policy and military institutions.

1 EIA.
2 SAFE analysis based on data from EIA.

FIGURE 2

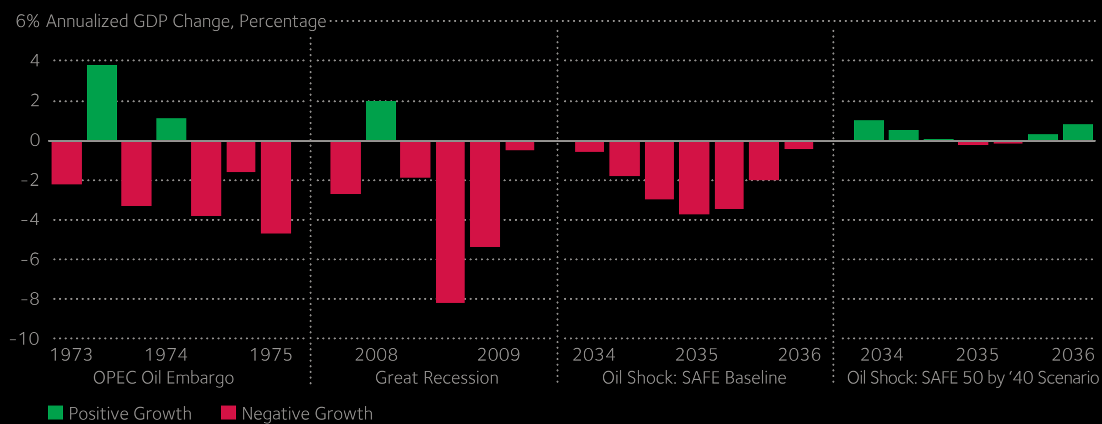
Share of Non-Petroleum Miles in U.S. Transportation Sector



Source: SAFE analysis and EIA

FIGURE 3

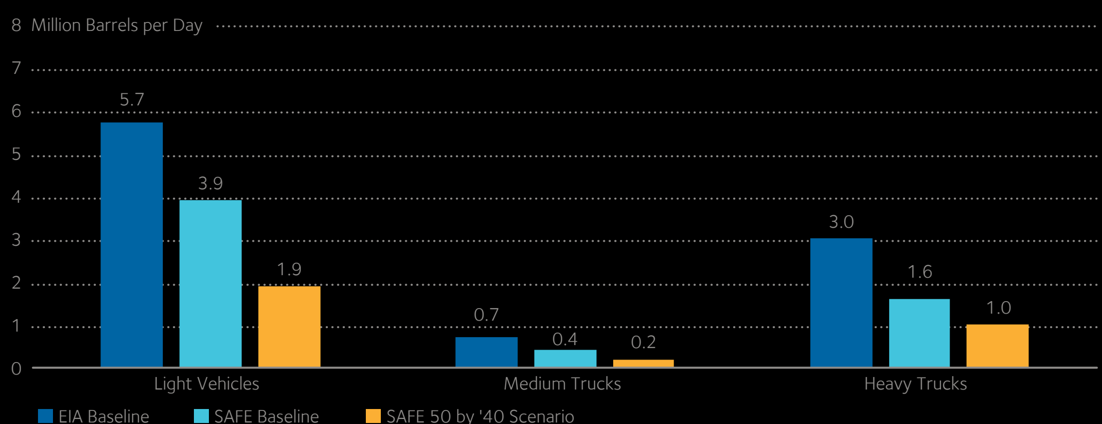
Quarter-to-Quarter Real GDP Growth: Historical Context and Scenarios



Source: SAFE analysis and BEA

FIGURE 4

Oil Consumption by Transportation Mode in 2040



Source: SAFE analysis and EIA

50 by '40 is SAFE's vision for severing the dangerous link between oil and U.S. national and economic security, leading to an America that is safer, more prosperous, and more resilient. SAFE measures oil displacement by the share of vehicle miles traveled (VMT) by advanced fuel vehicles (AFVs). These miles are weighted by segment-wide conventional vehicle fuel economy to account for the greater importance of individual freight miles in overall oil consumption versus light-duty vehicles. Reducing oil's share of transportation miles to 50 percent by 2040 percent is an ambitious, intuitive, and attainable target for the nation that, if successfully reached, can break the stranglehold placed on our economy by the lack of viable alternatives when events beyond our control induce volatile spikes in the price of oil. The more quickly oil's share of transportation miles can be reduced and fuel options can be diversified, the more quickly U.S. energy security will be improved. However, the speed of transition is limited by the rates of vehicle fleet turnover—the average age of a U.S. light vehicle today, for example, is 11.5 years and has been rising for at least a decade, meaning that many vehicles purchased this year will remain on the road into the late-2020s and beyond.[3] The 2020s is the crucial decade in which advancements in transportation technology—both advanced fuels and autonomy—will begin to catalyze a rapid transition away from oil, enabling the country to reach a tipping point in how transportation is powered by 2040.

This goal will be realized using existing, readily deployable technologies available to American consumers and businesses today. Plug-in electric vehicles have made enormous strides in recent years, and battery costs continue to drop, increasing range and affordability. Compressed and liquefied natural gas are already fueling many truck fleets with a domestically produced, cost-stable energy source. Advanced biofuels that can directly replace diesel or jet fuel in trucks and aircraft are showing promising early results, while hydrogen fuel cells also show potential and are beginning to power commercially available vehicles sold by major automakers. And the emergence of autonomous, or self-driving, vehicle technology could dramatically accelerate the transition from petroleum to many of these alternatives.

Together, the suite of energy sources ready to repower the U.S. transportation sector is exceptionally diverse, and consumers—motivated by cost savings or a desire to see a more energy secure or environmentally sustainable America—are beginning to use them by taking advantage of a new generation of advanced technology vehicles. However, this is not happening fast or widespread enough to address this critical economic and national security danger, and significant barriers remain to widespread market penetration by AFVs, including today's, but not necessarily tomorrow's, low oil price.

Putting aside the new and accelerating potential of autonomy, federal and state policies should work to internalize and reflect the energy security threat posed by U.S. oil dependence, taking into account the specific economic and national security risks created by that dependence. Effective policy should focus on both vehicle and advanced fuel supply- and demand-side challenges. On the supply side of these technologies, increasing research, development, and deployment (RD&D) efforts focused on oil displacement technologies and incentivizing the private sector to build out refueling infrastructure will lead to lower costs and increased adoption.

On the demand side, purchase incentives for vehicles not powered by oil should be refined, working to eliminate the uncertainty and ambiguity hindering widespread acceptance by wary buyers. Critically important and often overlooked, to overcome consumer hesitancy that comes from a lack of experience with AFVs, concerted projects to select cities to develop localized accelerator communities with strong support for deployment, including experiential marketing, can spread the word about the promise of emerging vehicle technologies while also serving as transportation laboratories for the nation. These policies should also be adapted for appropriate use within municipal and commercial fleets, the needs of which differ drastically from those of consumers.

To estimate the impacts of such policies on fuel diversity and oil displacement, SAFE developed a dynamic consumer acceptance model. With hundreds of inputs ranging from technical assumptions to

3 Oak Ridge National Laboratory, *Transportation Energy Data Book, Edition 34*.

direct policy levers, the model enables SAFE to simulate how different combinations of incentives and support for technological advances, in the form of both monetary and non-monetary initiatives, can strengthen and hasten the adoption of advanced fuel vehicles. The model also allows SAFE to estimate how such scenarios would alter oil consumption patterns in the United States as well as shift the distribution of vehicle miles traveled (VMT) by fuels in all segments of private on-road transportation and aviation.

The results show that no one policy lever can plausibly drive the transformation America needs (Figure 2). A coordinated, multi-pronged approach is necessary for policies to work in concert with one another. For example, efforts to lower the cost of AFVs by solely sponsoring research to bring down battery or natural gas engine costs or increasing purchase incentives for AFVs will do little to spur adoption if new fueling infrastructure remains so sparse that such vehicles appear unattractive options to potential buyers. Further, other policies are supported by efforts such as accelerator communities that help increase consumer familiarity and acceptance of new vehicle technologies, and non-monetary incentives like preferential access to high-occupancy vehicle lanes can help convince consumers to switch.

However, while a suite of such policies can drive much of the rapid change needed to diversify the transportation sector and displace oil from its central place in our economy, such progress can be greatly accelerated at negligible cost by harnessing the transformative, market-based power of autonomous, or self-driving vehicles. This can be achieved without government interference, which can be costly and carry unintended consequences; instead it is driven by unleashing innovation. Due in large part to their adaptability to carsharing applications, the deployment of autonomous vehicles (AVs) into the vehicle fleet is likely to induce additional travel. With AV carsharing expected to allow many individuals to shed their privately owned vehicles, many more miles will be concentrated in fewer vehicles with far higher usage rates than typical cars of today. This high mileage per vehicle will mean that electric vehicles in particular will be a far more economical choice for these new cars than conventional gasoline and diesel engines. As a result, using prudent regulatory frameworks to facilitate the entry of AVs into the market would deeply accelerate the transformation of the transportation sector. SAFE's modeling of a likely AV adoption scenario estimates that self-driving cars would allow America to reach 50 percent oil displacement in 2035, five years earlier than in its non-autonomous scenario.

The suite of energy sources ready to repower the U.S. transportation sector is exceptionally diverse.

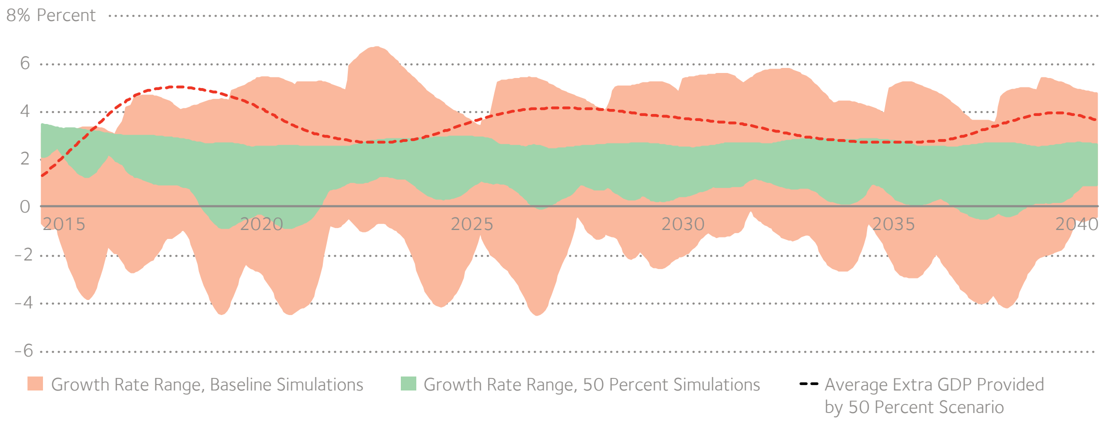
Influenced heavily by the OPEC cartel and state-owned national oil companies (NOCs), this market is decidedly not-free and dominated by many actors whose interests in many instances are contrary to those of the United States. The benefits of developing new policies to address the artificial volatility of the global oil market are numerous. De-linking the transportation sector from its wholesale dependence on petroleum will produce a number of positive economic and national security outcomes, the most important of which is increased insulation from the global oil market.

In addition, the anti-competitive behavior in the market has also led to a singular transportation infrastructure, the dominance of which suppresses alternatives to petroleum fuels. Moving to reduce oil's influence will enhance competition across the entire sector, with fuels and drive technologies challenging one another with continued efficiency and performance improvements. Specific applications can be matched to the most cost-effective power source, and tailor-made infrastructure solutions will be developed to meet those needs, such as fleet-sponsored private-public natural gas stations already springing up across the United States.

From short-hop city commutes to long-haul trucking, a variety of energy sources will allow consumers to choose their vehicle and fuel as opposed to being forced to use petroleum. Consumer spending will be distributed more evenly across a larger set of industries and products, contributing to greater macroeconomic stability.

FIGURE 5

Range of GDP Growth Rates from 20 SAFE Model Simulations, Baseline Scenario Versus 50 Percent Alternative Fuel Scenario



Source: SAFE analysis

As with many industries, innovation and development in one area produces even greater gains in others, a "ripple effect" with compounding benefits for multiple sectors. Expanded federal research and development into oil displacement technologies will not only benefit American consumers but will further establish the United States as an international leader in advanced fuels and vehicles, and American businesses will benefit as a result, able to export their cutting-edge products and expertise around the globe.

SAFE's *50 by '40* vision represents an ambitious approach to reducing U.S. oil dependence and addressing oil price volatility. This reliance reaches into every aspect of American life, with oil the only resource to do so at such a scale. Energy security lies firmly at the nexus of economic and national security. Thus, the United States must embrace a strong, comprehensive energy security policy, and this will start by charting a path to arriving at *50 by '40*. The alternative is remaining highly vulnerable to a manipulated global oil market and risking the health of our economy.

How does substantially decreasing oil consumption in the transportation sector strengthen the U.S. economy?

Achieving a future in which the share of oil powering the U.S. transportation sector declines to 50 percent will create much greater fuel diversity. This will provide the U.S. economy far more resilience in the event of oil price volatility. This volatility has historically undermined businesses' ability to budget and plan effectively, consumers' spending choices, and the strength of the economy overall.

To help illustrate the benefits of increasing fuel diversity in the transportation sector, SAFE modeled an 18-month oil shock in 2035, which consisted of a supply disruption peaking at 5 percent of global production, which is in line with historical precedent and not overly aggressive (Figure 3). The simulation found that, under the current business-as-usual trajectory, the U.S. economy would enter a deep recession, catastrophically facing seven consecutive quarters of negative growth rates. However, if the United States had cut oil's share of transportation to 50 percent, the damage from the oil recession would be minimized, as annualized GDP growth would drop to -0.2% for two quarters before the economy resumed an upward trajectory.

Even when no oil shock was modeled, the SAFE model showed remarkable benefits from cutting oil out of the economy. Twenty randomized scenarios were run, using historical levels of oil price volatility, each examining two cases: one in which the United States followed a business-as-usual path, and one in which the nation immediately cut oil's share of VMT to 50 percent. In those 20 simulations, the business-as-usual case saw 69 total oil-price induced recessions, compared with only four in the 50 percent scenario (Figure 5). Further, economic volatility was drastically reduced by cutting oil to 50 percent, and on average $18.4 trillion was added to U.S. economic output over 27 years. The purpose of this simulation was to show the impact of oil price volatility on the economy. It is not realistic to reduce oil in the transportation sector by 50 percent immediately. However, it does show that the faster we achieve this goal, the more resilient the U.S. economy will be.

Summary of Recommendations

The recommendations presented by the Energy Security Leadership Council are designed around one clear goal: to safeguard the security of the United States by significantly reducing our dependence on oil. This report is divided into four parts outlining these recommendations in detail.

PART I

Increasing Fuel Diversity in Transportation

While continued improvements in fuel efficiency will have positive implications for energy security, the priority should be shifted to advancing policies that maximize oil displacement in the transportation sector.

RECOMMENDATIONS FOR LIGHT-DUTY VEHICLES

Reform incentives for light-duty advanced fuel vehicle purchases. Consumer adoption of advanced fuel vehicles (AFVs) remains hindered by higher prices relative to comparable conventional vehicles, especially during the current period of low gasoline prices. Even when higher gasoline prices increase the consumer savings generated by AFVs, these benefits accrue over several years and have proven of less value to consumers than the lower up-front purchase price of conventional vehicles.

The existing credit is only available for the first 200,000 vehicles sold by the manufacturer through 2025. The current credit does not align manufacturer incentives with early adoption or rapid technological advancement. The Council believes that first movers should be rewarded, not penalized. The Council, therefore, recommends that all volume limitations on the current tax credit be lifted and that it be phased out beginning in 2021, and expire completely in 2023. These revised tax credits should also begin phasing out at suggested vehicle retail prices of $40,000 and end at $55,000. In addition, the Council recommends extending the availability of the credit to all vehicles that operate primarily on advanced fuels.

Increase federal research and development investments in automotive-grade batteries and natural gas storage tanks. Plug-in electric vehicles (PEVs) and natural gas vehicles (NGVs) each have high incremental costs compared to conventional vehicles, due primarily to a single component in each vehicle: batteries in PEVs and storage tanks in NGVs. The government should dedicate additional research and development (R&D) dollars to improving the performance and cost-competitiveness of these two components.

Initiate a National Accelerator Community Program. AFVs require the support of new networks and are only likely to succeed if accompanied by changes throughout multiple products, systems, and industries. SAFE's experience in Northern Colorado demonstrates the success that experiential marketing and community-based programs can have in accelerating AFV adoption. Such communities help spur faster and higher rates of adoption and become models for others to follow. To this end, the Council recommends establishing a fuel-neutral National Accelerator Community Program for AFVs. The program should develop a process to select 20 communities on a competitive basis, with successful applicants demonstrating the broadest community support and the most promise of deploying AFVs in large numbers as demonstrated by PEV sales.

Support creation of non-monetary incentives for advanced fuel vehicles. Incentives that offer vehicle owners added convenience have proven a major factor influencing vehicle purchasing decisions. These may include free or lower-cost access to high-occupancy vehicle and toll lanes, workplace charging or refueling, the construction of plug-in ready parking garages and lots, vehicle emissions testing exemptions, and free parking.

The Environmental Protection Agency and National Highway Traffic Safety Administration should propose a plan for regulating vehicle efficiency post-2025. Finalized in 2012, current National Highway Traffic Safety Administration (NHTSA) rules governing vehicle fuel economy and are in effect through 2021 and coincide with EPA's rules concerning greenhouse gas emissions through 2025. In establishing the standards, NHTSA and EPA committed to a midterm review of the program. If the review finds the current EPA standards and NHTSA's tentative standards are appropriate, then NHTSA can confirm the standards it outlined for 2022-2025 through a notice and comment rulemaking, and EPA's standards will remain unchanged. If the midterm review finds that the standards need to be adjusted, then EPA and NHTSA will jointly issue new rules.

In the short term, the Council continues to support the National Program. The Council also believes the agencies should begin studying additional policy options that could either complement or replace the National Program. Specifically, NHTSA and EPA should consider examining the transportation system as a whole, instead of just the vehicles. In addition, a revenue-neutral gasoline tax may be the most economically efficient and effective option for replacing the National Program. This system could serve in lieu of the currently more complicated regulatory structure and allow consumers the freedom to choose the types of vehicles they want to buy based on a clear price structure for fuels.

Increase federal deployment of advanced fuel vehicles. With over 400,000 non-tactical vehicles and over $1.2 billion dollars in annual fuel costs, the federal government has an enormous opportunity to help promote the use of AFVs and advanced fuels. Such adoption would demonstrate that AFVs can meet a wide range of transportation applications, generating important data and lessons. The Council recommends the federal government take the following steps to increase federal fleet-wide AFV use: work with states to make bulk vehicle purchases, encourage the General Services Administration (GSA) to join in seeking to lower the cost of AFVs at all levels of government; increase the use of E85 in the federal flexible-fuel vehicle fleet; right-size charging infrastructure; and incorporate AFVs into the next-generation Post Office Fleet.

RECOMMENDATIONS FOR LONG-HAUL TRUCKS

Create incentives for medium- and heavy-duty advanced fuel vehicle purchases. While NGVs, in particular, have seen impressive market share growth in certain applications—transit buses and refuse trucks being prime examples—penetration into freight and delivery markets has been slower. The Council recommends that Congress pass tax credits for advanced fuel medium- and heavy-duty trucks. Tax credits should be established that offer, at a maximum, $25,000 for dedicated AFVs weighing between 14,000 pounds and 26,000 pounds, and $40,000 for dedicated AFVs weighing more than 26,000 pounds. The precise amount should be determined, and recalculated on a quarterly basis, using the price differential (DGE) between diesel and the applicable advanced fuel. The credit should decline by 25 percent for every 50 cents per gallon difference in fuel price.

The credit should be allowed for vehicles placed in service after December 31, 2015, and before January 1, 2021, to promote faster adoption and limit costs. For vehicles placed in service in calendar year 2020, the credit would be limited to 50 percent of the otherwise allowable amount.

Congress should establish a grant system for the installation of CNG and LNG fueling stations along high-priority corridors. The federal government can facilitate the creation of a network of natural gas fueling corridors that will obviate the range concerns of long-haul truck owners and fleet managers. LNG would benefit especially from such a policy; its high energy density makes it attractive to operators traveling long distances carrying heavy cargoes. Without sufficient LNG refueling stations on the National Highway Freight Network, companies without the volume to justify building their own stations have largely refrained from switching from diesel.

The Council recommends that natural gas refueling infrastructure be prioritized along corridors that are responsible for a large proportion of long-haul medium- and heavy-duty trucking. Through the establishment of a grant system, Congress can ensure that fueling stations exist no more than 200 miles apart alongside the more than 51,000 miles of the National Highway Freight Network.

Congress should pass a two-year extension of the Alternative Fuel Excise Tax Credit. In December 2015, Congress passed legislation that extended the Alternative Fuel Excise Tax Credit through December 31, 2016. This credit provides $0.50 per gallon for CNG, LNG, and propane autogas, among other advanced transportation fuels. The current extension is short-term and creates tremendous uncertainty for investment in longer-term projects. The Council urges Congress to pass a two-year extension of the Alternative Fuel Excise Tax Credit so that such uncertainty is eliminated.

Establish a diesel gallon equivalent standard in order to create consistency and clarity in the marketing and dispensing of CNG and LNG fuel. The opportunity to save on fuel costs is a major motivation for car and truck fleet owners to switch from petroleum to natural gas and other alternatives. This shift depends, however, on the fuel cost savings being transparent and easily understood by truck operators and fleet owners. Simplicity and clarity in fuel measurement can do much to aid consumer acceptance of an alternative fuel like natural gas. For this reason, the National Conference of Weights and Measures (NCWM) should approve the creation of a uniform diesel gallon equivalent (DGE) standard as the primary unit for dispensing and pricing LNG. Similarly, the NCWM should vote to allow for CNG to be measured and priced in DGE where sold primarily to medium- and heavy-duty vehicles.

States and localities should establish their own incentive programs, particularly around regional and urban goods movement. Many states and regions have established advanced fuel heavy-duty vehicle incentives. Most are financial incentives for the purchase of vehicles or construction of fueling infrastructure. For example, the New York State Energy Research and Development Authority (NYSERDA) is providing incentives for alternative fuel trucks and buses. DOT Tiger and DOE Clean Cities grants should be made eligible for these local programs to support state and municipality efforts nationwide.

Localities should also consider non-traditional incentives, such as access to HOV lanes, preferred delivery times for advanced fuel delivery vehicles, preferential treatment in the awarding of local government freight contracts, adjusting urban freight facility zoning rules to reward the use of advanced fuel freight vehicles, allowing access to municipal advanced fuel fueling stations, and assisting freight operators with obtaining federal grants and other incentives for advanced fuel medium- and heavy-duty vehicles.

Create performance-based standards for freight trucks. Millions of avoidable truck trips occur every year, leading to unnecessary expenditures on fuel and labor. Such inefficiencies are the result of a burdensome set of prescriptive standards that limit the length of trucks and trailers. These outdated policies are poised to inflict even more damage upon U.S. businesses, as recently released projections from the Department of Transportation indicate freight levels will grow 40 percent by 2045. The Council recommends the adoption of performance-based standards (PBS) that will enhance freight efficiency and significantly reduce oil consumption without negatively impacting road infrastructure or safety. PBS allow for flexibility, enhancing industry's creative capacity to design and manufacture trucks specialized for their intended cargo. Because the development of, and agreement on, a suite of safety and infrastructure criteria for PBS will take time, the Council recommends that in the interim Congress immediately update a 1982 law by extending the length of twin trailers from 28 to 33 feet.

The Department of Transportation should promulgate rules on truck platooning. Platooning is a driver-assist technology that allows two or more freight trucks to be “connected” through vehicle-to-vehicle (V2V) communication. The connected trucks maintain a close, constant distance, through automatic speed, acceleration, and braking control. In recent tests conducted by the National Renewable Energy Laboratory, the lead truck demonstrated fuel savings of approximately 5 percent while the trailing truck saved approximately 10 percent. In addition to the fuel savings, these technologies are important precursors to fully autonomous vehicles. Congress and the Department of Transportation should establish standards that all states adopt on the National Highway Freight Network to allow truck owners to invest in platooning technology systems.

RECOMMENDATIONS FOR AVIATION

Increase funding for research and development related to advanced biofuels. Advanced biofuels are uniquely positioned as the only near-term alternative to petroleum-based jet fuel, a particular concern given the projected growth of the aviation industry and continued volatility in the price of oil and its derivatives. Achieving cost parity nevertheless remains a challenge. The federal government should provide more support to accelerating the development of advanced biofuels, particularly in terms of identifying low-cost pathways to deploy hydrocarbon substitutes from non-food crop feedstocks.

Permit the Department of Defense flexibility in purchasing advanced fuels and vehicle technologies. The Department of Defense (DoD) plays an important role in supporting the development of advanced fuels and advanced energy technologies. First, DoD faces unique incentive structures in evaluating cost effectiveness: energy systems that reduce exposure to enemy combatants, for example, can justify higher costs. Second, DoD can serve as a technology incubator given its significant purchasing power and its need to provide the armed forces with the most advanced technology possible to maintain U.S. strategic advantages.

The DoD should also be given the flexibility to participate in public-private advanced fuel-purchasing consortia at the national or regional level. A purchasing consortium could provide significant long-term certainty to advanced biofuels producers, scaling up the supply chain and driving down costs. This kind of industry “best-value” approach is not workable today, as current procurement policy requires that the DoD issue a request for proposal and separate source selection (choosing of a government contractor through a competitive negotiation period).

PART II

Advancing the Next Generation of Transportation Technologies

Autonomous and connected vehicles (AVs) have emerged as a technology with the potential to transform the transportation system and accelerate adoption of AFVs. Although AVs will generate broad societal benefits, there are several obstacles that could slow deployment. Urgent action is required at all levels of government to ensure that private-sector research, development, and adoption does not needlessly lag as a consequence of inadequate or over-zealous regulation.

RECOMMENDATIONS

The federal government should remove regulatory obstacles to the deployment of autonomous vehicles. Important benefits of AVs will not be fully realized if a driver is required to be engaged and ready to take over. For example, such a mandate would prevent a vehicle from self-relocating to pick up a waiting owner or the next passenger (which would be necessary to allow for shared, autonomous mobility-on-demand and accelerate AFV adoption). Individuals who could not serve as a suitable driver, such as those with disabilities or the elderly, would not be able to drive a vehicle that required a driver's supervision.

The government should neither require nor limit differing levels of automation or technology development trajectories. It is likely that most of the safety benefits of autonomous vehicles are accessible to NHTSA level 3 autonomous vehicles. Regulators should allow industry to deploy its choice of autonomous vehicle technology as long as it is as safe as today's vehicles, and let the marketplace choose which technology best meets consumer needs.

Since the design and ownership model of AVs differ from conventional vehicles, varying state AV standards likely would require different vehicle models. Avoiding this outcome is the exact reason the Supreme Court upheld federal pre-emption of state-level safety standards. Consistent with this approach, federal rules on AVs should pre-empt state standards.

The federal government should "learn through doing" by facilitating autonomous vehicle deployment communities to inform any necessary regulation. Just as technology is developed through real-world testing, regulations for AVs should be created iteratively. New technologies are also not created in a vacuum; they are often tested before scaled production. NHTSA has the authority to exempt AVs from standards that are incompatible with the technology. This authority should be used to coordinate with local and state governments to develop a diverse range of communities where private companies provide AV technology to the public on a trial basis. These deployment experiences should be used to inform necessary safety, business model, and liability regulations.

V2X technology will contribute to AV functionality once there is widespread deployment, or sooner in areas targeted for use of V2X-enabled vehicles. The federal government should not endanger the potential benefits of this technology by allocating the necessary 5.9 GHz spectrum to other uses without first ensuring that the spectrum can safely be shared.

Create an alternative liability framework for early autonomous vehicle deployment. In 1988, the National Vaccine Injury Compensation Program was created to compensate those injured by childhood immunizations in response to a small number of adverse reactions to the pertussis portion of the DPT vaccine. Concerned that manufacturers of vaccines would stop production because of the threat of lawsuits, Congress created an alternative claims process funded by a fee on all vaccines. The claims process was part of broader legislation requiring the reporting of all adverse events to a national database and the establishment of a federal, no-fault system for adjudicating claims of harm from a vaccine. Not only has this structure preserved U.S. vaccine manufacturing capability, but the fund has run at a surplus.

The Council recommends a similar approach to AVs as liability concerns could delay deployment and undermine significant safety and health benefits. The terms governing the earliest public deployments of AVs will likely be the product of a negotiation between the company manufacturing the vehicles, and federal, state, and local governments. Even after all efforts are made to ensure that AVs meet a satisfactory safety standard, manufacturers will still require safeguards to limit their liability to proceed to deployment. Any arrangement should be designed to retain a strong financial incentive for companies to deploy only AVs that have been tested and rigorously certified as safe.

The federal government should promote pilots of automated trucks; all levels of government should maintain flexibility and openness to innovative urban delivery approaches. At least one trial deployment of AVs should center on trucks. This would require the Federal Highway Administration, in coordination with states and municipalities, to designate a specific Interstate highway corridor as one where vehicle automation would be permitted on a test basis. The Federal Motor Carrier Safety Administration should participate in these pilots to explore how vehicle automation can reduce driver fatigue. Driver work hour rules should also be updated to account for autonomous features and incentivize the deployment of technologies that will make drivers safer.

Innovative AVs might offer a solution to the "last-mile" problem associated with high cost of delivery from a central depot to the final destination relatively nearby. Several companies are testing AVs designed specifically for this purpose, including a small, slow-moving box that travels on the sidewalk alongside pedestrians. Such approaches may present new challenges for local regulation, which should prioritize flexibility and openness.

Incentivize ridesharing and autonomous vehicles in addition to the current emphasis on vehicle-level efficiency. Fuel economy requirements have been a powerful policy lever for reducing U.S. oil consumption, and impacted car design. These standards, however, are not designed to account for the broad system efficiencies that could result from increased ridesharing and deployment of AVs.

Congress should require agencies to update fuel efficiency standards to do the following:

> **Incentivize more efficient autonomous vehicles**. Just as fuel efficiency standards have led to more efficient engines, they should incentivize software developers to create more efficient algorithms.
>
> **Account for the "off-cycle" benefits of autonomy.** Once quantifiable, gains from autonomy—such as reduced congestion due to better traffic routing and reduced accident frequency resulting from improved safety—should be accounted for.
>
> **Recognize the different use profiles of shared and privately-owned vehicles.** A shared AV should be able to drive more than ten times as many miles in a year than a privately owned, non-autonomous cars. Fuel efficiency standards should recognize the increased impact of shared AVs and increase their representation in calculating fleet-wide average fuel economies. This might be accomplished by including a credit multiplier for vehicle sales to a fleet operator.

State and federal governments should encourage the utilization of autonomous vehicles to expand mobility options for underserved groups. The potential for AVs to deliver increased mobility is immense, but, given the state of the technology, largely unproven. Piloting the use of AVs for underserved populations will set the stage for capturing these societal benefits, by demonstrating benefits and economic value to government actors and the private sector. If some states do not take necessary steps to include underserved groups in AV deployment, the federal government has important levers to encourage compliance, such as withholding highway funding.

Federal regulation of automotive safety should evolve to a more flexible and collaborative model based on performance-based standards. A shift to performance-based standards would position the government to avoid committing to specific technologies as autonomous vehicles rapidly evolve. The FAA recently overhauled its certification processes for small aircraft so that safety innovations could be more rapidly adopted rather than having to go through years of evaluations. It accomplished this by writing safety objectives broad enough to cover future unanticipated technologies and limiting prescriptive and technology-dependent elements. Applying these principles to the auto industry would accelerate the adoption, not just of AVs, but of other important safety technologies as well.

However, it is vital to emphasize the importance of maintaining the current practice of manufacturer self-certification of vehicle compliance. This method allows for automotive companies to bring a broad range of models to market (in 2015, 222 different models were sold in the United States) while reducing the cost of regulatory compliance. Manufacturers may need to allow the government to audit the results of tests proving compliance with performance standards, but there should not be a shift to a regulatory model where the government is deeply involved in continuous surveillance of companies to monitor compliance.

A single office at a restructured Department of Transportation and an interagency working group with special hiring authorities should lead federal action on autonomous vehicle policy and necessary regulations. The regulatory and technology issues surrounding AVs do not fit neatly into the modal agencies that currently compose the DOT. Autonomous vehicle technology has relevance to urban transit, individual and shared light-duty passenger vehicles, and the heavy-duty or motor coach fleet. Autonomous vehicle-related activity could be centered in the office of a new Assistant Secretary, or NHTSA could be expanded appropriately with resources and AV-related regulatory functions from the modal administrations.

To ensure that the benefits of AVs are captured in the decision-making process, the Executive Office of the President should establish an interagency working group to be funded through the budget of participating agencies. Today, ad hoc collaborations exist between agencies on AV-related issues, but a more formal approach is needed. Agencies with missions that intersect with AVs and have relevant expertise should be included.

PART III

Bolstering American Oil Production

While U.S. production of oil and natural gas has achieved remarkable growth over the past several years, the country could do more to maximize its resources and diversify its production portfolio. In particular, vast tracts of federal lands and waters remain unavailable for exploration and development.

RECOMMENDATIONS

Require the Department of the Interior to begin work on a revised Five-Year-Program covering the period from 2017-2022. In January 2015, the Department of the Interior released a Draft Proposed Plan for the 2017-2022 period that included 14 potential lease sales in eight planning areas: ten in the Gulf of Mexico, three in the Alaska OCS, and one in the Mid- and South Atlantic Planning Area that was to initiate exploratory drilling operations in the waters of Virginia and Georgia in 2021. However, in March 2016, the subsequent Proposed Program for 2017-2022 did not include Mid- and South Atlantic Planning Area lease sales. The Obama Administration cited its concern for interference with military operations in affected areas.

First, Congress should require the Department of the Interior to develop a revised Five-Year Program covering the period 2017 to 2022. To determine the areas made available in such a plan, eligible coastal state legislatures should have the opportunity to opt into the program. Eligibility should extend to any coastal state with an approved Coastal Zone Management Plan in place. States that opt-in should have their portion of their OCS planning areas—as determined by State Administrative Boundaries—included for at least one lease sale in the revised 2017-2022 Five-Year Program. In order to provide clear incentives for coastal states to opt into future OCS development plans, higher revenue sharing rates currently benefiting Texas, Louisiana, Alabama, and Mississippi should be extended to all coastal states that participate in OCS development. Second, Interior should establish a set of safety performance metrics for the industry that cover a range of indicators, including spills, discharges of chemicals and other materials, and inspection violations. Individual companies that fall below a specified minimum performance rating should be ineligible to bid on new leases until they regain compliance.

Support responsible energy production in the Arctic. For decades, commercial access to the Arctic expanse has been limited by the complexity of operating safely in a remote and challenging region. However, experience garnered from producing oil and gas in other regions, advances in technology, reduced ice cover, and the ongoing search for untapped energy resources have renewed focus on the region. Federal policy can support responsible energy production in the Arctic in two key areas. First, regulators should evaluate equipment and ice management techniques every two years to determine if the drilling season can be extended. Second, Arctic lease terms should be extended beyond ten years to accommodate for environment-based project complexity and the relatively short drilling season.

Facilitate limited development of the Arctic National Wildlife Refuge using extended reach drilling and strict surface occupancy restrictions. Although Northern Alaska possesses just 11 percent of fully inaccessible federal territory, these lands hold more than two-thirds of the inaccessible onshore undiscovered technically recoverable oil resources. After decades of debate, federal protections that restrict industry development in ANWR are unlikely to be abandoned in their entirety. However, recent developments may provide an opportunity for the industry to leverage technology to access oil resources with a minimal footprint. Specifically, long-range extended reach drilling (ERD) is an increasingly common technology being deployed by industry to access hydrocarbon reservoirs in remote or environmentally sensitive areas around the world. The federal government should initiate a program in cooperation with the State of Alaska to use state lands and waters adjacent to ANWR as Extended Drilling Zones.

Establish an Energy Security Trust Fund seeded with some revenues from new Outer Continental Shelf and Alaskan oil and natural gas production and use it to fund research and development into technologies that improve competition in the transportation fuels market. Investment in cutting-edge research and development can address critical energy security and related economic challenges, reducing oil intensity and increasing viable substitutes that expand fuel diversity and consumer choice. Incremental OCS revenues from newly developed regions should be used to support investment in advanced energy technologies and infrastructure. The scope of eligible investments should be defined as broadly as possible within the narrow context of oil displacement and should prioritize research and development aimed at supporting advanced vehicles and fuels. Fifty percent of the federal share of all royalty revenue from energy development in new regions should be placed into the ESTF. The maximum threshold for receipts should be $500 million annually. *Note: President Obama unveiled a similar proposal modeled on this recommendation during his State of the Union address in 2013, although his proposal should be expanded to include greater access to new oil and gas resources.*

PART IV

Combating Oil Market Manipulation

OPEC nations and others with national oil companies (NOCs) impede the free and efficient functioning of the global oil market. States with vast oil reserves leverage high spare production capacity and low costs to shift the balance of power in the global oil market. The United States should use newfound technological innovations, economic levers and international law to inhibit the destructive manipulation of global oil prices.

RECOMMENDATIONS

Establish a commission to investigate and better understand the role of OPEC, its member states, and other national oil companies in the maintenance of the unfree global oil market. To gain a greater understanding of the role these external actors play and their impacts, the United States should establish a bipartisan commission tasked with enumerating and quantifying the impacts external actors have on U.S. consumers, oil producers, industries, energy security policy, and national security.

This commission, which would have one year to investigate and provide findings and recommendations to which the President would be required to promptly respond, would be supported by full access to information from all relevant federal agencies. Its members would be selected based on professional, regulatory, and analytical experience in areas that include oil market dynamics, oil and gas exploration and production, crude oil refining, oil and gas pipelines, transportation-related fuel consumption, oil use efficiency, national security, foreign policy, macroeconomics, labor, environment, logistics, shipping, tourism, consumer goods, manufacturing, and tourism.

Among its many responsibilities, the commission could explore the possibility and feasibility of bringing legal action against OPEC member states for violations of the General Agreement on Tariffs and Trade (GATT). With many OPEC members, including Saudi Arabia, also members of the WTO, they could be subject to litigation for any violation of Article XI of the GATT. Article XI prohibits restrictions by any means other than tariffs on the export or sale of any product, and the commission would investigate whether production quotas and deliberate production decreases aimed at moving the market price of oil constitute punishable violations.

Build an international consensus among oil-consuming nations on the importance of shared responsibility and coordinated action to deal with future oil supply interruptions. Global unplanned crude oil outages averaged 2.8 mbd over the past two years, largely due to supply disruptions in OPEC nations. Major OPEC nations with the ability to increase production in the event of major disruptions, such as that which occurred at the height of the Libyan civil war, cannot be counted on to do so. Thus, the United States should lead a new effort of multilateral consultations aimed at increasing international response mechanisms to quickly release oil stocks to the market in the event of a disruption, bringing in major nations that are not currently IEA nations like China and India.

Use the full diplomatic force of the U.S. government to push—especially through hydraulic fracturing technology—the development of oil and natural gas resources around the globe. An estimated 10 percent of global oil resources lie in shale formations, which the United States has been a global leader in extracting. Recent technological advances in tight oil drilling have led to a surge in U.S. oil production, particularly since 2008, and encouraging the spread of this technology to allies worldwide could help give the world market a greater buffer of responsive oil and gas production to protect against the effects of unplanned disruptions or OPEC supply cuts. By making this an interagency priority, the U.S. government could use the State Department, Treasury Department, and other organs to encourage the sale of advanced extractive technology by the U.S. and foster resource law reform in other nations to improve private sector access to tight oil resources.

Encourage nations to cut oil subsidy programs. Subsidies are widely and inefficiently used in welfare spending programs by many nations, and have long distorted the oil market. Most notably, they result in excessive oil consumption, adding upward pressure to prices and exacerbating periods of market tightness. But in some forms, by limiting the prices that can be charged domestically they also deter investment in potentially higher-cost resources that would be undertaken under free-market conditions. Even leaving out the cost of externalities from overconsumption, $267 billion was spent worldwide on oil subsidies in 2014. These subsidies are estimated to add 6 percent to oil prices on average. The United States should use its diplomatic and trade leverage to encourage more nations, particularly allies, to reform and dismantle their oil subsidies programs, resulting in a more efficient market and lower prices for consumers worldwide and at home.

Develop a quantitative country index assessing respect for hydrocarbon production contracts. Complex, unfavorable contract terms, often motivated by populist tendencies toward resource nationalism have long deterred foreign direct investment in upstream projects that would otherwise be profitable. Further, the enforceability and reliability of signed contracts with government partners vary to a great degree across oil-producing nations, often increasing reluctance from potential investors. The public diplomacy impact of a comprehensive assessment of respect for oil and gas contracts—whether done by a government agency, similar to the State Department's annual Country Reports on Human Rights Practices, or by an independent group, as in Freedom House's annual Freedom in the World Index—could be used to encourage greater transparency and rule of law in upstream investment worldwide.

INTRODUCTION

Energy Security in the New Oil Market Paradigm

Introduction

In November of 2014, the Organization of the Petroleum Exporting Countries (OPEC) convened for what would become a historic meeting in Vienna, Austria. After peaking at more than $115 per barrel (bbl) in June of that year, as Islamic State militants captured large portions of Iraq and appeared on the verge of threatening Baghdad, the price of oil declined steadily to less than $80/bbl on the eve of the cartel's deliberations, sharply eroding its members' export revenues. Initially, the decline in prices was driven by the realization that Iraq's southern oil complex near Basra was unlikely to be seriously threatened by insurgents. But over time, an emerging imbalance in global oil markets, driven largely by the upstart American shale industry, came into focus as the key driver of continuously falling oil prices.

Between 2012 and 2014, the American shale industry grew at an unprecedented rate, increasing its production of crude oil and other liquid fuels by a total of more than 1 million barrels per day (mbd) each year over that time period. By the end of 2014, the dozens of independent energy companies that comprise the U.S. shale industry were pumping an incremental 3.8 mbd of total oil supply into the global market compared with 2011 levels—a level of production that made them collectively the sixth largest oil producer in the world. While this rapid growth presented the American economy and consumers with a wide range of benefits—from reduced spending on imported oil to increased job growth and capital spending—it represented an existential threat to OPEC.

Beginning in mid-2013, oil supply growth outside of OPEC began to consistently outpace global oil demand growth for the first time in decades, a situation that would have been nearly unimaginable just a few years earlier (Figure 6). For a significant period of time, the effects of this shift in the balance of power in oil markets was masked by supply disruptions in Libya as a result of that country's civil war and sharply reduced oil production in Iran as a result of sanctions. But by the time OPEC convened to discuss its strategy in late 2014, the world was becoming less dependent on OPEC oil in a way that presented the cartel with its first structurally shrinking market in at least a generation (Figure 7).

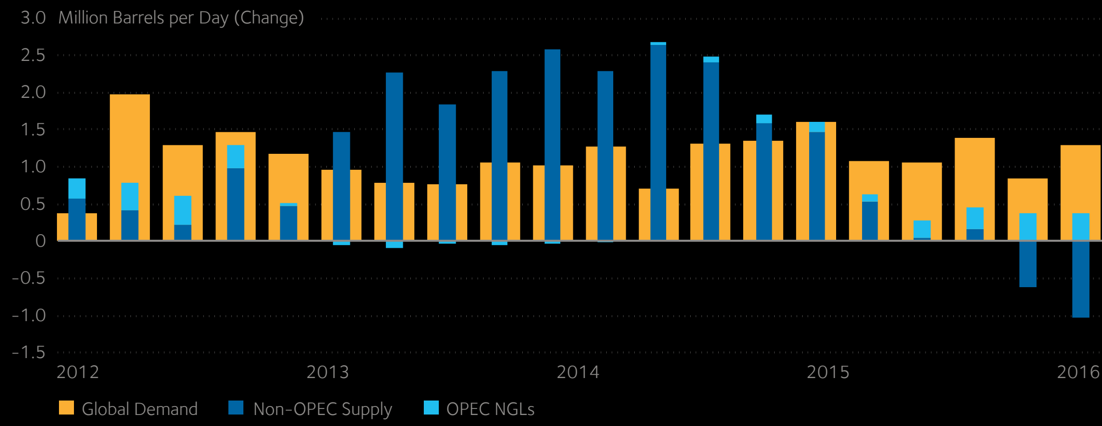
Based on OPEC's decades-long strategy of market manipulation—sometimes executed effectively, sometimes not—in pursuit of favorable oil prices, most market observers and participants anticipated that the cartel would respond to these dynamics with a reduction in output intended to erode or eliminate the market imbalance, preserving high prices and maximizing its short-term oil export revenues. Instead, Saudi Arabia and other Arab Gulf states including Kuwait, Qatar, and the United Arab Emirates, broke with the rest of the cartel and embarked on a different strategy. Facing rising levels of competition from outside the cartel—as well as soaring production from Iraq and the impending re-integration of Iran into global oil markets—Saudi Arabia and its allies initiated a global price war designed to recapture the market.

The Saudi Strategy

In the months that followed the November 2014 OPEC meeting, oil prices collapsed. The 2014-2016 fall in oil prices ranks among the most precipitous in history in terms of both speed and magnitude

FIGURE 6

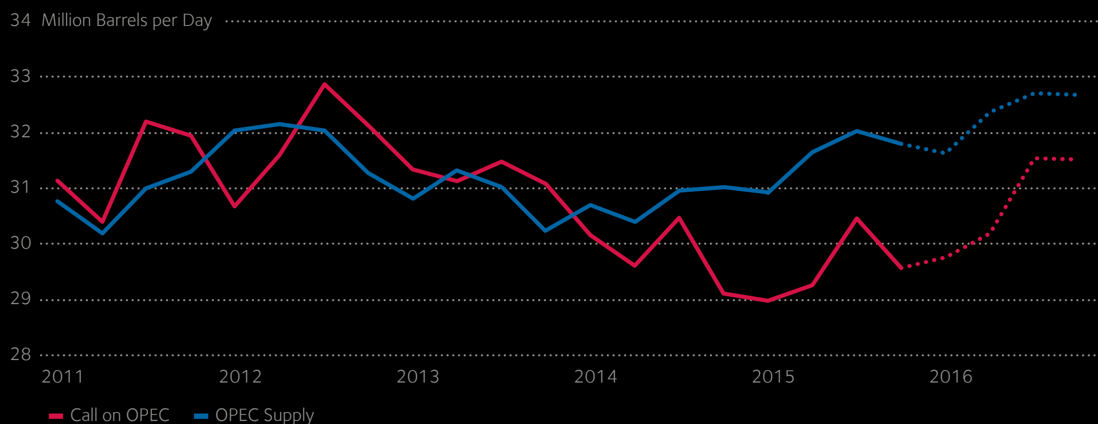
Year-Over-Year Change in Non-OPEC Oil Supply and Global Oil Demand



Source: SAFE anaysis based on data from EIA

FIGURE 7

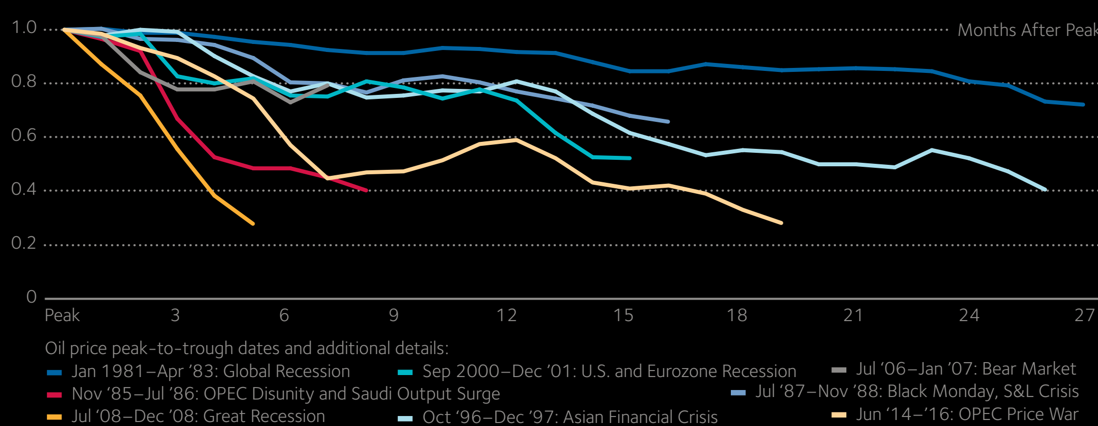
OPEC Crude: Call versus Supply



Source: SAFE anaysis based on data from EIA

FIGURE 8

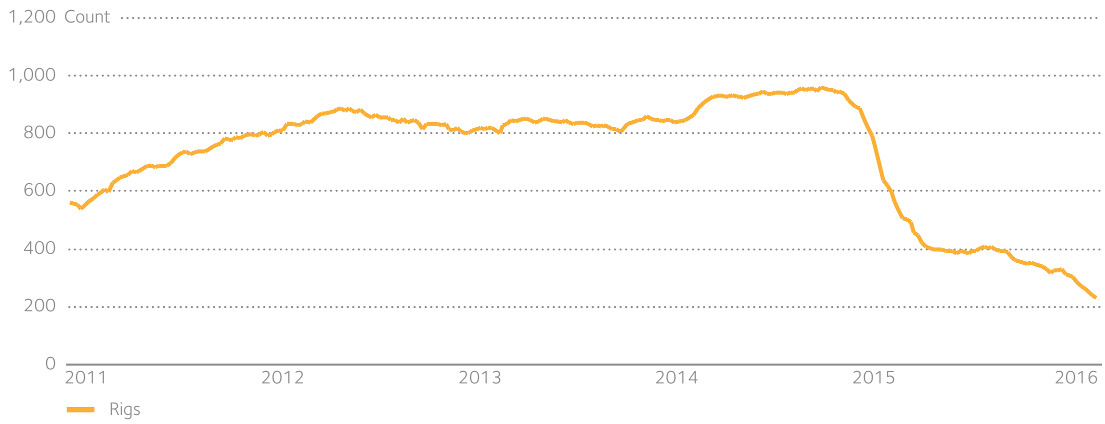
Historical Oil Price Declines



Source: SAFE analysis based on data from EIA

FIGURE 9

Total Rigs Drilling for Oil: Bakken, Permian and Eagle Ford



Source: Baker Hughes

(Figure 8). While several factors supporting the initial decline in prices can be traced to normal market dynamics, two other factors played important roles in making this price correction especially severe and destructive. First, the typical process of price discovery does not work in the oil market, because of an utter lack of transparency in OPEC's decision-making process. While participants in markets for other goods can make educated guesses about other participants' plans based on their best estimate of a competitor's costs, OPEC members often establish quotas based on non-market criteria or goals which can be far more difficult to estimate. Markets are essentially forced to guess what decision a group of oil producers representing more than one-third of global crude supplies would make—and in 2014 the markets guessed wrong. Given the complex mix of political, social, security and other non-market factors that were at play in OPEC's deliberations, this poor guess was perhaps not surprising.

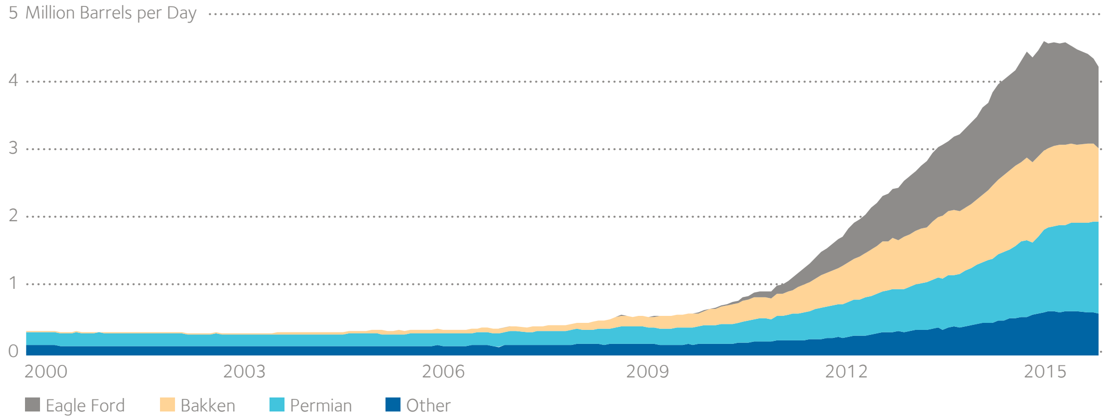
Second, and more important, in the months that followed the decision, Saudi Arabia initiated a steady and concerted effort to draw down its spare capacity and flood the global oil market with excess supply. In November 2014, Saudi crude production totaled 9.6 mbd. Four months later, in March 2015, it had reached 10.2 mbd, an increase of 600,000 barrels per day.[1] Based on production since then, this appears to be the current floor for Saudi output, with levels rising still higher during months of elevated summer demand within the Kingdom. Combined with increases in Iraqi output as that country seeks to rebuild its economy and fund an ongoing conflict with the Islamic State, the increases from Saudi Arabia have sharply exacerbated the condition of oversupply in global oil markets over the past 18 months. Contrary to the notion that Saudi Arabia is simply allowing the market to rebalance itself, this deliberate action to draw down spare capacity and sharply increase production at a time of low global oil prices suggests that the Saudis—and by extension their allies within OPEC—have a clear strategy.

In short, the Saudi strategy aims to use an extended period of extremely low oil prices to structurally rebalance the oil market on terms that will benefit OPEC and other large global oil exporters over the coming decade. Their goal is to return the market to a condition of relative short-term scarcity in which sellers have substantial leverage over buyers, thereby maximizing OPEC's ability to manipulate prices and extract large resource rents from oil consumers across the globe. The Saudi strategy has four main components: (1) recapture short-term market share from U.S. shale and other responsive sources of global supply; (2) undermine investment in capital intensive long-term non-OPEC oil supplies such as global deepwater resources and Canadian oil sands; (3) stimulate short-term oil demand through low prices; and (4) undercut global policy to reduce oil consumption, including fuel economy standards, as well as competition to oil, such as electricity and natural gas. There is compelling evidence that all four components are already succeeding.

1 SAFE analysis based on data from IEA.

U.S. Tight Oil Production

FIGURE 10



Source: SAFE anaysis based on data from EIA

1. The War on Shale

In the near term, U.S. shale production will be a primary casualty of the Saudi strategy. The number of rigs drilling for oil in the Permian, Bakken, and Eagle Ford shale basins peaked at 960 in late October 2014 and held steady between 950 and 940 through mid-November.[2] Almost immediately after the Saudis announced their market share strategy and prices started falling, drilling activity in these basins began to collapse, plunging below 900 by the end of 2014. Over the following five months, the decline in drilling activity averaged nearly 30 rigs per week, before briefly stabilizing at 400 in May, representing a decline of nearly 60 percent from its peak. Following a short stabilization in oil prices, drilling continued to collapse, and the oil-directed rig count in the three key shale plays stood at just 229 in March 2016 (Figure 9).[3]

The sharp drop in drilling activity did not immediately translate to similar declines in oil production as shale operators worked quickly to improve operational efficiency, cut costs, and focus drilling activity on the most productive areas within each region. In fact, despite the fact that drilling slowed sharply in 2015, average annual shale production increased in 2015 relative to 2014 by 0.6 mbd.[4] However, absolute production levels are a fairly misleading metric for evaluating the production impact of the lower oil prices witnessed since 2014. Evaluating the counterfactual—actual production versus *expected* production prior to the collapse—presents a more useful perspective.

For example, in its November 2014 oil market forecast, the Department of Energy (DOE) projected that U.S. crude production in the onshore region of the lower-48 states (a good proxy for shale production) would increase by 0.5 mbd between January and December of 2015.[5] Today, DOE estimates that lower-48 production actually declined by 0.23 mbd over that period, a swing of 720,000 barrels per day in actuals compared to expectations.[6]

Even in absolute terms, the near term picture for shale suggests significant production declines. On a monthly basis, total shale oil production is estimated to have peaked at more than 4.6 mbd per day in March 2015 before dropping to less than 4.3 mbd by the end of the year—a decline of 8 percent. (Figure 10).[7] The Department of Energy currently expects U.S. crude production in the lower-48 states to decline by nearly 0.9 mbd on average in 2016 compared to 2015 and an additional 0.63 mbd in 2017.[8] These reductions—if they materialize—will be key contributors to a near-term oil market tightening.

2 SAFE analysis based on data from Baker Hughes.
3 Id.
4 EIA, *Short-Term Energy Outlook*, March 2016.
5 EIA, *Short-Term Energy Outlook*, November 2016.
6 Id.
7 EIA, Presentation on "North American Energy Markets," delivered January 26, 2016.
8 EIA, *Short-Term Energy Outlook*, March 2016.

2. The Long-Term Supply Crunch

While the reductions in shale production are central to near-term oil market balancing, the impact on more capital intense non-OPEC oil supplies is likely to be of greater importance in the medium- and long-term. In 2015 and 2016, for example, estimates suggest that upstream investment in global oil supplies declined for two consecutive years for the first time since the mid-1980s, a combined reduction of $225 billion (Figure 11).[9] Investment in the Middle East was flat over this period, while investment in Russia dropped 20 percent in 2015 (recovering slightly in the first quarter of 2016). The majority of the reductions in capital spending have occurred in North America—particularly in deepwater resources and Canadian oil sands—and other costly basins such as offshore in Latin America.

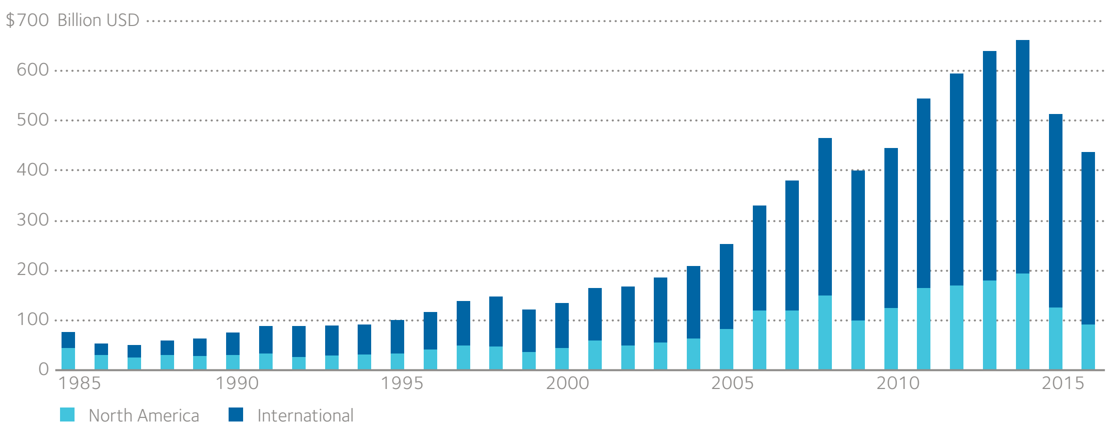
The impact of these reductions in spending is likely to be substantial and result in materially tighter oil markets by the end of the decade based on current oil demand forecasts. In early 2016, investment bank UBS estimated that sanctioned oil projects in 2015 and 2016 were running well below normal levels and will add just 0.63 mbd and 0.6 mbd respectively at their peak to future global oil production (Figure 12). This compares with annual additions of 2.7 mbd on average from 2005-2014. As a result, UBS noted, global upstream project cancellations could create a 4 mbd "hole in global oil supplies" by 2020.[10] Similarly, in March 2016, investment bank Morgan Stanley argued that cumulative global oil supply capacity will average 4 mbd less than December 2014 expectations throughout the period from 2018-2020.[11] Nearly half of this 4 mbd supply hole stems from the United States in 2018. By 2020, U.S. production recovers but ongoing supply gaps in oil sands and offshore Brazil keep the gap at about 4 mbd.

The primary means of bridging this gap will be sharply higher oil prices, which will be needed to moderate demand and increase supply. While it is difficult to estimate the exact level that prices will need to reach, one key driver will be cost of developing the marginal barrel of non-OPEC oil globally. Based on current resources and industry economics, this is likely to be a combination of Canadian oil sands, global deepwater resources, and offshore Arctic. Another key driver will be the oil price needed to stimulate a return to rapid annual growth in U.S. shale.

While breakeven costs for oil projects are notoriously difficult to pinpoint, it is important to appreciate that resources such as deepwater oil and oil sands are among the most costly supplies to develop and require oil prices well in excess of today's prices to initiate project cycles. For example, oil consultancy Rystad Energy estimates the average 2020 breakeven price for developing Canadian oil sands to be $88 per barrel, with some projects requiring in excess of $100 per barrel.[12] The estimate for global

FIGURE 11

Global Upstream Oil Spending

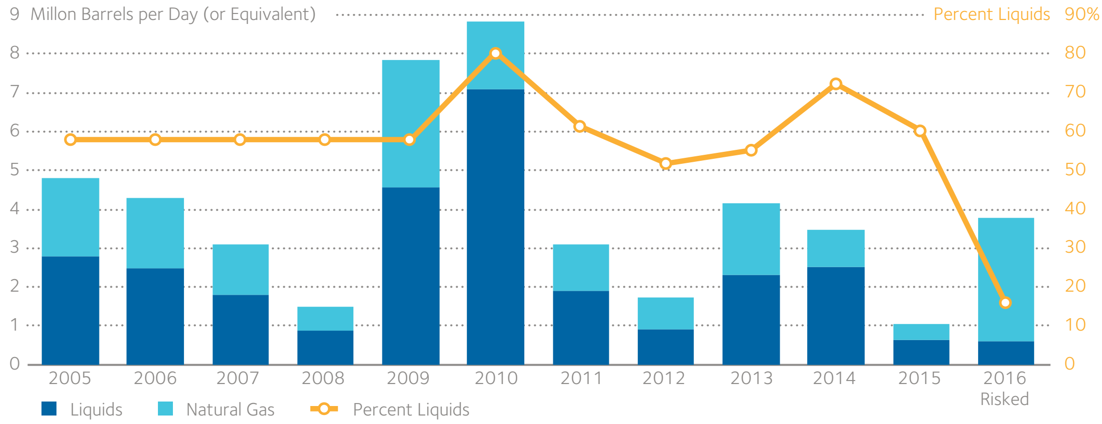


Source: Barclays

9 Oil and Gas Journal, "Barclays: Global E&P Budgets to See Double Dip in 2016," January 13, 2016.
10 UBS, "Major Projects Database Update: Trouble Down the Line," February 2, 2016.
11 Morgan Stanley, Crude Oil Global Supply Tracker, March 23, 2016.
12 Rystad Energy, "Global Liquids Cost Curve," October 2015.

FIGURE 12

Major Upstream Project Final Investment Decision by Year



Source: UBS

ultra-deepwater resources ranges from as low as $45 per barrel to as much as $70 per barrel. While U.S. shale will undoubtedly play an important role in increasing global oil supplies as prices rise, most observers suspect that driving annual growth to pre-2015 rates in excess of 1 mbd annually would require prices of at least $80 per barrel.[13]

It is also important to note that tighter market conditions—and therefore higher prices—could last for a period of years, not months. This is because large capital projects such as oil sands development or offshore drilling in the Gulf of Mexico require significant lead times to be developed. For global deepwater, the time from discovery to a final investment decision currently averages 5 years.[14] After a decision to invest is made, the typical project cycle lasts three years, after which a field enters production. In other words, even currently sanctioned projects that have been delayed due to low oil prices will require three years of development to reach first production when oil prices increase. New discoveries in global offshore will require nearly 10 years to reach production. To the extent that investment in these resources is required to meet future global oil demand, these project cycles will help determine the length of the next high price cycle.

3. Short Term Demand Rebalancing

While undermining growth in U.S. and other non-OPEC oil supplies is a critical component of the Saudi strategy, the Kingdom's goals for the broader market are comprehensive and designed to drive meaningful changes in oil consumption as well as production. Saudi Arabia aims to leverage the extended period of low prices to stimulate oil demand in key regions in the short term—including the United States and China—and to undermine technological and policy-related threats to oil in the long term.

First, it is important to understand that a number of trends developed in the years immediately following the 2007-09 financial crisis that were almost certainly worrisome for OPEC and other global oil exporters. Most prominently, numerous observers suggested that global oil demand growth would moderate in the short term and diminish more significantly and fundamentally in the long term.

In the United States, the number of miles traveled on roads and highways throughout the country declined by 2.5 percent during the recession and was effectively flat from 2009 to mid-2014, the first such period since federal records began in 1970.[15] In fact, measured on a per capita basis, U.S. vehicle travel actually declined in all but one year from 2004 to 2013, an unprecedented decline (Figure 13).[16] Combined with modest increases in the efficiency of the U.S. vehicle fleet due to fewer purchases of

13 SAFE conversations with oil company executives. See also, e.g., Bank of America Merrill Lynch, "Global Energy Weekly: Look out for W in WTI," March 18, 2016.
14 Christopher M. Barton, "Industry continues to provide solutions for deepwater production challenges," Offshore Magazine, May 6, 2015.
15 Federal Highway Administration, Traffic Volume Trends Report Archive.
16 SAFE analysis based on data from Federal Highway Administration and Bureau of Economic Analysis.

FIGURE 13

U.S. Vehicle Miles Traveled, 1997–2016

Source: SAFE analysis based on data from EIA

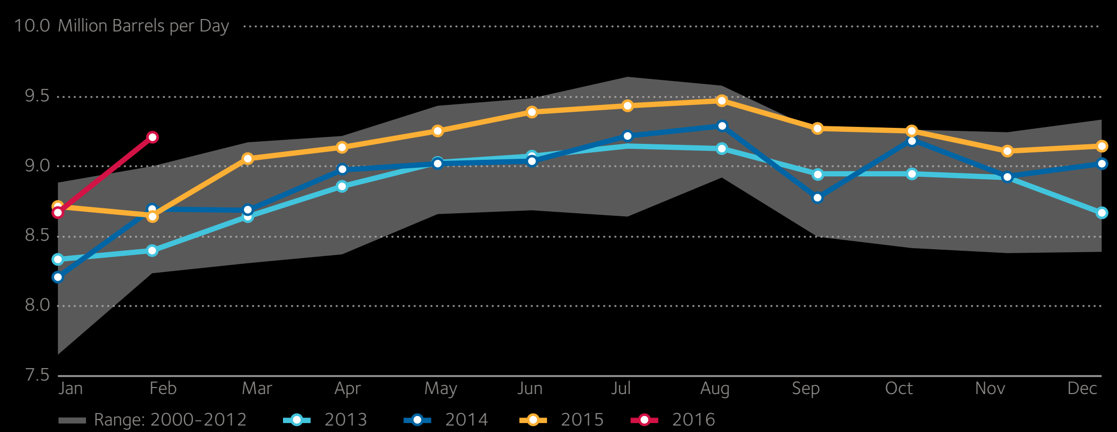
FIGURE 14

Light Truck Share of U.S. Auto Sales

Source: SAFE analysis basd on data from BEA

FIGURE 15

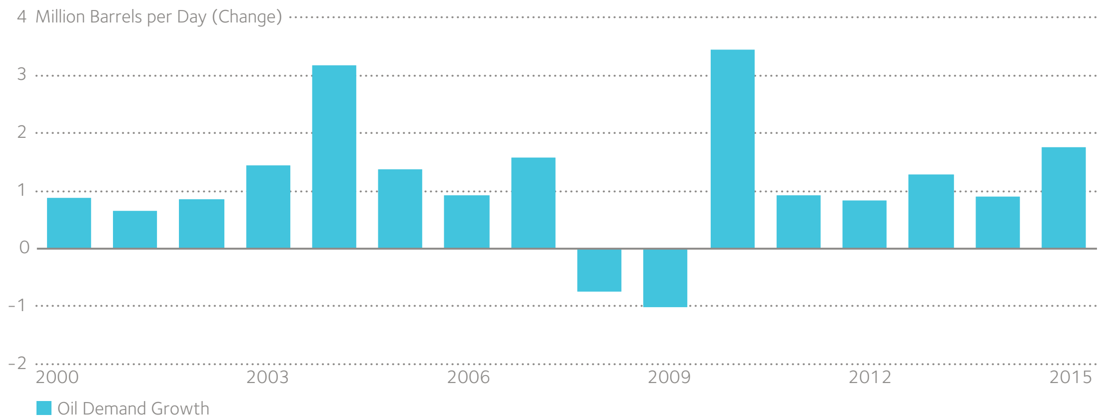
U.S. Motor Gasoline Demand



Source: SAFE analysis based on data from EIA

FIGURE 16

Global Oil Demand Growth



Source: SAFE analysis based on data from IEA

trucks and SUVs, reduced travel resulted in a significant drop in American gasoline demand over this period. Gasoline demand, which peaked at 9.3 mbd in 2007, averaged just 8.8 mbd from 2011 to 2014.[17]

Globally, a similarly-challenging picture was emerging for oil demand. According to the International Energy Agency, after oil demand growth averaged 1.4 mbd annually from 2000 to 2007, it averaged less than 1.0 mbd annually in the post-recession period from 2011 to 2014 (Figure 16).[18] While it is certainly the case that a significant portion of this slowdown was driven by trends in industrialized countries—OECD demand actually declined by 1.0 mbd between 2011 and 2014—developments in emerging markets also raised concerns for oil exporters.[19] In China, a key future market for Middle East oil exporters, demand growth averaged just 340,000 b/d annually in 2013 and 2014 after averaging nearly 500,000 b/d over the previous decade.[20] Given rapidly rising levels of oil production outside of OPEC—and increased competition from Iraq and Iran within the cartel—this flattening of demand presented Saudi Arabia and its allies with a rapidly shrinking market for their oil exports.

Measured against these near-term demand metrics, the Saudi strategy is clearly succeeding. Once considered an early indicator of peak demand for travel and fuel consumption in America, U.S. vehicle miles traveled (VMT) increased at its fastest pace in at least 45 years in 2015, and now stands at its highest level in history (Figure 13). Even on a per capita basis, VMT in 2015 surged to levels last seen in 2007, prior to the financial crisis. Meanwhile, the light-truck and SUV share of passenger vehicle sales set an all-time record in December 2015 at more than 60 percent of total light-duty sales and has been steadily rising for months (Figure 14). As a result, U.S. gasoline demand averaged 9.2 mbd in 2015, very near its all-time high (Figure 15).[21]

Similar effects have unfolded around the world as a result of low oil prices. Total demand in China surged by nearly 600,000 b/d in 2015, the third-highest annual growth of the century as demand for consumer fuels like gasoline began to play a more important role than industrial fuels like diesel.[22] Globally, oil demand increased by 1.8 mbd last year according to IEA, also the third highest annual increase since 2000, trailing only 2004 and the post-recession recovery in 2010 (Figure 16). Taken in the aggregate, these data suggest that newly invigorated global oil demand growth will play an important role in helping to balance the oil market in the years to come. More importantly, they suggest that the global economy and consumers around the world remain heavily dependent on oil.

17 EIA, *Petroleum Supply Monthly.*
18 IEA, Data Services.
19 Id.
20 Id.
21 EIA, *Petroleum Supply Monthly.*
22 IEA, *Oil Market Report*, March 2015

4. Long Term Demand

While short term increases in oil demand stimulated by lower prices and higher levels of driving will help balance markets in the near term, they will not preserve oil's dominance in transportation over the long term. The Saudis recognize that high prices will inevitably return, placing downward pressure on miles driven and once again incentivizing American and other global motorists into more efficient cars and even cars powered by fuels other than oil. This is a key reason for the extended nature of Saudi Arabia's effort to facilitate low oil prices: while a short period of low prices is not capable of affecting long-term change, an extended period of low prices could accomplish multiple goals that will have lasting effects on oil demand and U.S. energy security.

First, low oil prices are likely to undermine technological competition to oil in transportation in the United States, most notably advanced fuel vehicles (AFVs) powered by electricity and natural gas. The threat to these technologies follows a decade of concentrated investment. Federal government spending on advanced vehicle research, development, and deployment (RD&D) alone totaled more than $4.1 billion since 2000.[23] In terms of private investment, Bloomberg New Energy Finance places U.S. venture capital and private equity investment in electric vehicles at $4.5 billion between 2007 and 2012.[24]

Although these significant levels of investment clearly indicate a strong commitment to AFVs by policymakers, automakers, and even advanced fuel companies, the technologies for the vehicles are generally more expensive than internal combustion engine vehicles. The individual value proposition for plug-in electric and natural gas vehicles is that their higher purchase price is offset by lower fuel and maintenance costs over their lifetime. Indeed, most analysts argue that this total cost of ownership proposition must be significantly positive for AFVs in order for potential customers to be willing to overlook other sacrifices, including range limitations and longer refueling times.

Low oil prices are likely to undermine technological competition to oil in transportation in the United States.

As a result of the plunge in oil prices, petroleum fuels like gasoline and diesel are now among the least expensive transportation fuels in the United States (Figure 18). As of January 2016, for example, both gasoline and diesel fuel were less expensive than compressed natural gas (CNG), meaning an owner of a CNG-powered vehicle might never recoup the higher purchase price of their vehicle unless prices rise.[25] Similarly, while electricity still remains less expensive than gasoline on an energy-equivalent basis, the margin has narrowed to such a significant extent that the owner of a Ford Focus EV, for example, has seen their payback period increase from approximately two and a half years at $4.00 gasoline to more than five years at today's prices when compared to a gasoline-powered Focus.[26]

This altered economic playing field is having a clear impact on U.S. AFV sales. Annual sales growth slowed dramatically beginning in mid-2014, just as oil prices began falling, and turned negative in early 2015. After increasing from just 17,000 in 2011 to nearly 120,000 in 2014, U.S. sales of plug-in electric vehicles (PEVs) declined year-over-year by 4 percent in 2015.[27] Models that most clearly compete based on economic value, such as the Nissan Leaf, Chevy Volt, and most Ford models experienced the sharpest declines as oil prices plummeted. Models that compete in luxury segments, where consumers are less price sensitive, have fared slightly better.

It is certainly too early to write-off the global electric and natural gas vehicle industries. High fuel taxes in Europe and substantial air quality issues in China will likely provide important support for the industry in the coming years, and many analysts continue to expect strong sales growth in these regions. Indeed,

23 Kelly Sims Gallagher and Laura Diaz Anadon, "DOE Budget Authority for Energy Research, Development, and Demonstration Database," Energy Technology Innovation Policy, John F. Kennedy School of Government, Harvard University, September, 2015.

24 SAFE interview with Bloomberg New Energy Finance.

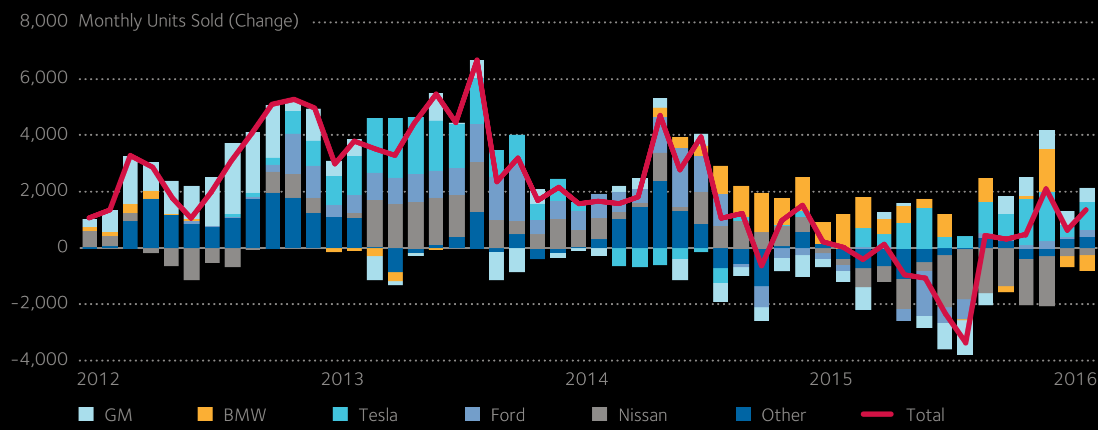
25 Office of Energy Efficiency and Renewable Energy, Alternative Fuels Data Center.

26 Note: Includes the federal tax credit and $1,000 cost for EVSE. Does not account for residual value loss.

27 SAFE analysis based on data from HybridCars.com.

FIGURE 17

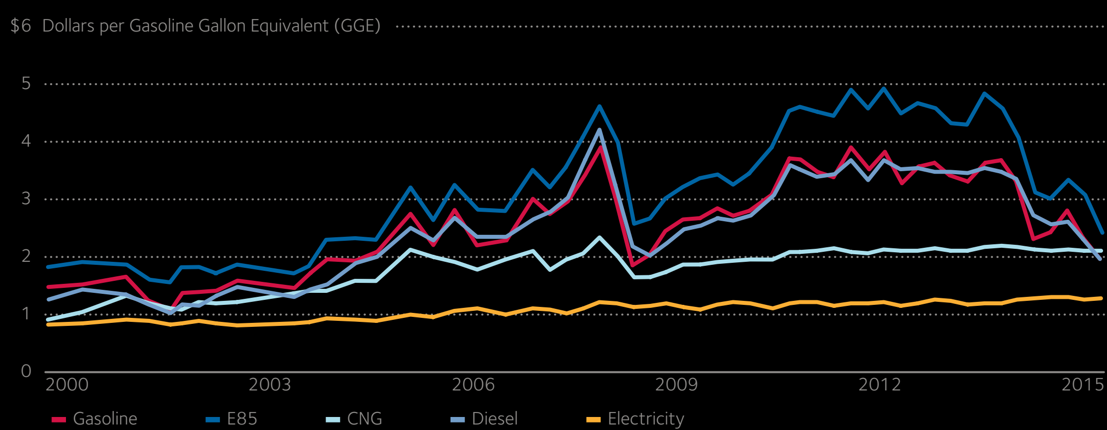
Year-Over-Year Plug-in Electric Vehicle Sales Growth by Auto Manufacturer



Source: SAFE analysis based on data from HybridCars.com

FIGURE 18

Retail Fuel Price



Source: SAFE analysis based on data from Clean Cities Alternative Fuel Price Reports

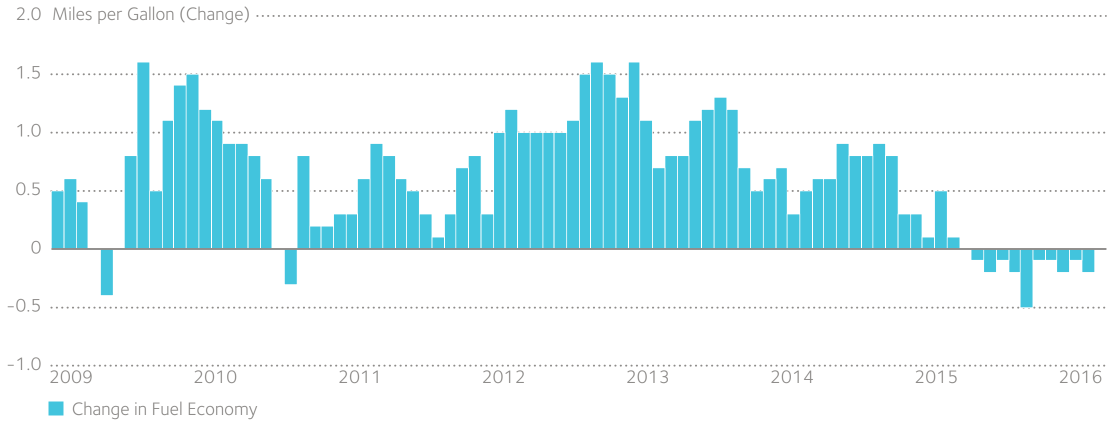
FIGURE 19

Oil Savings from Fuel Economy

Source: EPA

FIGURE 20

Year-Over-Year Change in U.S. Fuel Economy



Source: SAFE analysis based on data from Michael Sivak and Brandon Schoettle, University of Michigan Transportation Research Institute

despite trends in the United States (Figure 17), global electric vehicle sales surged by nearly 60 percent in 2015, reaching 462,000 units compared to 289,000 in 2014.[28] The growth was entirely driven by sales in the Chinese and European markets, both of which surpassed the United States for the first time.

Sales in Europe and China may continue to lead the way. Research by investment bank UBS released in March 2016 suggested that electric vehicles would be cost-competitive with internal combustion engine vehicles in Europe by 2021 and China by 2025.[29] The same analysis found that EVs would *not* be cost-competitive in the United States for the foreseeable future based on current and expected fuel prices and existing public policy. Whether an extended period of weak sales reduces automakers' willingness to invest in marketing and selling PEVs in the United States remains to be seen. The United States, however, cannot relinquish leadership on the various technologies despite the threat low oil prices pose to the rate of adoption.

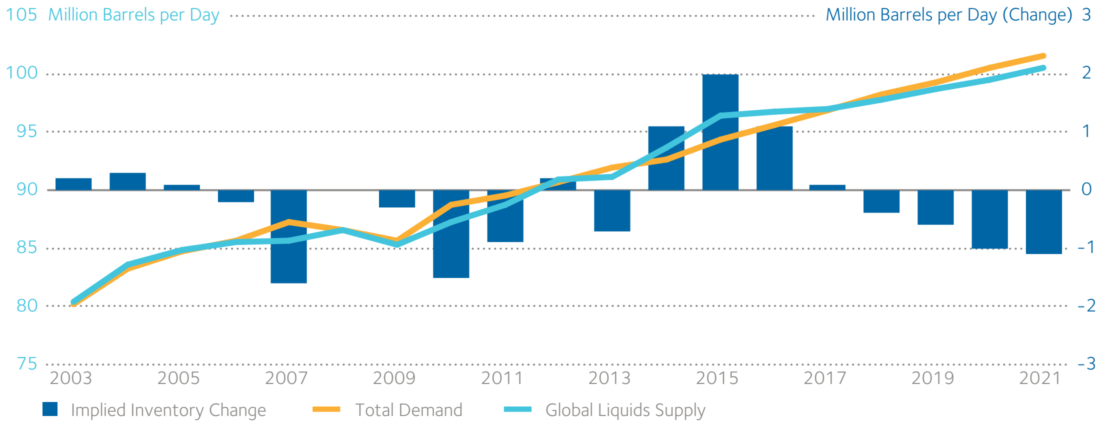
An additional and perhaps more significant threat of low oil prices relates to U.S. policy, and fuel economy standards in particular. The current U.S. standards, enacted in 2011 and 2012 and covering light-duty vehicles sold between 2012 and 2025, were projected by the Environmental Protection Agency (EPA) to reduce U.S. gasoline consumption by 3.2 mbd in 2030 compared to business as usual (Figure 19).[30] The standards are a cornerstone of U.S. oil policy and contain key incentives for electric and natural gas vehicles that are core to sustaining investment in those technologies as well as to achieving continuous improvements in gasoline engine technology.

Yet the new standards are now facing their most significant challenge since enactment. As fuel prices have plummeted, American consumers have rapidly turned back to purchasing heavier and less efficient vehicles. In fact, at 25.2 miles per gallon, the fleet-wide efficiency of new passenger vehicles sold in the United States is nearly unchanged from late 2013, when it stood at 25 miles per gallon (mpg).[31] In fact, on a year-over-year basis, fuel economy has actually been declining since April 2015 (Figure 20).[32]

In 2016, EPA and the Department of Transportation will initiate a midterm review of the standards to review progress and any new information, including unexpected hurdles that would prevent automakers from meeting the standards. Already, automakers are pointing to lower fuel prices and sagging sales of lighter, more efficient vehicles as reason for EPA to consider relaxing the standards.[33]

28 FS-UNEP Collaborating Centre for Climate and Sustainable Energy Finance, "Global Trends in Renewable Energy Investment, 2016," March 2016.
29 See, e.g., Eric Wesoff, "How Soon Can Tesla Get Battery Cell Costs Below $100 per Kilowatt-Hour?" Greentech Media, March 16, 2016.
30 EPA, *Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards.*
31 Michael Sivak and Brandon Schoettle, University of Michigan, Transportation Research Institute.
32 Id.
33 Mike Spector and Christina Rogers, "Clash Looms Over Fuel Economy Standard," Wall Street Journal, April 20, 2016.

Global Oil Supply and Oil Demand Balance



Source: SAFE analysis based on data from IEA

This argument ignores an important feature of fuel economy standards since 2010: they are tailored to individual vehicle size, measured by the vehicle's physical footprint. Rather than requiring each automaker to meet a pre-determined, fleet-wide standard, the new standards simply require that each size vehicle improve over time, and the requirements for larger vehicles are less stringent than those of smaller cars. Therefore, while the industry can remain in compliance even as Americans opt for heavier vehicles, the oil savings from the footprint-based standards may fall well short of policymakers' goals.

Yet, regardless of the technical definition of compliance with the standards, it is clear that low fuel prices are undermining the overall efficiency of vehicles sold in the United States. While Saudi Arabia and its allies have not explicitly stated that they expect low oil prices to undermine U.S. policy, they are almost certainly aware of the policy implications of an extended period of low oil prices in the world's largest oil consumer and largest gasoline market. In fact, if past is prologue, the Saudis would be sound in expecting low oil prices to result in a relaxation of U.S. policy. After enacting the nation's first-ever fuel efficiency standards in the mid-1970s during an era of high oil prices, U.S. policymakers allowed the standards to stagnate for more than 20 years from the mid-1980s through 2007 throughout two decades of low prices.[34] This cannot happen again.

The Coming Market Balance

The net result of Saudi Arabia's short term objectives—rising global oil demand and curtailed supply from existing production—is that the oil market is on track to return to a condition of relative balance by 2017, according to the International Energy Agency.[35] Some market observers, including the Department of Energy, expect the balance to come slightly later, while others, including numerous investment banks and oil companies, expect it to come sooner. But very few observers expect oil markets to remain fundamentally oversupplied indefinitely.

Yet, while supply will approach fundamental alignment for a period of time, IEA and other observers expect this alignment to be short-lived, with the market overshooting and moving to a condition of undersupply in relatively short order. In a sense, this is the classic challenge that has long afflicted the oil industry. Inelastic supply and demand fundamentals lead to periods of overshooting and undershooting, which can only be regulated by extreme swings in prices.

The coming period of undersupply, characterized by net inventory withdrawals rather than additions, is currently expected to be prolonged and relatively severe by historical standards. As of early 2016, IEA expects markets to roughly balance in 2017 followed by four consecutive years of net inventory withdrawals from 2018 to 2021, which average a steep 1.0 mbd in 2020 and 2021 combined and would remove a total of 1.1 billion barrels of oil from global inventories across the entire period (Figure

34 See, e.g., National Highway Transportation Safety Administration, "Summary of Fuel Economy," December 2014.
35 IEA, *2016 Medium-Term Oil Market Report.*

21).[36] The most recent analogous oil market occurred between 2007 and 2011, a period of record oil prices. Moreover, it should be noted that there is significant upside risk to these numbers given the fact that initial upstream investment numbers for 2016 are likely to be sharply revised downward.[37]

This anticipated structural imbalance is perfectly consistent with the longer-term elements of the Saudi strategy—including sharply reduced investment in developing new non-OPEC oil supplies, reduced competition to oil in transportation, and potential structural shifts in oil policy in the United States and other consuming countries. In effect, these trends will reduce the market's already-limited capacity to respond flexibly as prices rise, requiring significantly higher prices to balance the market.

The New Oil Market Paradigm

As the oil market emerges from the effects of the Saudi strategy, global oil consumers and producers will be facing a new reality. The defining characteristic of this new reality will be a paradox. On the one hand, the oil market will benefit from the presence of U.S. shale, a more flexible source of non-OPEC oil supplies in the middle of the global oil cost curve. Shale investment cycles are short compared to large, conventional resources—perhaps as short as 18 months versus roughly 40 months for post-investment decisions for deepwater projects. The innovation that has occurred in the U.S. shale patch cannot be unlearned, and drillers have achieved large, structural gains in efficiency during the current price route that will ultimately benefit them as prices rise.

Yet, on the other hand, shale resources are not as flexible as OPEC spare capacity. Throughout much of the past 45 years, Saudi Arabia and other OPEC members have maintained ample levels of spare production capacity that could be brought online in a matter of weeks during times of crisis and pump additional crude supplies into the market indefinitely. Over the past several years, OPEC countries such as Venezuela, Nigeria, Iraq, Libya and Iran saw their spare capacity levels dwindle due to domestic political crises, poor investment levels, and violent conflict. Countries such as Angola, Algeria, and Ecuador were widely known to routinely exceed their production quotas and produce at maximum capacity out of dire fiscal and economic need. But Saudi Arabia and its Arab Gulf allies consistently maintained a commitment to hold spare capacity.

Over the past several years, OPEC countries such as Venezuela, Nigeria, Iraq, Libya and Iran saw their spare capacity levels dwindle due to domestic political crises, poor investment levels, and violent conflict.

That commitment appears to be over for the time being. Without question, Saudi Arabia and other members of OPEC will return to a policy of limited production and even production cuts in the future as market conditions evolve to support it. Indeed, even in early 2016 several OPEC members and Russia openly discussed an "oil production freeze" at January 2016 levels, a policy that would have resulted in a de facto cut of nearly 600,000 barrels per day by Saudi Arabia during the summer months as domestic demand surged due to summer power demand.[38] Nonetheless, such temporary reductions aside, Saudi Arabia and other Gulf Cooperation Council (GCC) members have apparently abandoned their role as the world's swing suppliers for the time being, having drawn spare capacity levels down sharply from 3.1 mbd in November 2014 to an average of 2.2 mbd during the second half of 2015 (Figure 22).[39] These figures reflect official balances. Numerous market observers have suggested that current spare capacity is likely no more than 1.0 mbd.[40]

Going forward, the market may increasingly rely on inventories to balance supply and demand during emergencies and other shortfalls. In one sense, this is advantageous. Inventories are stored above the ground, and the majority are held in industrialized countries. The excess oil that has been pumped into

36 SAFE analysis based on data from IEA, *Medium-Term Oil Market Report 2016* and *2015 Oil Market Report Statistical Annex*.
37 Tenzin Pema, "Global E&P spending may drop 15 percent in 2016, says Barclays," Reuters, January 13, 2016.
38 SAFE analysis based on data from Joint Oil Data Initiative.
39 SAFE analysis based on data from IEA, *Oil Market Report*, February 2016.
40 See, e.g., Morgan Stanley, Crude Oil Global Supply Tracker, March 23, 2016.

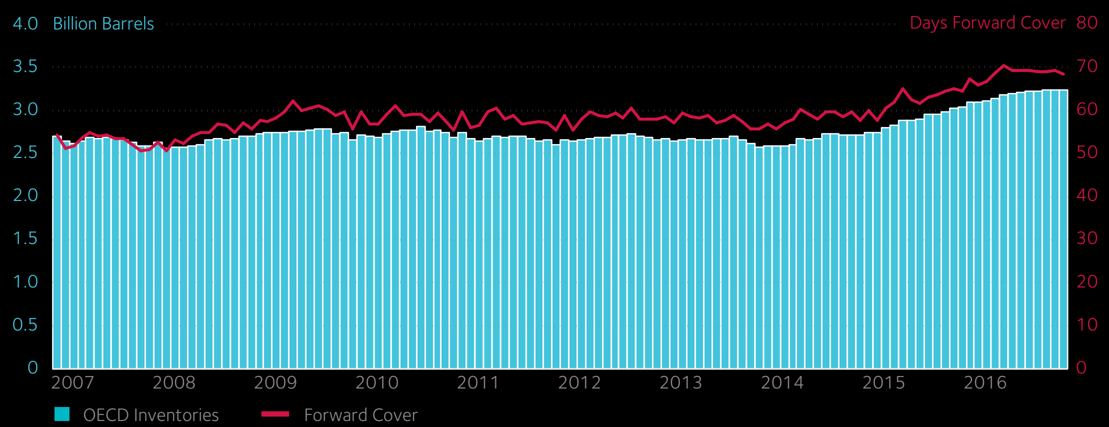
FIGURE 22

OPEC Spare Crude Production Capacity

Source: SAFE analysis based on data from IEA

FIGURE 23

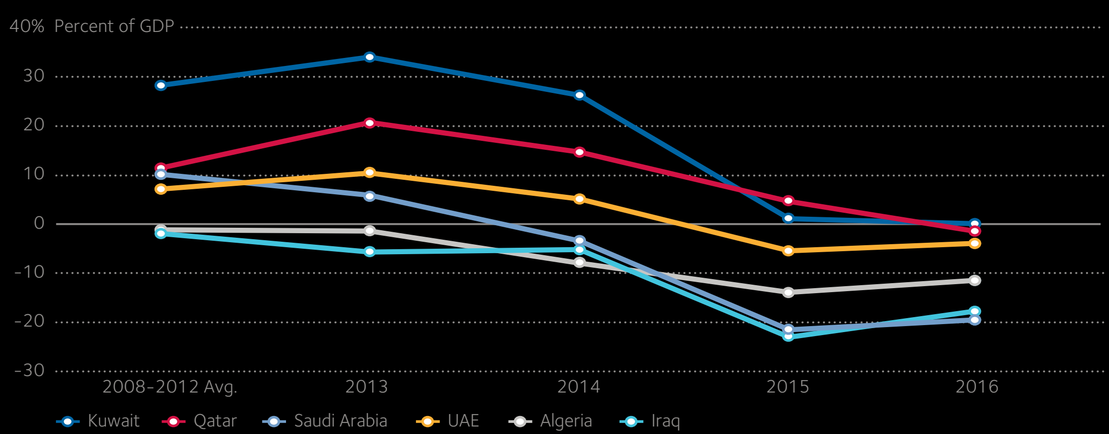
OECD Inventories and Days Forward Cover



Source: SAFE analysis based on data from EIA

FIGURE 24

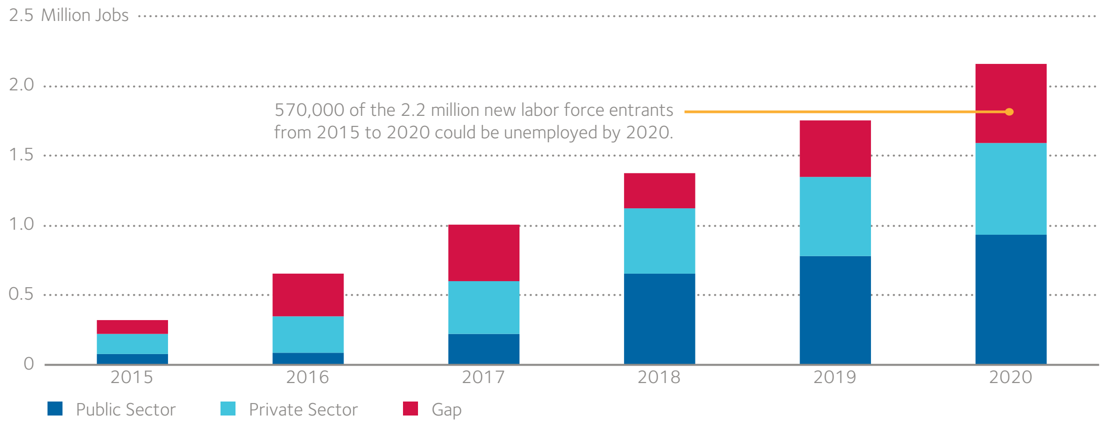
Fiscal Balances of Select Countries



Source: SAFE analysis based on data from IMF

FIGURE 25

Employment Outlook in the GCC



Source: SAFE analysis based on data from IMF

markets over the past two years has made its way to storage tanks throughout the United States, Europe, and Japan. In fact, OECD commercial inventories currently stand at 3.2 billion barrels, nearly 600 million barrels in excess of their 2000-2013 average and enough, in theory, to meet total OECD oil demand of approximately 46 mbd for 70 days (Figure 23).[41] Inventories in government-owned strategic stocks in the United States, Europe, and China bring total world oil stocks to more than 4 billion barrels.

Yet, there are important downsides to this approach as a means for balancing markets during crises. Most importantly, stocks are finite and the market is acutely aware of this. A crisis on the order of the Libyan Civil War, which removed 1.5 mbd from the market in 2011, would eliminate the OECD commercial crude oil surplus in approximately one year unless other global stocks were also drawn down. A crisis that removed Iraq's or Saudi Arabia's oil production from the market would eliminate the OECD surplus in five or two months respectively. Perhaps more tangibly, the net inventory withdrawals envisioned by IEA between 2018 and 2021—which are simply the result of market dynamics—will alone eliminate 75 percent of the increase in global inventories witnessed between 2014 and 2017.[42]

The economic and security risks of this new oil market paradigm are potentially significant. At some point within the next two years, the market is likely to shift from a period of near-record surplus to one of near-record deficit. Yet unlike previous such periods, there may be very little if any OPEC spare capacity that can be tapped in the event of an emergency. Already, the odds of such an emergency are growing increasingly sizeable. From Venezuela and Russia to the Middle East, North Africa and Central Asia, major oil exporters across the globe are confronting sharply reduced oil export revenues, soaring public debt, stalled economic growth, and rising unemployment.

In the Arab Gulf states alone, the IMF estimates that more than 570,000 new labor force entrants between 2005 and 2020 will be unable to find employment as public sector hiring stalls amid soaring fiscal deficits (Figures 24 and 25).[43] As the Islamic State and other militant groups continue to recruit, grow and metastasize in the heart of the world's key oil-producing region, such figures should raise alarm.

In the near term, confronting these challenges amid the rise of the new oil market paradigm will require careful policy consideration to manage risk. But over the longer term, as the conditions of the global oil market evolve in new and unpredictable ways, the lessons of the past five years should be clear: U.S. dependence on oil as basically the sole transportation fuel is the core problem. As long as America remains singularly dependent on the current oil market as it is structured to provide the fuel that powers mobility throughout its entire economy, the country will be at substantial risk. In the best case,

41 SAFE analysis based on data from EIA, *Short-Term Energy Outlook*, March 2016.
42 SAFE analysis based on data from IEA, *Medium-Term Oil Market Report 2016.*
43 IMF, *Regional Economic Outlook, Middle East and Central Asia,* October 2015.

this risk amounts to the steady extraction of wealth and economic rents through anti-competitive practices. At worst, it amounts to a likely social and economic crisis for which the country remains poorly prepared today—more than four decades after OPEC first struck at the American way of life.

We need a much different approach. We need to clear the path for the future. The strategy that follows gets us there.

PART I

Increasing Fuel Diversity in Transportation

Increasing Fuel Diversity in Transportation

Oil dependence threatens U.S. national security and long-term economic vitality, and it is the core energy security challenge facing the country today. Although robust domestic liquid fuels production has the potential to reduce some of the negative consequences of oil dependence, energy security is primarily a function of consumption, not production. U.S. energy security is determined by oil's role in the economy, and transportation sector in particular. Mobility—the movement of people, goods, and services throughout the country—is a central component of U.S. economic competitiveness and a cornerstone of the American way of life. Today, this mobility is almost entirely powered by petroleum fuels, which accounted for 92 percent of the energy consumed by cars, trucks, planes, and ships in 2015.[1] Taken as a whole, the U.S. transportation sector consumes more than 14 million barrels of oil per day (mbd), a volume that exceeds the *total* oil consumption of any other nation in the world.[2]

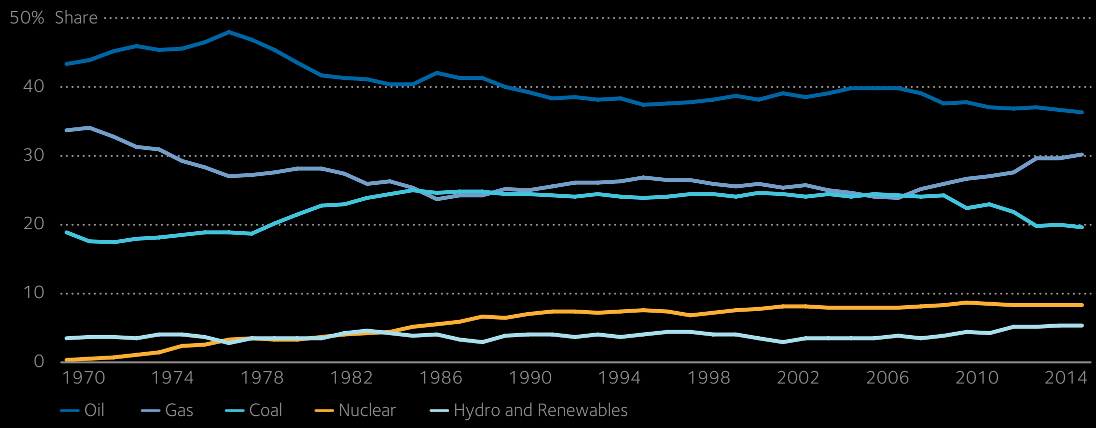
Consumption is largely driven by demand from surface transportation modes—cars and trucks in particular. The roughly 260 million passenger cars and light trucks on U.S. roads today consume an estimated 8.6 mbd, primarily gasoline, accounting for roughly two-thirds of the nation's total transportation-related oil consumption (Figure 27).[3] Eleven million medium- and heavy-duty trucks add 3.0 mbd of oil demand, primarily in the form of diesel fuel.[4] Overall, petroleum fuels accounted for 37 percent of U.S. primary energy demand in 2015, a larger share than any other fuel (Figure 26).[5] Though this level marks a slight reduction compared to decades past, consumption of petroleum still easily exceeds consumption of natural gas, the second largest contributor to total U.S. energy demand, by a meaningful margin.

After surpassing a record $400 billion annually from 2011 to 2014, U.S. household spending on petroleum fuels stood at approximately $306 billion in 2015.[6] In total, economy-wide spending on petroleum fuels averaged $800 billion annually from 2007 to 2014, equal to approximately 5 percent of GDP, before falling back to $580 billion in 2015, or 3.2 percent of GDP.[7] Although these spending figures are at their lowest levels since the Great Recession, it is important to note that the decline in spending was entirely the result of the collapse in global oil prices rather than any change in consumption patterns or dependence levels. In fact, U.S. gasoline demand in 2015 stood at 9.2 mbd, only slightly less than its all-time high of 9.3 mbd reached in 2007.[8] Based on current trends, U.S.

1 EIA, *Annual Energy Outlook 2015*.
2 Id.
3 SAFE analysis based on data from EIA; and IHS Automotive, "Average Age of Light Vehicles in the U.S. Rises Slightly in 2015 to 11.5 years, IHS Reports," July 29, 2015.
4 SAFE analysis based on data from EIA and Oak Ridge National Laboratory.
5 EIA, *Annual Energy Outlook 2015*.
6 Bureau of Economic Analysis, National Income and Product Account Tables, Consumer Spending, Table 2.4.5.
7 SAFE analysis based on data from EIA, State Energy Data System; and Bureau of Economic Analysis.
8 EIA, *Petroleum Supply Monthly,* February 2016.

FIGURE 26

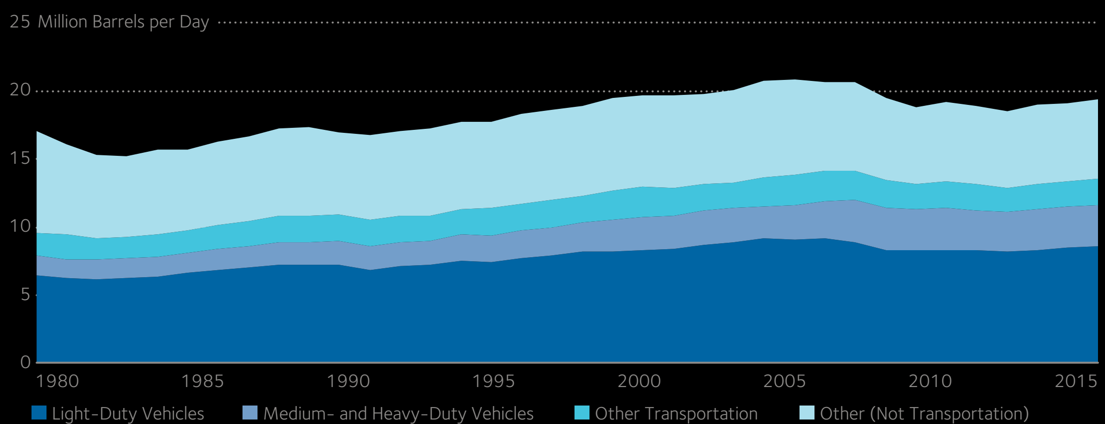
Share of U.S. Primary Energy Demand



Source: SAFE analysis based on data from BP plc., *Statistical Review of World Energy 2015*

FIGURE 27

U.S. Transportation Oil Demand

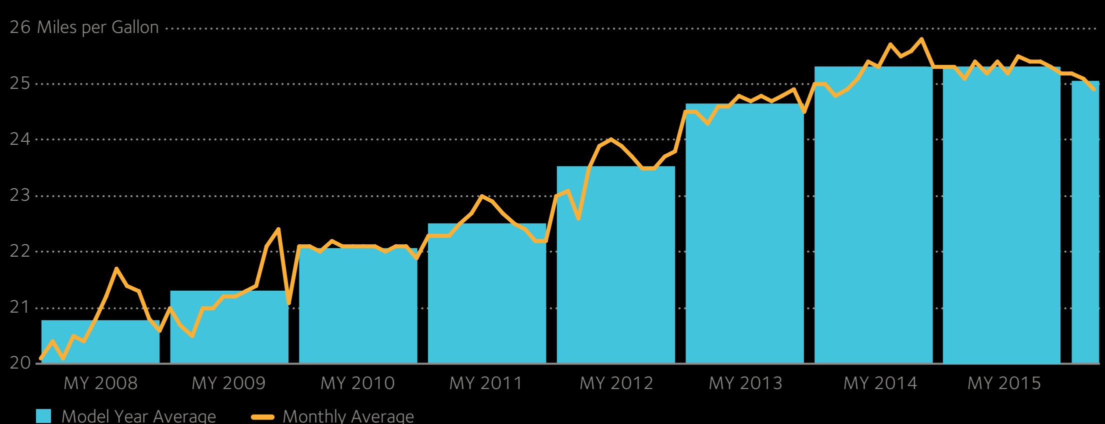


Note: Allocation of total 2014 and 2015 demand is estimated.

Source: SAFE analysis based on data from EIA and ORNL

FIGURE 28

New Light-Duty Vehicle Sales Fuel Economy Ratings



Note: Average sales-weighted fuel-economy rating of purchased new light-duty vehicles.

Source: SAFE analysis based on data from Michael Sivak and Brandon Schoettle, University of Michigan Transportation Research Institute gasoline demand is expected to set a new record in 2016. Given the consistent and ongoing nature of U.S. oil dependence, spending levels are likely to rise substantially in the coming years as global oil prices rise, absent policy change.

Achieving significant reductions in the oil intensity of the U.S. economy has been a long-standing goal of public policy as it relates to energy security. This approach prioritizes reductions in the volume of oil needed to produce each unit of GDP, a strategy that can mitigate the economic impacts of volatile oil prices. Therefore, fuel economy standards remain a core policy. Updated standards passed in 2012 target a light-duty vehicle fleet average of 54.5 miles per gallon (mpg) by 2025, which the government forecast will reduce total oil consumption by approximately 3.2 million barrels per day (mbd) by 2050.[9] Last year, proposed standards for medium- and heavy-duty vehicles were introduced that hold the potential to reduce oil consumption by an additional 0.5 mbd by 2030.[10] Such standards place the transportation sector on a trajectory for oil savings that will have clear, positive implications for U.S. energy security in the coming years.

Yet, even as the country has become a more efficient consumer of oil overall, the recent low oil price environment has nudged consumers toward purchasing larger and more inefficient vehicles, complicating the long-term outlook for both the standards and energy security more broadly. In 2015, sales of light-duty trucks, including SUVs, approached historically-high levels, accounting for nearly 55 percent of all new light-duty vehicle sales.[11] The average window-sticker fuel-economy rating of new light-duty vehicles changed accordingly, declining thus far to 25.1 miles per gallon (Figure 28) for Model Year (MY) 2016 vehicles (monthly average ratings reached highs of above 25.5 mpg in the summer of 2014).[12] In this sense, America's reliance on volatile and anticompetitive oil markets is a double-edged sword. While just a few years ago high and rising oil prices were regarded as a threat to the U.S. economy, today's low oil prices are threatening to undermine the potential gains that could be achieved through the adoption of more efficient technologies.

Truly strengthening U.S. energy security will come from developing a transportation system that is no longer predominantly beholden to the global oil market and its structural price volatility.

Truly strengthening U.S. energy security will come from developing a transportation system that is no longer predominantly beholden to the global oil market and its structural price volatility. Advanced fuel vehicles (AFVs) powered by fuels derived from something other than petroleum, such as electricity, natural gas, hydrogen, or advanced biofuels are an attractive solution. Plug-in electric vehicles (PEVs) draw energy from the electric grid, which generates electricity from a diverse range of largely domestic fuels, and whose retail price is not volatile. Moreover, petroleum was used to generate less than one percent of the electricity generated in the United States in 2015.[13] Similarly, U.S. natural gas supplies are almost entirely domestic, and newly abundant resources have the potential to keep natural gas transportation fuel prices low and stable for the foreseeable future. For aviation, advanced biofuels offer the only near-term alternative to oil, and are already being approved for use and blending with petroleum-based jet fuel.[14]

While natural gas vehicles (NGVs), hydrogen fuel cell vehicles (FCVs), PEVs, and advanced biofuels offer economic and energy security benefits, each faces considerable barriers to broader commercialization. While all rely on existing technologies, NGVs, FCVs, and PEVs in particular impose on consumers a larger

9 Note: Figure reflects cumulative oil savings associated with 2012-2016 and 2017-2025 fuel economy rules and EPA, *Final Rulemaking to Establish Light-Duty Vehicle GHG Emission and Corporate Average Fuel Economy Standards, Regulatory Impact Analysis*, April, 2010, at 6-15; and EPA, *Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle GHG Emissions and Corporate Average Fuel Economy Standards*, August 2012, at 5-26.

10 SAFE and Meszler Engineering Services analysis based on EPA and National Highway Traffic Safety Administration proposed Rulemaking, *Phase 2 Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles*, June 2015.

11 SAFE analysis based on data from Bureau of Economic Analysis.

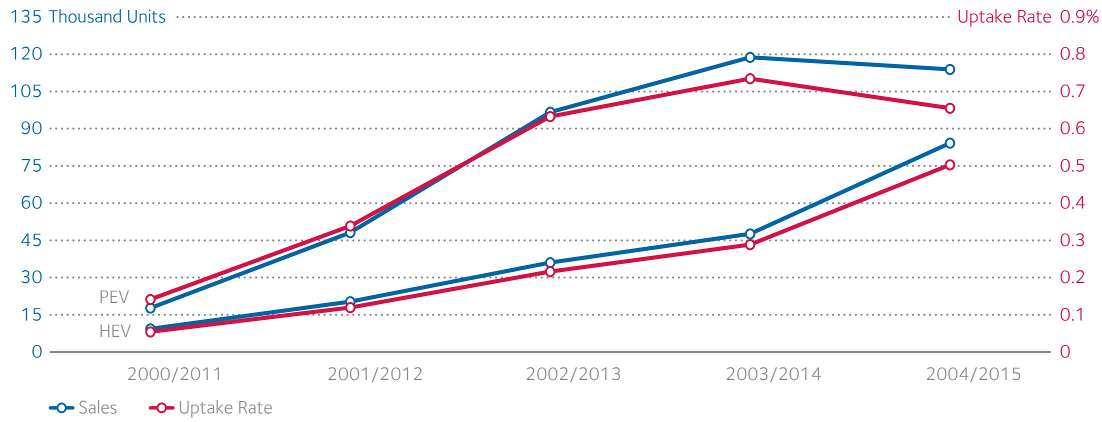
12 SAFE analysis based on data from Michael Sivak and Brandon Schoettle, University of Michigan Transportation Research Institute.

13 Oak Ridge National Laboratory, *Transportation Energy Data Book, Edition 34*, Table 1.13.

14 Note: Advanced biofuels have been approved for use in up to 50 percent blends with conventional jet fuel.

FIGURE 29

Hybrid and Plug-in Electric Vehicle Sales from Year of Introduction



Note: Uptake rate is the proportion of PEV or HEV sales of total LDV sales in each respective year since introduction.

Source: SAFE analysis based on data from ORNL and Hybridcars.com

upfront investment and suffer from some degree of uncertainty regarding refueling infrastructure. Advanced biofuels may be compatible with existing infrastructure, but the cost of production has not yet reached parity with traditional jet fuel. The ongoing debate about the appropriate role for government in supporting the development of energy technology is both healthy and necessary. In the case of America's dependence on oil, however, the overwhelming economic and national security costs of the status quo provide ample justification for public policy in support of AFVs.

The capital assets and infrastructure that comprise and support the U.S. transportation sector represent decades of investment by energy providers, automakers, and government agencies at all levels in a system designed to function on petroleum. Transitioning this system away from its current heavy reliance on oil toward a more diverse mix of fuels that does not expose the broader economy to the volatility of global oil markets will take time, technological advancements, and targeted public policy.

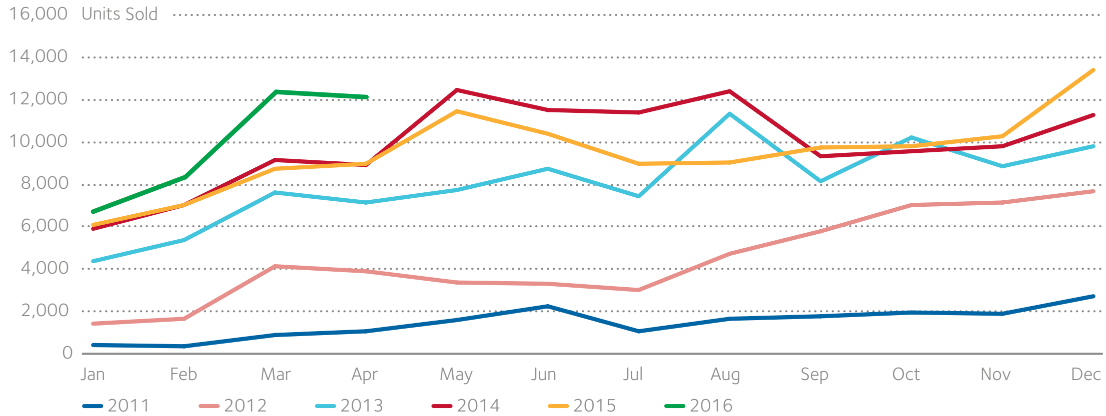
Advanced Fuel Vehicles

Throughout the past decade, the U.S. public and private sectors have invested heavily in the development of AFVs, particularly PEVs and NGVs. Federal government spending on advanced vehicle research, development, and deployment (RD&D) alone has totaled more than $4.1 billion since 2000.[15] In terms of private investment, Bloomberg New Energy Finance places global venture capital and private equity investment in advanced transportation at $4.5 billion between 2007 and 2012.[16] Acquisitions contributed an additional $600 million to the private sector total over the same period. Meanwhile, Ford alone has pledged a $4.5 billion investment by 2020 in electrified vehicle solutions.[17] Similarly, General Motors (GM) has invested considerably to support the launch of its forthcoming Bolt, including $245 million in updates to a manufacturing plant, and $160 million for equipment and tooling.[18] Tesla Motors recently unveiled its third generation vehicle, the Model 3, and continues to expand its network of more than 3,500 free charging stations.[19] While most investment to date has focused on vehicle technologies, infrastructure investments are beginning to gain momentum as well. One recent estimate suggests natural gas refueling infrastructure will reach almost 30,000 units by 2022 if investments maintain their current trajectory.[20]

15 Kelly Sims Gallagher and Laura Diaz Anadon, "DOE Budget Authority for Energy Research, Development, and Demonstration Database," Energy Technology Innovation Policy, John F. Kennedy School of Government, Harvard University, September 2015.
16 SAFE interview with Bloomberg New Energy Finance.
17 Ford, "Ford Investing $4.5 Billion In Electrified Vehicle Solutions, Reimagining How To Create Future Vehicle User Experiences," December 10, 2015.
18 General Motors, "GM Invests $245 Million for New Vehicle Program," June 22, 2015.
19 Tesla, "Supercharger."
20 See, e.g., MarketWatch, "Natural Gas Refueling Infrastructure Market is Estimated to Reach USD 50,250.11 Million at CAGR of 10.17% from 2014 to 2022: Transparency Market Research," July 22, 2015.

FIGURE 30

U.S. Plug-in Electric Vehicle Sales, 2011–Present



Source: SAFE analysis based on data from HybridCars.com

These investments have been motivated by a range of factors. The era of high and volatile oil prices that began in 2003 generated numerous damaging economic outcomes, including shocks to business and consumer budgets that exacerbated the effects of the 2007-2009 economic downturn. Today, low oil prices, while a boon for many consumers, threaten to undermine much needed long-term investments that will help insulate the economy when high petroleum prices inevitably return.

While not all public and private investments in advanced transportation technologies have been successful, the broader industry has achieved important progress in recent years. For example, there are currently now more than two dozen light-duty PEV models available to U.S. consumers, and cumulative light-duty PEV sales have surpassed 400,000 units in the United States since January 2011 (Figure 30), placing them well ahead of the sales pace achieved by traditional hybrids like the Toyota Prius during their own initial years of availability in 2000 and 2001 (Figure 29).[21] Perhaps most importantly, the AFV supply is expected to grow further in the coming years, offering consumers more vehicle options, greater availability, and longer range, including PEVs ranging from two-wheeled vehicles to SUVs and NGVs of all sizes. Nevertheless, the progress has not met the high expectations that President Obama set in establishing as a goal the sale of 1 million PEVs by 2015 or the overly optimistic sales forecasts by automakers set prior to the introduction of many vehicles to the market.

Commercial vehicle fleets have also increasingly worked to explore opportunities to deploy AFVs. A number of commercial truck manufacturers offer plug-in hybrid and battery electric trucks ranging in size from class one to class six, as well as several offerings of electric buses. Natural gas fuels have long been competitive in heavy-duty applications, including vocational trucks and transit buses, and new natural gas-powered systems are increasingly competing for long-haul freight business. Natural gas has also made inroads into the light-duty truck space in 2016 with new offerings, including the Ford F-150, capable of running on CNG or propane.[22]

The use of advanced biofuels is also increasing, especially in aviation. However, there are currently only three approved biofuels for aviation use. Additional bio-based jet fuel options are in the process of passing certification, but certification can cost more than $30 million and take up to three years for approval.[23] Despite such challenges, more than 2,000 commercial flights across 20 different airlines have been fueled, at least in part, by biofuels.[24] Beginning in March 2016, United Airlines became the first U.S. airline to use advanced biofuels for regular commercial operations (using a blend containing 30 percent advanced biofuels).[25] More progress is needed to achieve substantially greater scale.

21 SAFE analysis based on data from Hybridcars.com.
22 Ford, "2016 F-150 with Class-Exclusive Compressed Natural Gas, Propane Capability Grows Ford's Alternative Fuel Leadership," May 4, 2015.
23 Midwest Aviation Sustainable Biofuels Initiative, "Fueling a Sustainable Future for Aviation," 2013, at 23.
24 See, e.g., International Air Transport Association, "IATA 2015 Report on Alternative Fuels," December 2015, at 3.
25 See, e.g., Chelsea Harvey, "United Airlines is Flying on Biofuels. Here's Why That's a Really Big Deal," Washington Post, March 11, 2016.

Despite positive indicators, advanced fuel vehicles only account for approximately one percent of new light-duty sales due to ongoing barriers that come down to issues of cost and convenience. The most notable barrier is purchase cost, though obstacles aside from cost still remain that could prevent AFVs from achieving broad commercial success. The most significant is that vehicles powered by fuels like electricity and natural gas are inherently disruptive technologies that can only be truly successful if they drive major changes throughout multiple products, systems, and industries. Infrastructure development and public awareness campaigns will be critical to the widespread adoption of these technologies. Facilitating these necessary developments will require a high level of coordination and communication among multiple stakeholders from automakers and their suppliers to public officials, municipalities, energy suppliers, utilities, infrastructure providers, consumers, and more. Communities that effectively bring together these stakeholders will successfully drive rates of adoption far higher than the average.

Demand for advanced fuel and efficient vehicles is also affected by volatile petroleum fuel prices.[26] However, many of the most recent gasoline price spikes have also been both sharp and temporary, a phenomenon that often leads vehicle purchasers to underinvest in efficiency, as they lack confidence that prices will stay high for a long enough period to recoup their capital outlay. A recent report evaluated the effects of the current price decline on consumer behavior and confirmed, again, that lower prices do in fact incentivize consumers to purchase new vehicles with lower fuel economy.[27]

Public sector research, development, and deployment (RD&D) initiatives have complemented private activity thus far. However, advances are needed to increase the technological capacity of automotive energy storage systems, including PEV batteries and NGV storage tanks, as well as advanced biofuels. The creation of federal and state tax credits for AFV purchases and refueling infrastructure installations has also played a crucial role, reducing the incremental costs (and therefore payback periods) involved. Ensuring these incentives remain properly aligned as the AFV market matures will be crucial to the AFV marketplace in the short to medium term. A variety of adjustments to these incentives, in addition to a host of regulatory changes that render trucking in particular more efficient, could also help drive faster adoption of alternative vehicles and fuels in the sector. Finally, the federal government, as the largest vehicle fleet operator in the country, can lead by example at this crucial time by incorporating more AFVs into its fleet and promoting the use of other fuels. It is well positioned to send a strong signal to vehicle and fuel providers that alternatives to oil are the future.

Combined, R&D, deployment activities, and advanced fuel- and vehicle-specific incentives and regulatory adjustments will help to reduce costs, enhance desirability, and ultimately accelerate the transition to alternative vehicles and fuels. Even with these critical improvements and investments, the United States is on the cusp of an innovation revolution that might serve as the accelerant to AFV adoption—driving massive deployment of alternatives to oil. Part II explores the promise and potential of autonomous vehicles.

26 See, e.g., Bloomberg New Energy Finance, "Oil Price Plunge and Clean Energy – The Real Impact," December 22, 2014.
27 Resources for the Future, "Fuel Prices, New Vehicle Fuel Economy, and Implications for Attribute-Based Standards," February 2016.

Policy Recommendations

RECOMMENDATION FOR LIGHT-DUTY VEHICLES

Reform incentives for light-duty advanced fuel vehicle purchases.

Consumer adoption of AFVs remains hindered by higher prices relative to comparable conventional vehicles especially during the current extended period of low gasoline prices. Even when gasoline prices increase the consumer savings generated by AFVs, these benefits accrue over several years and have proven of less value to consumers than the lower up-front purchase price of conventional vehicles. Tax credits that aim to mitigate these disincentives should be reformed to strengthen their impact on vehicle adoption.

The existing tax credit was, and still is, intended to help absorb the incremental cost of new large-format batteries, key components of plug-in vehicles that are responsible for much of their incremental cost. The credit is available to approximately the first 200,000 vehicles sold by each manufacturer. This structure was intended to ensure that the credit benefited each automaker, no matter when they began selling plug-in vehicles.

The market leaders in the production and sale of plug-in vehicles are beginning to approach the sales volume at which the tax credit will no longer be available for vehicles they manufacture. It is now clear that a structure which caps the number of vehicles that qualify for a tax credit disadvantages these first movers who invested in the technology when it was more expensive, while remaining available to other automakers who have waited for battery costs to decline before investing.

The Council believes that the current tax credit could do more, at a lower cost, to accelerate production of advanced fuel vehicles in a way that encourages first movers rather than penalizes them. The Council recommends that all volume limitations on the current tax credit be lifted and that the tax incentive system as a whole be phased out beginning in 2021, and expire completely in 2023.

As of February 2016, GM and Nissan had used nearly 50 percent of their credits (selling an estimated 98,000 and 91,000 vehicles, respectively) while other automakers lagged significantly behind (using between 1 to 34 percent of their credits).[28] While Tesla has sold 68,000 U.S. vehicles, the automaker recently received 180,000 reservations over a 24-hour period for its Model 3. If converted to sales, Tesla would likely become the first automaker to exhaust their tax credits. The proposed reform will extend the availability of the credit until the Council believes that the cost of large-format batteries should have declined to a point where plug-in electric vehicles can compete against other vehicles without federal tax credits.

The revised tax credit should begin phasing out at suggested retail prices of $40,000 and end at $55,000, and be transferable. The Council believes that consumers in the market for the most expensive plug-in electric vehicles do not need federal assistance in the purchase of their vehicles. Further, the current structure of the tax credit means that purchasers only receive the effective value of the benefit after filing for taxes, potentially more than one year after purchasing the vehicle. Making the tax credits transferable would enable buyers to monetize them at the point of sale. This would

28 SAFE analysis based on data from Hybridcars.com.

enable a larger number of consumers who were financially unable to pay the incremental monthly car payment for a lengthy period of time to afford an AFV. In addition, these up-front savings are far more likely to persuade consumers that AFV purchases are beneficial. Analysis of state-level HEV incentives, for example, has demonstrated that the average point-of-sale tax waiver triggered three times as large an increase in HEV purchases as the income tax credit program, despite being only 54 percent of the average income tax credit.[29]

Finally, the Council also recommends extending the availability of the credit to all cars that operate primarily on advanced fuels. Accordingly, the credit should be expanded to cover all other AFVs, which employ technology that is not widely used (as determined by the Secretaries of Energy and the Treasury), and for which the vehicle efficiency exceeds the footprint-based requirements in the fuel economy program by at least 25 percent. The value of the credit would be $5,000 plus 100 times the percentage by which the vehicle's fuel economy rating exceeds the footprint based requirement, capped at $7,500. The credit would remain in place through 2023, though its value would be reduced by 25 percent each year beginning in 2021. This new tax credit would level the playing field for all AFVs by expanding eligibility from vehicles with batteries to all AFVs, including natural gas and hydrogen.

RECOMMENDATION FOR LIGHT-DUTY VEHICLES

Increase federal research and development investments in automotive-grade batteries and natural gas storage tanks.

Plug-in electric vehicles and natural gas vehicles are two of the most promising commercially-available AFV technologies on the market today. These alternatives to conventional, petroleum-powered vehicles represent an opportunity for meaningful displacement of gasoline and diesel use in the transportation sector over the long term. In fact, both technologies have already achieved rising levels of initial uptake by private and commercial customers, and an increasing number of models are available across the vehicle spectrum, with further options under development. Both PEVs and NGVs nevertheless face significant challenges related to their onboard energy storage systems and powertrain components. Current limitations associated with batteries for PEVs and fuel storage tanks for NGVs could ultimately undermine or delay commercial success.

The current generation of large-format, lithium-ion automotive batteries represents a sizeable energy and power density improvement compared to its lead-acid and nickel-metal hydride predecessors. Yet even after achieving these gains, the batteries in today's PEVs are too expensive to offer most consumers a compelling economic value proposition with sufficient range, and energy densities well below those of traditional petroleum fuels. The disparity is such that, even after adjusting for the higher efficiency of electric motors compared to combustion engines, battery electric vehicles available in the marketplace today typically have a range of only 80 to 200 miles per charge. Meanwhile, a passenger car with an efficiency rating of 30 miles per gallon and a 14-gallon fuel tank could travel up to 420 miles before refueling.

Today, automakers are focused primarily on improvements in battery technology in order to achieve increased range, the largest barrier to widespread adoption. After a certain point, automakers and battery manufacturers will begin experiencing diminishing returns on those investments directed at increased range and instead divert their money and focus toward improvements in cost reduction. Increased R&D investment now will accelerate the time it takes to reach such an inflection point. Nevertheless, over the next several years both technologies are likely to benefit from continued declines in production costs due to rising efficiencies and economies of scale in manufacturing, as global

29 Kelly Sims Gallagher and Erich Muehlegger, "Giving Green to Get Green? Incentives and Consumer Adoption of Hybrid Vehicle Technology," *Journal of Environmental Economics and Management* 61, 2011, at 1-15.

automakers introduce dozens of new PEV and NGV models, and as early adoption levels continue to increase globally.

However, cost savings from scale alone may not be enough to drive AFV energy storage technologies to price points that are sufficiently compelling for mainstream consumers. Instead, technological innovation provides an opportunity for both performance improvements and cost reductions that could perhaps be much greater and more sustainable than the near-term gains from increased manufacturing scale. Therefore, although the existing group of lithium-ion battery chemistries and natural gas storage tanks will be used in the new suite of vehicle offerings set to enter the marketplace, scientists and engineers are continuing to explore the opportunities presented by different materials, chemistries, processes, and designs.

For batteries, necessary research is being conducted in many areas and includes efforts to facilitate battery operation at higher voltages (enabling higher capacity per unit weight and volume) and the development of higher capacity electrode materials, such as silicon or tin anodes.[30] New battery chemistries also offer the possibility of higher energy density as well as significant reductions in the need for thermal systems, ultimately resulting in long-term performance, life, and cost improvements. Entirely new battery technologies are also being developed, such as lithium sulfur or zinc-air.[31]

The goals for CNG storage tanks with respect to energy storage capacity and affordability are similar, and the technological possibilities for reaching them equally wide-ranging. Tanks utilizing adsorbent internal materials are of particular interest because they could enable higher-density CNG storage at significantly lower pressure. These technologies currently remain expensive, and mostly in the research and testing phases, but ultimately they can facilitate the use of smaller, thinner-walled tanks that can be manipulated into a variety of more practical shapes suitable for vehicles of all types and sizes. The successful development of higher-density, lower-pressure storage tanks could also help to reduce the expense associated with natural gas compression. Further optimization of existing tank technologies also remains important, from the use of high-strength metallic materials to alterations in composite material winding patterns (to reduce carbon fiber use).[32]

Federally-funded R&D designed to improve the cost and performance of AFV energy storage systems through technological improvement is crucial to—and consistent with—efforts to strengthen U.S. energy security. Without question, important efforts have been initiated in recent years. The Advanced Research Projects Agency-Energy (ARPA-E) has, for example, received more than 1.6 billion in appropriations since 2009.[33] While ARPA-E's portfolio of high-risk energy R&D includes numerous technologies, its Batteries for Electrical Energy Storage (BEEST) initiative has awarded more than $35 million to 12 projects since 2010.[34] The program aims to double the energy density of today's batteries at 30 percent of today's battery cost.[35]

Natural gas vehicles have also recently benefited from high-risk R&D funding. In 2012, ARPA-E initiated its Methane Opportunities for Vehicular Energy (MOVE) program. MOVE has funded 13 projects totaling $42.6 million designed to develop innovative, low-cost natural gas storage technologies and methods to lower pressure in vehicle tanks.[36] It is critical that programs like BEEST and MOVE continue to receive the necessary funding going forward. Similarly, the wide range of energy storage research occurring in the Office of Science, the Office of Energy Efficiency and Renewable Energy and throughout the nation's national laboratories must be consistently re-evaluated and monitored to

30 Argonne National Laboratory, Transportation Technology R&D Center, Advanced Battery Research, Development, and Testing.

31 See, e.g., ARPA-E, BEEST Program.

32 Working document of the National Petroleum Council Future Transportation Fuels Study, "Advanced Storage Technologies for Hydrogen and Natural Gas," August 1, 2012.

33 Kelly Sims Gallagher and Laura Diaz Anadon, "DOE Budget Authority for Energy Research, Development, & Demonstration Database," Energy Technology Innovation Policy Research Group, Belfer Center for Science and International Affairs, Harvard Kennedy School, September 2015.

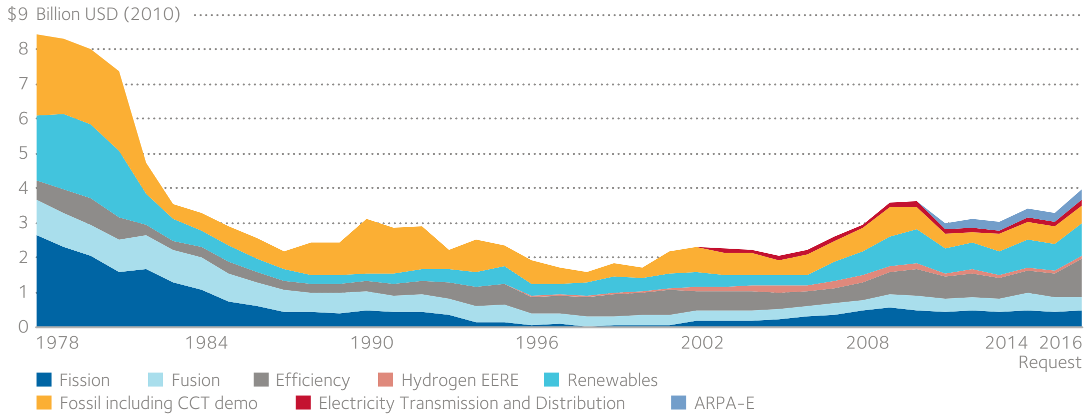
34 ARPA-E, Batteries for Electrical Energy Storage in Transportation.

35 Id.

36 ARPA-E, Project Selections – Methane Opportunities for Vehicular Energy.

FIGURE 31

U.S. Department of Energy Spending on Energy R&D



Note: Figure excludes one-time funding from the American Recovery and Reinvestment Act of 2009.

Source: Kelly Sims Gallagher and Laura Diaz Anadon, "DOE Budget Authority for Energy Research, Development, & Demonstration Database," Energy Technology Innovation Policy research group, Harvard Kennedy School, September 2015

ensure adequate funding. Federal funding for energy storage should be increased by a factor of two by FY 2018, with incremental appropriations being derived from the federal Energy Security Trust Fund described in Part III of this report.

RECOMMENDATION FOR LIGHT-DUTY VEHICLES

Initiate a National Accelerator Community Program.

Advanced fuel vehicles require the support of new networks and are only likely to succeed if accompanied by changes throughout multiple products, systems, and industries. Making these changes will require coordination and communication among multiple stakeholders, from automakers and their suppliers to cities, fuel suppliers, utilities, infrastructure providers, drivers, and others. Ultimately, successful AFV commercialization requires the development of holistic ecosystems within individual communities that contain the appropriate infrastructure, regulatory and permitting environments, engaged stakeholders and decision makers, and access to AFV inventory. Ideally, these efforts should create a demand pull and technology push for consumer adoption.

The disparity between government resources dedicated to vehicles and infrastructure and those devoted to community readiness and consumer education is significant. In addition, the absence of actively engaged independent coordinators—those without a financial stake in selling either vehicles or infrastructure—further explains why there has been so much emphasis on installing infrastructure. In fact, the National Research Council recently recommended that the federal government refrain from any additional charging infrastructure investments until it is clear that more public charging stations would have a positive impact on PEV adoption.[37] A broader approach that recognizes strategically-placed infrastructure as just one piece of a holistic system required to support AFVs would likely witness greater success.

To this end, the ESLC recommends establishing a fuel-neutral National Accelerator Community Program for AFVs. The program should select a number of communities on a competitive basis, with successful applicants demonstrating the broadest community support and the most promise of deploying AFVs in large numbers.

37 Transportation Research Board and National Research Council, *Overcoming Barriers to Deployment of Plug-in Electric Vehicles*, 2015, at 5.

Drive Electric Northern Colorado

Communities across the nation can play a crucial role in promoting widespread adoption of plug-in electric vehicles. Drive Electric Northern Colorado (DENC) is among the first communities to lead a comprehensive and successful effort in support of this goal.

DENC is a partnership of the Electrification Coalition, the City of Fort Collins, the City of Loveland, and Colorado State University. Among other activities, DENC staff coordinate with local vehicle dealerships to organize ride-and-drive events for potential buyers, work with the area's largest employers to give more than 15,000 employees access to workplace charging, develop innovative "group buy" programs, build a regional and strategic charging network, and educate consumers about electric vehicles in the region.

DENC implements its mission by combining traditional organizing principles with technical expertise. Launched in February 2013, the effort already serves as a model for other communities seeking to promote adoption of EVs. In 2015, for example, EV sales rates in the region were nearly twice that of the U.S. average. The program is already being replicated in other communities around the country and has consistently demonstrated results that are double the national EV sales rate.

Consumer education efforts can be accelerated through an initial and geographically diverse selection of 20 communities. These efforts should develop a consistent set of empirical metrics to measure progress. By utilizing the data obtained and the lessons from these initial communities, additional cities can be chosen to maintain national momentum toward the adoption of AFVs.

While programmatic flexibility should be retained, funds will be most effective if used to help overcome adoption barriers rather than provide infrastructure subsidies. Although the initiative will take advantage of existing government incentives and some dedicated government funds, the goal should be to create a foundation to spur private investment. Choosing small- and medium-sized communities minimizes costs to the government, and allows for benefits to accrue more quickly and acutely while sharing lessons more widely. Other criteria, such as the existence of financial and non-financial state-level incentives, the support of state and local government and business leaders, commuter patterns that will maximize AFV benefits, and the presence of a strong local media market (among others) should also be considered when evaluating communities for participation in the program.

SAFE's early experience in Northern Colorado demonstrates the success that experiential marketing and community-based programs can have in accelerating AFV adoption. Thus far, sales rates have consistently exceeded national averages despite certain local characteristics, such as frequent extreme temperatures, which have negatively impacted EV sales in other regions. Furthermore, it is important to note that these successes have occurred despite the fact that Colorado is not a zero-emission vehicle (ZEV) state and, therefore, no mandate exists for automakers to sell any AFVs at all; sales in Colorado are purely demand driven. That demand was on full display in Q4 2015 when, for example, PEV sales in the DENC region were three times higher than the national average.[38]

The DENC region is home to approximately 400,000 people. SAFE estimates that the initial spending required to promote adoption rates of this level is approximately $200,000 to $300,000 per year. SAFE strongly believes that momentum continues to grow since it launched its program in early 2013, and therefore anticipates that such levels of spending could be lowered over time. It may even be possible that a self-sustaining PEV ecosystem in the region can be established in less than 5 years.

38 SAFE analysis based on data from DENC.

DENC can be replicated elsewhere at varying scales and with flexible levels of financial support.[39] After an in-depth programmatic analysis, DENC identified several broad components to successfully implementing an accelerator community including engaging stakeholders, conducting ride and drive events, developing recharging infrastructure, tracking metrics, and advocating for EV-friendly codes, regulations, and policies.

To meet such targets, funding must be frontloaded over the first two years to create a significant base of early adopters who can help solidify a positive ecosystem within each community. In addition, by frontloading funding it is more likely accelerator communities will reach an early majority and become self-sustaining in the later years, when funding levels can be tapered as AFV sales goals are met. By leveraging lessons from early cities and developing a strong understanding of what has driven EV adoption in other parts of the country, subsequent efforts in future accelerator communities should witness quicker success. When possible—and particularly with respect to the consumer LDV segment—direct competition between AFV technologies within and across communities nationwide should be minimized to avoid discontinuities in infrastructure and other priorities.

RECOMMENDATION FOR LIGHT-DUTY VEHICLES

Support creation of non-monetary incentives for advanced fuel vehicles.

Monetary incentives, like tax credits for vehicle purchasers, are crucial to spurring widespread adoption of AFVs. Incentives that offer vehicle owners added convenience have proven to be a major factor influencing purchasing decisions.[40]

The Council believes that these measures are important for growing the pool of early adopters, and include:

High-Occupancy Vehicle and Toll Lane Access. For over a decade several states have offered new technology vehicles access to high-occupancy vehicle (HOV), high-occupancy toll (HOT), or toll lanes without requiring them to carry multiple passengers. Access was initially granted in some states for traditional hybrid vehicles, though that was generally phased out as the vehicles entered the mainstream. Several states now offer such access for plug-in or natural gas vehicles. This has proven to be an effective incentive, particularly in areas with substantial traffic where access to HOV lanes can meaningfully reduce the length of a commute (something many drivers value highly). The Council recommends that states allow qualifying AFVs to use HOV, HOT, and toll lanes as an incentive to purchase AFVs.

Continued Expansion of Workplace Charging Program. While most drivers charge their plug-in vehicles at home, the ability to charge a vehicle at work can effectively double its daily range. DOE's partners in its Workplace Charging Challenge—whose goal is to meet the workplace charging demand for all of their employees—have more than 5,500 chargers available in more than 600 workplaces serving 1 million plus employees. There are expected to be 500 employer partners by 2018.[41] The Council recommends that DOE work with the relevant state agencies to bring more employers into the program, and both raise the goal and accelerate its achievement. As an extension of this program, communities, particularly those that are interested in promoting their environmental consciousness or adoption of new technology, ought to promote the adoption of AFVs by creating community recognition programs, which would bring attention to participants and allow them to demonstrate their leadership in the community.

39 SAFE analysis based on DENC interviews.
40 International Council on Clean Transportation, "Evaluation of State-Level U.S. Electric Vehicle Incentives," October 2014, at iv.
41 Office of Energy Efficiency and Renewable Energy, "Workplace Charging Challenge: Join the Challenge."

Tax Treatment of Workplace Charging as a De Minimis Benefit. Through its efforts on the Workplace Charging Challenge, DOE has learned that employers would like clearer guidance on the tax treatment of vehicle charging provided by employers. The uncertainty exists with respect to whether the IRS will treat the provision of free charging as a taxable fringe benefit, and thus require a charging system that can accommodate accounting for the amount of electricity provided to individual employees. Many employers believe that the equipment needed to track electricity used to charge vehicles, and the administrative costs of tracking and accounting for that electricity, is slowing the growth of workplace charging. The IRS, it appears, is reluctant to characterize the value of vehicle charging to be a non-taxable de minimis benefit, not only due to uncertainty over its value, but also because of the precedent it might establish, even though the average monthly value of power consumed is likely to be less than $14.[42] The Council recommends Congress clarify that the provision of workplace charging be treated as a non-taxable de minimis benefit.

Construction of Plug-In Ready Garages and Parking Lots. The most expensive aspect of installing public chargers is often the installation. To install chargers within surface parking lots or alongside on-street parking, installers must often dig a trench to bury electrical wires, a process that is both expensive and disruptive. As expensive as it is to bury wires under existing sidewalks or parking surfaces, there is only a de minimis cost to make a parking area "plug-in ready" by burying conduit through which wires can later be run to reach both new electrical panels, if needed, and vehicle chargers. The Council recommends that federal, state and local government property managers adopt a practice of installing conduit whenever repaving parking lots at their facilities, and that appropriate government authorities consider adding such a requirement to commercial building codes where they exist.

Emissions Testing Exemption. Numerous states require emissions inspections and exempt electric vehicles, creating additional cost- and time-saving benefits for electric vehicle owners who do not have to pay for the inspection fees required of other vehicle owners.

Free Parking. At least two states and several communities offer free on-street parking to electric vehicles. The Council recommends that states and local communities consider allowing AFVs to park for free in publicly owned parking spaces.

RECOMMENDATION FOR LIGHT-DUTY VEHICLES

The Environmental Protection Agency and National Highway Traffic Safety Administration should propose a plan for regulating vehicle efficiency post-2025.

The National Program to improve fuel economy and reduce greenhouse gas emissions of light-duty vehicles for model years 2017–2025 included two sets of rules.[43] Rules finalized in 2012 by the National Highway Traffic Safety Administration (NHTSA), under the authority of the Energy Policy and Conservation Act, govern fuel economy and are in effect through 2021.[44] While the agency plans for standards to become increasingly stringent through 2025, and NHTSA previously outlined what it expected those standards to be as part of the 2012 rulemaking, it must set the 2022-2025 standards through a forthcoming rulemaking because its authorizing statute allows it to set standards for only five model years at a time.[45] The Environmental Protection Agency (EPA) rules are authorized under the

42 See, e.g., Advanced Energy Corporation - NCPEV Taskforce, "Employee Guide for Workplace Charging," 2014.

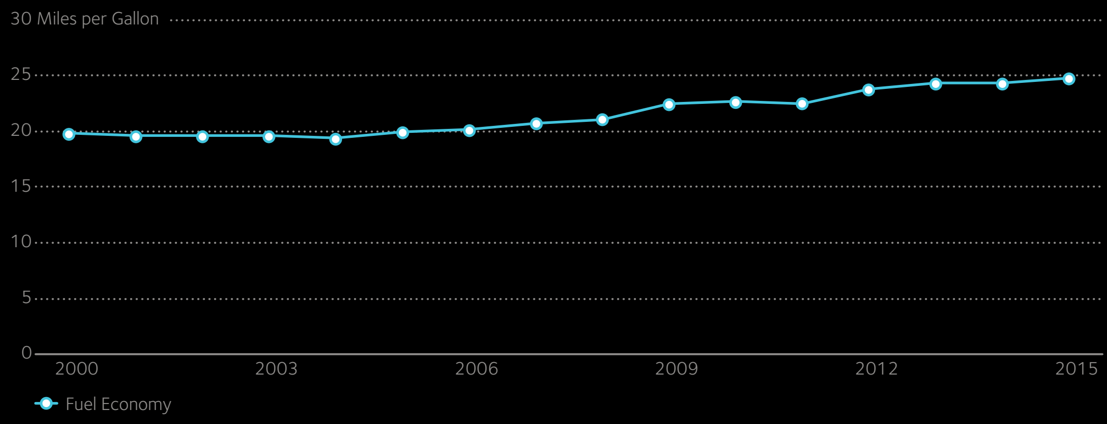
43 EPA and National Highway Traffic Safety Administration, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards,* October 15, 2012.

44 Id., at 62,624.

45 Id., at 62,627.

FIGURE 32

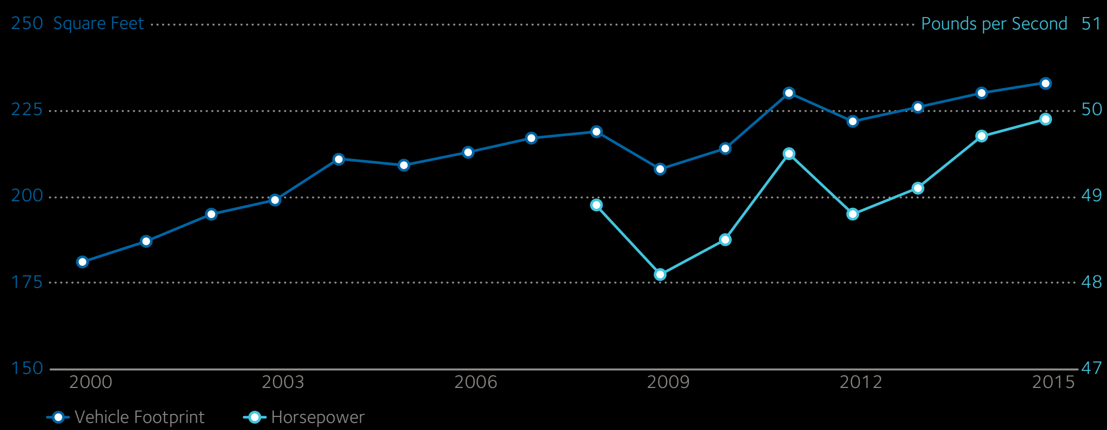
EPA Adjusted Fuel Economy



Source: EPA 2015 Fuel Economy Report

FIGURE 33

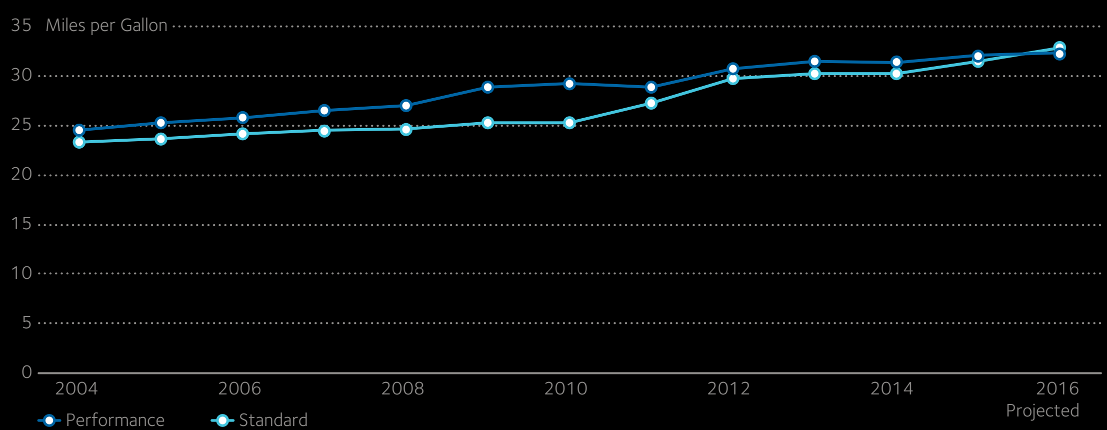
Vehicle Fleet Horsepower and Footprint, 2000–2015



Source: EPA 2015 Fuel Economy Report

FIGURE 34

Fleet Fuel Economy Performance Versus Fuel Economy Standard



Source: NHTSA, CAFE Public Information Center

Clean Air Act, and govern greenhouse gas emissions.[46] They are designed to be similar to the NHTSA rules, but because the Clean Air Act does not limit the period over which regulations may be in effect, EPA's are already in place through 2025.[47]

In establishing the current standards, NHTSA and EPA committed to a midterm review given the long time frame over which the standards will be in effect and NHTSA's obligation to conduct a further rulemaking in order to establish final standards for 2022-2025. If the midterm review finds the current EPA standards and NHTSA's tentative standards are appropriate, then NHTSA can confirm the standards it outlined for 2022-2025 through a notice and comment rulemaking, and EPA's standards will remain unchanged.[48] If the midterm review finds that the standards need to be adjusted (either to be more or less stringent), then EPA and NHTSA will jointly issue new proposed and final rules. The agencies have affirmed their commitment to coordinate their process with the state of California in order to continue to maintain a single National Program for fuel economy standards, which aligns federal and California standards.[49]

The 2012 rulemaking committed the agencies to complete the midterm review draft Technical Assessment Report (TAR) by November 15, 2017, in order to provide regulators adequate time for a reasonable public comment period while enabling the agencies to determine, by April 1, 2018, whether the standards established for MY 2022–2025 are appropriate.[50] EPA and NHTSA are currently planning to accelerate the issuance of the TAR so that it will be completed during the Obama Administration in 2016, in advance of its 2017 deadline.[51] Doing so also is intended to establish an administrative record in support of more stringent standards to guide future policymaking.

Short Term: Maintaining Current Standards

EPA and NHTSA are in the midst of the midterm review of the 2017-2025 standards through which they will determine if the standards set in 2012 should be adjusted or not. In setting the standards, the agencies examined the cost-effectiveness of different fuel-saving technologies and determined whether they can be relied upon to meet the overall standards. At the time the 2017-2025 standards were issued, EIA's most recent forecast was for gasoline to average $3.81 per gallon in 2015 and $4.95 in 2025, when the price in fact averaged just $2.52 per gallon in 2015.[52] Gasoline is currently forecast to average $3.63 in 2025.[53] In fact, with fuel prices now far lower than they were forecast, some technologies that the agencies determined were cost-effective at the time of the rulemaking may no longer be cost-effective, opening the door for automakers to argue that the agencies should relax the standards. Likewise, other technologies may have advanced further than earlier forecasted, making it more cost effective to meet the standards than when the standards were established.

The Council continues to support the National Program, and the important role it plays in reducing oil dependence. While gasoline prices have certainly declined over the past 24 months, they are nonetheless likely to rise substantially over the course of the program. Furthermore, today's price decline in many ways is an important validation of public policies that support long-term goals like efficiency, regardless of short-term market fluctuations. Indeed, in the absence of fuel-economy standards, global oil price volatility would likely prevent nearly any gains in efficiency whatsoever, leaving the country even more exposed to oil price shocks than it is currently.

While the Council believes regulators should not relax the stringency of the program, there is an opportunity to lay the early groundwork for the introduction of autonomous vehicles, which will present

46 Id., at 62,624.
47 Id.
48 Id., at 62,627, 30.
49 Id., at 62,628, 62,652.
50 Id., at 62,787.
51 EPA, "Midterm Evaluation of Light-duty Vehicle Standards for Model Years 2022-2025," February 23, 2016.
52 EIA, *Annual Energy Outlook 2012*, at Table A12; and EIA, "Weekly Retail Gasoline and Diesel Prices."
53 EIA, *Annual Energy Outlook 2012*, at Table A12.

an opportunity to substantially reduce oil consumption by promoting the adoption of AFVs and reducing petroleum vehicle miles traveled. Autonomous vehicles are now poised for a first-generation test cycle under real world conditions. To encourage the development of this technology, the Council recommends that EPA and NHSTA establish a mechanism to give automakers substantial extra compliance credits if the manufacturers can establish a program to send a minimum quantity of AVs, at a reasonable production price, into a single community by a certain date in order to demonstrate the capabilities of autonomous vehicles and promote their broader acceptance.

Medium Term: Meeting the 2025 Goal

At the time the standards were issued, EPA and NHTSA stated that they would result in an average industry fleetwide emissions level which was the equivalent to 54.5 miles per gallon (mpg) if achieved exclusively through fuel economy improvements.[54] While that calculation assumed that automakers would meet the standard entirely through increased efficiency, they could also meet the standard in part by other means, including by improving vehicle air conditioning systems that will increase efficiency and reduce leakage, and by using alternative refrigerants with lower hydrofluorocarbon emissions, and bonus credits for the sales of plug-in electric vehicles.[55] Taking into account that the standards will not be met entirely through increased efficiency, the average fuel economy of the U.S. light-duty fleet in 2025 would be closer to 40 miles per gallon.[56]

However, even though automakers should be able to meet the requirements of the fuel economy standards, the standards are unlikely to achieve the program's overall fuel economy goals. The original CAFE program required a true fleet average, in which the average fuel economy of every car sold had to meet a standard. That created an incentive to produce smaller more efficient cars to offset the poor fuel economy of larger cars.[57] This approach was criticized for, among other things, forcing manufacturers to make smaller, less safe cars that consumers did not want to buy.[58] The 2007 Energy Independence and Security Act required that the fuel economy program transition into an attribute-based program. The program does not require fleet-wide averages for either fuel economy or emissions, but instead imposes a requirement for each which is a function of the size of the vehicles actually sold in each compliance period.[59] This means that rather than pressuring automakers to build smaller cars, it pressures them into building more efficient cars in every size.

When promulgated, EPA and NHTSA forecast that the sale of new light duty vehicles in 2025 would be 62 percent cars and 38 percent trucks.[60] Based on those assumptions, the program was expected to achieve an average fuel economy in the light-duty fleet of 54.5 mpg, which would save a total of 4 billion barrels of oil and reduce oil consumption by more than 2 million barrels a day by 2025, while reducing emissions by 2 billion metric tons over the life of the program.[61]

However, due to lower-than-forecast gasoline prices, it appears likely that the composition of the LDV fleet will be more heavily weighted to SUVs and heavier vehicles than expected (Figure 34). In the rule, EPA and NHTSA assumed that in 2017, 57 percent of LDV sales would be cars and 43 percent would be trucks.[62] By 2015, however, the government was forecasting that in 2017 only 49.8 percent of LDV sales would be cars and 50.2 percent would be trucks, and that by 2025, 52 percent would be cars

54 See, e.g., The White House, "Obama Administration Finalizes Historic 54.5 MPG Fuel Efficiency Standards," August 28, 2012.

55 Id., at fn.3.

56 See, e.g., Shiraz Ahmed, "Fed and Automakers Prepare to Review 54.5 mpg CAFE Goal," Automotive News, April 18, 2016.

57 National Highway Traffic Safety Administration, *Average Fuel Economy Standards for Light Trucks Model Years 2008–2011; Final Rule*, April 6, 2006.

58 Id.

59 Id.

60 EPA and National Highway Traffic Safety Administration, *Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards,* August 2012, at 1-14 to 1-15.

61 EPA, "Fact Sheet: EPA and National Highway Traffic Safety Administration Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks," August 2012, at 3.

62 EPA and National Highway Traffic Safety Administration, *Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards,* August 2012, at 1-14 to 1-15.

and 48 percent would be trucks.[63] With more trucks entering the sales mix than anticipated, the federal government may find itself in a difficult position. Automakers may continue to comply with regulatory standards by producing more efficient trucks and taking advantage of AFV bonus credits. Nevertheless, the program may still fall short of its oil savings goals as the fleet skews more heavily toward trucks. Ultimately, even highly efficient trucks are not as efficient as passenger cars.

Moreover, low gasoline prices make it more difficult to sell advanced fuel vehicles, undermining the incentive to continue manufacturing and selling them. Based on current price forecasts, this problem may persist, slowing the U.S. transition to highly efficient vehicles that will meet the country's emission target and enhance energy security. The Council recognizes that it is difficult to address this issue at this point in the program's life, but believe that the current situation reinforces the importance of not weakening the standards as part of the midterm review.

Long Term: Planning for Post-2025

EPA and NHTSA face a longer-term question about the future of the program after 2025, which will be the 50th anniversary of the CAFE program. There appears to be a reasonable likelihood that in 2025 the country will not have met its fuel economy (or the emissions reduction) goals of the National Program because of lower-than-forecast fuel prices and a fleet mix that is more heavily weighted to larger vehicles than expected when crafting the rule. At that point, the agencies will have several choices. They could continue to increase the stringency of the current program, abandon the attribute-based approach and revert to the approach used before 2010, forcing drivers into smaller cars, or explore complementary or substitute policies. The Council recommends that after the completion of the midterm review, the agencies begin studying the following policies which could complement or replace the National Program:

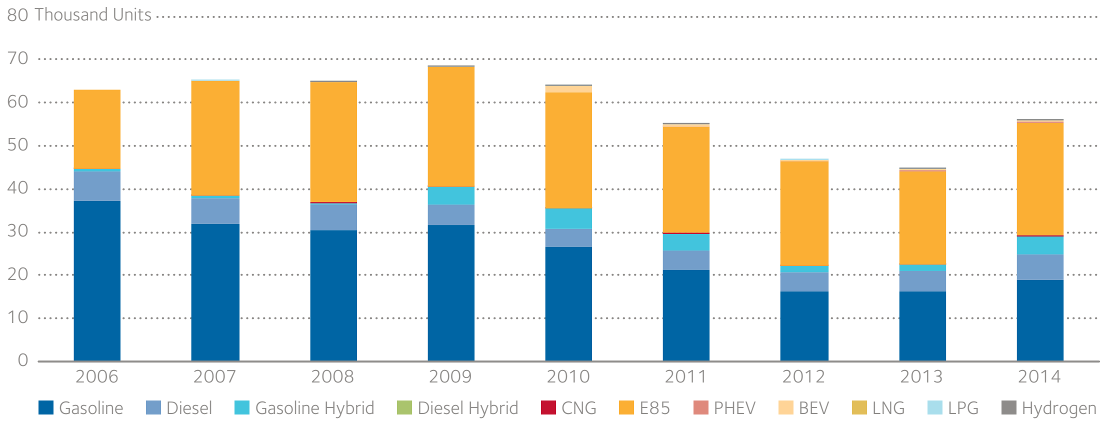
Examining the Transportation System Instead of Just the Vehicles. The Council envisions a future that could involve widespread ride-sharing. That transition offers substantial opportunities to reduce energy consumption in the ground transportation system if the most efficient vehicles are used in the ride-sharing market. In addition, the advent of autonomous vehicles could accelerate the use of AFVs in ride-sharing vehicles, which will reduce oil use. The current approach to regulating fuel consumption, however, is focused on regulating the efficiency of the individual vehicles and not systems of vehicles. NHTSA and EPA should examine the opportunity to account for the increased efficiency and reduce oil consumption resulting from actual miles traveled so that the most efficient or non-oil using vehicles accumulate the most miles per year.

Gasoline Tax. A gasoline tax would be the most economically-efficient and effective option for replacing the National Program. It also has the benefit of working not only to increase vehicle fuel efficiency, but also to account for vehicle miles traveled. In order to minimize volatility, the tax could be designed to act similar to a floor on the price of gasoline. In addition, this tax should be designed to be revenue neutral for Americans. They could receive a quarterly refund or a reduction in payroll taxes or other taxes that disincentivize production as opposed to consumption. Such a fee would incentivize drivers to choose more efficient vehicles by internalizing the external costs of driving an inefficient car, and incentivize them to switch to other vehicles. This system could serve in lieu of the currently more complicated regulatory structures. It would allow consumers the freedom to choose the types of vehicles they want to buy based on a clear price structure on fuels, reduce the need for government to regulate the types of vehicles that need to be produced and limit the growth of government by keeping the fee revenue neutral.

63 EIA, *Annual Energy Outlook 2015.*

Federal Fleet Acquisitions by Technology Type, FY 2006-2014

FIGURE 35



Source: GSA and ORNL

RECOMMENDATION FOR LIGHT-DUTY VEHICLES

Increase federal deployment of advanced fuel vehicles.

As the largest vehicle fleet operator in the country, the federal government is well situated to be a significant force in the market for advanced fuel vehicles.[64] Greater federal adoption of advanced technology vehicles would send a strong signal to automakers that would: demonstrate there is a market for AFVs, drive down lifetime vehicle costs, and meet federal emission reduction goals. By placing large orders that replace significant portions of regional federal fleets, the government can help accelerate the pace of technological advancement and reduce AFV costs.

The federal government's opportunity for leadership has been recognized through several statutory requirements, executive orders, and presidential memoranda concerning the federal fleet over the last 25 years, most recently President Obama's March 2015 Executive Order (EO) No. 13693.[65] This EO requires agencies to ensure that 20 percent of all new agency passenger vehicle acquisitions are zero-emission vehicles or plug-in hybrid vehicles by December 31, 2020, and 50 percent by December 31, 2025.[66]

Despite two decades of statutes and executive orders that direct agencies to purchase efficient and advanced vehicles, agencies often choose to meet the requirements by purchasing vehicles with the lowest upfront capital cost. This has too often meant purchasing flexible-fuel vehicles that—though capable of running on E85—operate on gasoline due to the unavailability of E85 (Figures 35 and 36).[67] Thus, although AFV *acquisition rates* have come close to meeting the requirements in the Energy Policy Act of 1992 (requiring that 75 percent of new acquisitions be alternative fuel vehicles), actual alternative fuel *use* in federal fleets was only 3.9 percent of total fleet fuel consumption.[68] This is

64 See, e.g., Fleet Central, "300 Top Commercial Fleets," 2013; and General Services Administration, Federal Fleet Report, 2014.

65 Federal Register 15871, Executive Order No. 13693, *Planning for Federal Sustainability in the Next Decade*, Volume 80 Number 57, March 19, 2015; Federal Register 52117, Executive Order No. 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, Volume 74, Number 194, October 5, 2009; The White House, Presidential Memorandum, "Implementation of Energy Savings Projects and Performance-Based Contracting for Energy Savings," December 2, 2011; The White House, Presidential Memorandum, "Driving Innovation and Creating Jobs in Rural America Through Biobased and Sustainable Product Procurement," February 21, 2012, at Section 1; The White House, Presidential Memorandum, "Federal Leadership on Energy Management," December 5, 2013; The White House, Presidential Memorandum, "Federal Fleet Performance," May 24, 2011; and Executive Order 13693 revoked Executive Order 13423 as of January 24, 2007.

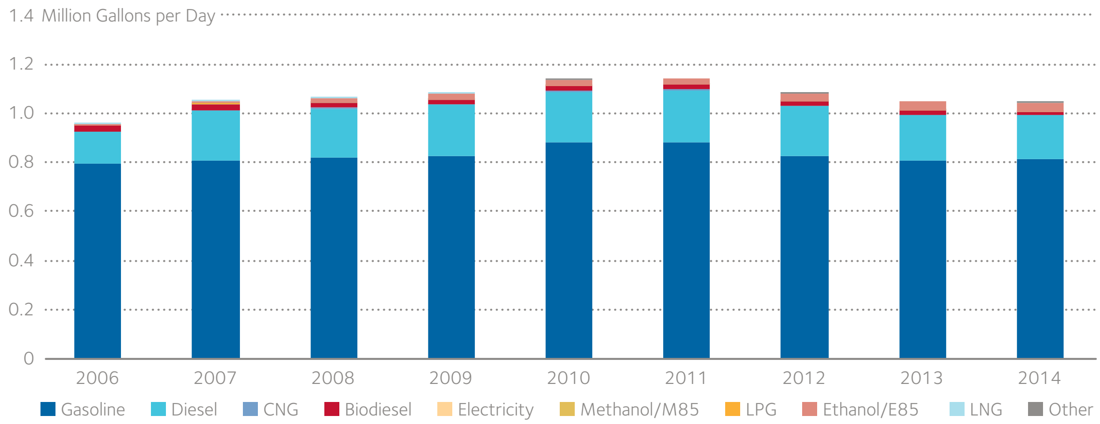
66 White House Council on Environmental Quality, Office of Federal Sustainability, "Implementing Instructions for Executive Order 13693 Planning for Federal Sustainability in the Next Decade," June 10, 2015.

67 Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, "2015 Waivered Alternative Fuel Vehicles," October 30, 2014; and Federal Register 77420, EPA, *Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016* and *Biomass-Based Diesel Volume for 2017 Final Rule I*, Volume 80, Number 239, December 14, 2015.

68 42 U.S.C. § 13212 Ð Minimum Federal Fleet Requirement; and General Services Administration, "FY 2014 Federal Fleet Report Open Data Set," March 31, 2015, at Tab 5-1T.

FIGURE 36

Fuel Consumed by Federal Fleets, FY 2006-2014



Source: GSA and ORNL

primarily because the average government flexible-fuel vehicle uses less than 70 gallons of E85 a year, ultimately achieving very little improvement in U.S. energy security.[69]

With over 400,000 non-tactical vehicles and over $1.2 billion dollars in annual fuel costs, the federal government has a significant opportunity to adopt AFVs and alternative fuels, which would demonstrate that these vehicles can meet a wide range of transportation applications, generate important data and lessons regarding the use of AFVs, and help ensure a ready market for AFVs.[70] In short, a significant federal effort to incorporate AFVs into its fleet could catalyze adoption in state and local government fleets, as well as with businesses and consumers. The Council recommends the federal government take the following steps to increase federal fleet-wide AFV use:

Work with States on Bulk Purchases. The federal government should work with states to make bulk AFV purchases that can drive down costs. In 2012, Oklahoma and Colorado led a multi-state agreement issuing a joint request for proposals for the purchase of natural gas vehicles for themselves and local governments.[71] Automakers responded by offering several vehicle models at a savings of up to $8,000 per vehicle over the best previously available price.[72] Oklahoma is initiating a new agreement that includes all AFVs. DOE and the General Services Administration (GSA) should join with the states in seeking to lower the cost of AFVs at all levels of government. If there are legal obstacles to entering into such agreements with the states, DOE and GSA should identify changes to the applicable laws, regulations or requirements that would allow them to work with the states.

Appropriate Funds to Directly Offset the Incremental Cost of AFVs to Agencies. AFVs often have high capital costs that are offset over a vehicle's lifetime by lower operations and maintenance (O&M) costs. While the lower O&M costs will help lower vehicle lifecycle costs, agencies may not have the funds available to incur higher up-front capital costs because budgets are tight, or because capital and operating costs are funded separately and one cannot easily offset the other. This situation may make it unnecessarily difficult for federal fleet managers to purchase AFVs. GSA and DOE should seek funding to establish a program that offsets some portion of the incremental costs of AFVs and any associated infrastructure purchased by federal agencies. Directly appropriating funds for that purpose would allow agencies to procure AFVs without taking scarce funds away from their core missions.

69 Id., at Tabs 5-1, 5-1T, and 5-3.
70 Id., at Tab 2-1; and Id., at Tab 5-2.
71 Office of Energy Efficiency and Renewable Energy, "Memorandums of Understanding—Broadening the Impact of State Actions," February 9, 2015.
72 Tom Hunt, "Implementation of Multi-State NGV MOU," Colorado Energy Office, January 10, 2014.

GSA Should Report on Opportunities for Leasing from Third Parties. The GSA and the Federal Energy Management Program should prepare a report examining a range of issues related to the purchase and leasing of AFVs. The report should include recommendations on how to:

Resolve the difficulty fleet managers have in paying for the incremental cost of AFVs, and the extent to which those difficulties result in most agencies only choosing flexible-fuel vehicles (the AFVs with the lowest incremental cost) and then operating them on gasoline instead of E85.

Exploit opportunities for agencies to lease vehicles at a lower cost from third parties as compared to GSA, including opportunities for federal agencies to monetize federal and state tax credits, rebates, and/or grants.[73]

Identify opportunities for federal agencies to acquire AFVs through energy savings performance contracts.

Increase Use of E85 in the Federal Flexible-Fuel Vehicle Fleet. The federal government owns approximately 185,000 flexible-fuel vehicles, of which more than 55,000 were waived from meeting the 2005 Energy Policy Act (EPAct) alternative fuel use requirements because the vehicles were housed too far from an E85 refueling station. Other flexible-fuel vehicles appear to have not used E85, despite not obtaining a waiver.[74] The federal government should identify 20 areas where the government has a high concentration of flexible-fuel vehicles without access to E85, and contract with private fuel providers for convenient access to E85 for the vehicles. If access is not easily obtained, the government should install its own fueling infrastructure, so that the vehicles purchased can be fueled as intended.

Rightsizing Charging Infrastructure. Commercial facilities often focus on installing revenue-grade Level 2 chargers because of the faster charging times and their ability to measure power, which gives the provider the information they need to recover the costs associated with installation, maintenance, and operation. Agencies should, however, explore the opportunities for non-revenue grade slower chargers, which are far less costly, even though they charge slower and do not meter the power used. With the average vehicle in the federal fleet traveling less than 35 miles a day, most vehicles can meet their agencies' needs with slower overnight charging.[75] Moreover, the incremental cost of chargers that collect data to charge customers for the power they use often exceeds the cost of the power itself.[76] Agencies should identify where it would be more cost effective to buy less expensive infrastructure and not charge for the power. If government regulations prove an obstacle to not charging for power, then GSA and DOE should inform Congress of this situation and propose a way to address it.

Incorporate AFVs in Post Office Fleet. The United States Postal Service (USPS) is in the midst of a process to replace its current delivery fleet of Grumman Long Life Vehicles (LLVs) trucks, with up to 180,000 "Next Generation Delivery Vehicles" (NGDVs) that are designed to operate for at least 20 years.[77] This procurement is expected to cost $6.3 billion.[78] An average LLV on the road today has been in operation for more than 24 years, and now lacks many

73 See, e.g., Federal Business Opportunities, "Information About the Navy Program for Electric Vehicle Leasing"; and see, e.g., 26 U.S. Code § 30D(f)(3).
74 Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, "2015 Waivered Alternative Fuel Vehicles," October 30, 2014.
75 Oak Ridge National Laboratory, *Transportation Energy Data Book, Edition 34*, September 30, 2015, at Figure 7.2.
76 Office of Energy Efficiency and Renewable Energy, "Costs Associated With Non-Residential Electric Supply Vehicle Equipment," November 2015, at 9-12.
77 PostalReporter.com, "USPS issues Next Generation Delivery Vehicle (NGDV) Prototype Request to Prequalified Suppliers," October 20, 2015.
78 USPS, RFI, "Next Generation Delivery Vehicle (NGDV) Acquisition Program," 2015.

of the technological advancements developed in recent decades, including anti-lock brakes and air conditioning.[79] LLVs also only get 10 mpg, which is significantly less than comparable vehicles available today.[80] Moreover, given the age of these custom-built vehicles, the fleet of LLVs cost $450 million annually to maintain.[81] If USPS moves forward with its current procurement plan, to again purchase custom-built vehicles while keeping them for decades, it will make a costly mistake that will deprive one of the world's largest civilian fleets of integrating safety and fuel efficiency technologies that will be developed in the coming years.

Analysis prepared for SAFE identified an alternative approach using a combination of lightly modified "off-the-shelf" vehicles, some of which are replaced after 10 to 12 years, and AFVs for shorter routes. This approach could generate approximately $2.8 billion in savings for USPS over 24 years, mostly through reduced fuel and maintenance costs.[82] The off-the-shelf vehicle procurement approach is used by private sector delivery companies such as UPS and FedEx, and nearly all foreign postal delivery services. As part of this approach, the USPS could systematically incorporate more fuel efficient and advanced fuel vehicles into its fleet, all while reducing costs, particularly at a time of USPS's precarious financial standing.

RECOMMENDATION FOR LONG-HAUL TRUCKS

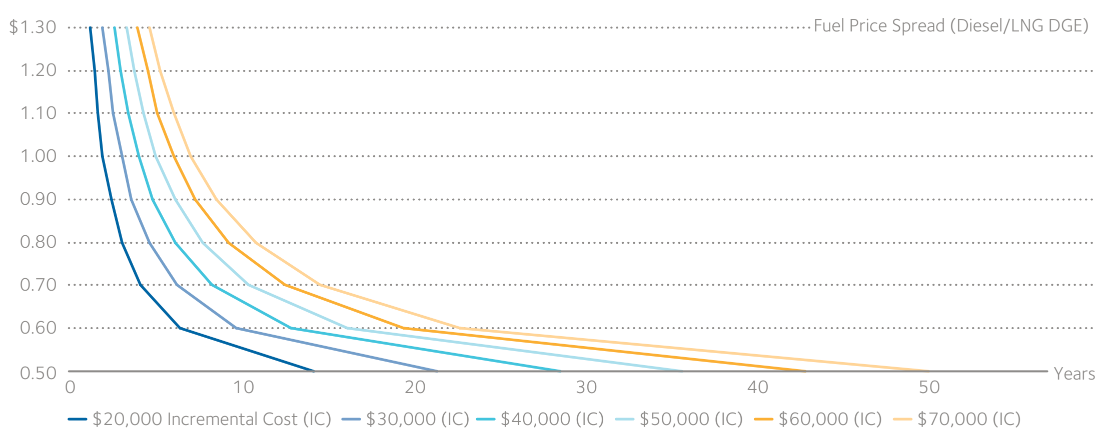
Create incentives for medium- and heavy-duty advanced fuel vehicle purchases.

In noticeable contrast to the LDV segment, energy and oil use in the MDV and HDV segment is forecast to rise, not fall over the next quarter century.[83] However, advanced fuel MDVs and HDVs can carry substantial upfront price premiums over their ICEV counterparts. This price disparity poses a significant deterrent to purchasing advanced vehicles, despite the long-term total cost of ownership (TCO) benefit of AFVs that can be derived due to lower fuel, maintenance, and other costs (Figure 37).

While NGVs in particular have seen impressive market share growth in certain applications—transit buses and refuse trucks being prime examples—penetration of freight and delivery markets has been slower. The Council recommends that Congress pass tax credits for advanced fuel medium- and

FIGURE 37

LNG Long-Haul Truck Payback Periods



Source: ACT Research Co., LLC 2015

79 USPS, IG Report DR-MA-14-005, "Delivery Fleet Replacement," 2014.
80 USPS, IG Report DA-AR-10-005, "Delivery Vehicle Replacement Strategy," 2010.
81 USPS, IG Report DR-MA-14-005, "Delivery Fleet Replacement," 2014.
82 Securing America's Future Energy, "USPS Fleet Procurement for the 21st Century," September 28, 2015.
83 EIA, *Annual Energy Outlook 2015*.

heavy-duty trucks. Tax credits should be established that offer, at a maximum, $25,000 for dedicated advanced-fuel vehicles weighing between 14,000 pounds and 26,000 pounds, and $40,000 for dedicated advanced-fuel vehicles weighing more than 26,000 pounds. The precise amount should be determined, and recalculated on a quarterly basis, by the price differential (DGE) between diesel and the applicable advanced fuel. The credit should decline by 25 percent for every 50 cents per gallon difference in fuel price. EIA prices should be used to calculate the price differential on the first day of every quarter. This price differential should then be used to calculate a fixed credit amount for the entire quarter, with a new credit amount being determined on a quarterly basis.

The credit would be available to the manufacturer of the vehicle, but the manufacturer would have the option to transfer the credit to a dealer that sells the vehicle or to the vehicle's end-use purchaser. If the credit is transferred to an end-use business purchaser, the purchaser would not be required to reduce the basis of depreciable property by the amount of the credit. Furthermore, the credit amount should reflect the timing of the buying decision or agreement, not the delivery date of the vehicle.

To promote faster adoption and limit costs, the credit should be allowed for vehicles placed in service after December 31, 2015, and before January 1, 2021. For vehicles placed in service in calendar year 2020, the credit would be limited to 50 percent of the otherwise allowable amount.[84]

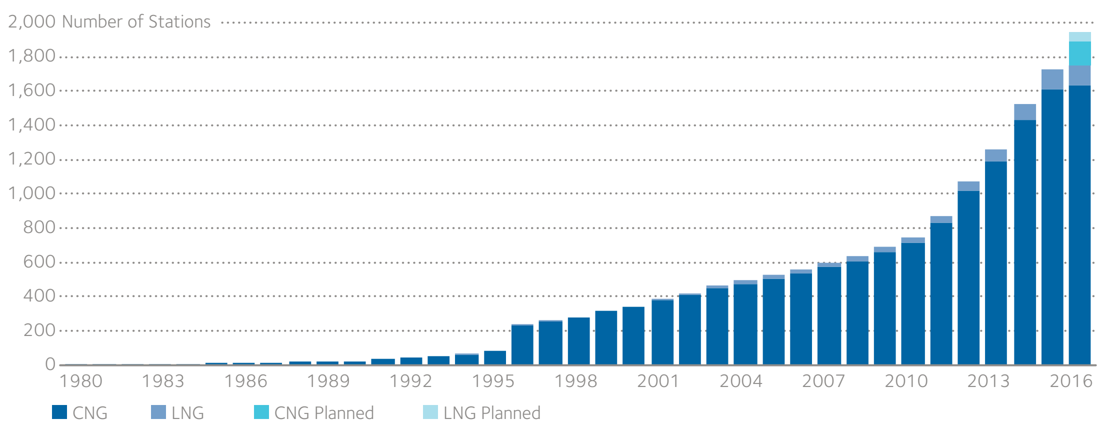
RECOMMENDATION FOR LONG-HAUL TRUCKS

Congress should establish a grant system for the installation of CNG and LNG fueling stations along high-priority corridors.

The lack of widespread and suitable fueling infrastructure adversely affects the adoption of NGVs, even though these vehicles have the potential to drastically reduce oil dependence in the medium- and heavy-duty segments (Figure 38). In turn, the lack of widespread adoption of NGVs has been cited by many potential fuel providers as a justification for limiting their investment in new infrastructure. This has been the case for both CNG and LNG, although especially in the LNG market. For example, Clean Energy Fuels planned to open a coast-to-coast LNG refueling corridor, but efforts have been hampered by low LNGV penetration levels, with many stations remaining shuttered rather than operate at significant expected losses.[85]

Natural Gas Fueling Stations

FIGURE 38



Source: SAFE analysis based on data from Alternative Fuels Data Center

84 Department of the Treasury, "General Explanations of the Administration's Fiscal Year 2017 Revenue Proposals Proposed US Budget," February 2016.
85 Office of Energy Efficiency and Renewable Energy, Alternative Fuels Data Center.

To break this cycle, the federal government can facilitate the creation of a network of natural gas fueling corridors that will obviate the range concerns of long-haul truck owners and fleet managers. LNG would benefit especially from such a policy; its high energy density makes it attractive to operators traveling long distances carrying heavy cargoes, but without sufficient LNG stations on the National Highway Freight Network, companies without the volume to justify building their own stations have largely refrained from switching from diesel. The current Alternative Fuel Infrastructure Tax Credit—valid through December 31, 2016—equal to 30 percent of the cost of refueling equipment up to a maximum of $30,000 is insufficient given the high risk of new investment in natural gas infrastructure and the potential of even relatively small CNG and LNG stations to cost $1 million to $3 million to build.[86]

Thus, the Council recommends that natural gas refueling infrastructure be prioritized along high-priority corridors that are responsible for large degrees of long-haul medium- and heavy-duty trucking. Through the establishment of a grant system for the installation of CNG or LNG stations, Congress can ensure that fueling stations exist no more than 200 miles apart alongside the more than 51,000 miles of the National Highway Freight Network.[87] Funding should be determined through a competitive grant application program, which would allow for the prioritization of high-impact projects. This would enable the government to allow for worry-free natural gas adoption by fleet operators and independent truck owners at a cost of $500 to $900 million.

RECOMMENDATION FOR LONG-HAUL TRUCKS

Congress should pass a two-year extension of the Alternative Fuel Excise Tax Credit.

In December 2015, Congress passed legislation that extended the Alternative Fuel Excise Tax Credit through December 31, 2016. This credit provides $0.50 per gallon for CNG, LNG, and propane autogas, among other advanced transportation fuels.[88] The current extension is short-term and creates tremendous uncertainty for investment. The Council urges Congress to pass a two-year extension of the Alternative Fuel Excise Tax Credit so that such uncertainty is eliminated. This will encourage the expansion of natural gas fleets, and have a lasting, positive impact on U.S. energy security in the heavy-duty segment.

RECOMMENDATION FOR LONG-HAUL TRUCKS

Establish a diesel gallon equivalent standard in order to create consistency and clarity in the marketing and dispensing of CNG and LNG fuel.

The opportunity to save on fuel costs is a major motivation for car and truck fleet owners to switch from petroleum to natural gas and other alternatives. The shift depends, however, on the fuel cost savings being transparent and easily understood by truck operators and fleet owners.

For this reason, the National Conference of Weights and Measures (NCWM) should refrain from voting to require LNG to be sold in kilograms at their next annual meeting, and instead should allow for the creation of a uniform diesel gallon equivalent (DGE) standard as the primary unit for dispensing and pricing LNG. Over the past century, companies and consumers have grown accustomed to purchasing liquid fuels in gallons, and operators of heavy-duty trucks will be far more able to make clear and

86 SAFE conversations with industry participants.
87 Federal Highway Administration, National Highway Freight Network, March 23, 2016.
88 Office of Energy Efficiency and Renewable Energy, "Alternative Fuel Excise Tax Credit."

informed decisions about switching to LNG if it is priced in DGE, rather than kilograms. Similarly, the NCWM should commit to maintaining the current convention of gasoline gallon equivalents (GGE) for CNG sales, but also vote to allow for CNG to be measured and priced in DGE where sold primarily to medium- and heavy-duty vehicles. Simplicity and clarity in fuel measurement can do much to aid consumer acceptance of an alternative fuel like natural gas.

RECOMMENDATION FOR LONG-HAUL TRUCKS

States and localities should establish their own incentive programs, particularly around regional and urban goods movement.

Many states and regions have established advanced fuel, heavy-duty vehicle incentives. Most are financial incentives for the purchase of vehicles or construction of fueling infrastructure. For example, the New York State Energy Research and Development Authority (NYSERDA) is providing incentives for alternative fuel trucks and buses. Incentives are released on a staggered schedule and include:

Vouchers that provide up to $60,000 for the purchase or lease of all-electric Class 3 through 8 trucks in the state of New York.[89]

Vouchers for private and non-profit fleets that provide up to $40,000 for the purchase of compressed natural gas, hybrid electric and all-electric Class 3 through 8 trucks in New York City.[90]

To support state and municipality efforts nationwide, DOT Tiger and DOE Clean Cities grants should be made eligible for these local programs.

The Transportation Investment Generating Economic Recovery, or TIGER Discretionary Grant program, allows DOT to invest in road, rail, transit and port projects. Grants are awarded through a competitive application program to fund projects that have a significant impact on the United States, a region or a metropolitan area.[91] For 2016, $500 million is budgeted for this program.[92] It is primarily focused on multimodal infrastructure projects, but should be expanded to allow funding of meaningful AFV and fueling infrastructure projects as well.

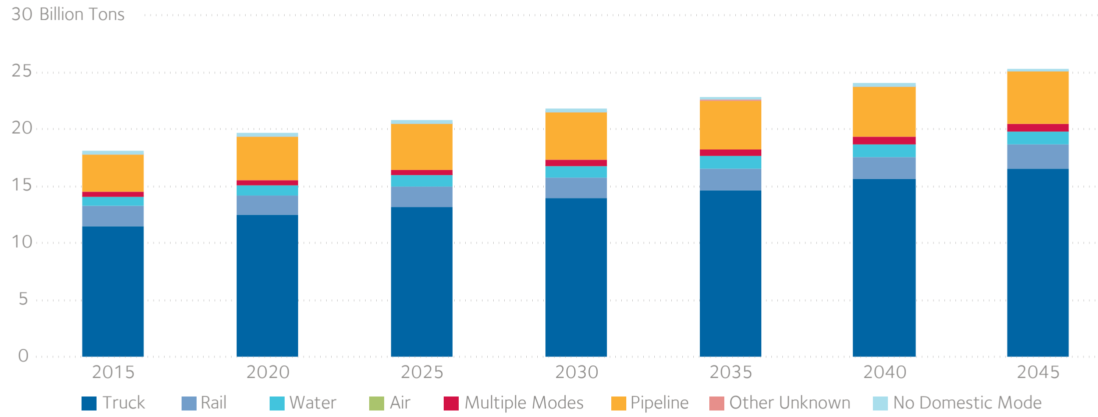
The DOE's Clean Cities program should be expanded to not only support local action to reduce petroleum use in transportation, but to provide funding for specific heavy-duty AFV purchases and construction of associated fueling infrastructure. At present the program is only funded at $55 million, and acts primarily as a convener of interested parties and as an information provider, with no authority to provide direct funding to jump start worthy initiatives.

Localities should also consider non-traditional incentives such as access to HOV lanes, preferred delivery times for advanced fuel delivery vehicles, preferential treatment in the awarding of local government freight contracts, adjusting urban freight facility zoning rules to reward the use of advanced fuel freight vehicles, allowing access to municipal advanced fuel fueling stations, and assisting freight operators with obtaining federal grants and other incentives for advanced fuel medium- and heavy-duty vehicles.

89 Office of Energy Efficiency and Renewable Energy, Alternative Fuels Data Center, "Heavy-Duty Alternative Fuel and Advanced Vehicle Purchase Vouchers."
90 Id.
91 DOT, "About TIGER Grants," October 29, 2015.
92 Id.

FIGURE 39

Growth of Freight Tonnage, Forecast



Source: FHWA

RECOMMENDATION FOR LONG-HAUL TRUCKS

Create performance-based standards for freight trucks.

Every year, freight trucks transport millions of tons in goods along U.S. highways. These trucks are often not right-sized for the goods they carry. As a result, millions of avoidable truck trips occur every year, leading to unnecessary expenditures on fuel and labor that amount to more than $27 billion in annual costs to U.S. businesses.[93]

Such inefficiencies are the result of an unnecessary and burdensome set of prescriptive standards that limit the length of trucks and trailers in the United States. These outdated policies are poised to inflict even more damage upon U.S. businesses as recently released projections from DOT indicate freight levels will grow 40 percent by 2045 (Figure 39).[94] To accommodate the growing demand for freight on U.S. highways, the Council recommends the adoption of performance-based measures that will enhance freight efficiency and significantly reduce oil consumption without negatively impacting road infrastructure or safety.

Performance-based standards (PBS) are an alternative to existing regulations that govern size and weight restrictions on heavy-duty freight trucks. In particular, PBS allow for flexibility, enhancing industry's creative capacity to design and manufacture trucks specialized for their intended cargo.[95] These trucks are evaluated based on several dimensional and component categories that include the trucks' tracking stability, group and combination axle loadings, and gradeability, among others. These all contrast with the currently prescriptive standards that are largely based on vehicles' size (length, height, width) and weight.[96] Australia's National Transport Commission, for example, estimated that PBS will accrue substantial benefits, including reduced fuel use and road degradation as well as improved safety.[97]

While the development and agreement on a suite of safety and infrastructure criteria for performance-based standards may take time, the Council recommends that in the interim Congress immediately update a 1982 law by extending the length of twin trailers—from 28 to 33 feet—with no increase to federal weight standards. Adding five feet to trailers, while allowing them to operate on interstate

93 Coalition for Efficient and Responsible Trucking, "Mythbuster," May 27, 2015; and Coalition for Efficient and Responsible Trucking, "LTL Fact Sheet – Frequently Asked Questions," Webpage.

94 Federal Highway Administration, "Freight Analysis Framework Data Tabulation Tool, February 26, 2016.

95 Australia National Transport Commission, *Performance Based Standards: Regulatory Impact Statement*, March 2011.

96 See, e.g., Phil Taylor, "Performance Based Standards a win, win, win," Prime Mover, February 2015.

97 Australia National Transport Commission, *Performance Based Standards: Regulatory Impact Statement*, March 2011.

highways, will increase the cargo carrying capacity of these units by 18 percent. This modest change will result in a 1.3 billion-mile reduction in truck VMT.[98] The reduced congestion would prevent upwards of 1,000 crashes per year.[99]

According to research from the University of Michigan Transportation Research Institute and the U.S. Department of Transportation, extending the wheelbase of twin trailers by five feet would make them more stable than twin 28-foot trailers; they would also have a tighter turning radius than a single 53-foot trailer configuration.[100] The Florida Turnpike—the nation's third-busiest toll road—has experienced twin 33s traveling more than 1.5 million miles over the past six years without any accidents.[101] In North Dakota, twin 33s have logged more than 54,000 miles without a single accident since 2014.[102]

In addition to the congestion and safety benefits, an update to the twin trailers law, perhaps accomplished through adoption of PBS, would enable the LTL industry to save more than 200 million gallons of diesel fuel per year.[103] Finally, allowing twin 33-foot trailers would also produce financial savings for the federal government and states because the longer wheelbase decreases stress on bridges.[104]

In 2015, language authorizing twin 33s to operate on U.S. interstate highways was passed by the U.S. House of Representatives and the Senate Appropriations Committee. However, this language was not enacted in law. In 2016, the Council recommends that lawmakers reconsider this proposal until a comprehensive suite of performance-based standards can be implemented.

RECOMMENDATION FOR LONG-HAUL TRUCKS

The Department of Transportation should promulgate rules on truck platooning.

Truck platooning is a driver-assist technology that allows two or more heavy-duty trucks to be "connected" through vehicle-to-vehicle (V2V) communication. The "connected" trucks maintain a close, constant distance, automatically maintaining the gap between the vehicles by controlling the speed, acceleration, and braking of the platooned vehicles. Drivers are still required to steer and monitor the system. Demonstrations of truck platooning systems by Peloton in the United States, and Daimler and Volvo in Europe, confirm that truck platooning systems increase fuel economy, reduce emissions, improve safety, reduce traffic congestion, and assist drivers. In recent tests conducted by the National Renewable Energy Laboratory, using Peloton's technology, the lead truck demonstrated fuel savings up to 5.3 percent while the trailing truck saved up to 9.7 percent.[105]

Platooning is not dependent on any infrastructure changes or federal investment. It is an add-on technology that can be retrofitted where appropriate on the legacy heavy-duty fleet or installed by truck manufacturers. Many successful demonstrations have been performed around the world and many large truck fleets are showing interest. Existing following distance and signal laws are inconsistent among various states and stand as an impediment to adoption of this technology.

In addition to the immediate fuel savings, congestion reduction, and safety benefits attributable to platooning and other driver-assist technologies (i.e., frontal crash avoidance, automatic emergency

98 Small Business & Entrepreneurship Council, "Coalition for Efficient & Responsible Trucking (CERT) Letter to Congress," May 13, 2015.
99 Coalition for Efficient and Responsible Trucking, "LTL Fact Sheet – Frequently Asked Questions."
100 See, e.g., Tom Berg, "Twin 33s Would Be Safer than 28s, U of Michigan Researcher Says," TruckingInfo, April 23, 2014.
101 See, e.g., Retail Industry Leaders Association, "Retailers Back Plan to Allow Twin 33 Truck Trailers," November 18, 2015.
102 Coalition for Efficient and Responsible Trucking, "CERT Speaks on Safety," January 2015.
103 Id.
104 Woodrooffe Dynamics LLC, "Comparative Performance Evaluation of Proposed 33 ft Double Trailers Combinations with Existing 28 ft Double Trailers," April 11, 2011.
105 National Renewable Energy Laboratory, "Transportation Research," May 22, 2015.

braking, lane departure warning, rollover stability control), these technologies are important precursors to fully autonomous vehicles. Congress and the Department of Transportation should establish standards that all states must adopt on the National Highway Freight Network to allow truck owners to invest in platooning technology systems and benefit from the associated fuel savings and safety enhancements.

RECOMMENDATION FOR AVIATION

Increase funding for research and development related to advanced biofuels.

Non-petroleum liquid fuels have gained considerable attention as an alternative for both heavy-duty trucks and commercial airplanes. In particular, synthetic diesel fuels derived from biomass, so-called advanced biofuels, could offer aviation and trucking applications many of the benefits of petroleum fuels—ease of transport, access to existing infrastructure, and high energy density—while eliminating many of the critical drawbacks of oil combustion, including lifecycle greenhouse gas emissions. Moreover, displacement of oil demand in the U.S. economy with domestically produced advanced biofuels would provide the country and national economy with important benefits, including reduced oil imports and corresponding improvements in the trade deficit.

These advanced biofuels are uniquely positioned as the only near-term alternative to petroleum jet fuel, a particular concern given the projected growth of the aviation industry and continued volatility in the price of jet fuel. Jet fuel prices tripled between 2002 and 2012, resulting in jet fuel becoming the largest operational cost for airlines at approximately 30 percent of total costs (Figure 40).[106] Jet fuel prices recently fell on lower global oil prices, but consumption nevertheless accounted for approximately 11 percent of the total petroleum fuel used in the U.S. transportation sector in 2015 and is expected to account for approximately 15 percent by 2040.[107] It is not only the passenger airlines exploring bio-jet fuels. For example, FedEx Corporation, which operates one of the largest civilian aircraft fleets in the world and uses 1.1 billion gallons of jet fuel each year, announced a partnership in July 2015 with Red Rock Biofuels to use 3 million gallons of aviation biofuels.[108]

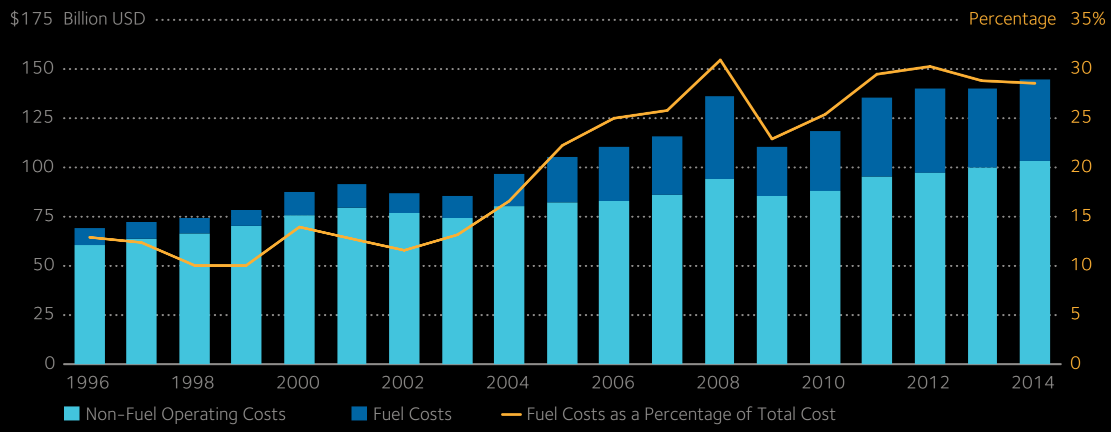
Despite its currently limited use, advanced biofuels hold immense promise. In 2012, Air Canada conducted the first civilian jet flight powered entirely by unblended biofuel, and other tests have followed. The Department of Defense has also assessed advanced biofuel blends—50 percent waste cooking oil and algae oil, and 50 percent petroleum—in a carrier strike group popularly known as the "Great Green Fleet."[109] In fact, tests in the private sector have shown such promise that the aviation industry stated its desire to achieve carbon-neutral growth, with 2020 emissions not to exceed 2005 levels.[110]

While advanced biofuels are a promising alternative to petroleum-based jet fuel, achieving cost parity remains a challenge. One Department of Defense official indicated a potential cost of $150 per gallon for algal fuel produced in small quantities for testing.[111] However, drop-in jet fuel produced at scale with soybeans through the hydro-processed esters and fatty acids (HEFA) process is projected to cost $3.80 per gallon, depending on soybean prices and the co-products produced.[112] Various federal agencies and military branches have instituted agency-wide standards for renewable fuel usage,

106 EIA, "High Airline Jet Fuel Costs Prompt Cost-Saving Measures," June 13, 2012.
107 SAFE analysis based on data from EIA, *Monthly Energy Review*, July 2015, at Table 3.7c; and EIA, *Annual Energy Outlook 2015*, at Table 36.
108 See, e.g., The Denver Post, "Red Rock Biofuels to Power FedEx Jets Under New Contract," July 21, 2015.
109 U.S. Navy, Energy, Environment, and Climate Change, "Great Green Fleet."
110 See, e.g., National Renewable Energy Laboratory, "An Overview of Aviation Fuel Markets for Biofuels Stakeholders," July 2014, at vi.
111 Government Accountability Office, *Alternative Jet Fuels*, May 2014, at 22.
112 See, e.g., Winchester et. al, "Market Cost of Renewable Jet Fuel Adoption in the United States," MIT Joint Program on the Science and Policy of Global Change, January 2013, at 14.

FIGURE 40

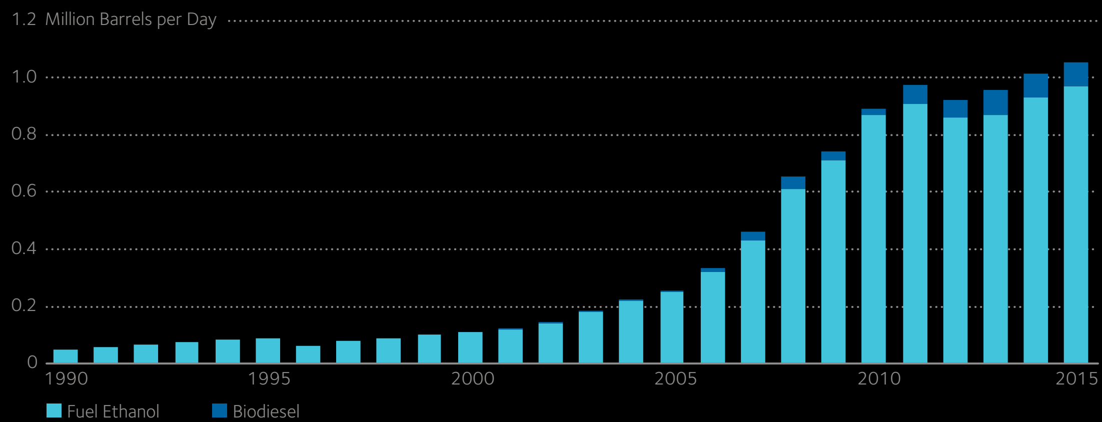
Airline Operating Costs



Source: SAFE analysis based on data from MIT Global Airline Industry Program

FIGURE 41

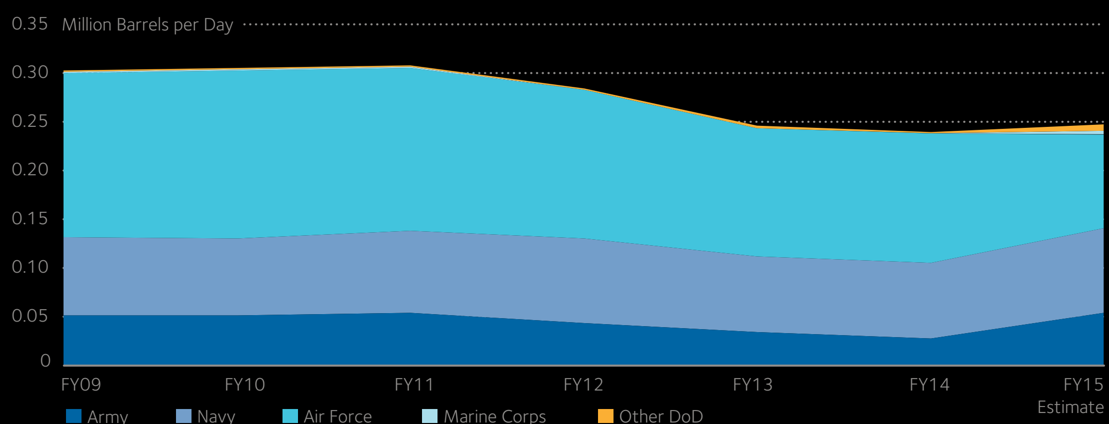
U.S. Biofuels Production, 1990–2015



Source: EIA

FIGURE 42

DoD Operational Energy Demand



Source: Department of Defense, Operational Energy Annual Report, June 2015 particularly renewable jet fuel. The Federal Aviation Administration (FAA) created a target of one billion gallons of alternative jet fuel utilized annually by 2018, while the Navy set a goal of 50 percent of energy consumption from alternative fuels by 2020.[113] The U.S. Air Force has followed suit, and now plans to increase the use of "drop-in alternative jet-fuel blends for non-contingency operations to 50 percent of total consumption by 2025."[114]

Sourcing biomass in close proximity to refineries (within 50 miles), when possible, can significantly reduce costs.[115] Aviation biofuels hold additional promise due to the fact that they are compatible with the infrastructure that is already in place for conventional aviation fuels.[116] Since the infrastructure already exists, the next step is for airlines to introduce the fuels into the supply chain. The first example of this introduction on a commercial basis happened recently with a partnership between United Airlines and AltAir Fuels to deliver 5 million gallons of bio-based jet fuel each year for flights traveling between Los Angeles and San Francisco.[117] AltAir Fuels began regular deliveries of its biofuels to United Airlines in March 2016.[118]

Research and development could have a significant impact on production and production costs. Currently, conversion efficiency ranges from 25 to 50 percent, which translates to producing between 46 and 64 gasoline gallon equivalent (gge) per dry ton of feedstock.[119] Increasing efficiency relies on improving process catalysts and streamlining process configurations. Enhancing efficiency particularly impacts capital costs, as improvements in efficiency are expected to help decrease these costs by an estimated one percent annually through 2050.[120] Economies of scale are also necessary to reduce capital costs. The FAA, Department of Defense, and Department of Energy all support research and development activities related to economic and environmental evaluation, as well as testing. In fact, it is estimated that the Department of Defense has generated 80 percent of the testing data needed for the certification of previous production pathways.[121]

Aviation biofuels hold additional promise due to the fact that they are compatible with the infrastructure that is already in place for conventional aviation fuels.

Given the potential benefits of biofuels in aviation, the Council recommends the federal government support the accelerated development of advanced biofuels, particularly in terms of identifying low-cost pathways to deploy hydrocarbon substitutes from non-food crop feedstocks. The Plants Engineered to Replace Oil (PETRO) program at ARPE-E awarded $46.1 million to such projects since 2012, and DOE's Office of Energy Efficiency and Renewable Energy was appropriated more than $225 million in FY 2015 for research, development, demonstration, and deployment (RDD&D) related to advanced biofuel feedstocks and conversion processes.[122] While these funds are significant, the Council recommends funding be increased by a factor of two.

113 Government Accountability Office, *Alternative Jet Fuels*, May 2014, at 10-11.
114 Id., at 12.
115 Government Accountability Office, *Alternative Jet Fuels*, May 2014, at 25.
116 See, e.g., National Renewable Energy Laboratory, "An Overview of Aviation Fuel Markets for Biofuels Stakeholders," July 2014, at 30.
117 See, e.g., Chelsea Harvey, "United Airlines is Flying on Biofuels. Here's Why That's a Really Big Deal," Washington Post, March 11, 2016.
118 See, e.g., International Air Transport Association, "IATA 2014 Report on Alternative Fuels," December 2014; and Fueling Growth, Mary Solecki, "AltAir Fuels to Produce Renewable Jet Fuel for United."
119 National Research Council, *Transitions to Alternative Vehicles and Fuels,* March 2013, at 48.
120 Id.
121 Government Accountability Office, *Alternative Jet Fuels*, May 2014, at 27.
122 Office of Energy Efficiency and Renewable Energy, "Bioenergy Technologies Office FY 2016 Budget At-A-Glance," March 2015.

RECOMMENDATION FOR AVIATION

Permit the Department of Defense flexibility in purchasing advanced fuel and vehicle technologies.

The Department of Defense (DoD) can play an important role in supporting the development of advanced fuel and energy technologies. Such a role is justified from at least two perspectives. First, DoD faces unique incentive structures in evaluating cost effectiveness; energy systems that reduce exposure to enemy combatants, for example, can vindicate higher costs. Second, DoD can serve as a technology incubator given its significant purchasing power and its need to provide the armed forces with the most advanced technology possible to maintain U.S. strategic advantages.

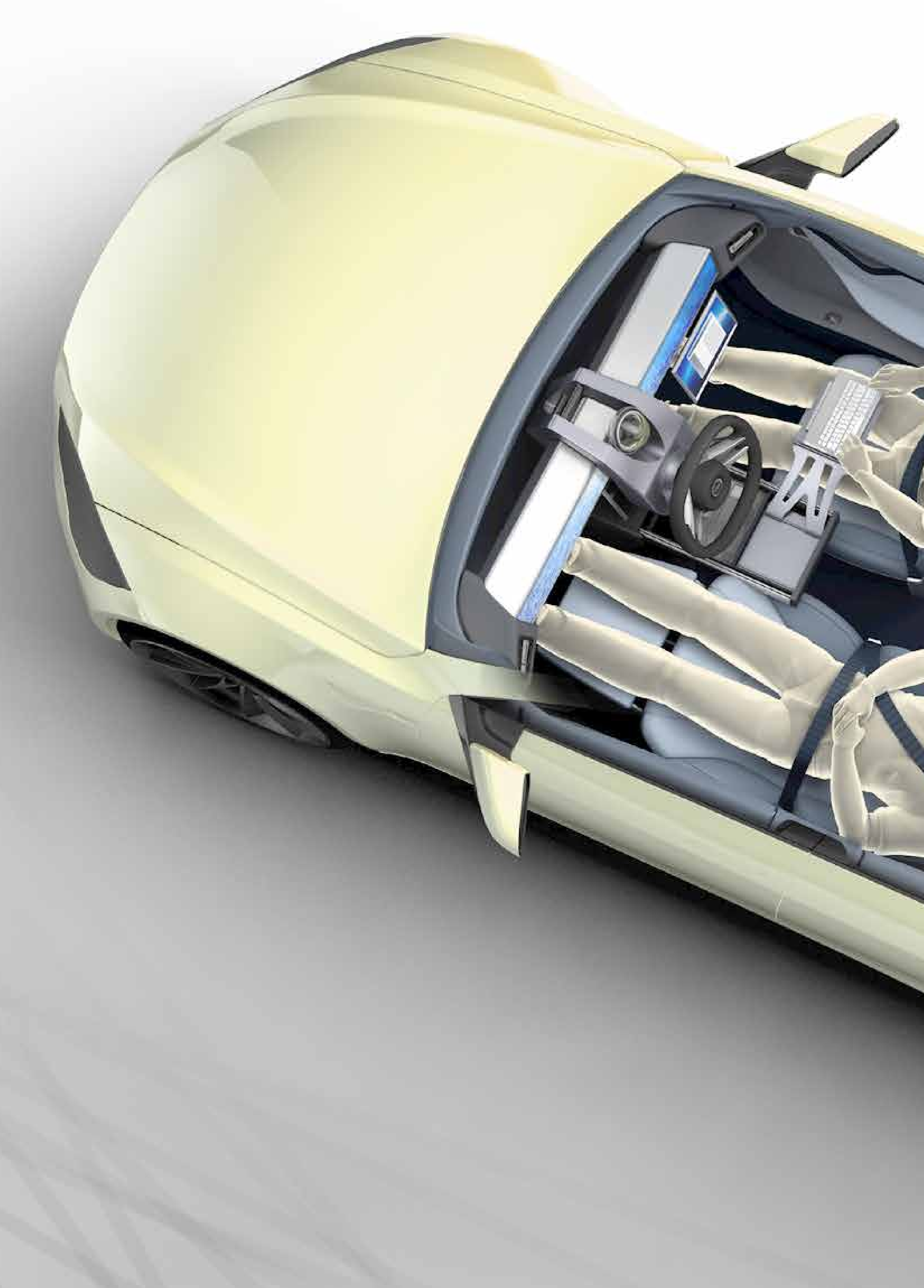
The total cost of delivering diesel fuel to operate power generators at forward operating bases is more than the base cost of the commodity. The total cost is referred to as the fully-burdened cost of fuel. This cost can reach up to $400 per gallon for use at forward operating bases in places like Afghanistan, according to Pentagon officials.[123] This fuel price alone allows DoD to consider a larger range of more expensive alternatives than typical consumers—such as generators operated by distributed energy sources—even strictly from an economic perspective. Of course, economics is often not the military's sole, or even primary, justification for adopting various energy technologies. Minimizing the length of fuel supply lines in combat zones reduces risks to troops.

Nonetheless, all efforts to promote fuel diversification must prioritize fuels that in some way enhance DoD capabilities or reduce tactical or non-tactical costs. Investments in highly-efficient or advanced technology vehicles, such as those powered by electricity, can be appropriate. In FY 2014, the DoD operated approximately 176,000 non-tactical cars and trucks, which consumed a reported 74 million gallons of petroleum fuels at a cost of $200 million.[124] Replacing these vehicles with more cost-effective platforms could yield significant budget savings.

Moreover, the Defense Logistics Agency is currently permitted to purchase ethanol at prices that exceed the price of conventional fuels. This exemption should be extended to advanced biofuels and any other advanced fuel. To mitigate the risk of imprudent investments, the exemption should be modified for all fuels to apply only when the supplier submits a credible plan for achieving competitive pricing during the term of the contract.

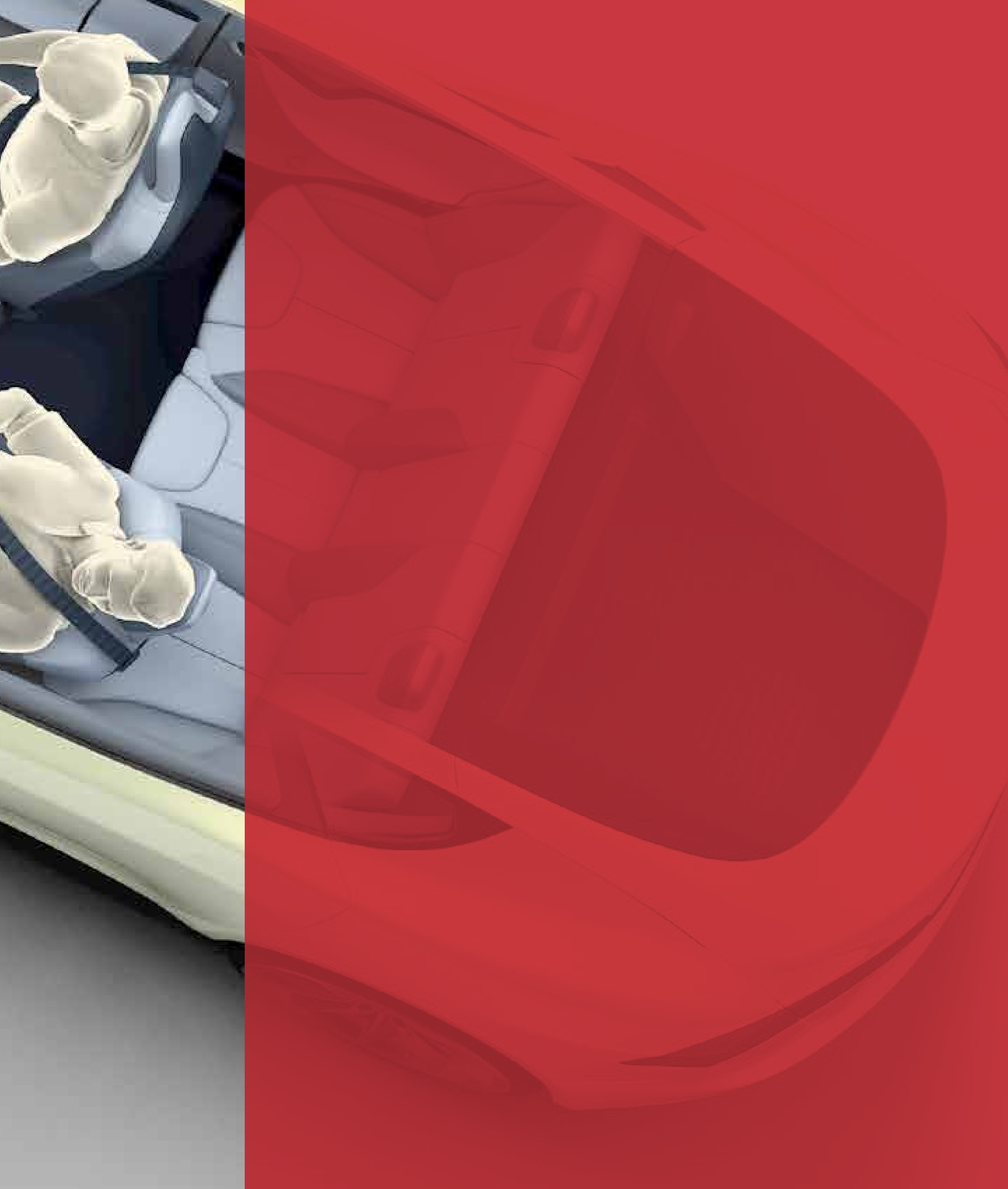
The DoD should also be given the flexibility to participate in public-private alternative fuel-purchasing consortia at the national or regional level. A purchasing consortium could provide significant long-term certainty to advanced biofuels producers, scaling up the supply chain and driving down costs. This kind of industry "best-value" approach is not workable today, as current procurement policy requires that the DoD issue a request for proposal and separate source selection (choosing of a government contractor through a competitive negotiation period).

123 Lockheed Martin, "Fuel Cell Technology Offers a More Efficient Solution for DOD's More Than 100,000 Generators," November 3, 2015.
124 General Services Administration, "FY 2014 Federal Fleet Report Open Data Set," March 31, 2015, at Tab 1.1.; and DoD, "Annual Energy Management Report", Fiscal Year 2014, May 2015, at 17.; and Department of Defense, "Operational Energy Annual Report", Fiscal Year 2013, October 2014, at 12.



PART II

Advancing the Next Generation of Transportation Technology



Advancing the Next Generation of Transportation Technology

In the last few years, autonomous and connected vehicles have emerged as a technology with the potential to spur enormous social change. Public interest has grown steadily since late 2010, when Google first publicly disclosed its self-driving car project, and grew dramatically during 2015.[1] Autonomous vehicles are stoking the public's imagination by offering the promise of hassle-free, more productive travel, increased safety, broader access to mobility options for underserved populations, and other benefits.

Additionally, autonomous vehicles offer enormous potential energy security benefits.[2] The widespread availability of autonomous vehicles would trigger the greatest revolution in transportation since the invention of the automobile. Specifically, autonomous technology represents an opportunity to fundamentally reshape the transportation system, and mobility more generally, by eliminating inefficiencies in how vehicles are owned, used, sized, and fueled.

Change will not be easy or proceed in a predictable fashion. The vast expanse of the U.S. transportation system, with its hundreds of millions of vehicles and millions of miles of roads, will resist rapid transformation. Entrenched consumer behaviors, the unpredictable evolution of technology, and the limitations of policy levers inhibit the ability to project with full confidence the impact and trajectory of autonomous vehicles. Still, the inefficiencies of the current system and the potential for autonomous vehicles to offer significant and rapid improvement merits vigorous effort from society and policymakers to realize their full potential.

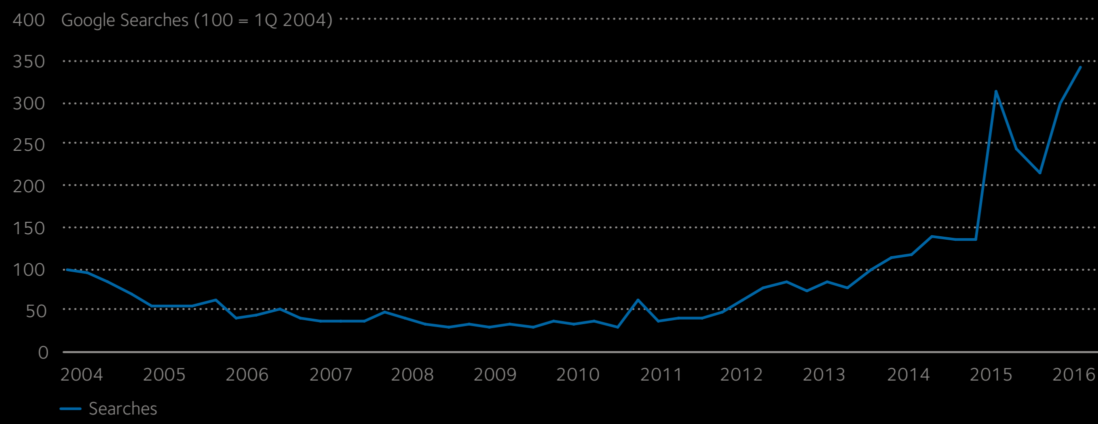
SAFE modeling demonstrates that economic realities are likely to encourage the rapid adoption and heavy utilization of shared, autonomous vehicles once they are available. Although shared, autonomous vehicles will likely induce greater demand for travel, modeling shows that the vast majority of such vehicles will be advanced fuel vehicles (AFVs) (Figure 44), and therefore petroleum use will decline substantially.[3] The availability of shared, autonomous vehicles should encourage accelerated adoption of AFVs which share design synergies and are a more economic choice for heavily utilized vehicles. These factors have the potential to drive transportation oil use from current levels of over 11 million barrels a day to under 4 million barrels a day by 2040, even as road travel increases by 30 percent.[4]

Although autonomous vehicles will generate substantial benefits, there are several obstacles that could slow deployment. While significant technological development is still required for deployment, regulatory risk remains the largest unknown factor: existing rules governing motor vehicles generally do not contemplate autonomous vehicles. This could dramatically slow or even prevent marketplace innovation of autonomous technology. Urgent action is required at all levels of government to ensure that private-sector research, development, and deployment does not needlessly lag as a consequence of inadequate or obsolete regulation.

1 Note: Public interest is measured by volume of Google searches (Figure 43).
2 Note: For brevity, the term "autonomous vehicle" is used to refer to vehicles with both autonomous and connected capabilities.
3 SAFE modeling assumes that shared, autonomous vehicles are available from 2019.
4 SAFE modeling.

FIGURE 43

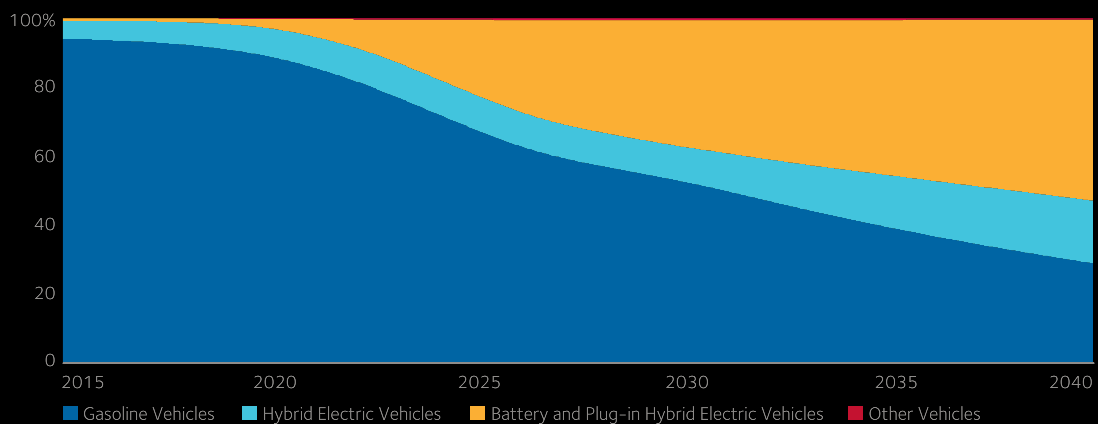
Public Interest in Autonomous Vehicles



Source: Google Trends

FIGURE 44

Light Duty Fleet Composition with Shared, Autonomous Vehicles

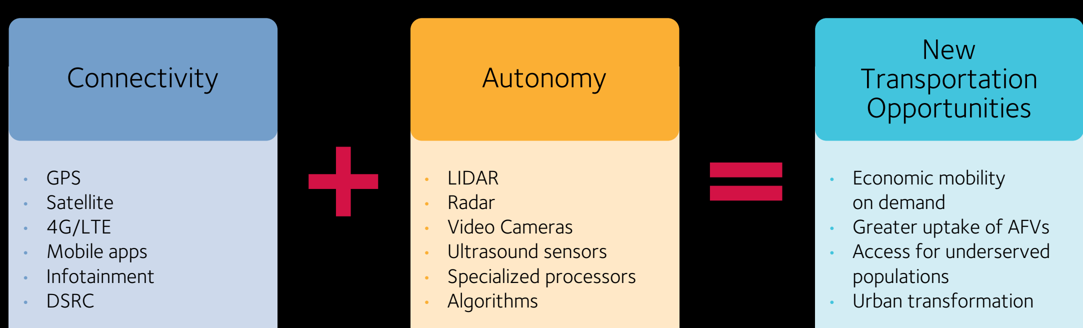


Note: Model assumes supportive policy environment for AFVs.

Source: SAFE modeling

FIGURE 45

Connected and Autonomous Technologies Work in Concert



Source: SAFE analysis

Autonomous Vehicles and AFVs

Under current conditions, the adoption of AFVs will continue to be incremental. The Energy Information Agency currently projects continued slow adoption of EVs and other AFVs. In essence, AFVs do not yet offer most consumers a sufficiently compelling value proposition.[5] Given the realities of well-established consumer preferences in the United States, even a rapid decrease in the cost of advanced fuel technologies might not spur significant increases in adoption.

In important ways, the strategic value of autonomous vehicles is the mirror image of AFVs. The autonomous vehicle technology platform is intrinsically neutral in terms of fuel type, but, based on a compelling consumer value proposition, it offers the most significant opportunity to reshape personal transportation since the invention of the automobile.[6]

The current transportation system is vastly inefficient. For example, on average only 4 percent of household vehicles are in use at any given time, and peak utilization is about 11 percent.[7] The vast majority of vehicle trips take place with just one or two passengers onboard and several empty seats. Limited road infrastructure leads to system congestion and wasted time and fuel. More fuel and space is wasted in the search for parking, which also contributes significantly to urban congestion.[8] Most of the fuel burned in motor vehicles is lost to friction and engine inefficiencies; even the fuel converted to forward motion is mostly used to propel the vehicle and not the passengers riding inside. On average, only 1 percent of the energy in gasoline is used to move passengers.[9] Generally speaking, time spent driving vehicles, especially when commuting for work, is unproductive compared to time in an office, at home, or as a vehicle passenger.

Autonomous vehicle technology can address these inefficiencies while also providing safe, reliable, and on-demand transportation. This shift would change the economic calculus of personal vehicle ownership, choice of transportation mode, and vehicle technology platforms.[10] Driven by compelling consumer benefits across multiple areas, the rapid adoption of autonomous vehicles powered by electricity and other fuels would set the stage for a rapid decrease in oil consumption.

However, even with a compelling economic rationale and consumer value proposition, the need for further technological development and the lack of a regulatory framework will delay the transition to autonomous vehicles.[11] Given the potential for significant energy security benefits, removing regulatory obstacles preventing the deployment of autonomous vehicles should be a priority for policymakers and regulators.

"Think big, start small, scale quickly" should be the guiding principle used to inform both commercial endeavors and public policy on autonomous vehicles.[12]

> **Think Big.** Energy security benefits do not accrue incrementally with the deployment of autonomous vehicles, but result from a broad transformation of the transportation system. Governments should adopt flexible policies and remove obstacles to autonomous vehicle innovation.

5 EIA, *Annual Energy Outlook 2015*.

6 Lawrence Burns, et al., "Transforming Personal Mobility," The Earth Institute, January 27, 2013.

7 Id.

8 Donald Shoup, "Cruising for Parking," 2006.

9 SAFE analysis.

10 James M. Anderson, et al., *Autonomous vehicle technology: A guide for policymakers,* January 2014.

11 DOT, "Secretary Foxx Unveils President Obama's FY17 Budget Proposal of Nearly $4 Billion for Automated Vehicles and Announces DOT Initiatives to Accelerate Vehicle Safety Innovations," January 2016; and Tao Jiang et al.,"Self-Driving Cars: Disruptive or Incremental?," Applied Innovation Review, Issue 1, June 2015.

12 SAFE interview with Lawrence D. Burns, March 2016.

Start Small. One of the lessons of early deployment efforts for EVs is that deployment is best stimulated through targeted, local efforts to install necessary infrastructure such as charging stations.[13] Therefore, initial consumer deployment of autonomous vehicles should occur within a limited number of deployment communities. This will build comfort with the technology, demand for further deployment, and political support for necessary actions.

Scale Quickly. An iterative policy framework should be established to promote rapid scaling of autonomous and connected transportation systems incorporating the lessons of early deployment trials. This will allow governments to avoid the difficult task of regulating pre-commercial technologies.

Autonomous and Connected Vehicles

Autonomous vehicle technology does not intrinsically reduce petroleum usage, but can promote greater efficiencies in the transportation system through higher utilization and better aligning supply and demand; this transformation, in turn, promotes the usage of more efficient vehicles and those with advanced propulsion technologies.

Public discussion of autonomous vehicles often conflates the "autonomous" and "connected" aspects of the technology.[14] While these technologies are highly complementary and have the greatest impact when working in concert, each technology set has a distinct boundary and raises an independent set of issues. A car can be highly connected without being autonomous, and the reverse can be true as well.[15]

Connected Vehicle Technology

Connected vehicles are collectively enabled by a broad range of communication technologies. Satellite connectivity is used for GPS devices, for satellite radio entertainment, and for emergency connectivity through programs such as OnStar. On-vehicle cellular connections are used to create "hot spots" for vehicle passengers and, in the case of at least one OEM, download software upgrades to improve the car's capabilities. Control over connected vehicle content, bandwidth, and software is a relatively mature, competitive market which is projected to be worth $47 billion by 2020.[16]

Connectivity plays a key role in integrating individual vehicles into the broader transportation system and enables a shift to "transportation as a service."[17] Connected vehicle technologies allow for real-time traffic updates, which enables more efficient routing. Information about vehicles is already transmitted to manufacturers, consumers, and fleet managers, allowing more effective maintenance and fuel consumption management. On-demand ridesharing, such as by Uber and Lyft, is facilitated by connected technology.

Two prominent connected vehicle technology platforms are vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I), collectively called V2X. V2X uses transponders installed in vehicles and key infrastructure to enable communication between elements of the transportation system, preventing crashes and enabling more efficient traffic flow. Thus far, the development of these technologies has primarily focused on safety applications, such as alerting a driver to the presence of other cars at a blind intersection. It uses Dedicated Short Range Communications, a wireless communications technology. At present, there is little commercial deployment of V2X technology in the United States. Since two cars on a collision trajectory would both need to be equipped with V2V for it to be effective, V2X will be most impactful once a significant percentage of vehicles are equipped with the technology. This reasoning has led NHTSA to begin the process of mandating that all new vehicles be equipped with V2V

13 IEA, *EV City Casebook: A Look at the Global Electric Vehicle Movement,* 2012.
14 Jeffrey Zients and John P. Holdren, "American Innovation in Autonomous and Connected Vehicles," December 2015.
15 J.D. Glancy, "Autonomous and Automated and Connected Cars-Oh My: First Generation Autonomous Cars in the Legal Ecosystem," *Minn. JL Sci. & Tech.*, 16, 619, 2015.
16 Markets and Markets, "Connected Car Market worth $46.69 Billion by 2020," 2014.
17 Sampo Heitanen, "Mobility as a Service – the new transport model?" Eurotransport, Volume 12, Issue 2, 2014.

equipment, likely by the early 2020s.[18] Because of its significant applications, and the high stakes of the rulemaking process, some consider V2X technology to be synonymous with "connected vehicles."[19]

V2V based on short-range communication in the 5.9 GHz band differs from other connected vehicle technologies due to its low "latency" or ability to exchange messages with very short lag time (several milliseconds). This feature positions V2X technology for important uses, such as preventing crashes, particularly those resulting from vehicles that are not in each other's direct line of sight, and vehicle platooning, which will improve fuel efficiency. V2V and sensor-based approaches to autonomy are complementary and will likely be pursued in concert to maximize safety and other benefits.

One unresolved issue is whether the spectrum band for this technology can be opened up for sharing with unlicensed devices such as Wi-Fi without degrading V2X performance and endangering the important benefits offered by V2X.[20] Efforts are ongoing to develop and test a method for robustly sharing the band while maintaining the integrity and reliability of V2X.

Autonomous Vehicles

Discussion of autonomous vehicle technology uses a broad range of descriptive terms, including "autonomous vehicles", "self-driving cars", "robocars", and "highly automated vehicles."[21] NHTSA has established a 5-level definition for "automated vehicles", ranging from level 0 ("no automation") to level 4 ("Full Self-Driving Automation").[22] Generally speaking, "automation" refers to machines that independently "step through pre-determined processes," even if they utilize highly sophisticated algorithms. An "autonomous" machine has a "broader sense of self-determination than simple feedback loops" and "incorporates a panoply of ideas imported from artificial intelligence and other disciplines."[23]

Certain vehicle functions have been automated for decades such as cruise control and anti-lock brakes.

A vehicle is "automated" if some of its functions can be conducted without human input. These functions are considered "automated" and a car with automated features is an "automated car" (NHTSA Levels 1-2). Vehicles with high degrees of automation, usually combining the automation of several driving features, begin to take over much of the driver's role. These vehicles are "highly automated" or "partially autonomous" cars (NHTSA Levels 2-3). "Autonomous vehicles" or "self-driving vehicles" are capable of fully taking over for the driver, letting the driver disengage, or not be present in the car (NHTSA Level 4). It is possible for a vehicle to function as an autonomous vehicle under some circumstances, and as a partially autonomous vehicle under others. The Society of Automotive Engineers has created its own autonomous vehicle classification system with a special category for a vehicle that can always operate autonomously.[24]

Certain vehicle functions have been automated for decades (such as cruise control and anti-lock brakes).[25] Relatively new entrants to the auto industry have been influential. Google began its autonomous vehicle work in 2009, and as of March 2016, the company has "driven" more than 1.5 million miles in autonomous mode on public roads.[26] Tesla Motors has provided a suite of automated features known as "Autopilot," which enable almost completely autonomous highway driving if necessary conditions are met.[27]

18 National Highway Traffic Safety Administration, *Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application,* 2014.
19 KPMG and Center for Automotive Research, *Self-Driving Cars: The Next Revolution,* July 2012.
20 Global Automakers, "Safety Benefits of Connected Vehicles."
21 Wikipedia, "Autonomous Car," March 2016.
22 National Highway Traffic Safety Administration, "Preliminary Statement of Policy Concerning Automated Vehicles," 2013.
23 Martin Ford, *Our Robots, Ourselves,* 2015.
24 SAE International, "Automated Driving," January 2014.
25 Royal Automobile Club of Victoria, *Effectiveness of ABS and Vehicle Stability Control Systems, 2004.; Teetor, Ralph, Patent US2519859 A: Speed control device for resisting operation of the accelerator,* 1950.
26 Google, "Google Self-Driving Car Project Monthly Report March 2016," April 2016.
27 Tesla Motor Company, "Model S Software Version 7.0."

Automotive companies have not ignored this important trend. Most have announced autonomous vehicle development activities, although they differ in whether they are aiming for "full automation" where the driver is rendered unnecessary, or using autonomous technology as a "backup driver" to improve safety and reduce accidents.[28] Some automakers are also experimenting with new business models such as ridesharing and other mobility-on-demand services, while others believe that personal vehicle ownership will remain the near-exclusive paradigm for decades to come.[29]

Growing commercial interest in autonomous vehicles can be seen through the increased generation of intellectual property, especially by the private sector. This is reflected in the soaring rates of patent applications related to autonomous driving (Figure 46).[30] Additionally, the last few years have seen considerable startup activity in automotive technology, a space historically viewed as inhospitable to venture capital.[31] Taken together, these trends indicate that companies active in the autonomous vehicle space and the funders who perform due diligence on investments in early-stage technology are increasingly confident in the future of autonomous vehicle technology.

As autonomous vehicle technology matures, related regulatory and legislative activity is accelerating. In 2011, Nevada became the first state to pass a law regulating autonomous vehicles. As of March 2016, 33 states had considered legislation related to self-driving cars; laws have been enacted in four states and the District of Columbia (Figure 57).[32] In 2013, NHTSA adopted a preliminary policy framework and plans to issue guidance on deploying autonomous cars in mid-2016.[33] DOT and NHTSA have signaled potential flexibility in allowing autonomous vehicles on the road, and have identified key issues with the current Federal Motor Vehicle Safety Standards (FMVSS) that need to be resolved.[34] The state of California began the process of regulating autonomous vehicles for testing in 2012, with finalized regulations for the commercial deployment of these vehicles expected sometime in 2016. To date, officials in Sacramento have declined to create a path towards the certification of autonomous vehicles and proposed prohibiting the operation of an autonomous vehicle without a licensed driver in the vehicle.[35] California's position has raised concerns that a patchwork of incompatible regulations may emerge and underscores the need for the federal government to play a leading regulatory role.

New Mobility Options: The Next Few Years

The traditional trajectory of new technology adoption in the light-duty vehicle market is through the gradual adoption of features, first in luxury vehicles and gradually diffusing to less costly models. The product cycle for a vehicle model is five to seven years. Together, these trends usually mean that new technologies take several decades to penetrate across the entire fleet.

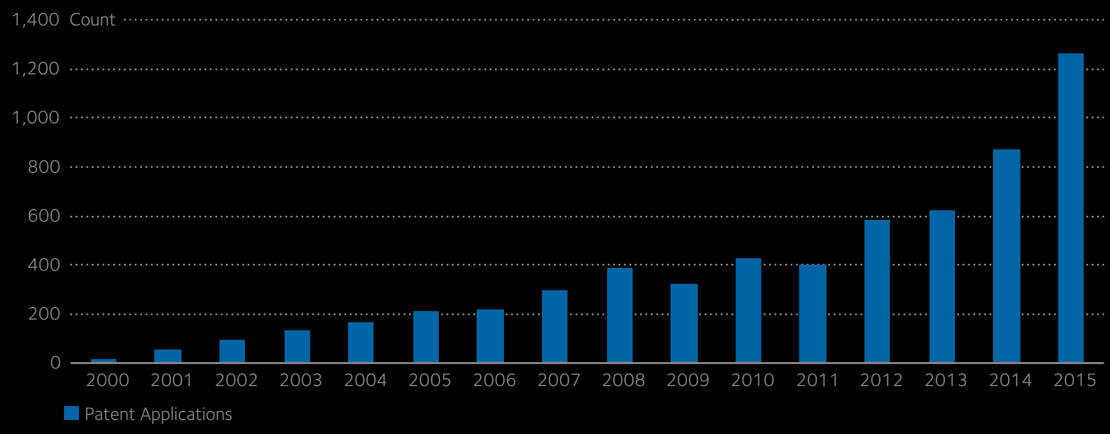
One potential deployment trajectory for autonomous vehicles is the "Iterative Autonomy" paradigm. The current generation of vehicles has significant uptake of automated features such as automatic emergency braking (AEB), adaptive cruise control (ACC), and lane keeping assist (LKA). The next generation will have more advanced autonomous features, and, in a number of product generations, full autonomy would be possible.

The second potential autonomous vehicle deployment trajectory is not evolutionary through Iterative Autonomy, but rather "revolutionary" by including the introduction of fully autonomous vehicles immediately. Even if it is not feasible in the near future to deploy fully autonomous vehicles on all roads

28 General Motors, "GM to Acquire Cruise Automation to Accelerate Autonomous Vehicle Development"; and Toyota, "Transcript: 2016 Consumer Electronics Show (CES) Press Conference," April 2016.
29 Nathan Bomey, "Ford forms 'smart mobility' division," March 2016; and Daimler Mobility Services.
30 Thomson Reuters, *The 2016 State of Self-Driving Automotive Innovation*, 2016.
31 Dustin Walsh, "When the Motor City becomes Startup City," January 2015.
32 Stanford Center for Internet and Society, "Automated Driving: Legislative and Regulatory Action."
33 National Highway Traffic Safety Administration, "Preliminary Statement of Policy Concerning Automated Vehicles," 2013.
34 David Shepardson, "U.S. regulators could waive some safety rules for self-driving cars," January 14, 2016; and Kim, Anita et al., Review of Federal Motor Vehicle Safety Standards (FMVSS) for Automated Vehicles, March 2016.
35 Mike Ramsey and Alistair Barr, "California Proposes Driverless-Car Rule," December 2015.

FIGURE 46

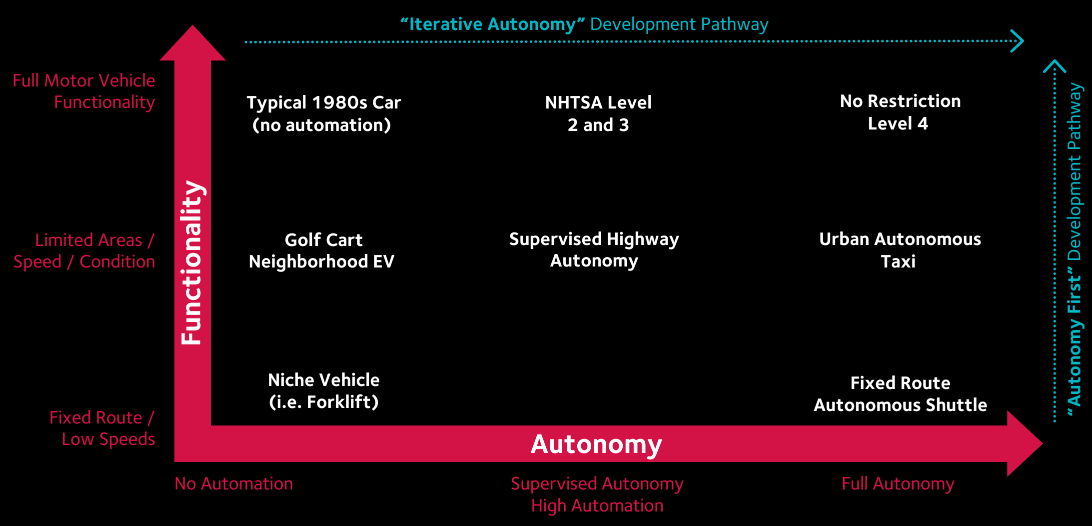
U.S. Autonomous Vehicle Patent Applications



Source: SAFE and Ryan Koppelman (Alston & Bird LLP) analysis

FIGURE 47

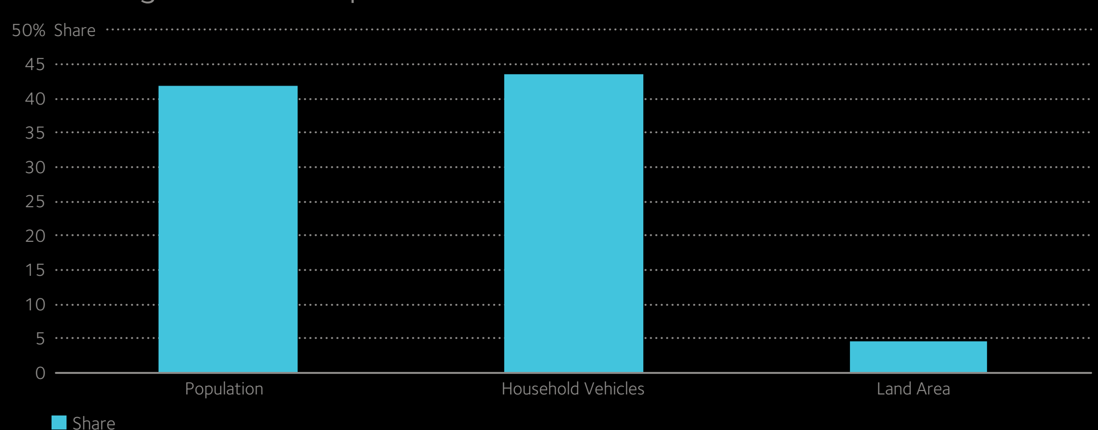
Autonomous Vehicle Development Trajectories



Source: SAFE analysis

FIGURE 48

Concentration of Population, Vehicles, and Land in the Largest 25 Metropolitan Areas



Source: SAFE analysis based on data from Census Bureau and in all conditions without human supervision, this does not mean that the vehicles should not be deployed at all. Instead, deployment of fully autonomous vehicles may occur in limited areas and with limited functionality, such as lower maximum speeds. A likely initial deployment would be in areas such as private developments, limited-access highways or, more ambitiously, an urban core where most traffic flows slowly. Vehicles could be deployed initially in cities with more favorable climates if, for example, the technology to handle autonomous driving in snow requires further development.[36] As the technology improves, more and more areas will be made accessible to autonomous vehicles. Eventually, autonomous vehicles will be able to navigate nearly any road at any time and at any lawful speed with virtually no human supervision. The "Autonomous First" paradigm deploys autonomous vehicles in the areas and under the conditions in which they can operate safely, without waiting for autonomous vehicles to work everywhere.

The two potential autonomous vehicle deployment trajectories are illustrated in Figure 47. The vertical axis represents the range of transportation tasks that a vehicle can execute. Vehicles lower on this axis cannot travel at full speed or may be unable to operate on certain roads or under certain conditions. The horizontal axis represents increasing automation. The Iterative Autonomy approach gradually increases the autonomy of today's cars until they are fully autonomous. The Autonomy First approach takes today's state-of-the-art autonomous vehicles, which are limited in their functionality, and gradually broadens the operating domain in which they can safely operate.

The Iterative Autonomy approach will take significant time given the slow pace of implementing a new technology across a manufacturer's product line. Additionally, even a partially autonomous vehicle will require a driver at all times, as their autonomous functions will not be robust enough to eliminate the driver. Consequently, private household ownership of multiple vehicles and the use of the oil-dependent internal combustion engine will likely remain the dominant paradigm for the foreseeable future under the Iterative Autonomy pathway.

The Autonomy First approach would build upon some of the fully autonomous vehicles that are currently in use or nearing deployment, traveling fixed routes or in geographically limited areas. These vehicles would then be deployed commercially at a neighborhood or city level. Because preparing an area for the deployment of autonomous vehicles will be resource-intensive, likely requiring the preparation of expensive high-definition maps and careful coordination with local officials, small scale deployment is a likely initial scenario. This approach can reach many Americans rather quickly, however—the 25 most populous metropolitan areas contain 42 percent of the population and 44 percent of vehicles, even though they represent just 5 percent of U.S. land area (Figure 48).

Both of these approaches offer societal benefits, and the market will ultimately guide the progression to fully autonomous vehicles; both may co-exist for some time. The Autonomous First pathway, however, offers a more immediate route to the benefits of autonomous vehicles. However, it is more difficult to implement from a legal, regulatory, and according to some, technological perspective, as it would represent a significant departure from current vehicle functionality. A broad range of national, state, and local level regulations would need to be altered or streamlined to allow for this deployment trajectory. These changes will be discussed later in this section.

Heavy-Duty Truck Automation

The freight industry will likely be an important early adopter of autonomous vehicle technology. Most freight transportation occurs on limited-access roads such as the Interstate Highway system, which presents a less complex environment than urban roads. This reduces the technical requirements to provide high degrees of automation; much of the necessary technology to support basic highway

36 Note: According to Lawrence D. Burns, about one half of the world's vehicles never encounter snow during their operational lifetime.

automation is already available.[37] In 2013, heavy trucks consumed 22 percent of U.S. petroleum usage, even though they represented only 9 percent of highway travel (Figure 49) and 4 percent of the vehicles on the road.[38] Additionally, freight vehicles are often managed in large fleets by owners who are highly sensitive to economic efficiencies at the vehicle level—and automation provides significant opportunities to save on fuel, time, and labor costs.[39] Perennial driver shortages, increasing demand for freight shipment, and pressure to reduce costs will incentivize fleet owners to rapidly adopt autonomous technology once it becomes economically rational to do so.

One early application of automation that has already seen significant on-road testing is platooning, where two or more trucks closely follow each other to reduce fuel normally lost to aerodynamic drag for both vehicles, with the trailing truck enjoying an efficiency boost of 10 percent in some cases.[40] Extensive on-road trials of platooning are ongoing.[41] In addition, highly automated trucks are being tested in both the United States and Europe.[42]

Autonomous Vehicles and Energy Transformation

The impact of autonomous vehicles on energy usage likely will happen in two phases. In the first wave, additional autonomous capabilities will impact vehicle energy consumption—both positively and negatively. In the second wave, significant market penetration of autonomous vehicles will allow for changes in vehicle design, performance specifications, and ownership patterns. At this point, the first wave effects will deepen as well. Collectively, these changes will have a deep impact on the energy use profile of the transportation sector. Some developments will promote efficiency, but there is also the potential to increase travel, as well promote less efficient driving patterns.[43] If autonomous vehicles can drive the rapid adoption of electric vehicles, that will be more important than any other factor, reducing petroleum dependence by as much as 75 percent.[44] Under all cases, however, autonomous vehicles likely will reduce oil intensity and generate significant economic gains. Figure 50 captures some of the efficiency-related impacts of vehicle autonomy and the range of potential impact. It focuses mainly on shifts in individual autonomous vehicle energy use, rather than systemic impacts.

First Wave Impacts

- Mitigation of congestion through improved traffic flow and reduced accident frequency (accidents cause congestion and fuel waste). This effect has begun with connectivity (better traffic directions), but will accelerate with autonomous vehicles.

- Smoother braking/acceleration and other driving maneuvers leading to reduced energy consumption. This impact results from high degrees of automation (e.g. highway autonomy) and accelerates with autonomous vehicles.

- Vehicles may be allowed to safely follow one another at short distances, reducing fuel losses to air resistance, increasing highway throughput, and reducing congestion. This is already feasible and may be further enabled by high degrees of automation, such as highway autopilot. Early adoption of this practice is being closely studied in the freight system.

37 Reuters, "Daimler's self-drive trucks are going to be tested in Nevada," May 6 ,2015; and Roland Berger, "On the road toward the autonomous truck," January 2015.

38 Oak Ridge National Laboratory, *Transportation Energy Data Book, Edition 34*; and Federal Highway Administration, *Freight Management and Operation.*

39 David Morris, "In trucking, a little automation saves a lot of money," May 2015.

40 Peloton Technologies, "How It Works."

41 Christoph Sommer and Falko Dressler, *Vehicular Networking,* Cambridge University Press, 2015.

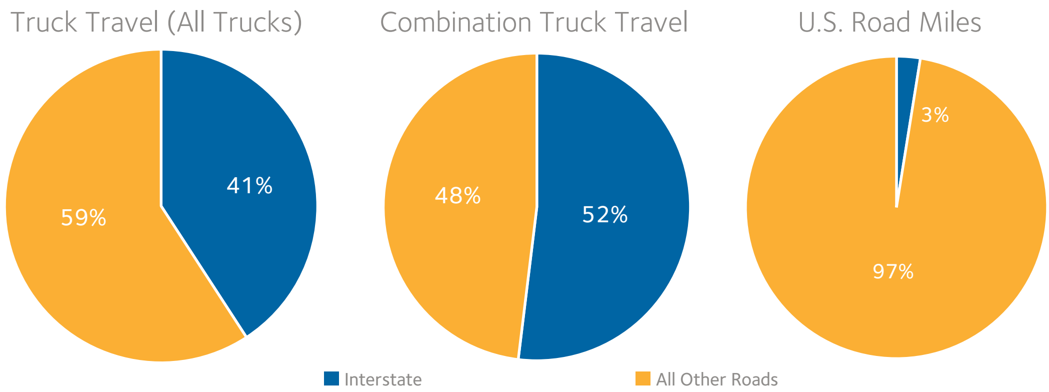
42 Reuters, "Daimler's self-drive trucks are going to be tested in Nevada," May 2015.

43 Austin Brown, J. Gonder, and B. Repac, "An analysis of possible energy impacts of automated vehicles," *Road Vehicle Automation,* at 137-153, Springer International Publishing, 2014; and Z. Wadud, D. MacKenzie, and P. Leiby, "Help or hindrance? The travel, energy and carbon impact of highly automated vehicles," *Transportation Research Part A: Policy and Practice,* 2016.

44 Austin Brown, et al., 2014.

FIGURE 49

Highway Usage by Trucks



Source: SAFE analysis based on data from FHWA

Second Wave Impacts

- As accidents become less common, vehicle weights could safely decrease, improving fuel efficiency.
- As humans spend less time in control of the driving experience, consumers may be more likely to purchase cars that are optimized for fuel efficiency.
- As autonomous vehicles become more common, they may be allowed to travel at higher maximum speeds on freeways, reducing fuel efficiency.

Transformational Impacts

The previous section discussed how vehicle efficiency may evolve as autonomous vehicles are deployed. These changes focused on the efficiency of a single vehicle. However, most of the opportunity for altering energy usage resides in the potential for autonomous vehicles to transform the transportation system.

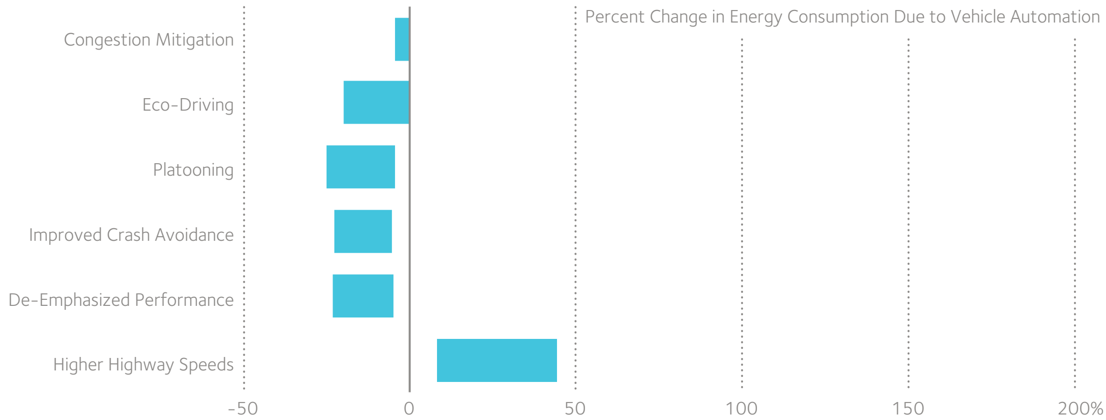
Today, personal vehicle ownership is the dominant transportation paradigm. In 2014, over 90 percent of U.S. households owned (or leased) a vehicle, and the average household owns 1.75 cars. Car ownership is even higher outside the dense cities where few viable alternatives to personal ownership exist.[45] The convenience of using a single vehicle for multiple purposes motivates individuals to make purchasing decisions based on their most intense use case (e.g. purchasing a high-powered SUV for the few times a year it is used to haul a boat and using it primarily for a short commute); 53 percent of light-duty vehicle sales in early 2015 were either SUVs or pickup trucks.[46] Vehicles typically carry enough fuel for over 300 miles of driving, even though the average vehicle trip is under 10 miles, and the average vehicle travels less than 30 miles in a day.[47]

As of January 2015, there were just under 1.2 million U.S. members in paid carsharing services (e.g. ZipCar, Car2Go).[48] The total population of licensed drivers in the U.S. is just over 210 million.[49] Carsharing, without autonomy, does not appear well positioned to significantly impact vehicle purchase and usage habits in the foreseeable future.[50]

45 Census Bureau, *2014 American Community Survey.*
46 Tom Libby, "SUVs Climb to 40% of U.S. New Vehicle Sales," IHS Automotive Blog, October 2015.
47 DOT, *National Household Travel Survey*, 2009.
48 Susan Shaheen and Adam Cohen, "Innovative Mobility Carsharing Outlook," June 2015.
49 Federal Highway Administration, "Highway Statistics Series," 2011.
50 Julian Bert, et al., *What's Ahead for Carsharing: The New Mobility and Its Impact on Vehicle Sales,* Boston Consulting Group, 2016.

FIGURE 50

Summary of Energy Impacts of Vehicle Automation



Source: Transportation Research Board

However, there is already evidence of a market for a more efficient alignment of transportation needs with on-demand supply. Uber was founded in 2009 and has provided more than one billion rides and facilitates 2 million rides per day globally.[51] A recent study showed that, in all but the most saturated markets, cars participating in on-demand ridesharing were far more efficient at picking up passengers and reducing empty miles than conventional taxis.[52]

Autonomous vehicles can reduce the inefficiencies inherent in personal ownership. Autonomous technology offers a consumer proposition in the form of easier, safer, more accessible trips. Combined with connected vehicle technologies that better sync transportation supply and demand, this may provide, for many Americans, a viable—and in many cases economically preferable—alternative to private ownership. This is especially true in urban areas, where the cost of maintaining private vehicle ownership is greater and levels of vehicle ownership are lower.[53] As illustrated in Figure 56, households tend to own fewer—or even zero—vehicles in areas of higher population density. This is because of the alternatives to private vehicle ownership offered in dense cities and the higher cost of vehicle ownership in these areas. Studies have found that individuals in urban areas who use ridesharing, car-sharing, and bike-sharing services are more likely to use public transportation, own fewer vehicles, and spend less on transportation.[54] This suggests that if autonomous vehicles offer a compelling functional and economic alternative to private vehicle ownership, consumers will choose to own fewer vehicles.

Some observers are skeptical that the transportation system will pivot away from family-owned vehicles. Many experts believe that Americans are attached to their cars and will not forego personal ownership.[55] Others believe that economics inexorably points toward either a partially or almost fully shared future for personal transportation.[56]

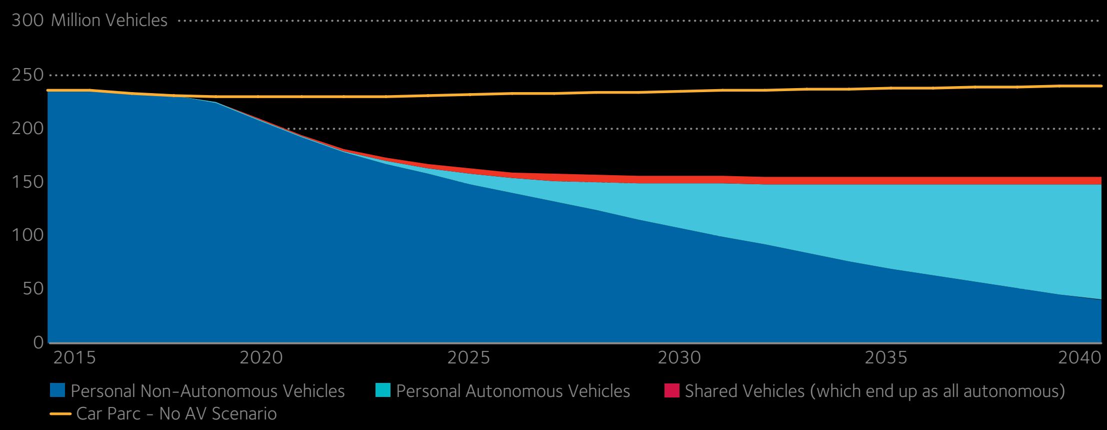
SAFE modeling shows that significant private ownership of vehicles will persist even with the emergence of autonomous, shared vehicles (Figure 51). Governments should not force a particular type of transportation service on the public, but the compelling economic proposition of cheap, reliable, on-demand service will encourage many consumers to reduce the numbers of vehicles per household to about one. Today, most households have two or more cars.

SAFE's model tested how consumers would react to the commercialization of shared, autonomous vehicles. The model showed that if autonomous vehicles never become available, the car parc would

51 Max Chafkin, "What Makes Uber Run," 2015.
52 Judd Cramer, and Alan B. Krueger, "Disruptive Change in the Taxi Business: The Case of Uber," 2015.
53 Elena Holodny, "This might be the only time it's cheaper to use Uber instead of owning your own car," March 2016.
54 American Public Transportation Association, *Shared Mobility and the Transformation of Public Transit*, 2016.
55 Lindsay Chappell, "Ghosn stands apart on consolidation, car sharing," 2016.
56 Brian Johnson, *Disruptive Mobility*, Barclays Equity Research, 2015; and Neil, Dan, "Could Self-Driving Cars Spell the End of Ownership," 2015.

FIGURE 51

Modeled U.S. Car Parc

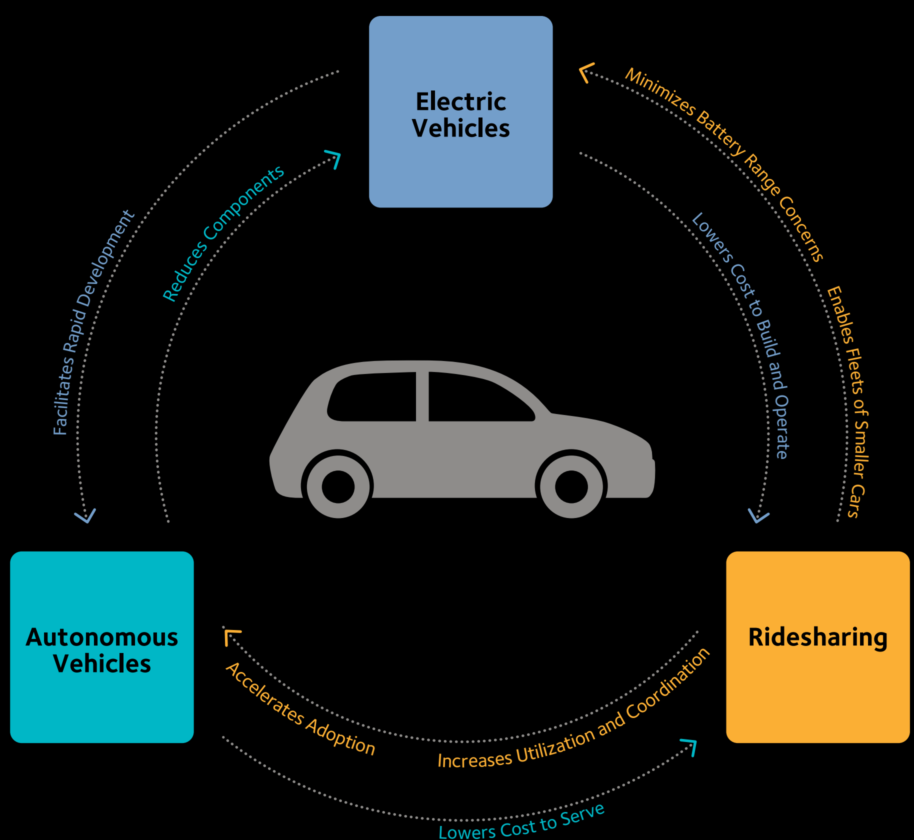


Note: Model does not account for effects of duty cycle matching ("right-sizing").

Source: SAFE modeling

FIGURE 52

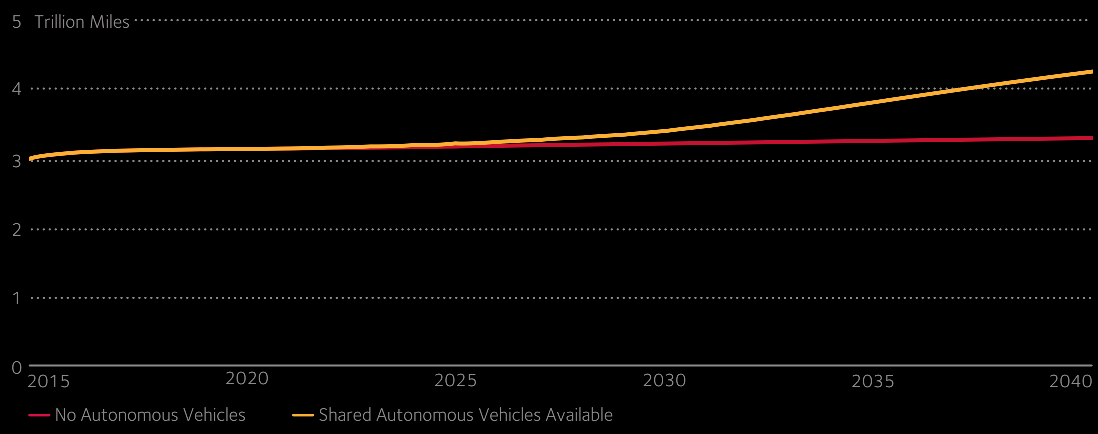
Virtuous Cycle Between EVs, Autonomous Vehicles, and Ridesharing



Source: SAFE analysis

FIGURE 53

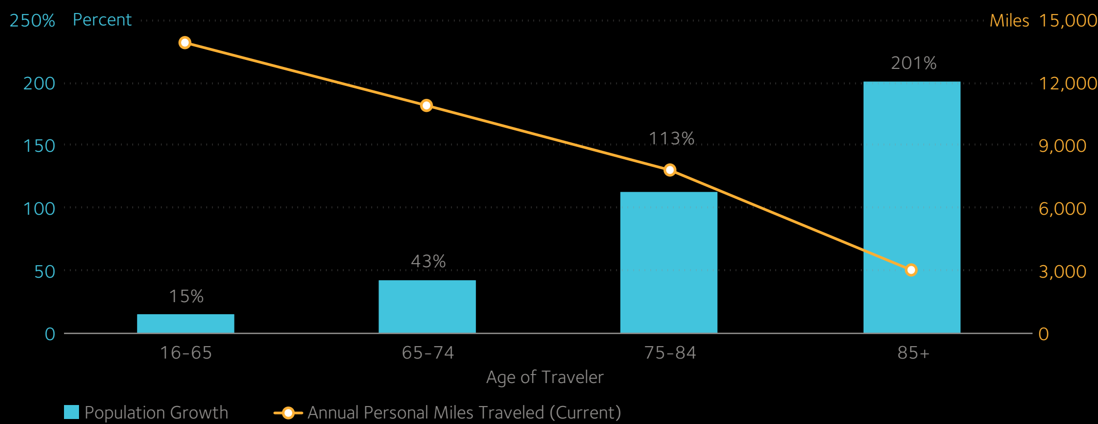
Modeled Impact of Autonomy on VMT



Source: SAFE modeling

FIGURE 54

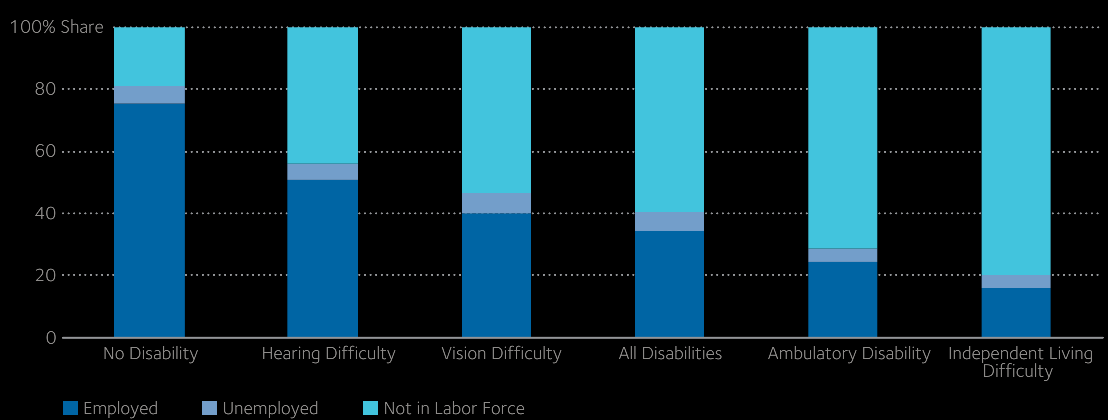
Projected Population Growth, 2015–2050, and Personal Travel By Age



Source: Census Bureau and NHTS

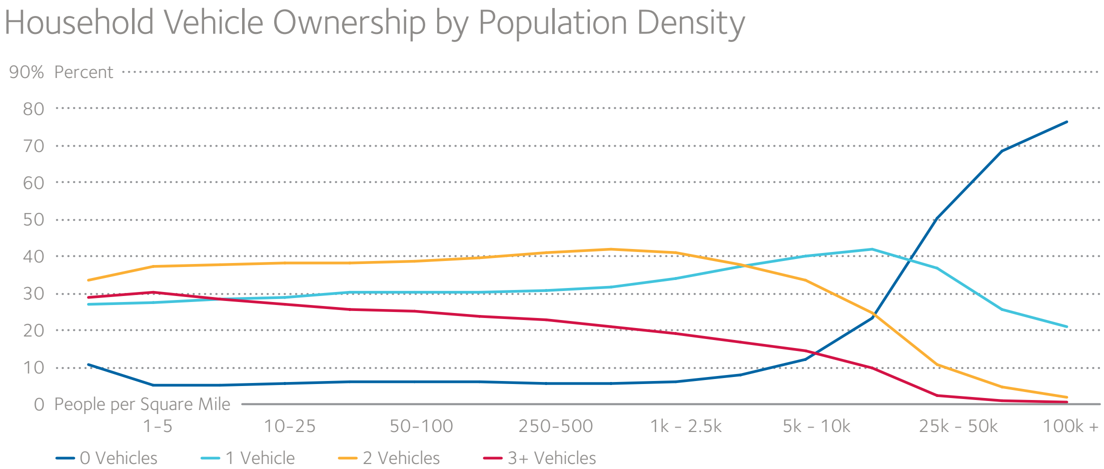
FIGURE 55

Disabilities and Labor Pool Participation



Source: Census Bureau

FIGURE 56



Source: SAFE analysis based on data from Census Bureau

grow slowly over time. However, if autonomous, shared cars become available, consumers significantly utilize these vehicles. Each shared, autonomous vehicle replaces about 10 personally-owned vehicles, and the total number of light-duty vehicles in the United States goes down by 75 million, from a baseline of about 250 million. This would represent a massive realignment for the auto industry.

Still, the vast majority of the car parc would remain personally owned vehicles. This entire change occurs rapidly, in a period of about 10 years. After that period, individual households increasingly buy autonomous vehicles for their individual use, but the number of vehicles in the fleet stays nearly constant. Any prediction of the future of the car parc has a high degree of uncertainty, but the persistence of personal ownership in SAFE modelling is a manifestation of the power of personal vehicle ownership in the United States. Personally owned autonomous vehicles can find their own parking, serve as storage for families, give rides to multiple family members, and run errands. A key factor will be the cost differential between shared and owned vehicles; a large differential may drive personal ownership even lower.

Beyond the efficiencies introduced at the vehicle level, a system which dynamically matches mobility needs with on-demand autonomous vehicles will allow for a matched duty cycle. For example, a solo rider would be placed in a small, single-occupancy vehicle. Groups that wish to travel together would order a vehicle that could accommodate them. Similarly, the fuel capacity of the vehicle might be matched to the task. A car with a smaller battery might be dispatched to meet the demand for short trips, whereas a larger battery might be used for longer trips. This would avoid expensive battery overcapacity. As a whole, such a system would produce two important impacts:

> **As 90 percent of personal trips have one or two passengers, most travel demand will be filled by small, light vehicles which consume less fuel.** In addition to being intrinsically more efficient, a light car can go farther on a battery or other advanced fuel, making electric vehicles an increasingly attractive choice.

> **Shared vehicles will have higher rates of utilization, which flip the economics of ownership to favor electric or other advanced fuel vehicles which typically have lower operating costs.** If an electric vehicle (or other AFV) costs an additional $5,000 in up-front costs, but has operating costs that are lower by 10 cents per mile (a conservative estimate), the EV becomes economically advantageous at about 50,000 miles. SAFE modeling showed that a shared, autonomous vehicle can reach this mileage in several months, making EVs a rational investment for fleet managers.

A recent study from the Lawrence Berkeley National Laboratory modeled what a shift to fully autonomous taxis would do to national energy consumption. The results of the study: "Oil consumption would… be reduced by nearly 100 percent."[57] The "virtuous cycle" between EVs, autonomous vehicles, and Mobility on Demand is illustrated in Figure 52. The convergence of these trends have the potential to create a positive feedback loop and transform the transportation system.[58]

SAFE's model showed that even though total travel soars by about 30 percent with the availability of shared, autonomous cars (Figure 53), there is a rapid adoption of AFVs, which reduces overall petroleum use in the transportation system. Autonomous vehicles also increase the use of shared vehicles by a factor of ten relative to a world with autonomy, further increasing the proportion of miles driven by AFVs.

Mobility Access for the Underserved

By removing the need for a driver, autonomous vehicles have the potential to offer accessible mobility for many who do not have it today – groups such as Americans with disabilities, older Americans, children, and low-income Americans who struggle with the current cost of transportation.

Individuals with Disabilities. The disabilities community could be transformed through better access to mobility. The American Association for People with Disabilities reports that 31 percent of people with disabilities have insufficient transportation compared to 13 percent of the general population. As a result, many individuals with disabilities cannot reliably vote, work, attend medical appointments or otherwise enjoy full independence. According to the U.S. Census Bureau, the labor force participation rate for individuals with an ambulatory disability is only 25 percent, compared to 75 percent for the broader population (Figure 55). With the cost of a paratransit trip far outstripping the cost of fixed route transportation—and rising quickly—access to autonomous vehicles would help this population better integrate into society.[59]

Older Americans. By 2050, the number of Americans older than 65 will approach 90 million, more than double today's number.[60] A recent survey found that as Americans enter their 70s and 80s, they sharply reduce travel, largely due to age-related factors (Figure 54).[61] Autonomous vehicles can provide mobility and dignity to older Americans; better integrating seniors into the economy through autonomous vehicles will contribute significantly to economic growth.

Low-Income Americans. Access to efficient, quick, and reliable transportation significantly helps individuals escape poverty by allowing access to a broader range of jobs and opportunities.[62] One transportation policy expert stated that, in New York City, "it's far more important to have a MetroCard than a college degree" for economic mobility.[63] For the vast majority of cities that have been unable to sustain the expense of a broad, reliable public transportation network, autonomous vehicles will increase economic mobility and help low-income Americans access better employment.

Health-Care Cost Savings. Studies have shown enormous potential for health-care cost savings by improving the availability of transportation. The National Academies estimated in 2005 that 3.6 million American miss or delay non-emergency medical care each year because of transportation issues. This population contains a high proportion of individuals with chronic diseases for whom the lack of non-emergency care can lead to expensive hospitalizations.[64] Autonomous vehicles have the potential to significantly improve quality of life and decrease health costs for the significant population without access to transportation for non-emergency medical treatment.

57 Jeffrey B. Greenblatt, and Samveg Saxena, "Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles," Nature Climate Change, 2015.
58 Chunka Mui, "The Virtuous Cycle Between Driverless Cars, Electric Vehicles And Car-Sharing Services," 2016.
59 Government Accountability Office, "ADA Paratransit Services: Demand Has Increased, but Little is Known about Compliance," November 2012.
60 Census Bureau, "Population Projections."
61 Federal Highway Administration, *Summary of Travel Trends: 2009 National Household Travel Survey,* June 2011.
62 New York Times, "Transportation Emerges as Crucial to Escaping Poverty," May 2015.
63 Gothamist, "Public Transit Helps New Yorkers Earn More Money," January 2015.
64 Transportation Research Board, *Cost Benefit Analysis of Providing Non-Emergency Medical Transportation,* 2005.

Improved Safety

The impact of motor vehicle accidents is staggering. In the United States, there are more than 6 million crashes, causing more the 2 million injuries each year. In 2015, accidents caused 38,300 fatalities, a sharp increase from the year before, which is partially blamed on an increase in distracted driving.[65] The death toll is the equivalent of a fully-loaded Boeing 747 crashing *each week*. A recent estimate for the total annual costs of accidents amounted to $836 billion.[66]

Driver-assist technologies already deployed in the marketplace demonstrate the impact of partial autonomy on safety. Adaptive cruise control systems, a NHTSA Level 1 feature, automatically regulates the speed of motor vehicles. AAA estimates that this feature helps prevent 13,000 crashes per year.[67] Higher levels of automation where a combination of safety systems work in unison have even greater impacts. The Insurance Institute for Highway Safety estimates that if all vehicles on the roads today incorporated Level 2 features, such as dynamic brake support, forward collision and lane departure warning, blind spot assistance, and adaptive headlights, nearly one-third of accidents could be prevented.[68] In 2013, NHTSA found that 93 percent of accidents resulted from human error, and an autonomous vehicle would be able to mitigate or eliminate the vast majority of those crashes.[69]

Potential Obstacles

Technology Development

Currently, autonomous vehicles capable of travelling on public roads are not broadly available for commercial use, and there are diverging opinions as to when this will change.[70] The technology requires further development for the sensors which "see" the world, the algorithms that "fuse" together input from multiple sensors and plan a safe trajectory for the autonomous vehicle, the high-definition maps that may be required for navigation, and the computational power required to manage driving-related tasks.[71]

Some autonomous vehicles are currently in or close to commercial deployment, although they are vehicles with considerably less functionality than a typical car. Driverless "pods" capable of low-speed travel in small areas will be deployed in several British cities later this year.[72] A driverless bus is currently being tested, with passengers on public roads in the Netherlands, travelling on a fixed route.[73] As of March 2016, 12 entities had been issued permits to test autonomous vehicles on public roads in California. A number of companies have demonstrated autonomous vehicles over long distance trips.[74]

A major challenge in bringing autonomous vehicles to market is understanding when they have sufficiently demonstrated enough safety for commercial deployment.[75] One metric proposed for measuring the reliability of autonomous vehicles is "miles between failures" of the autonomous vehicle; as the technology becomes more robust, failures will become increasingly rare. Early research suggested that reaching one million miles between safety failures would take until at least 2025.[76] The difficulty is

65 National Highway Traffic Safety Administration, "2014 Motor Vehicle Crashes: Overview," December 2014; National Safety Council, "NSC Motor Vehicle Fatality Estimates," Feburary 2016.

66 National Highway Traffic Safety Administration, "New NHTSA Study Shows Motor Vehicle Crashes Have $836 Billion Economic and Societal Impact on U.S. Citizens," May 28, 2014.

67 AAA Foundation for Traffic Safety, "Adaptive Cruise Control."

68 James M. Anderson, et al., "Autonomous Vehicle Technology: A Guide for Policymakers," January 2014.

69 Automotive Digest, "Automation Could Reduce the Fatality Rate," June 13, 2012.

70 Lee Gomes, "Urban Jungle a Tough Challenge for Google's Autonomous Cars," July 2014.

71 Jonathan DiClemente, et al., *Autonomous Car Policy Report*, Carnegie Mellon University, 2014.

72 Jane Wakefield, "London's first driverless cars based on Heathrow 'pods'," January 2016.

73 Madhumita Murgia, "First driverless buses travel public roads in the Netherlands," January 2016.

74 Wired, "I Rode 500 Miles in a Self-Driving Car and Saw the Future. It's Delightfully Dull," January 2015; and CNN Money, "Driverless car finishes 3,400 mile cross-country trip," April 2015.

75 RAND Corporation, "How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?" April 2016.

76 Matthew Michaels Moore and Beverly Lu, "Autonomous vehicles for personal transport: a technology assessment," 2011.

determining what constitutes a failure, especially when an accident between an autonomous vehicle and a conventional vehicle is often not the fault of the autonomous vehicle.

California has required that autonomous vehicles tested on its roads report miles between "disengagements," which is defined as when a human driver must manually take over the car because of safety concerns.[77] While capturing some information about the state of autonomous technology, the broad definition of "disengagements" limits its utility as a metric, as it allows companies to choose and report different interpretations. Additionally, variations in the disengagement rate are driven by factors aside from the maturity of the autonomous technology, such as the choice of testing conditions and whether the autonomous vehicle is learning new operational maneuvers. A disengagement does not mean that the autonomous vehicle would have crashed had the safety driver not taken over; Google claims that its software simulations demonstrate that only a tiny proportion of disengagements would have resulted in accidents had the driver not intervened.

Based on publicly released data covering September 2014 to November 2015, Google's autonomous vehicle fleet improved during this period from several thousand disengagements per million miles to about 100 disengagements per million miles.[78] As noted, changes in the disengagement rate are not a full measure of technological progress, as other factors can impact the rate. Even so, the rapid decrease in the disengagement rate is evidence that rapid improvement of autonomous vehicle technology is both possible and currently ongoing.

Level 3 versus Level 4

An area of ongoing discussion is the proper role of the human-vehicle interface and whether the driver should be given the responsibility of re-engaging in certain circumstances, or removed from the system entirely. Studies shows that effectively handing over control can take about 10 seconds, in which a car at highway speeds can travel nearly 1000 feet.[79] This has long been recognized as an issue in aviation; the National Transportation Safety Board found that improper monitoring of automated functions causes the overwhelming majority of plane crashes.[80] Early experiences in testing their self-driving cars with volunteers convinced Google that inattention is unavoidable in partially autonomous vehicles and that fully autonomous vehicles were the only safe development pathway.[81] The deployment of autonomous vehicles will require either skipping Level 3 or finding a solution to mitigate some of the dangers of "The Handoff Problem."

Cybersecurity

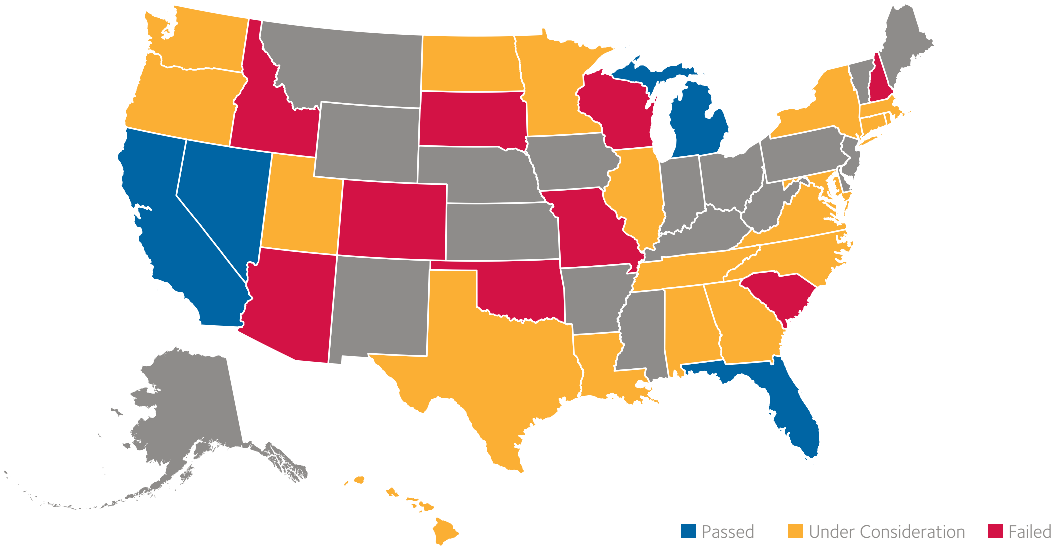
Cybersecurity is broadly recognized as an important vulnerability for networked systems, which increasingly includes vehicles. Development of cybersecurity defenses will be important for the deployment of autonomous vehicles.[82] As electronic control units (ECUs) became more common in vehicles in the 1980s, the Controller Area Network (CAN) bus protocol was developed to carry messages from point to point within the car. For decades, it has proven to be a relatively robust and secure technology. However, as connected vehicle technology offered the ability for external actors to access internal vehicle communications, cybersecurity concerns have become more prominent, highlighted by recent incidents in which security researchers have demonstrated the capability to gain remote access and control of vehicles.[83]

Vehicle connectivity, which is present in many of today's cars and will be ubiquitous on new cars in the near future, creates vulnerability to hacking. Although autonomous vehicles may have additional vulnerabilities relative to non-autonomous vehicles if hacked, cybersecurity is a major present-day

77 California Department of Motor Vehicles, "Autonomous Vehicles in California."
78 Robbie Diamond and Amitai Bin-Nun, "Hands Off: The Future of Self-Driving Cars," March 2016.
79 Alex Davies, "Ford's Skipping the Trickiest Thing About Self-Driving Cars," November 2015.
80 National Transportation Safety Board, *Safety Study: A Review of Flight Crew Involved Major Accidents of U.S. Carriers, 1978 Through 1990*, 1994.
81 Google, "Google Self-Driving Car Project Monthly Report: October 2015," 2015.
82 Guillaume Delepine, *Protecting Our Robotic Chaffeurs*, Princeton University Senior Thesis, 2015
83 The Institution of Engineering and Technology, "Automotive Cyber Security: An IET/KTN Thought Leadership Review of risk perspectives for connected vehicles," 2015; and Andy Greenberg, "Hackers Remotely Kill a Jeep on the Highway—With Me in It," July 2015.

Current Status of Autonomous Vehicle Legislation

FIGURE 57



Source: Stanford Center for Internet and Society

concern for automakers and should be addressed regardless of the pace of autonomous vehicle development.

In July 2015, automakers announced the formation of a voluntary Information Sharing and Analysis Center (ISAC) to serve as a "central hub or intelligence and analysis, providing timely sharing of cyber threat information and potential vulnerabilities in motor vehicle electronics or associated in–vehicle networks."[84] The ISAC has potential to convene automakers to promote common industry cybersecurity standards and updating them as needed.

Some have advocated legislation to mandate cybersecurity and privacy standards for vehicles. While setting mandatory standards guarantees full and uniform adoption by automakers and suppliers, such standards will necessarily be formulated through the regulatory process which takes a long time relative to the pace at which new cyber threats and defensive technologies emerge. Any standards would likely be obsolete by the time that they are deployed.

Regulations Patchwork

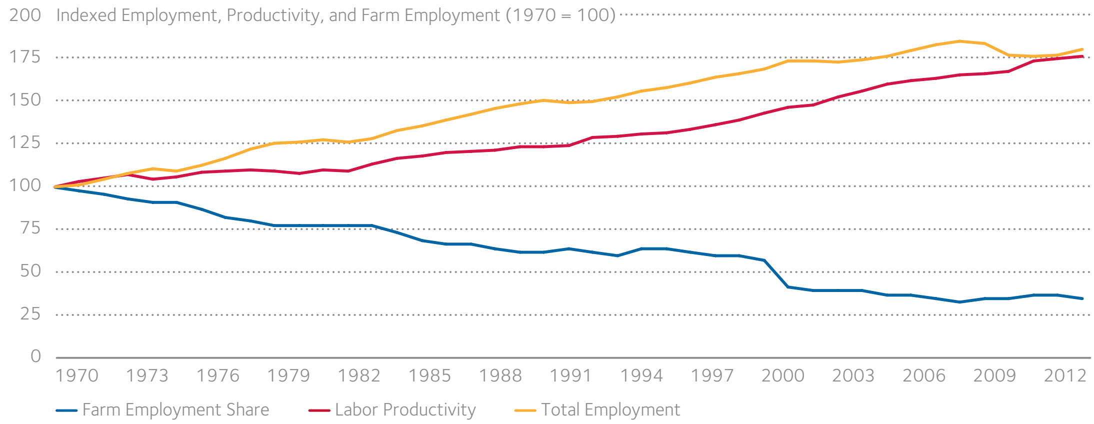
The task of regulating autonomous vehicles requires addressing a complex set of issues.[85] Already, 33 states and the federal government (Figure 57) have considered legislation related to autonomous vehicles, with 4 states and the District of Columbia passing legislation.[86]

Already, differing standards have emerged. In California, legislation mandated that the state DMV create regulations for the deployment of autonomous vehicles. In December 2015, the CA DMV proposed draft regulations that did not permit the operation of vehicles without a licensed driver who would be able to assume control at any time.[87] On the other hand, Florida's legislature recently passed a bill explicitly allowing the operation of an autonomous vehicle with no operator inside.[88] The potential

84 Alliance for Automobile Manufacturers, "Automakers Announce Initiative to Further Enhance Cyber-security in Autos," July 2015.
85 Katherine Sheriff, "Professional Liability after Quantum Leaps in Technology: The Advent of Autonomous Vehicles and Technology's Uncertain Fit within Existing Tort Law," October 2014.
86 Stanford Center for Internet and Society, "Legal Aspects of Autonomous Driving."
87 California Department of Motor Vehicles, "Express Terms."
88 Florida Senate, "House Bill 7061."

FIGURE 58

Employment and Productivity Trends



Source: SAFE analysis based on data from BLS and Federal Reserve Economic Data

emergence of varying regulations in different states have led to calls for the federal government to take the lead on establishing national-level standards for autonomous vehicle regulations.[89]

Autonomous vehicles, like conventional vehicles, fall under the authority of the federal government to regulate the "instrumentalities of interstate commerce."[90] A key issue is whether federal standards for permitting an autonomous vehicle should pre-empt state-level positions that establish different standards or prohibit autonomous vehicles entirely.

At the federal level, it is unclear whether the Department of Transportation and NHTSA have the legal authority necessary to permit autonomous vehicles, or whether doing so will require Congress to grant DOT new authorities.[91] Additionally, several issues may need to be addressed at different levels of government (Figure 59).

Researchers at the Emory University School of Law identified several broad areas of law and policy where sustained research will be necessary to create viable options for lawmakers before the widespread commercial use of autonomous vehicles.[92] They include:

Privacy. What data is collected from an autonomous vehicle, and how can the autonomous vehicle owner use the data?

Criminal Law. Is information gleaned from autonomous vehicles protected by the 5th amendment?

Crimes Against Autonomous Vehicles. Are existing cybersecurity laws appropriate for prosecuting those who compromise autonomous vehicles through hijacking or other interference?

Tort Liability. How must traditional tort liability standards based on human conduct be updated for autonomous vehicles?

Road Infrastructure Standards. Should legislation be specific as to infrastructure standards necessary for smooth autonomous vehicle operations? This will likely include the significant information technology infrastructure required by autonomous vehicles.

89 Chris Urmson, Testimony of Dr. Chris Urmson, Director, Google Self-Driving Car Project, Google [x] Before the Senate Committee on Commerce, Science and Technology, March 2016.
90 Interview with Mark Goldfeder of Emory University.
91 National Highway Traffic Safety Administration, *FY 2017 Budget Estimate*, 2016.
92 Mark Goldfeder, Katherine Sheriff, Vaibhav Sharma, and Mason Raphaelson, Emory University School of Law Autonomous Vehicle Legal Project.

Legal Issues for Autonomous Vehicles

FIGURE 59

International	The 1949 Geneva Convention on Road Traffic, to which the United States is a party, may prohibit vehicles without a driver in control. It is likely that the Convention is not enforceable against private companies, but the federal government might play a role in international efforts to modify the convention.[96]
National	The Department of Transportation has noted that there are significant elements of the FMVSS Code that present compliance challenges for autonomous vehicles.[97] NHTSA has attempted to mitigate some of these challenges by interpreting any reference to a driver as referring to the software "driver" of the vehicle.[98] However, many of the provisions of the vehicle code explicitly disallow new designs that one would expect in autonomous vehicles (e.g. no steering wheel or brake pedals) and may not be changeable without new Congressional authorities.[99]
State	Necessary insurance levels and liability frameworks are governed by a combination of state-level tort and financial responsibility laws.[100] These differ from state to state, although groups such as the Uniform Law Commission and other advocacy groups may attempt to harmonize laws by creating and promoting model legislation across different states.[101] Driver permitting and licensing issues, as well as many traffic laws, have traditionally been the purview of the states. Some states may use this authority to regulate who may or may not be licensed to "drive" an autonomous vehicle, but the federal government has the ability to discourage states which, for example, exclude certain groups from the benefits of autonomous vehicles.
Local	Municipalities often have their own traffic laws, particularly around parking. Signage often varies from state to state as well. A move towards uniform design and laws will help the smooth deployment of autonomous vehicles in broader areas. Mobility-on-demand business models will need to comply with local regulations on rides-for-hire, which differ in nearly every locality.[102] Ridesharing services have spent considerable resources working to change for-hire regulations on a city-by-city basis.[103] Unless this is addressed, autonomous vehicle operators who wish to use a mobility-on-demand business model may have to repeat this extended battle, which may delay the deployment of autonomous vehicles or even prevent autonomous vehicles from operating in some areas.

Tax. If autonomous vehicles lead to the rapid uptake of AFVs, how will revenue from the gas tax be replaced?

Emergency Vehicles. Standards will be necessary for autonomous emergency vehicles.

Vehicle Insurance. Will requirements and insurance models need to change?

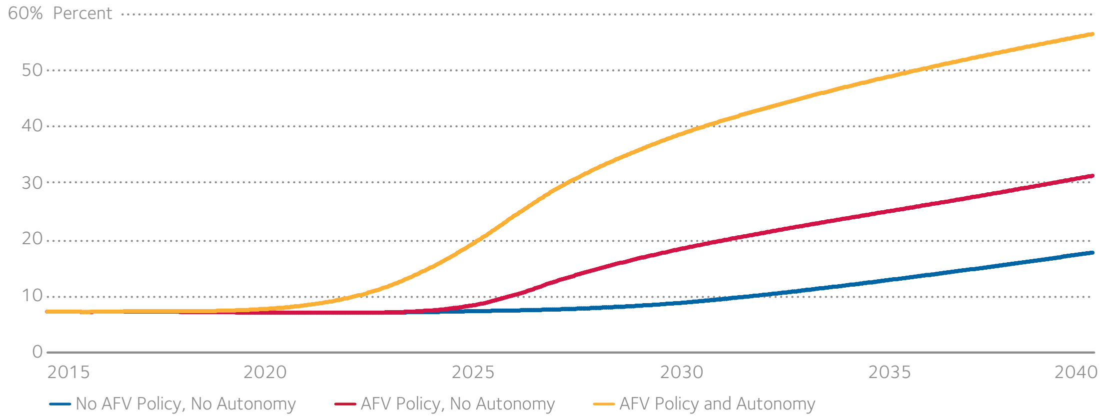
Consumer Acceptance

Autonomous vehicles offer potential benefits that include safer driving, enhanced productivity, more access to driving for underserved groups, a more enjoyable riding experience, and cheaper mobility. Despite these advantages, there is some evidence that consumers may resist autonomous vehicle adoption. AAA found that only 20 percent of U.S. drivers would trust an autonomous vehicle to drive them around, with women less likely to trust an autonomous vehicle than men. However, individuals who have had experience with semi-autonomous features are more likely to trust autonomous vehicles, consistent with the idea that consumers tend to be resistant to technology before they have experienced it.[101] A recent focus group on autonomous vehicles found considerably more consumer interest in the technology *after* being educated about self-driving car technology.[102] Recently, a survey by the Boston Consulting Group found significant enthusiasm for autonomous vehicles, but also suggested that high initial costs would slow adoption.[103] Focus groups by KPMG revealed significant

93 Bryant Walker Smith, "Automated Vehicles Are Probably Legal in the United States," Tex. A&M L. Rev., 1, 411, 2013.
94 Anita Kim et al., Review of Federal Motor Vehicle Safety Standards (FMVSS) for Automated Vehicles, March 2016.
95 Paul Hemmersbaugh, Letter to Chris Urmson, NHTSA, February 2016.
96 Anita Kim et al., March 2016.
97 James M. Anderson, et al., January 2014.
98 Goldfeder et al., 2016.
99 Mark Frankena and Paul Pautler, An Economic Analysis of Taxicab Regulation, Federal Trade Commission, 1984.
100 Rosalind Helderman, "Uber pressures regulators by mobilizing riders and hiring vast lobbying network," December 2014.
101 AAA, "Three-Quarters of Americans "Afraid" to Ride in a Self-Driving Vehicle," March 2016.
102 KPMG, *Self-driving cars: Are We Ready?,* 2013.
103 Xavier Mosquet et al., *Revolution in the Driver's Seat: The Road to Autonomous Vehicles,* Boston Consulting Group, 2015.

FIGURE 60

Modeled Impact of Autonomy on Petroleum Displacement



Note: Model does not account for positive impact of duty cycle matching ("right-sizing").

Source: SAFE modeling

interest in using autonomous vehicles and mobility-on-demand to create new options for children and older Americans unable to drive themselves.[104]

Consumer exposure to autonomous vehicles and the value proposition they offer may stimulate additional demand, but there will continue to be some uncertainty around predicting the adoption of a technology that has not yet been deployed. Therefore, early testing of autonomous vehicle technology will be important, not just for engineers to learn more about the technology, but for the public to gain exposure as well.

Workforce and R&D Issues

Autonomous vehicles are one element in a broader discussion of how automation impacts the labor market and contributes to increased productivity. Some economists argue that technology raises earnings for both high- and low-skilled workers—the latter due to induced demand for low-skilled labor.[105] Other economists believe that new technologies are eliminating jobs faster than they are created.[106] Within the auto industry, some analysts have predicted a significant reorientation of jobs away from incumbent auto manufacturers to new players, as fewer mass-market cars are produced for private sale.[107] There would be broad social ramifications of such a shift, given the 1.6 million direct jobs provided by automakers in the United States.[108] Additionally, according to the Bureau of Labor Statistics, 3.8 million Americans work as motor vehicle operators, with an annual mean wage of $36,460, with potentially up to $140 billion of driver wages at risk.[109] Autonomous vehicles could contribute to the continued erosion of middle-class and manufacturing jobs, an issue which is an increasingly prominent element of current political discourse.

The United States has previously undergone major industrial shifts. At the beginning of the 20th century, nearly half the labor force worked in agriculture. As machines increased productivity, jobs shifted to manufacturing and other industries. Despite sharp reductions in farm employment, total U.S. employment grew robustly. Figure 58 shows the last few decades of this trend. Even though a major industry, agriculture, now employs a tiny fraction of the workforce it once did, increasing labor productivity has allowed agricultural output to grow, and other industries have absorbed the displaced labor. Vehicle automation has the potential to greatly increase worker productivity through freeing time

104 KPMG, *The Clockspeed Dilemma,* 2015.
105 David Autor and David Dorn, "The growth of low skill service jobs and the polarization of the US labor market," National Bureau of Economic Research, 2009.
106 David Rotman, "How Technology Is Destroying Jobs,"MIT Technology Review, 2013.
107 Brian Johnson, 2015.
108 Alliance for Automobile Manufacturers, "Auto Jobs and Economics."
109 Bureau of Labor Statistics, "Occupational Employment Statistics, May 2015."

and reducing productivity-sapping injuries. Still, even if the economy continues to grow in other areas, replacing wages lost to autonomous vehicles, the large-scale displacement of jobs increases the risk of social disruption.

New technologies such as autonomous vehicles and their associated productivity gains can become a major source of national economic competitiveness and employment. As countries such as Singapore or South Korea have take an active interest in autonomous vehicle development, the productivity gains offered by the technology will confer competitive advantage to countries leading in this space. Additionally, as autonomous vehicles sit at the nexus of multiple industries (i.e., technology, automotive, telematics), leadership in this area will attract a hub of activity with significant employment benefits.

Policy Recommendations

Organizing Principles

RECOMMENDATION

The federal government should remove regulatory obstacles to the deployment of autonomous vehicles.

Autonomous vehicles have the capability to provide on-demand transportation, driving down costs, boosting productivity, enabling access to mobility for underserved groups, and reducing petroleum usage (Figure 60). These benefits will not be fully realized if the car requires a driver to be engaged and ready to take over; non-autonomous vehicles could not self-relocate to pick up the next passenger, which would be necessary to allow for shared, autonomous mobility-on-demand. Individuals who could not serve as a suitable driver, including many in the disability or elderly communities, would not be able to ride in a vehicle that required a driver's supervision.

As illustrated in Figure 47, autonomous vehicles may not develop through the incremental automation of today's conventional vehicles, but by operating fully autonomously in increasingly complex, but still limited, domains. Both trajectories face challenges from the current regulatory framework. Without concerted and deliberate action, autonomous vehicles might be stymied or limited because of regulatory roadblocks.

Despite dramatic improvements in safety over the course of decades, motor vehicles remain far from perfectly safe. Autonomous vehicles should not be held to a standard of perfection applied to no other comparable technology, including current motor vehicles. Autonomous vehicles should be allowed to operate, without the need for a licensed driver, under any circumstances in which they have been demonstrated to be at least as safe as today's non-autonomous vehicles.

The government should neither require nor limit differing levels of automation or technology development trajectories. It is likely that most of the safety benefits of autonomous vehicles are accessible to NHTSA level 3 autonomous vehicles. Regulators should allow industry to deploy its choice of autonomous vehicle technology, and let the marketplace choose which technology best meets consumer needs.

Role of the Federal Government

Regulating autonomous vehicles presents a challenge because the technology does not exist yet in the form of a commercialized product, the pace of adoption is uncertain, and the delivery model (private, shared, or private and shared) to consumers is still unknown.

Government action to advance specific technologies is often justified on the grounds of internalizing societal benefits that are not easily captured by private markets. In the case of autonomous vehicles, the vast amounts of capital being spent by a broad range of companies suggests that there is limited room for government action to accelerate the deployment of autonomous vehicles through traditional "market pull" mechanisms such as subsidies or substantial investments in R&D.

However, there are a broad range of obstacles to the commercial deployment of autonomous vehicles that will be impossible to solve without coordinated national, state, and local government action. The federal government is best positioned to marshal the resources required to create model regulations and coordinate deployments across multiple states and cities. Federal action is required to modify or waive the FMVSS which currently do not allow autonomous vehicles to operate on the road.

Most states have considered autonomous vehicle legislation, threatening to impose a patchwork system of regulations and delay deployment. A pressing issue is whether autonomous vehicle standards established by the federal government should pre-empt state level standards or decisions to entirely prohibit autonomous vehicles. Today's model is a hybrid: states are allowed to set their own rules regarding driver licensing requirements. For vehicle safety, however, federal standards pre-empt state positions.[110] Vehicle emissions are regulated using a hybrid national/state level system. National level standards are set by NHTSA and by the EPA, but states are allowed to require the more stringent standards that are set by California.

Autonomous vehicles represent a conflation of vehicle and driver because the "driver" is the vehicle itself. Therefore, regulating autonomous vehicle certification is far more like creating a safety code for vehicles than it is like licensing a driver. Federal vehicle safety codes pre-empt state standards because of the compelling interest in not requiring different cars in each state. If autonomous vehicles were just vehicles with an "autonomous" switch, it would still be onerous to have differing requirements for turning on autonomy in neighboring states.[111] However, since the design and ownership model of autonomous vehicles will differ from conventional vehicles, varying state standards likely would require distinct vehicle models. Avoiding this outcome is the exact reason why federal pre-emption for safety standards was upheld by the Supreme Court in *Geier* and *Williamson*, where state tort claims were disallowed because the design in question was permitted by the FMVSS.[112] If existing law does not give NHTSA sufficient authority to pre-empt state laws obstructing the deployment of autonomous vehicles, Congress should grant such authority.

On other matters, such as tort actions, for-hire regulations, and on-road regulations, the traditional division that allows states and localities control over these issues could remain in place, as they do not directly impact the autonomous vehicle platform. The federal government should help create voluntary model frameworks for state and local adoption to encourage uniformity, but may choose not to pre-empt. If differing state regulations in this area prove to be a roadblock for the adoption of autonomous vehicles, the federal government should use incentives such as the withholding of federal highway funds to encourage the adoption of uniform standards. This approach was used to great effect in the past to encourage states to raise the drinking age, lower speed limits, and require motorcycle helmets.[113]

RECOMMENDATION

The federal government should "learn through doing" by facilitating autonomous vehicle deployment communities to inform any necessary regulation.

Just as technology is developed through real world testing, regulations for autonomous vehicles should be created iteratively. To take a recent example, ridesharing services provided by companies such as Uber and Lyft have grown dramatically in recent years. These services began in the absence of a regulatory framework, or in some cases, despite contrary regulation. Today, these companies are actively working with municipalities to craft legislation and regulations. Several years of experience have helped states and municipalities identify the need these services fill, mitigated concerns that

110 School Bus Manufacturers Technical Council, "Mini Guide to the Federal Motor Vehicle Safety Standards," May 2004.

111 Note: This argument is not fully applicable to vehicles with Level 3 autonomy or lower.

112 Technology Law and Policy Clinic, "The Risks of Federal Preemption of State Autonomous Vehicle Regulations," November 2014; and Katherine Sheriff, "Professional Liability after Quantum Leaps in Technology: The Advent of Autonomous Vehicles and Technology's Uncertain Fit within Existing Tort Law," April 2016.

113 Brian Resnick and Emma Roller, "Four Times the Government Held Highway Funding Hostage," July 2014.

may have been initially present, and identified concerns that may not have been anticipated, putting local governments in a far better position to regulate effectively. Market experience informs a better framework and context for regulation.

This is true of product engineering as well—technologies develop iteratively, gradually improving through testing. New technologies are not created in a vacuum—they are often tested before production to gauge and stimulate market demand.

The same lesson applies to regulation of autonomous vehicles. The state of California has drafted regulations for the deployment of self-driving vehicles and was not able to formulate clear specifications for certifying the safety of autonomous vehicles. This is a difficult question to answer without considerable commercial experience with autonomous vehicles. How will the public interface with autonomous vehicles? Will consumers choose to rely on these products in lieu of private ownership? Can the technology capture significant societal benefits? It is difficult to anticipate the answers to these questions before significant consumer deployment.

An example of an ineffective solution was offered by California, which chose to offer generalized guidelines that testing data must be turned over to expert third parties for testing and verification, and prohibited the operation of an autonomous vehicle without a licensed driver in the vehicle and maintaining responsibility at all times. This effectively placed a ceiling on autonomous vehicle technology at essentially current levels—California actually had to clarify that certain popular cars were not prohibited by the regulations. California's approach risks significantly setting back the deployment of autonomous vehicles.

Sometimes, regulators do not create the necessary framework for a new technology because they misjudge its utility. For example, AT&T approached regulators for help in deploying early mobile phone technology as early as the late 1940s, but the Federal Communications Commission preferred to allocate the necessary spectrum for other uses.[114] Actual consumer experience with autonomous vehicles will prove far superior to expert theories on deployment in informing action by legislators and regulators.

NHTSA has the authority to exempt autonomous vehicles from standards that are incompatible with the technology. This authority is currently limited to 2,500 vehicles, but Congress should increase this number to at least 10,000, enough to allow for several large scale demonstrations. The federal government should coordinate with local and state governments on lining up a diverse range of deployment communities where autonomous vehicle technology can be provided to the public on a trial basis. These deployment experiences should be used to inform necessary safety, business model, and liability regulations.

Foster State-Level Innovation

The significant progress that has been achieved to date on autonomous vehicle development reflects the critical role of states as innovation laboratories. The millions of real-world miles traveled by autonomous vehicles have occurred almost entirely under state regulatory regimes. Even as federal action should be pursued to avoid an unmanageable patchwork of state and local rules, states should retain the autonomy to experiment with autonomous vehicles. This blended approach will encourage a broad range of experimental deployments to help expose the public to the benefits offered by autonomous vehicles while mitigating risk associated with possible regulatory uncertainty at the federal level.

Specifically, Congress should ensure that states have the ability to authorize a limited number of autonomous vehicles for deployment without requiring federal approval. To allow each state to conduct a meaningfully sized deployment experiment, this number should be set at approximately 500

114 Jon Gertner, *The Idea Factory*, 2012.

vehicles per state. State-level exemptions should be provided in addition to, and not in lieu of, NHTSA's exemption authority.

Spectrum Sharing

V2X technology will contribute to autonomous vehicle functionality once there is widespread deployment, or sooner in areas targeted for use of V2X-enabled vehicles and infrastructure. The federal government should not endanger the potential benefits of this technology by allocating the necessary 5.9 GHz spectrum to other uses without first ensuring that the spectrum can be shared safely and not cause harmful interference.

Legal Issue Roadmap

Experience gained through test deployments of autonomous vehicles can best inform the regulatory process if they are designed to address specific knowledge gaps. A recent call to perform a "legal audit" of the status of autonomous vehicles underscore the need to create a road map of legal and policy issues to solve before the deployment of autonomous vehicles.[115] Legal scholars have already begun the process of analyzing proposed and enacted state-level legislation on autonomous vehicles to create a legal road map for issues requiring attention from regulators before the deployment of autonomous vehicles. Additionally, research should be initiated on a range of legal issues, such as privacy and tort liability, which will come to the fore as autonomous vehicles begin to reach widespread commercial use.

RECOMMENDATION

Create an alternative liability framework for early autonomous vehicle deployment.

Today, motor vehicle accident insurance is carried by individuals who own vehicles, broadly spreading out the cost of insurance. The minimum required insurance coverage for each vehicle varies by states, but is usually less than $100,000. However, proposed legislation in many states has called for significantly higher insurance coverage for the testing of autonomous vehicles, often around $5 million per vehicle.[116]

Similar insurance requirements for the commercial deployment of autonomous vehicles would represent a serious obstacle. Especially in the early stages of deployment, autonomous vehicles will likely be operated in fleets rather than sold to consumers. If one company wished to deploy a fleet of 2,000 autonomous vehicles, this would require an insurance policy of $10 billion dollars. Insurance companies may refuse to issue such a policy, or may charge a very high rate, until the risk levels of autonomous vehicles are fully understood. Very few companies can afford to set aside funds for a self-insurance policy of many billions of dollars.

Even if reasonable insurance policies were available, companies may be reluctant to deploy autonomous vehicles because their liability would be both large and uncertain, as there is little case law or precedent related to manufacturer liability for autonomous vehicles. There have been a range of proposed solutions to this issue.

Some have pointed to earlier federal programs to address situations where societal welfare is harmed by liability concerns. In 1988, the National Vaccine Injury Compensation Program was created to compensate those injured by childhood immunizations in response to a small number of adverse reactions to the pertussis portion of the DPT vaccine. Concerned that manufacturers of vaccines would stop production because of the threat of lawsuits, Congress created an alternative claims process funded by a fee on all vaccines. The claims process was part of broader legislation requiring

115 Bryant Walker Smith, "How Governments Can Promote Automated Driving," March 2016.
116 Goldfeder et al.

the reporting of all adverse events to a national database and the establishment of a federal, no-fault system for adjudicating claims of harm from a vaccine. Not only has this structure preserved U.S. vaccine manufacturing capability, but the Fund has run at a surplus.[117]

A similar case might be made for the manufacturing of autonomous vehicles, where liability concerns will delay deployment and the significant resulting safety and health benefits. The terms governing the earliest public deployments of autonomous vehicles will likely be the product of a negotiation between the company manufacturing the autonomous vehicles, and federal, state, and local governments. Even after all efforts are made to ensure that autonomous vehicles meet a satisfactory safety standard, autonomous vehicle manufacturers will still require safeguards to limit their liability in order to proceed with deployment. The federal government should prepare for this eventuality by studying and considering alternative liability arrangements, including an analogue of the Injury Compensation Program. Such arrangements should be designed to retain a strong financial incentive for companies to deploy only autonomous vehicles that have been tested and rigorously certified as safe, but, at the same time, remove a significant obstacle that disincentivizes the deployment of autonomous vehicles and delays benefits.

RECOMMENDATION

The federal government should promote pilots of automated trucks; all levels of government should maintain flexibility and openness to innovative urban delivery approaches.

Despite representing only 4 percent of the U.S. vehicle fleet, heavy trucks account for about 22 percent of U.S. petroleum consumption. The disproportionate energy consumption results from trucks' heavy weight and long distances, high-speed travel pattern. At the same time, this usage pattern and the economics of fleet operation represents an opportunity: highway automation is relatively easy to achieve and fleet managers are highly incentivized to seek even minor improvements in efficiency, quickly adopt technology that improves safety for their workers and the public, reduce labor costs and find ways to mitigate truck driver shortages.

Some savings can be gained through technology that is already available, such as using GPS data to better manage acceleration on stretches of highway with elevation changes. Platooning is a technology which is being extensively tested. These technologies should be incentivized by inclusion in fuel efficiency standards. Additionally, roadblocks, such as rules about vehicle following distances, should be removed.

At least one trial deployment of autonomous vehicles should center on truck automation. This would require designating a specific interstate highway corridor for testing automated trucks. This could be accomplished by the Federal Highway Administration in coordination with states and municipalities. The Federal Motor Carrier Safety Administration should participate in these pilots to explore how vehicle automation can reduce driver fatigue. Driver work hour rules should be updated to account for autonomous features and incentivize the deployment of technologies that will make drivers safer.

Innovative autonomous vehicles might offer a solution to the "last-mile" problem where much of the cost to ship a package across the country is accrued in the last leg from a central depot to its final destination in the same city. Several companies are testing innovative autonomous vehicle designs specifically for this purpose. Some of them are radical departures from the idea of a motor vehicle, such as a small, slow-moving box that travels on the sidewalk alongside pedestrians. These innovative

117 National Vaccine Information Center, "FAQ."

designs may present challenges for regulation as they represent a novel class of devices. Local governments should maintain flexibility and openness towards new delivery vehicle concepts.

Policies to Maximize Autonomous Vehicle Benefits

RECOMMENDATION

Incentivize ridesharing and autonomous vehicles in addition to the current emphasis on vehicle-level efficiency.

Autonomy and Ridesharing Reduce Petroleum Usage

The advent of autonomous vehicles has the potential to reshape the transportation system through the adoption of shared, electric, and autonomous vehicles. This can dramatically drive down the cost of travelling a mile ($0.76 per mile today for today's personal cars versus $0.15 per mile for future custom-built shared, autonomous vehicles), allow currently underserved groups more access to travel, and reduce petroleum dependency.[118] These are all highly desirable policy outcomes, but some have raised concerns that cheap and accessible travel will cause a sharp increase in the total volume of travel, with negative impacts.

However, petroleum reduction induced by the adoption of shared autonomous vehicles, in combination with policy support for AFVs, is quite dramatic, even with a projected 30 percent increase in VMT. In 2016, the U.S. transportation system, excluding aviation, produced about 700 miles of travel for every barrel of oil consumed (Figure 62). The increase in shared, autonomous, electric vehicles drives this number to around 3,400 miles per barrel by 2040, close to a five-fold increase.

The model found that the shift of the transportation system from petroleum-based to an increased reliance on shared, autonomous, and electric vehicles will rapidly reduce petroleum usage compared to a baseline case. Although VMT would rise, the share of miles driven by electric vehicles or other AFVs would increase dramatically as well (Figure 63).

With respect to energy security and petroleum use, the net impact of shared autonomous vehicles would be strongly positive, with the increase in VMT more than outweighed by the shift to AFVs. Additionally, it is important to separate the distinct policy objectives of improving mobility by making it cheaper, more accessible, safer, and less fuel intensive per "mile of transportation" from the question of mitigating impacts from increased travel. In a transportation system with significant shared autonomy, the ability to drive down the cost of each mile of service and expand to new markets by increasing access to mobility will produce enormous benefits that should be encouraged. There is little justification for the idea that VMT should be limited to current levels by denying mobility to underserved groups.

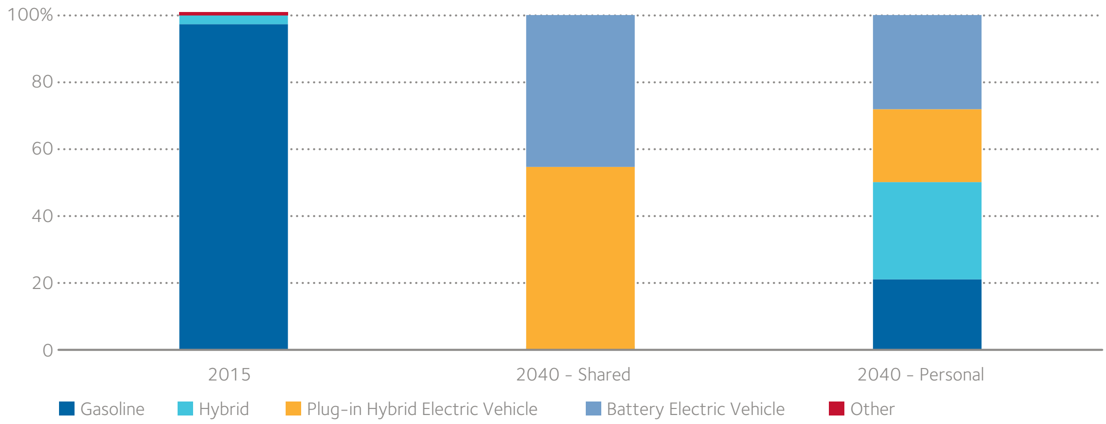
Some have raised concerns that increased travel/VMT may cause negative impacts, such as congestion and strain on infrastructure. However, given the relatively poor understanding of what autonomous vehicles will do to land use patterns, commuting habits, and the distribution of populations between urban, suburban, and rural areas, it is almost impossible to make the case that the impacts of increased travel would outweigh the positive benefits of autonomous vehicles. This is an important area for further study, but should not hold up deployment.

In the interim, any autonomous vehicle policy framework should have the goal of improving consumer choice, safety, cost, energy security, and access to mobility; this is more reliably accomplished through removing and avoiding barriers to innovation and consumer choice. Issues stemming from increased

118 AAA, "Your Driving Costs," 2015; and Burns, et al., 2013.

FIGURE 61

New Vehicle Sales by Fuel Type



Note: Analysis does not assume existence of policies supporting AFVs and does not account for positive impact of duty cycle matching ("right-sizing").

Source: SAFE analysis

mobility made possible by autonomous vehicles, however important to address, would be challenges associated with tremendous advancements in standard of living.

Update Fuel Efficiency Standards

Fuel economy and zero-emission vehicle mandates have been powerful policy levers for reducing U.S. oil consumption, and the design of these policies have significant impact on how manufacturers design their vehicles. These standards, however, are not designed in a way that accounts for the broader efficiencies that will result from ridesharing and autonomous vehicles.

By law, a vehicle's efficiency under Corporate Average Fuel Economy (CAFE) regulations is determined by its performance on two cycles or simulated conditions: a "city" cycle and a "highway" cycle. The tests are performed on a dynamometer (essentially a treadmill for cars) and do not account for variations in driver behavior.

This means that the CAFE standards do not, for example, incentivize increased efficiencies in the design of automated braking systems. The behavior of these systems in "stop and go" situations are not captured in the testing cycles. Since low-speed travel with frequent braking is very common in urban driving, algorithms optimizing efficiency can decrease urban fuel use by 10 percent. Algorithms that are poorly designed could actually increase fuel usage significantly, making it important to incentivize efficiency in autonomous vehicle software design.[119] However, the two-cycle test is codified into law by a 1975 law that requires that the EPA continue to use the exact same procedure to rate vehicles as it did at the time of the law's passage.[120]

Additionally, as discussed earlier, autonomous vehicles induce other efficiencies that will not be captured in a test of individual vehicles. Some efficiency impacts will result from accident reduction, which will mitigate congestion, and platooning, which are "off-cycle" benefits and are not currently accounted for. Longer term positive impacts include shifting the transportation system from its reliance on low-utilization personally owned vehicles to a highly utilized, shared system that will accelerate AFV adoption. Currently, there are no mechanisms to encourage either ridesharing or vehicle autonomy in current ZEV and fuel economy regulations.

119 Avi Chaim Mersky and Constantine Samaras, "Fuel Economy Testing of Autonomous Vehicles," *Transportation Research Part C: Emerging Technologies*, 2016.

120 Committee on the Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles, *Cost, Effectiveness and Deployment of Fuel Economy Technologies for Light-Duty Vehicles,* National Academies, 2015.

Congress should require agencies to update fuel efficiency standards to do the following:

Incentivize more efficient autonomous vehicles. Just as fuel efficiency standards have led to more efficient engines, they should incentivize software developers to create more efficient algorithms for vehicle automation.

Account for the "off-cycle" benefits of autonomy such as reduced congestion resulting from better traffic routing and reduced accident frequency, once such benefits are quantifiable.

Recognize the different use profile of shared vs. privately owned vehicles. A shared autonomous vehicle can easily drive more than ten times as many miles in a year as a privately owned, non-autonomous car. Additionally, SAFE modeling predicts that by 2040, with the availability of autonomous vehicles and even without policy support for AFVs, all sales to shared fleets will be battery or plug-in electric vehicles (Figure 61). Fuel efficiency standards should recognize the increased impact of shared autonomous vehicles and increase their representation in calculating fleet-wide average fuel economies. This might be accomplished by including a credit multiplier for vehicle sales to a fleet operator.

As discussed in greater detail in Part I, there is an ongoing and important debate on midterm fuel economy standards review and the long-term trajectory of these policies after the National Program concludes in 2025. The rapid pace of technological change and the growing opportunities presented by autonomous vehicle technology require that these ideas be taken into consideration as soon as possible—ideally for the midterm review. This should not be about providing loopholes to OEMs to meet fuel economy standards, but rather a serious, cost effective means of increasing efficiency and lowering greenhouse gas emissions in the context of California and EPA fuel efficiency regulations.

The greatest impact autonomous vehicles can have on fuel efficiency is through transforming the transportation system once they are deployed in significant numbers. Fuel efficiency policies should be updated to recognize and reward the positive impact that new technologies and business models offer. New policies should be put in place as soon as possible, and certainly no later than the end of the current National Program in 2025.

RECOMMENDATION

State and federal governments should encourage the utilization of autonomous vehicles to expand mobility options for underserved groups.

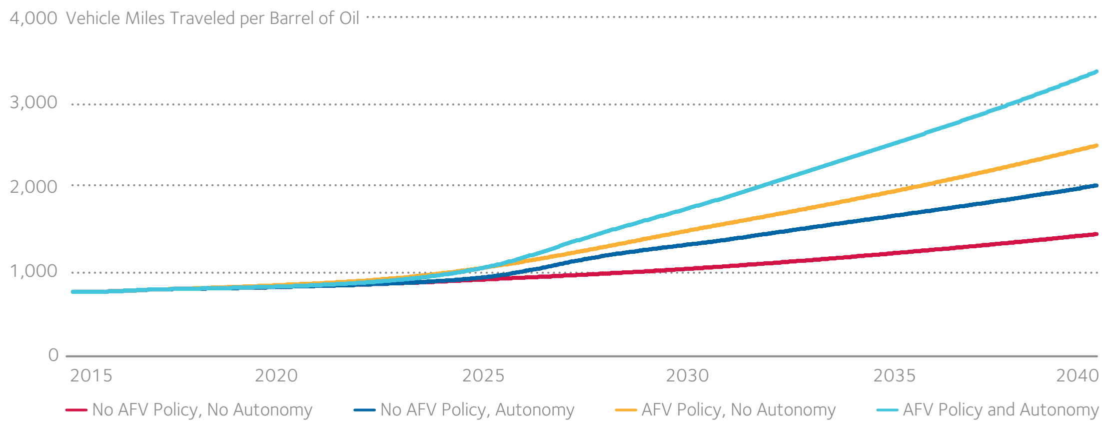
Identification of Benefits

Identifying potential benefits in the early stages of autonomous vehicle deployment encourages adoption. For example, the National Council on Disability (NCD) identified numerous obstacles that may delay or prevent the availability of autonomous vehicles for use by Americans with disabilities. This allowed the NCD to issue policy recommendations and raise awareness of the need to make autonomous vehicles accessible to all Americans; this may accelerate benefits to the disabilities community.[121]

121 National Council on Disability, *Self-Driving Cars: Mapping Access to a Technology Revolution*, November 2015.

FIGURE 62

Modeled Oil Use Efficiency, Select Scenarios



Source: SAFE modeling

A study should be commissioned to create a comprehensive list of societal benefits that could be realized by autonomous vehicles. Potential benefits should be assessed for their feasibility, likelihood of realization, and whether government actors have the necessary policy levers to encourage the benefits.

Coordination and Demonstration on Benefits

The near-term availability of Level 4 autonomy carries the potential for transformative benefits. However, unless there is a concerted effort to shape autonomous vehicle deployment to meet the needs of all Americans, it is possible that the technology and services will be designed in a way that does not fully realize these benefits or require retroactive integration; this would likely be more expensive and less effective. For example, an autonomous vehicle will still require modification to fully accommodate individuals with disabilities. Consumers may need demonstrations before adapting to a mobility-on-demand paradigm.

The federal government should work with state and local governments, as well as relevant stakeholders and advocates, to create and test a diverse set of autonomous vehicle use cases. The tests should be closely monitored and the results published so that autonomous vehicle developers can incorporate lessons into further autonomous vehicle development and deployment plans.

Early stage pilots for autonomous vehicles should be designed to demonstrate and validate potential social benefits. The Minnesota State Senate is considering legislation that would set up a pilot test using autonomous vehicles to serve individuals with disabilities. Developers are looking to set up an autonomous vehicle system within a retirement community in Florida. Early test deployments should carefully record data that can offer insight into how autonomous vehicles can impact energy and private vehicle usage. These projects have the capability to demonstrate the feasibility and commercial viability of socially beneficial autonomous vehicle use cases.

The potential for autonomous vehicles to increase mobility is immense, but given the state of the technology, largely unproven. Piloting the use of autonomous vehicles for underserved populations will set the stage for capturing these societal benefits by demonstrating benefits and economic value to government actors and the private sector. If some states hold out and do not take necessary steps to include underserved groups in autonomous vehicle deployment, the federal government has effective levers to encourage compliance, such as withholding highway funding.

Update Regulatory Structures for Autonomous Vehicle Technology

RECOMMENDATION

Federal regulation of automotive safety should evolve to a more flexible and collaborative model based on performance-based standards.

A complete regulatory framework for a technology requires detailed perspectives on two issues: One, the requirements for demonstrating its safety and, two, how the results of the safety demonstration are verified. To be certified as safe, motor vehicles are required to meet a long list of highly specific component specifications. These requirements must be updated and regulators must be more responsive to changes in technology. At the same time, the current method for verifying that vehicles meet requirements—manufacturer self-certification of compliance—should not be replaced.

NHTSA currently regulates vehicles by requiring them to adhere to the FMVSS. These standards include many highly detailed specifications for dozens of vehicle components such as brakes, seat belts, steering wheels, and windshields.[122] The vehicle standards are enforced through manufacturer self-certification.

Much of NHTSA's regulation is reactive. Recalls are initiated after the discovery of safety defects. New safety technologies are usually in the market for several years before NHTSA begins the process of creating a rule to require its use throughout the fleet. Recent rules have required as much as eight to ten years from the start of the process.

Given the rapid change currently underway in the auto industry, a regulatory model based on fixed component specifications can prevent useful new technologies from being deployed if not already fully compatible with the FMVSS. Elements of the FMVSS have not been updated in several decades, and updating the FMVSS requires a time-consuming and expensive rule-making process. The pace of adoption of new auto technologies has rapidly increased, software is an increasingly important component of vehicles, and over-the-air updates can continually change vehicle functionality.[123] Additionally, autonomous vehicles will likely bring extensive changes in both the hardware (for example: removal of mirrors, rear-facing "driver" seats) and performance of vehicles. Together, these changes have forced a rethinking of the relevance of the current vehicle regulatory structure and its prescriptive requirements for how a vehicle must look and the equipment that must be included.

Regulating autonomous vehicles will require a nimble, iterative regulatory framework. While it is premature to promulgate a full regulatory framework, as autonomous vehicle technology improves and is deployed broadly, a better understanding will allow for more effective regulation. Creating such a framework may require appropriating regulatory elements from other industries.

A shift to performance-based standards would position the government to avoid committing to specific technologies as autonomous vehicles rapidly evolve. For example, the Federal Aviation Administration (FAA) recently overhauled its certification processes for small aircraft so that safety innovations were able to be quickly adopted without going through years of evaluations. It accomplished this by writing safety objectives broadly enough to cover future unanticipated technologies and eliminating many prescriptive and technology-dependent elements from of the regulatory text.[124] Applying these principles to the auto industry would accelerate the adoption, not just of autonomous vehicles, but of other important safety technologies as well.

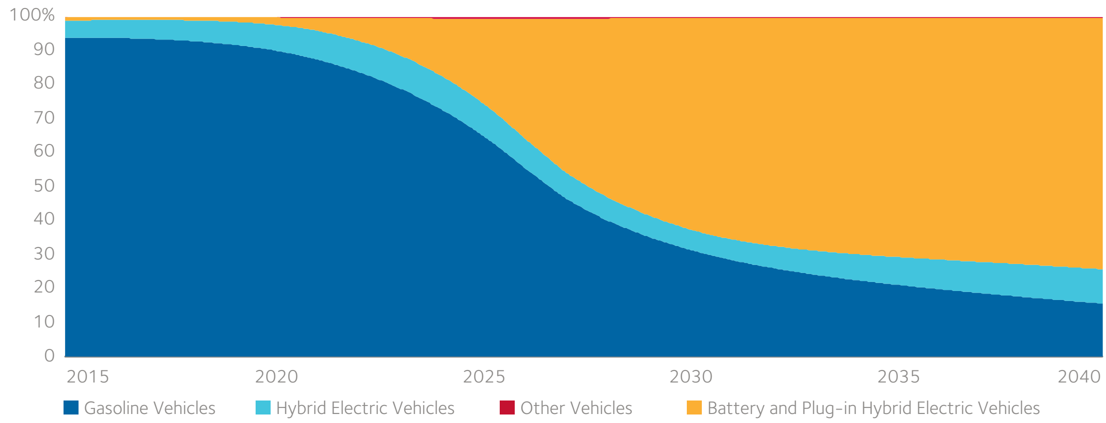
122 DOT, "Federal Motor Vehicle Safety Standards."

123 Stephen Zoepf, *Automotive Features: Mass Impact and Deployment Characterization*, MIT M.A. thesis, June 2011.

124 Dan Namowitz, "FAA: 'Innovation' the goal of aircraft certification reform," July 2013.

FIGURE 63

Light-Duty Vehicle Miles Traveled by Powertrain Technology



Note: Model assumes supportive policy environment for AFVs but es not account for positive impact of duty cycle matching ("right-sizing").

Source: SAFE modeling

Performance-based standards for software reliability and licensing limited to a subset of operational conditions are the norm at the FAA. The FAA requires that different hardware and software components, such as autopilot, be highly reliable (requiring tens of thousands or even millions of hours between failures of specific components), without prescribing exactly how the hardware and software systems should work. This regulatory framework could work well for autonomous vehicles. NHTSA could require certain levels of reliability from the component systems of autonomous vehicles such as sensor hardware, software fusing sensor data, or motion planning software.

The aviation industry has a reputation for working proactively with regulators to educate them on reasonable test procedures necessary to assure the safety of new technologies. This includes the ability for industry players to share safety failures such near-misses in an anonymous fashion and without fear of negative consequences such as litigation. This has led to valuable information sharing and increased safety. A similar process should take place in the auto industry. Currently, regulators do not understand how to determine if an autonomous vehicle is reliable. This undermines public trust and opens the door to poorly conceived regulatory schemes. Manufacturers should work with regulators to craft reasonable performance-based standards that are achievable and promote confidence in the safety of autonomous vehicles. NHTSA has recently sought to engage in more industry collaboration and consensus building, which is an important step in this direction. Some examples include the recent voluntary industry compact to standardize automatic emergency braking on most vehicles by 2022 without a government mandate and industry agreements to proactively share information to identify safety issues in the earliest stages.[125]

The aviation industry uses an operational licensing model that restricts the use of some technologies to conditions for which it is proven safe. For example, an autopilot functionality might not be allowed at night or during foggy conditions until further data is gathered to validate uses under those conditions. This concept would be valuable for autonomous vehicles, whose functionality might be limited initially to certain areas, conditions, or types of roads. This iterative model for regulation will dovetail with the iterative deployment advocated earlier in this chapter.

However, it is vital to emphasize the importance of maintaining the current practice of manufacturer self-certification of vehicle compliance. This method allows for automotive companies to bring a broad range of models to market (in 2015, 222 different models were sold in the United States)[126], while reducing the cost of regulatory compliance. Manufacturers may need to allow government to audit the results of tests proving compliance with performance standards, but there should not be a shift to

125 Chris Woodyard, "Automatic emergency braking coming to 99% of cars by 2022," March 2016; and Brent Snavely, "FAA and NHTSA using similar regulatory playbooks," February 2016.

126 Statista, "Total number of existing and new car models offered in the U.S. market from 2000 to 2015."

a regulatory model where the government engages in continual surveillance of companies to monitor compliance.

RECOMMENDATION

A single office at a restructured Department of Transportation and an interagency working group with special hiring authorities should lead federal action on autonomous vehicle policy and necessary regulations.

Department of Transportation Restructuring

The vast majority of the Department of Transportation's budget is organized around transportation modalities (e.g. highways, vehicle safety, transit, aviation, railroads). Regulatory activity and research agendas around each modality are controlled by agencies within the Department.

The entire DOT budget in FY2016 was just under $76 billion. Approximately $43 billion is allocated to the Federal Highway Administration (FHWA), $870 million to NHTSA, and $12 billion to the Federal Transit Administration. Additional agencies include the Federal Aviation Administration ($16 billion), the Federal Motor Carrier Safety Administration ($580 million), the Federal Railroad Administration ($1.7 billion), and others. Each agency effectively serves as an advocate for the transportation modality it sponsors.

The regulatory and technology issues surrounding autonomous vehicles do not fit neatly into the modal agencies that currently compose the DOT. Autonomous vehicle technology has relevance to urban transit, individual and shared light-duty passenger vehicles, and the heavy-duty and motor coach fleet. This presents two issues: not only does the use case of autonomous vehicles significantly overlap with several of the DOT agencies, but the scope of autonomous vehicle technology leans heavily on computer science disciplines and does not fit neatly into the current domains of expertise housed either at the DOT or its associated research facilities (such as the Volpe Center in Cambridge, MA).

Although the current Secretary of Transportation and Administrator of NHTSA are in the process of a major effort to advance the policy discussion around autonomous vehicles, ensuring long-term progress toward effective regulation will require restructuring the DOT. Additionally, a better regulatory framework will require funding that is better aligned with the scope of the new mission—NHTSA is not funded at a level which would allow it to assume greater responsibilities in a restructured DOT or enable it to significantly update its regulatory approach.

A reorganization should be an extension of steps Congress has already taken. In the Consolidated Appropriations Act of 2014, Congress consolidated the activities of the Research and Innovative Technology Administration (RITA) into the Office of the Assistant Secretary for Research and Technology (OST-R), which coordinates R&D across the modal agencies. Autonomous vehicle-related regulation could be centered in the office of a new Assistant Secretary, or NHTSA could be expanded appropriately with resources and autonomous-related regulatory functions from the other modal administrations. This office would also be well positioned to respond rapidly to industry inquiries on new technologies, a process which currently takes too long and holds back innovation.

The Department of Energy has taken several steps to reorganize away from its traditional, discipline-based approach to organizational structure and given greater emphasis to interdisciplinary and challenge-based innovation models. These moves are based on studies of effective innovation management and blue ribbon panel recommendations. They should be emulated by the Department of Transportation.

Need for an Interagency Working Group

At present, NHTSA is the agency at the center of autonomous vehicle regulation. NHTSA's mission centers on saving lives and reducing motor vehicle accidents, which are important metrics, but do not capture the full rationale for autonomous vehicle deployment. The potential benefits of autonomous vehicle technology go well beyond reduced crashes and improved safety, and include numerous other social benefits which have been discussed in detail earlier in this section.

To ensure that the benefits of autonomous vehicles are captured in any decision-making, the Executive Office of the President should establish an interagency working group to be funded through the budget of participating agencies. Today, *ad hoc* collaborations between agencies exist on autonomous vehicle-related issues, but a more formal approach is needed. Agencies with missions that intersect with autonomous vehicles and have relevant expertise should be included. Agencies will include the Department of Energy for its perspectives on capturing energy security benefits, Health and Human Services for mobility access for older and disabled Americans, the National Science Foundation for access to scientific expertise, the Department of Defense to help deal with security issues, including cyber attacks, that could make autonomous vehicles a tool for terrorists or other groups with ill intentions, and the Department of Housing and Urban Development for economic mobility.

Special Hiring Authorities for the Working Group

Robust autonomous vehicle policy development requires expertise that is highly valued in the private sector and will be hard to accumulate within the constraints of agencies' civil service structures. The DOT and interagency working group must seriously engage academic and industrial actors with the expertise to inform the autonomous vehicle regulatory process. Given that almost the entirety of an autonomous vehicle policy framework will be created—and repeatedly iterated—in the next several years, it is unlikely that an infrequently meeting advisory committee is the right mechanism for private sector and academic involvement in this process. The interagency group should use contracting mechanisms to bring on experts with relevant private sector and academic experience on at least a part-time basis. Flexible contracting mechanisms make it easier to pay experts an appropriate salary for their services and make hiring or firing decisions quickly.

To minimize conflict-of-interest risk, non-government participants of the working group should be limited to providing technical, neutral advice to government agencies on autonomous vehicle technology and the likely impacts of any policy measure. Congress should grant any relevant hiring authorities.

PART III

Bolstering American Oil Production

Bolstering American Oil Production

Following decades of near constant decline, U.S. crude oil production increased for seven consecutive years between 2008 and 2015, rising from 5.0 mbd to 9.4 mbd (Figure 65).[1] This was the most sustained period of production growth since the early 1980s and the most significant on a volumetric basis since the late 1960s. Much of the increase occurred in the Bakken Shale formation of North Dakota, as well as the Eagle Ford formation in Texas, where production grew from less than 60,000 barrels per day in 2010 to a peak of 1.7 mbd in mid-2015.[2] Nationwide, new wells drilled since the start of 2014 supplied an incredible 48 percent of total U.S. crude oil production in 2015, an increase of 22 percent over 2007 levels.[3] The surge in light-tight oil output—enabled by advances in horizontal drilling and well fracturing technologies—also masked declines in traditional sources of output such as Alaska's Outer Continental Shelf (OCS), which averaged less than 500,000 barrels per day in 2015, a 75 percent fall from its 1988 peak.[4]

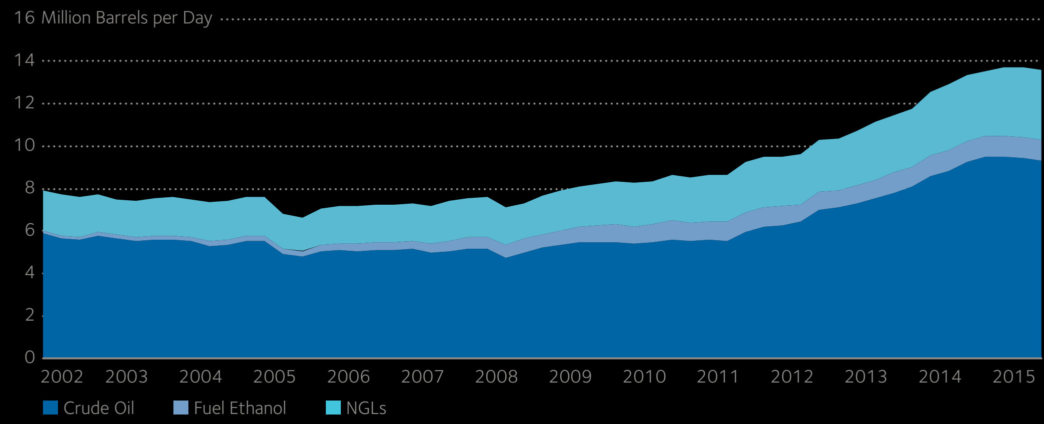
Overall, the increase in domestic production brought a host of benefits including job creation, wage growth, and an improvement in the U.S. trade balance. The United States has cut total oil imports from a record 60 percent of supplies in 2005 to just 23 percent in 2015,[5] and is keeping hundreds of billions of dollars of American wealth at home where it can be productively deployed. The United States even became a net exporter of petroleum products in 2011.[6] The rapid development of the U.S. shale industry also created 220,000 direct American jobs in just five years and supported hundreds of thousands more across related and supporting industries and activities, all while investing nearly a trillion dollars throughout the domestic supply chain.[7] Moreover, wage growth in states producing shale oil was consistently positive through mid-2014.[8] Workers in oil and gas extraction enjoyed an increase in average hourly pay from approximately $34 in early 2013 to almost $42 in mid-2015, while nationally the increase was less than $1.[9]

Nonetheless, the downturn in oil prices is now forcing producers to reduce the size of their workforces, idle rigs, and find other ways to improve efficiency, cut costs, and—in some cases—survive. For the first time since the Great Recession, employment in the U.S. oil and gas sector is falling consistently (while, by contrast, total private sector employment rises). As of September 2015, oil and gas jobs

1 EIA, *Short-Term Energy Outlook*, Annual data.
2 EIA, *Drilling Productivity Report*, Monthly data.
3 EIA, "Wells Drilled Since Start of 2014 Provided Nearly Half of Lower 48 Oil Production in 2015," March 22, 2016.
4 EIA, *Annual Energy Review 2011*, and *Short-Term Energy Outlook*, March 2016.
5 EIA, U.S. Imports by Country of Origin.
6 EIA, *Short-Term Energy Outlook*, annual data.
7 John England, Gregory Bean, and Anshu Mittal, "Following the Capital Trail in Oil and Gas," April 10, 2015; and DOL, Industry Employment at a Glance.
8 Shane Ferro, "U.S. Wage Growth and Shale Industry Wage Growth Are Two Totally Different Stories," Business Insider, April 16, 2015.
9 Tom DiCristopher, "Oil and Gas Jobs' Pay is Still Big, But Not Booming," CNBC, July 22, 2015.

FIGURE 64

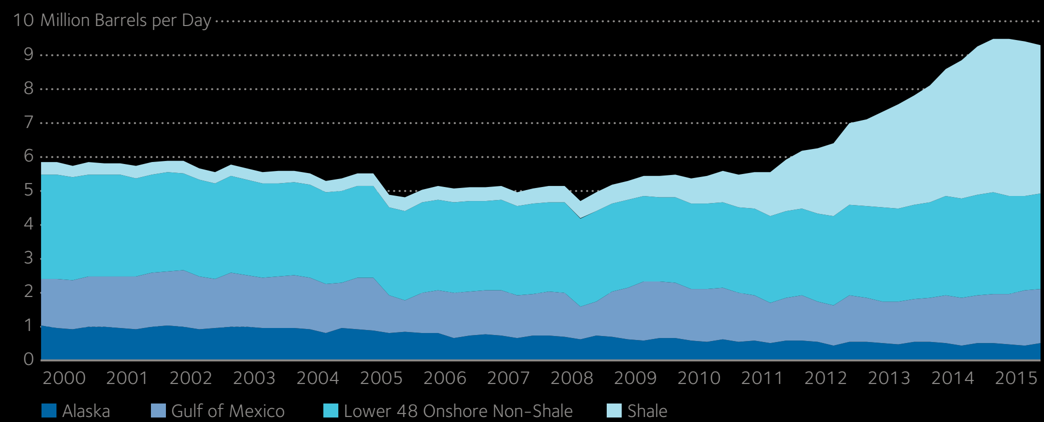
U.S. Liquids Production, 2002–Present



Source: SAFE analysis based on data from EIA

FIGURE 65

U.S. Crude Oil Production by Source, 2000–Present



Source: EIA

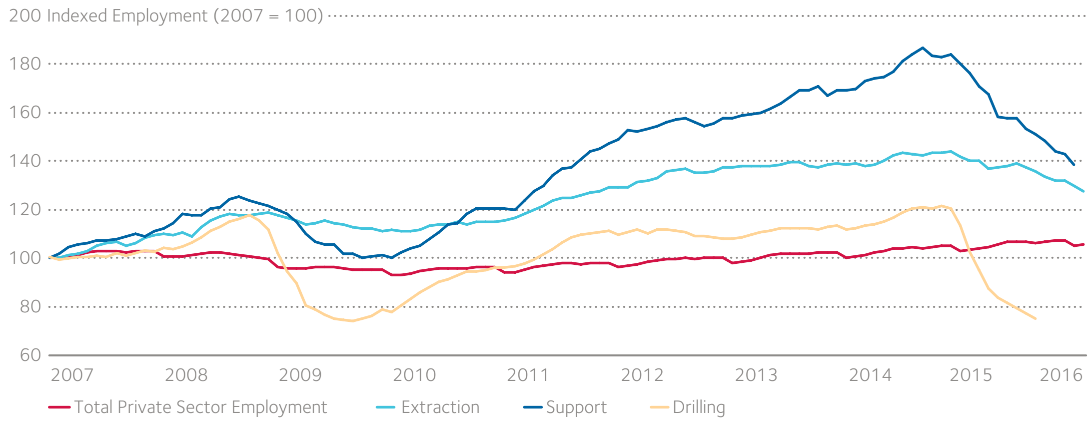
FIGURE 66

U.S. Oil Production and Rig Count

Source: EIA and Baker Hughes

FIGURE 67

Employment in Oil and Gas Drilling and Support Services



Source: SAFE analysis based on data from BLS, Current Employment Statistics Survey and Quarterly Census of Employment and Wages

have declined 28 percent below the high set one year earlier.[10] Much of this decline is driven by a massive reduction in drilling activity. The number of drilling rigs has fallen from 1,609 in October 2014 to 387 in March 2016, a 75 percent decline (Figure 66). Industry participants are undoubtedly becoming more efficient—tapping wells faster and less expensively, targeting the most resource rich areas—but many are producing below cost, paying interest on enormous lease and debt obligations, and significantly scaling back short- and medium-term capital spending priorities.

Increasing Domestic Supply

In December 2015, Congress lifted the 40-year-old embargo on crude oil exports. While the effects of lifting the ban may not manifest for several years due to the low-price environment, its removal will ultimately improve U.S. energy security by promoting greater domestic oil production. Furthermore, lifting the ban will create a more efficient global oil market, leading to increased wages and lower gasoline prices for consumers.[11] Alongside expanding the unconventional resource base, this change in policy provides ample justification to be confident in U.S. oil production prospects over the coming decade.

In this context, calls to expand industry access to federal lands currently unavailable for development may seem unnecessary or even misplaced to some. Indeed, much of the urgency regarding access to federally restricted areas both offshore and onshore has receded as the industry has turned its attention to developing unconventional resources on state and private lands.

This approach to managing the nation's energy resources is both short-sighted and misguided. The inclination of the nation's policy apparatus to prejudge which resources are most attractive for industry development has preempted the market's ability to allocate capital to the most efficient projects. Worse still, vast tracts of federal territory in the Atlantic, Alaskan, and Eastern Gulf OCS remain largely unexplored using modern technologies. Policymakers simply do not have adequate information at their disposal to make informed decisions or to develop anything approaching a comprehensive plan for deciding which of the nation's resources to develop and which to set aside.

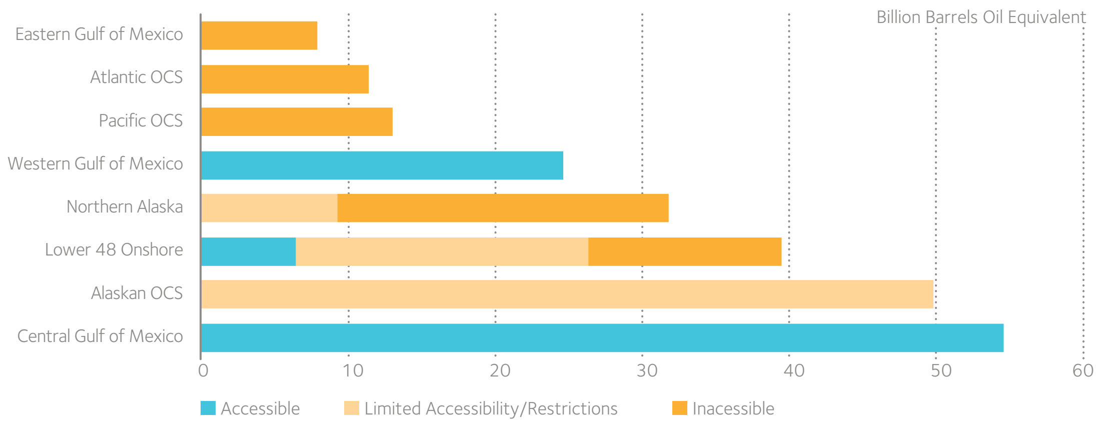
Given the gravity of the nation's energy security challenges, U.S. policy should continue to prioritize growth in domestic oil and natural gas production by increasing access to areas with high potential and letting industry invest in developing the most promising resources as long as they are meeting the highest performance, safety, and environmental standards. The recommendations that follow outline

10 SAFE analysis based on data from Bureau of Labor Statistics, *Current Employment Statistics Survey* and *Quarterly Census of Employment and Wages*, September 2015.

11 NERA Economic Consulting and Brookings Institution, "Economic Benefits of Lifting the Crude Oil Export Ban," September 9, 2014, at 12.

Undiscovered Technically Recoverable Oil and Gas Resources on Federal Lands and Waters

FIGURE 68



Source: DOI

an approach for doing so while remaining mindful that resource development must not come at the expense of the natural environment. The United States must also capitalize upon its development of energy resources by seeding an Energy Security Trust Fund with revenues from newly developed regions not accessible today. These incremental revenues can be used to support investment in advanced energy technology and infrastructure that will displace oil in the transportation sector through greater efficiencies and the wider use of alternatives.

The United States is a nation that is blessed with tremendous energy resources and, with the appropriate policy support, it can cement its status as an energy superpower for the foreseeable future, notwithstanding the current oil price environment. The Council believes that these critical choices in the short term will drive private investment and improve U.S. energy security in the long run.

Policy Recommendations

RECOMMENDATION

Require the Department of the Interior to begin work on a revised Five-Year Program covering the period from 2017-2022.

The U.S. Outer Continental Shelf—the region of offshore territory beyond state waters but within the exclusive economic zone of the United States—is resource rich. It contains what are believed to be some of the nation's most substantial undiscovered technically recoverable oil and natural gas resources, some of its most promising renewable energy potential, as well as many of the most productive fisheries and unique ecosystems found anywhere in the world. For commercial planning purposes, the OCS is broken up into four separate regions: The Gulf of Mexico, the Atlantic, the Pacific, and the Alaskan OCS. These regions are further divided into subregions, or planning areas. The vast majority of oil and gas wells drilled in federal waters to date have occurred in just two planning areas: The Western and Central Gulf of Mexico off the coasts of Texas, Louisiana, Mississippi, and Alabama.[12]

To be sure, the concentration of OCS oil and natural gas development in the Gulf of Mexico is based in part on resource potential. The U.S. offshore industry was born in the Gulf as producers sought to continue developing some of the nation's most prolific oil and gas fields, many of which extend into the shallow waters off the coasts of Texas and Louisiana. However, numerous federally-managed resource assessments have found that the broader OCS is likely to contain substantial oil and gas resources.

The majority of oil and natural gas resources in OCS regions beyond the Western and Central Gulf of Mexico have been withheld from development for decades.

The most recent assessment, completed by the Department of the Interior in 2011, and updated to include current estimates for the Atlantic OCS in 2014, placed undiscovered technically recoverable resources for the entire OCS at 90 billion barrels of oil, an increase of 1.6 percent from the previous assessment.[13] While the Western and Central Gulf contain 48 percent of the assessed resources, the Atlantic, Pacific, Alaskan, and Eastern Gulf planning areas all contain significant resources according to Interior (Figure 68).[14] Furthermore, the most recent seismic studies of the Atlantic and Eastern Gulf OCS regions were conducted in the 1970s and 1980s, a fact that suggests greater potential given the advances in exploration and development technology achieved in the decades since.[15]

For a variety of reasons, the majority of oil and natural gas resources in OCS regions beyond the Western and Central Gulf of Mexico have been withheld from development for decades. Congressional moratoria enacted between 1982 and 1992 barred the Department of the Interior from leasing tracts within roughly 85 percent of the OCS territory bordering the lower 48 states.[16] Complementary

12 SAFE analysis based on data from Bureau of Safety and Environmental Enforcement, *Oil and Gas Well Drilling on Federal Offshore Leases Since 1960*; and DOI, *Increased Safety Measures for Energy Development in the Outer Continental Shelf*, 2010, at 3.

13 Bureau of Ocean Energy Management, *Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Atlantic Outer Continental Shelf, 2014 Update*, 2014.

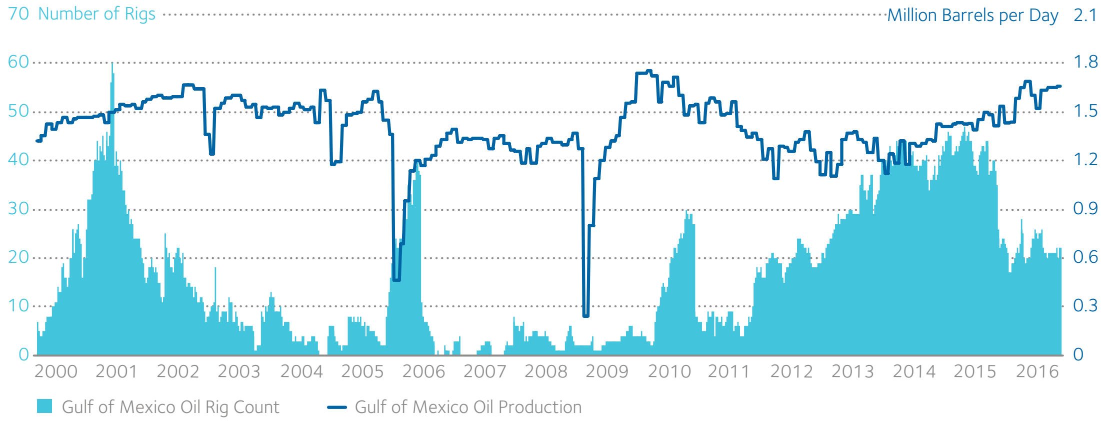
14 Id.

15 See, e.g., Bureau of Ocean Energy Management, "Atlantic OCS, Proposed Geological and Geophysical Activities," Mid-Atlantic and South-Atlantic Planning Areas, Draft PEIS," Volume 1, Chapters 1-8, 2012, at vii.

16 Curry Hagerty, "Outer Continental Shelf Moratoria on Oil and Gas Development," Congressional Research Service, March 23, 2011, at 7.

FIGURE 69

Gulf of Mexico Oil Production and Rig Count



Source: Baker Hughes and EIA

executive withdrawals affecting much of the OCS were first enacted by President George H.W. Bush in 1990 and extended by President Bill Clinton in 1998.[17] Finally, in 2006, Congress passed, and President George W. Bush signed, the Gulf of Mexico Energy Security Act (GOMESA), which allowed access to drilling in a portion of the Central Eastern Gulf that was previously off limits and also restricted access to the vast majority of the Eastern Gulf of Mexico planning area.[18]

In 2008, amid the record increase in energy prices and the political dynamics of a presidential election year, President George W. Bush ended all executive withdrawals on OCS territory and Congress allowed its moratoria to expire, though the Eastern Gulf region remained restricted by statute.[19] In January of 2009, in an effort to set forward a plan for developing newly available OCS regions, the Bush Administration's Interior Department released a Draft Proposed Program (DPP), including a plan to conduct 13 lease sales between 2010 and 2015 in the Atlantic, Pacific, Alaska, and Eastern Gulf of Mexico regions, assuming Congress lifted its statutory ban (a prospect that seemed eminently possible throughout 2009).[20]

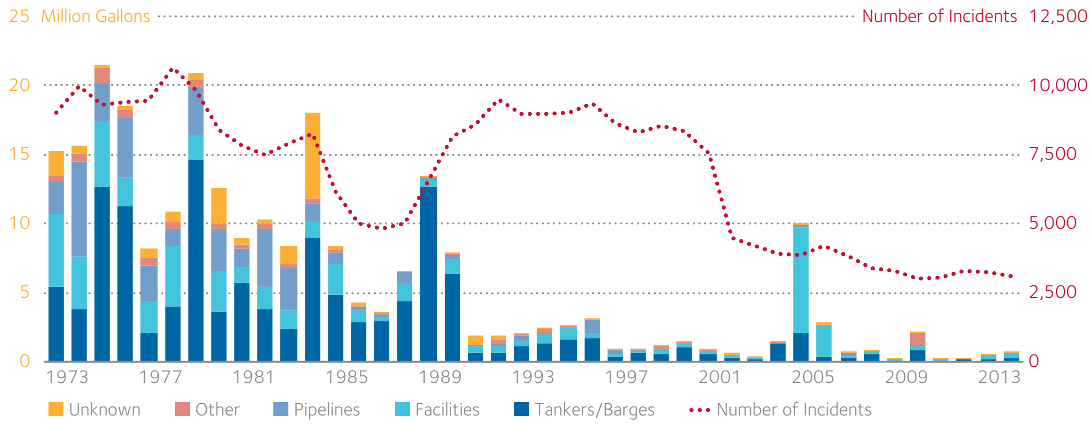
Upon entering office, and before it could fully evaluate the Bush DPP, the Obama Administration was confronted with a series of crucial issues with respect to offshore oil and gas development. Most notably, on April 17, 2009, the Federal Appeals Court for the District of Columbia vacated and remanded the existing 2007-2012 Five-Year Program in a suit that challenged the adequacy of the Environmental Impact Statement (EIS) conducted for certain leases in the plan. The court's decision required Interior to correct the EIS deficiencies and "rebalance the timing and location of the leasing program so as to obtain a proper balance between the potential for environmental damage, the potential for discovery of oil and gas, and the potential for adverse impact on the coastal zone."[21]

Nearly one year later, on March 31, 2010, the Obama administration announced its plans for addressing the Appeals Court decision on the 2007-2012 Five-Year Program and for moving ahead with a new one rather than begin implementation. Interior announced that it would cancel the four remaining 2007-2012 lease sales off the North Slope of Alaska in the Beaufort and Chukchi Seas to conduct further environmental impact analyses.[22] The president also issued a memorandum banning leases in the Bristol Bay area of the North Aleutian Basin until June 30, 2017.[23] The Revised Program retained two special-interest sales in Alaska's Cook Inlet.

17 EIA, *Overview of U.S. Legislation and Regulations Affecting Offshore Natural Gas and Oil Activity,* 2005, at 11.
18 Curry Hagerty, "Outer Continental Shelf Moratoria on Oil and Gas Development," Congressional Research Service, March 23, 2011, at 5.
19 Id., at 2.
20 Id., at 6.
21 DOI, "Preliminary Revised Program Outer Continental Shelf Oil and Gas Leasing Program 2007-2012," March 2010.
22 DOI, "A Comprehensive, Science-Based Offshore Energy Plan," May 27, 2010, at 2.
23 United States Court of Appeals, District of Columbia, Opinion No. 07-1247, at 3.

FIGURE 70

U.S. Annual Volume and Number of Oil Spills from Selected Sources, 1973-2014



Note: Excludes Deepwater Horizon.

Source: USCG

Finally, in March 2010, President Obama announced that the Bush administration DPP was being discarded. The Revised 2007-2012 Five-Year Program would remain in effect through its expiration. It was determined that the next Five-Year OCS Program would come into place on the regular scheduled date in June 2012 and run through 2017. The administration announced that the 2012-2017 plan would not include any areas in federal waters off the Pacific Coast, and that Atlantic OCS areas would only be included pending the result of an environmental analysis. The administration further indicated that it would consider lease sales in the southwest corner of the Eastern Gulf of Mexico—no closer to Florida than 125 miles, assuming Congress lifted the existing ban.[24] Interior would evaluate continued leasing off the North Slope of Alaska in the Beaufort and Chukchi Seas as part of future plans.[25]

The Deepwater Horizon oil spill occurred less than two weeks after the Obama Administration's announcements. In its aftermath, the administration significantly altered its proposed offshore development plans. With respect to the 2007-2012 Program, a sale off Virginia's coast was cancelled in May of 2010.[26] Regarding the forthcoming 2012-2017 Program, Interior announced in December 2010 that it was scaling back the OCS regions being considered for leasing, withdrawing the Mid- and South Atlantic as well as Eastern Gulf planning areas from the scoping process.

In mid-2012, Interior finalized its Five-Year Program for the 2012-2017 period. The plan contains 15 total sales: annual sales in the Western and Central Gulf of Mexico, two sales in the non-moratorium areas of the Eastern Gulf, and three potential sales off the coast of Alaska in 2016 and 2017. It did not contain sales in the Atlantic, Pacific or Eastern Gulf planning areas of the OCS.

In January 2015, the Department of the Interior released a similar-looking DPP for the 2017-2022 period that included 14 potential lease sales in eight planning areas; ten in the Gulf of Mexico, three in the Alaska OCS, and one in the Mid- and South Atlantic Planning Area that was to initiate exploratory drilling operations in the waters of Virginia and Georgia in 2021. However, in March 2016, the subsequent Proposed Program for 2017-2022 did not include the Mid- and South Atlantic Planning Area lease sale. The Obama Administration cited its concern for interference with military operations in affected areas.

The Proposed Program therefore does not contain sales in the Atlantic, Pacific, or Eastern Gulf planning areas of the OCS, essentially taking at least 20 billion barrels of oil off the table for development. The

24 DOI, "Notice of Intent to Prepare and Scope an Environmental Impact Statement for Offshore Oil and Gas Development and Exploration," March 31, 2010.
25 Id.
26 DOI, "Secretary Salazar Announces Comprehensive Strategy for Offshore Oil and Gas Development and Exploration," March 31, 2010.

members of the Council are uniquely qualified to comment on the issue of military operations. In fact, it is not a new concern, and it is not unique to the Mid-Atlantic region. In 2008 and 2009, the Council evaluated the issue in great detail with respect to the Eastern Gulf of Mexico.[27] In the case of Virginia—as in the case of the Eastern Gulf—energy development simply requires a high level of coordination between the career professionals at the Departments of Defense and Interior. Indeed, this coordination is already supported by an existing memorandum of understanding between Interior and DoD, and it is clearly built into the underlying statutory framework covering offshore oil and gas development, most notably the Outer Continental Shelf Lands Act of 1953 (OCSLA). The U.S. military has a long tradition of executing advanced logistics planning that would easily match the challenge of coordinating with domestic oil production operations.

Section 12 of OCSLA specifically states, "the United States reserves and retains the right to designate by and through the Secretary of Defense, with the approval of the President, as areas restricted from exploration and operation that part of the outer Continental Shelf needed for national defense." Section 5 of the Act, which deals with the administration of leases on the Outer Continental Shelf, states that "cancellation [of leasing] may occur at any time, if the Secretary determines, after a hearing, that continued activity pursuant to such lease or permit would probably cause serious harm or damage to … the national security or defense." Our recommendation here in no way removes or modifies this authority.

While it remains critical to balance environmental preservation and energy extraction, Interior's current approach falls short of striking such a balance. Interior is locking the nation into a Gulf-centric approach to offshore development that unnecessarily constrains access to potentially promising resources elsewhere. This should be revised through a two-step process that allows for greater access while promoting the highest levels of environmental protection and giving greater input to coastal states.

Step One

Congress should require the Department of the Interior to develop a revised Five-Year Program covering the 2017 to 2022 period. To determine the areas made available in such a plan, eligible coastal state legislatures should have the opportunity to opt into the program. Eligibility should extend to any coastal state with an approved Coastal Zone Management Plan in place. States that opt-in should have their portion of their OCS planning areas—as determined by State Administrative Boundaries—included for at least one lease sale in the revised 2017-2022 Five-Year Program. In order to provide clear incentives for coastal states to opt into future OCS development plans, higher revenue sharing rates currently benefiting Texas, Louisiana, Alabama, and Mississippi should be extended to all coastal states that participate in OCS development.

Step Two

The Council remains convinced that OCS access should be guided to a greater degree by an oversight process that measures companies' environmental performance. To this end, Interior should establish a set of safety performance metrics for the industry that cover a range of indicators, including spills, discharges of chemicals and other materials, and inspection violations. Individual companies that fall below a specified minimum performance rating should be ineligible to bid on new leases until they regain compliance.

The Deepwater Horizon disaster should continue to inform the way the country moves forward in the Outer Continental Shelf. Important progress has undoubtedly been made to improve the safety of offshore operations—largely through executive action. Yet, much more remains to be done to ensure that operations in the OCS meet or exceed the highest global safety and pollution standards. In addition, further steps can and should be taken to guarantee that financial capacity among operators will always be sufficient to ensure local populations and ecosystems are made whole in the event of an accident.

27 See, e.g., SAFE, "Eastern Gulf of Mexico Oil and Gas Exploration and Military Readiness," January 2010; and SAFE, "General James Conway and SAFE CEO: Obama Administration About-Face on Atlantic Offshore Development Threatens U.S. Energy Security," March 13, 2016.

Nonetheless, it is important to note that the Deepwater Horizon incident largely overshadowed two decades of remarkable progress in reducing oil spills due to offshore development. According to the Department of the Interior, the offshore oil and gas industry produced 10.8 billion barrels of oil between 1985 and 2010 with a spill rate of just .001 percent (Figure 70).[28] In fact, between 1990 and 1999, nearly two-thirds of the oil that entered North American coastal waters came from natural seeps, with only 5 percent coming from oil extraction and transportation.[29]

The turbulent 2005 Atlantic hurricane season—when Hurricanes Katrina and Rita tore through the Gulf of Mexico—was in some ways a demonstration of the industry's capabilities. Approximately 75 percent of the 4,000 federal OCS oil and gas facilities in the Gulf of Mexico were subjected to 175 mile-per hour winds and other hurricane conditions. Despite serious damage to 168 platforms, 55 rigs, and more than 560 pipeline segments, the U.S. Coast Guard and Department of the Interior reported no major oil spills in federal OCS waters.[30]

RECOMMENDATION

Support responsible energy production in the Arctic.

The Arctic, a region north of the Arctic Circle, is bordered by the United States, Canada, Denmark, Norway, and Russia. Although conditions do vary throughout the year, this region is most often characterized by extremely low temperatures, months of darkness, the presence of sea ice, and remoteness. Despite these challenges, the region holds immense promise for the production of oil and gas.

For decades, commercial access to the Arctic expanse has been limited by the complexity of operating safely in a remote and challenging region. However, experience garnered from producing oil and gas in other regions, advances in technology, reduced ice cover, and the ongoing search for untapped energy resources have renewed focus on the region.

The U.S. government estimates that the Arctic region contains approximately 525 billion barrels of oil equivalent (BBOE) of oil and gas, of which 426 BBOE is undiscovered.[31] This represents 25 percent of the world's remaining undiscovered conventional petroleum resources.[32] Approximately 2,200 trillion cubic feet (tcf) of gas represents about 70 percent of the total resource, plus 100 billion barrels of oil and 47 billion barrels of natural gas liquids.[33] Roughly 10 percent of the total resource, and 20 percent of the total crude oil is in the United States. Of this, approximately two thirds of the oil and 40 percent of the gas is offshore. The offshore areas include the Chukchi Sea, Beaufort Sea, and Hope Basin, and are estimated to hold 51 BBOE of conventional resources, including 27 billion barrels of oil and NGLs and 143 tcf of gas.[34] These volumes compare favorably to the approximately 16 billion barrels of crude oil that have already been produced in the Alaskan Arctic.[35] Nevertheless, these resources will not contribute to U.S. oil output during the 2030s and 2040s unless exploration activities begin in this decade.

In addition to the adoption of a performance-based approach to regulations governing offshore oil and gas activities, including those in the Arctic, the Council has identified two additional areas through which federal policy can support responsible energy production in the Arctic:

28 SAFE analysis based on data from Bureau of Ocean Energy Management, "Spills Statistics and Summaries 1996-2011," 2011.
29 Congressional Research Service, "Oil Spills in U.S. Coastal Waters: Background, Governance, and Issues for Congress," August 2007, at 30.
30 Note: The U.S. Coast Guard defines "major spills" as those in excess of 2,400 barrels.
31 National Petroleum Council, "Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources," March 27, 2015, at 11.
32 Id.
33 Id., at 1-6.
34 Id., at 1-10.
35 Id., at 1-9.

Regulators should evaluate equipment and ice management techniques every two years to determine if the drilling season can be extended. One of the most significant challenges facing producers in the Arctic is the length of the drilling season. Because the season is relatively short—typically just three to four months—drilling a single well can take more than a year, substantially increasing the cost and viability of a given project.

The length of the drilling season is limited by the presence of ice, which can threaten the integrity of drilling rigs and other production equipment.[36] The season is also shortened by a permit restriction requiring producers to be able to drill a relief well in the event of a blowout in the same season.[37] Because a relief well can take more than a month to drill, the drilling season is shortened further to accommodate this activity. Such permitting restrictions negatively affect the economics of operating in the Arctic region.

Every stakeholder, including those exploring for and producing oil and natural gas, appreciates the paramount importance of operating in a manner that minimizes the risk of accidents and oil spills, and protects the surrounding environment to the extent possible. Likewise, the industry understands that accidents will erode public confidence in their ability to safely and productively operate in the region.

Changes in operational behavior and technological developments have both helped lower the risk of incidents and strengthen the industry's capability to respond. For example, new devices, some developed after the Deepwater Horizon disaster, not only reduce the spill rate in the event of an incident, but can do so in a fraction of the time required to drill a relief well.[38] Moreover, the industry has substantial experience in both monitoring and managing ice flow, which helps ensure the risk of collisions between equipment and ice that might result in spills is minimized.[39]

Lease terms for the Arctic should be extended beyond ten years to accommodate for environment-based project complexity and the relatively short drilling season. Pursuant to the Outer Continental Shelf Lands Act, leases to produce oil and gas offshore are offered for a period of ten years.[40] These standards apply in all federal waters, including the Gulf of Mexico and the Arctic.

Production in the Arctic takes time not only because the drilling season is relatively short, but also because the oil fields are remote, large, topographically complex, and less heavily analyzed and assessed than those in areas like the Gulf of Mexico. There is little seismic data available about the offshore Arctic, and obtaining permits and collecting data could take several years. In addition, little is known about the geology of the Arctic, meaning producers will want to drill wells sequentially instead of simultaneously. Other countries with Arctic operations, including Norway and Greenland, allow for longer lease terms, and Russian producers recently requested that their government extend lease terms from ten to fifteen years.[41]

Finally, under current regulation, a lease expires if a producer suspends operations for 180 days, and the Department of the Interior treats suspension of activities over the winter as a suspension under these provisions. Although the producer can seek permission to extend the 180-day period by explaining the need for the delay, such delays are always required during normal Arctic operations.[42] This unnecessary requirement should be eliminated.

36 Id., at 2-3.
37 Id., at 4-11.
38 Id., at 4-12.
39 Id., at 1-15.
40 43 U.S.C. 1337 § (b)(2)(B).
41 National Petroleum Council, "Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources," March 27, 2015, at 4-20.
42 Id., at 4.22-4.23.

RECOMMENDATION

Facilitate limited development of the Arctic National Wildlife Refuge using extended reach drilling and strict surface occupancy restrictions.

The United States possesses significant reserves in onshore federal lands which are also not available for production (Figure 68). The Energy Policy and Conservation Act of 2000 directed the Department of the Interior to conduct a comprehensive review of all onshore oil and gas resources and to identify the impediments to their development. In 2008, a multi-agency process that integrated analyses from the Departments of Interior, Energy, and Agriculture, as well as the Environmental Protection Agency, produced an oil and gas inventory of the entire onshore United States.[43] The study estimated total undiscovered technically recoverable oil and gas resources (UTRR) beneath federal lands to be approximately 30.5 billion barrels of oil and 231.0 trillion cubic feet of natural gas.[44] Of these totals, 62 percent of the oil and 41 percent of natural gas resources were fully inaccessible due to regulatory restrictions.[45]

Many of the reserves surveyed by the federal government coincide with ecosystems and natural geological structures of tremendous scientific and national importance. Nonetheless, certain onshore areas likely possess large quantities of conventional resources. In particular, of all the areas surveyed, Northern Alaska is notable for possessing extremely large resources in a relatively confined space. While off-limits lands in the Northern Alaska Study Area represent just 11 percent of the fully inaccessible federal territory, these lands hold more than two-thirds of the inaccessible onshore UTRR oil resources (13.3 billion barrels).[46]

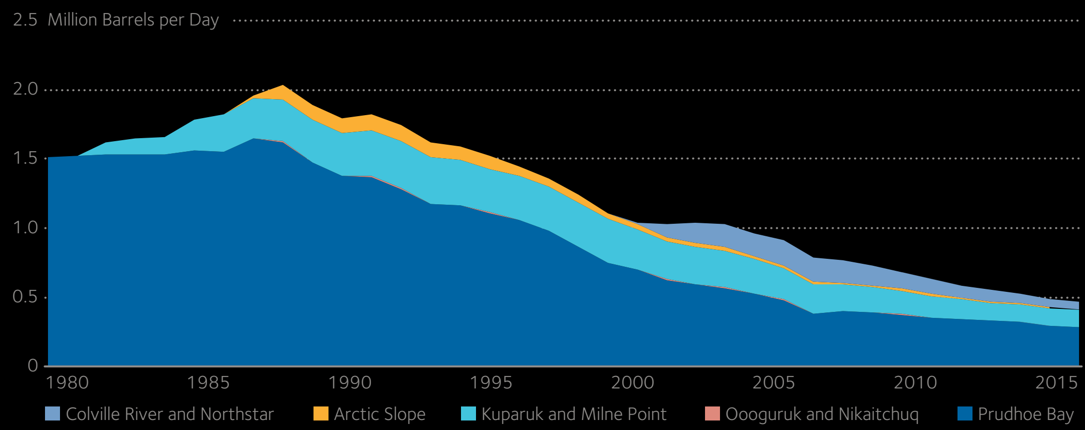
Historically, crude oil production from the accessible areas of Alaska's North Slope (ANS) has played an important role in overall U.S. output. Production began in the late 1970s and peaked in 1988 at more than 2.0 mbd, much of this from the mammoth Prudhoe Bay oil field, which had estimated oil in place of at least 24 billion barrels and has yielded cumulative production of approximately 13.3 billion barrels through 2015 (Figure 71).[47] As Prudhoe Bay has gone into natural decline, and potential replacement resources have been held off-limits, total ANS crude oil production has quickly trended downward. In fact, production fell below 600,000 b/d in State Fiscal Year 2012, a level many view as uncomfortably close to the minimal operational threshold for the Trans-Alaska Pipeline, which is estimated to be roughly 300,000 b/d.[48]

Opening limited areas of Northern Alaska to oil and natural gas production could reverse this trend. Specifically, of the 13.3 billion barrels of technically recoverable federally restricted oil in the Northern Alaska Survey Area, 7.7 billion barrels fall within the federal portion of the 1002 Area of the Arctic National Wildlife Refuge (ANWR).[49] An additional 2.7 billion barrels are on state and native lands within ANWR's 1002 Area.[50] While the full Refuge covers approximately 19 million acres, including 8 million acres designated as wilderness, the 1002 area covers just 1.6 million acres of coastal plain—or approximately 8 percent of the Refuge.[51] This land was set aside in the Alaska National Interest Lands Conservation Act of 1980 for the express purpose of further resource evaluation, including oil

43 DOI, USDA, DOE, "Phase III Inventory: Onshore United States," 2008.
44 Id., at 114.
45 Id.
46 Id., at 117.
47 Yereth Rosen, "Prudhoe Bay Loses Top Spot Among U.S. Oil Fields," Alaska Dispatch News, April 7, 2015; and Alaska Oil and Gas Conservation Commission, "Alaska's Average Daily Oil and NGL Production, 1958-2015," March 1, 2016.
48 Alaska Department of Revenue, Tax Division, "Crude Oil Production History," 2015.
49 EIA, "Analysis of Crude Oil Production in the Arctic National Wildlife Refuge," 2008, at 1.
50 Id.
51 EIA, "Potential Oil Production from the Coastal Plain of the Arctic National Wildlife Refuge, Updated Assessment," Part 1.

FIGURE 71

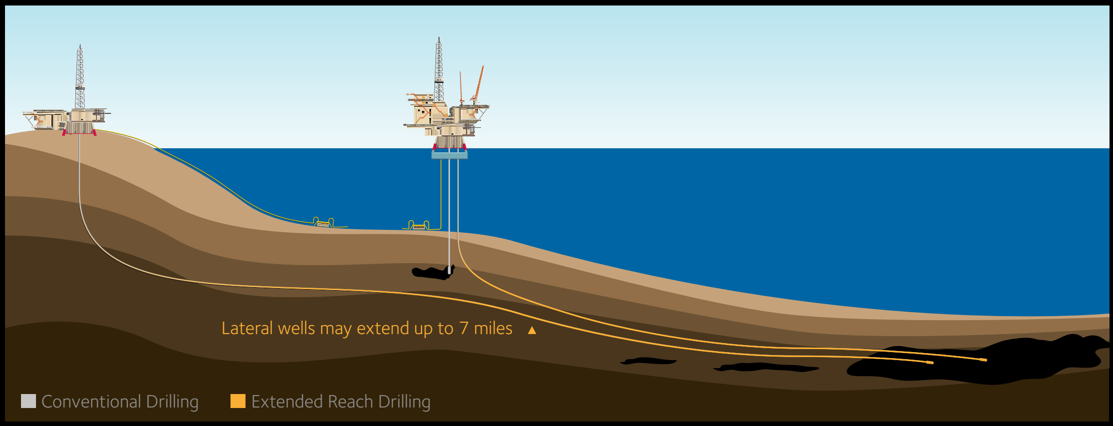
Alaska Crude OIl Production



Source: Alaska Department of Revenue

FIGURE 72

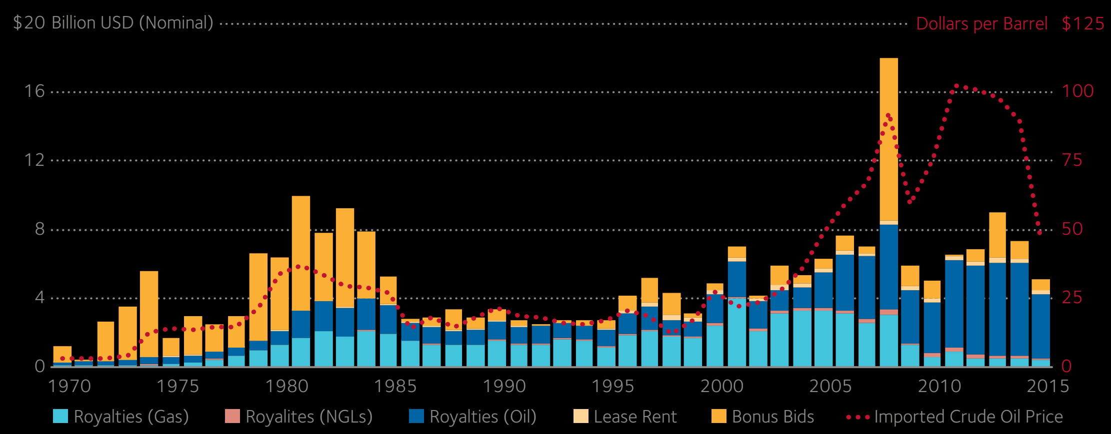
Extended Reach Drilling



Source: SAFE analysis

FIGURE 73

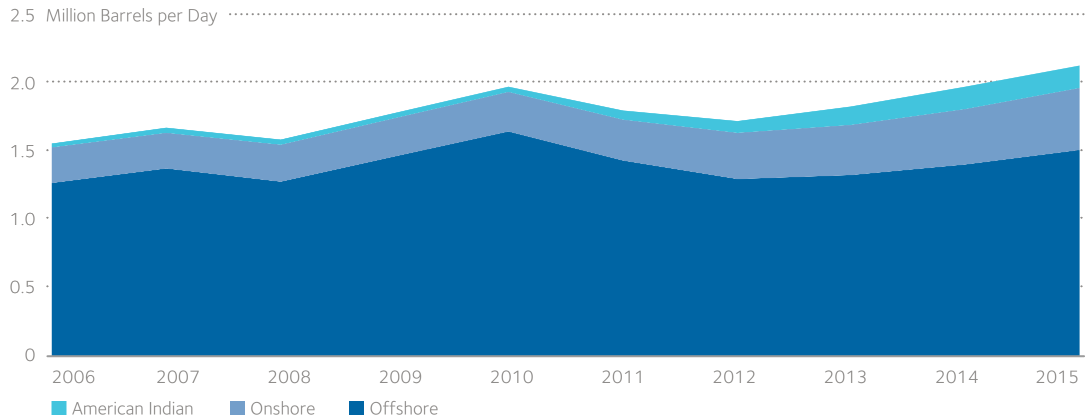
Federal Royalties Collected from OCS Activities



Source: ONRR and EIA

FIGURE 74

Liquids Production on Federal Lands



Source: SAFE analysis based on data from DOI

and gas potential.[52] It is considered highly prospective due to its proximity to other significant hydrocarbon discoveries.

After decades of debate, federal protections that restrict industry development in ANWR are unlikely to be abandoned in their entirety. However, recent developments may provide an opportunity for industry to leverage technology to access oil resources with a minimal footprint.

Specifically, long-range extended reach drilling (ERD) is an increasingly common technology being deployed by industry to access hydrocarbon reservoirs in remote or environmentally sensitive areas around the world (Figure 72). The longest such well drilled to date, measuring more than 7 miles, was completed by ExxonMobil on Russia's Sakhalin Island in 2011.[53] ERD technology was also used by BP to develop Poole Harbor in the UK, an ecologically sensitive and archeologically important area, from a disguised onshore drilling pad.[54] Though ERD wells have typically been used to develop reservoirs in shallow coastal waters, there has been increasing interest in using this approach to access a portion of ANWR in recent years. By some estimates, an extended-reach drilling program initiated from non-federal lands adjacent to ANWR could provide access to approximately 30 percent of the resource potential and leave no above-ground footprint within the Refuge itself.[55]

In fact, there is some precedent for deploying ERD technology in Alaska's North Slope. In early 2010, ExxonMobil drilled and cased its first development well on the Point Thompson project in Alaskan state lands approximately 60 miles east of Prudhoe Bay and directly adjacent to the 1002 Area of ANWR. The Point Thompson project features an onshore drilling pad with extended reach directional wells that extend 1.5 miles offshore into the Beaufort Sea.[56] Production is expected to start this year from a reservoir containing up to 8 tcf of natural gas and 200 million barrels of condensate.[57]

In order to facilitate limited ANWR development using ERD without changing current approaches to prohibiting surface disturbance within the federally protected sections of the Refuge, the Department of the Interior could structure leases to prohibit surface activity. Federal onshore leasing regulations stipulate a range of access categories. The most straightforward federal lands categories are either fully accessible (Leasing, Standard Lease Terms) or fully inaccessible (No Leasing). However, there are a number of incremental variations between these two ends of the spectrum, including access to lands that allows leasing and development of subsurface resources but without surface occupancy (Leasing,

52 Id.
53 ExxonMobil, "Sakhalin-1 Project Drills World's Longest Extended Reach Well," January 28, 2011.
54 Tim Webb, "BP to Sell Off North Sea Oil Fields and Controlling Stake in Wytch Farm," The Guardian, February 22, 2011.
55 SAFE analysis based on data from Bureau of Land Management, *Phase Three Inventory*, at 121; and Congressional Reserach Service, "Arctic National Wildlife Refuge: A Primer for the 112th Congress," at 1-3 and 21.
56 ExxonMobil, "About Point Thomson," 2016.
57 ExxonMobil, "ExxonMobil Resumes Drilling at Point Thomson," March 12, 2015.

No Surface Occupancy). The Bureau of Land Management describes these as "lands that can be leased, but ground-disturbing oil and natural gas exploration and development activities are prohibited." The agency further notes that, "at least some of the resources [on these lands] can be accessed by directional drilling from nearby lands where surface occupancy is allowed."[58]

In many cases, the development of a No Surface Occupancy land tract is accomplished by setting aside a portion of the protected area and designating it an Extended Drilling Zone. However, in the case of ANWR, this is unlikely to be a workable approach. Instead, the federal government should initiate a program in cooperation with the State of Alaska to use state lands and waters adjacent to ANWR as Extended Drilling Zones.

The Council is sensitive to the notion that restricting surface activity within ANWR is not, on its own, a blanket guarantee that development will leave local ecosystems—and the Refuge itself—undisturbed. Therefore, leasing under the approach described above should proceed in an extremely limited fashion, primarily through a pilot project. Cooperation between Interior and the State of Alaska should begin with a single lease sale in 2018. Within two years of initial production, Interior should produce a report detailing any successes and failures of the project, and whether to move forward with additional ERD leasing from lands adjacent to the 1002 Area.

RECOMMENDATION

Establish an Energy Security Trust Fund seeded with some revenues from new Outer Continental Shelf and Alaskan oil and natural gas production and use it to fund research and development into technologies that improve competition in the transportation fuels market.

Investment in cutting-edge research and development can address critical energy security and related economic challenges, reducing oil intensity and increasing viable substitutes that expand fuel diversity and consumer choice. As the Department of Energy noted in its 2011 Quadrennial Technology Review (QTR), "DOE is underinvested in the transportation sector relative to the stationary sector. [R]eliance on oil is the greatest immediate threat to U.S. economic and national security."[59] Although DOE modestly increased funding for the transportation sector over 2011 levels, the 2015 QTR finds it necessary to develop pathways that reduce oil consumption so that the United States is insulated against extreme periods of oil price volatility.[60]

The United States consistently underinvests in energy-related research and development (R&D) generally. In fact, the United States spent only $3.3 billion in 2015, roughly 40 percent below 1978 levels in inflation-adjusted 2010 terms (Figure 31).[61] Moreover, although the United States spends more than any other nation on energy R&D in overall spending terms, the country is consistently outspent by Asian and European competitors on spending as a share of GDP. Increased investment is crucial for the United States to compete globally.

To this end, and to provide additional, more consistent funding for energy technology R&D, the Council recommends the federal government establish an Energy Security Trust Fund (ESTF) designed specifically to invest in technologies whose long-term success would strengthen energy security by lessening oil dependence. The development of petroleum and natural resources that are currently

58 Bureau of Land Management et al., at 111.
59 DOE, *Report on the First Quadrennial Technology Review*, September 2011, Executive Summary, at IX.
60 DOE, *Quadrennial Technology Review*, September 2015, at 313.
61 Kelly Sims Gallagher and Laura Diaz Anadon, "DOE Budget Authority for Energy Research, Development, & Demonstration Database," Energy Technology Innovation Policy Research Group, Belfer Center for Science and International Affairs, Harvard Kennedy School, September 2015.

inaccessible in federal lands and waters would seed the fund's revenues, minimizing budgetary effects and cultivating future technologies with consistent R&D monies. Fifty percent of the federal share of all royalty revenue from energy development in new regions should be placed into the ESTF. The maximum threshold for receipts should be $500 million annually.

The priorities for the ESTF should include increased investment in research and development aimed at supporting new vehicles and fuels that differ significantly from conventional vehicles. Barriers to adoption, including PEV battery range and cost, CNG tank capacity and cost, and hydrogen fuel cell costs, should be particular priorities for the ESTF. Improved and advanced combustion technologies, vehicle efficiency, and onboard energy storage can also decrease the amount of oil used by conventional ICE vehicles and should be supported by the ESTF. Revenues from the fund could also support efforts that focus on a comprehensive approach to vehicle deployment. These funds would concentrate on the point of transition between applied research and scalable commercialization. The fund will focus on three areas of activity aimed at reducing oil consumption:

> **Research and development on the vehicles and fuels that have the potential to reduce oil consumption in the near and medium term.** Activities could also include research on technologies in other spheres with applicability to transportation.
>
> **Field or market R&D of the comprehensive systems required to support new vehicles and fuels.** Because some new transportation technologies require new consumer behaviors, due, for example, to different fueling processes, it is critical to determine the best practices required to facilitate vehicle adoption. These efforts should have a strong experimental design so that different deployment activities can be tested using quantitative metrics for various fuels. These field R&D projects will provide valuable lessons learned and best practices for the rest of the nation to use to ensure smooth deployment of advanced fuel vehicles.
>
> **Increased public-private R&D collaborations and more rapid technology transfer from the government to the private sector.** Many technologies are developed in national labs that have real world applications, but making the technology available to the private sector is not always a smooth process. Creating a more robust system to ensure that private companies are able to gain access to and commercialize government intellectual property is critical. Increased private sector collaboration with the national labs will facilitate faster commercialization of technologies that reduce oil dependence.

One mechanism that can be used to achieve the third area of activity is the Cooperative Research and Development Agreements (CRADA) program. These agreements allow private companies to keep their intellectual property while utilizing the scientific expertise of the national labs to collaborate on R&D projects. CRADAs for near- and medium-term transportation technologies can be given a special status and funding within DOE to encourage higher utilization of these collaborations.

Over the coming decade, the incremental costs of advanced fuel vehicles are expected to decline while their performance improves, realizing the technological improvements achieved over the past several years. In the near term, technologies are likely to benefit from continued declines in production costs due to rising efficiencies and economies of scale in manufacturing. However, cost savings from scale alone are unlikely to drive AFV energy storage technologies to price points that are sufficiently compelling for mainstream consumers. Technological innovation also provides an opportunity for both performance improvements and cost reductions that could be much greater and more sustainable.

The ESTF should be housed and administered by DOE. After establishing a framework for dividing the available funding between categories of appropriate technologies, the receipts from Interior should automatically transfer to the DOE-controlled fund. Current appropriations should supplement these funds so that various agencies accelerate the technology associated with internal combustion engines, electric vehicles, biofuels, natural gas vehicles, and fuel cell vehicles. The Council recommends that most of the funding be in the form of grants, but the use of other financial instruments could be considered where appropriate. DOE will set up a competitive process for grant making and will run staggered solicitations for the different technologies over the course of the year. The selection process should rely on an external merit review of the applications. Applications should contain a justification for the role that the technology will play in reducing oil consumption. Any government entity, national lab, or private company may apply for funding. Private sector entities that receive funding will be subject to the cost share enacted in section 988 of the Energy Policy Act of 2005—50/50 for demonstration and 80/20 for R&D projects. DOE should produce an annual report to Congress detailing funding allocations for various projects, major breakthroughs, and how the technologies transferred from government to the private sector. Also, the Secretary of Energy should engage his Advisory Board to provide input into the funding decisions as they are being made and in a review of quarterly and annual performance.


Third OPEC Summ

PART IV

Combating Oil Market Manipulation

Combating Oil Market Manipulation

Increasing fuel diversity in the transportation sector remains the most necessary mission for reducing U.S. oil dependence. Additionally, supporting the continued and sustainable growth of domestic U.S. oil production capacity will help displace imported crude oil, improving supply security of the nation and keeping more of the money spent on oil within U.S. borders where it can support American businesses and investment. However, fuel diversity in the transportation sector will require continued technological advancement and large-scale vehicle adoption, which will take many years.

Further, the ability to pursue these goals is subject to market conditions outside of U.S. control. While periods of high oil prices lead to a prioritization of policies to improve energy security through both supply- and demand-side policies, progress can quickly be derailed when prices are driven downward, creating greater long-term issues. Low prices can render higher-cost domestic production unprofitable, prevent further investment in upstream development, and create billions of dollars of losses through bankruptcies and lost jobs. Low prices also hurt demand for—and stifle much-needed continued investment in—AFVs and other emerging technologies by lowering the cost of ownership for traditional petroleum-fueled vehicles.

Thus, to protect progress toward necessary technological developments, the United States must work to minimize manipulation of the global oil market that results in volatile prices. OPEC's, and particularly Saudi Arabia's, ability to deliberately manipulate prices upward and downward, and the at times inexact and clumsy nature of their efforts to do so, stands in the way of American efforts to fight the effects of oil price volatility and facilitate the necessary sustained activities and progress needed to transform the nation's energy security. U.S. consumers and businesses would be better off if price discovery were more transparent and activities not based on free-market principles were removed from the oil market. It is imperative that the United States work to limit or even eliminate OPEC's market power by challenging it through a variety of legal, regulatory, and market mechanisms.

Background

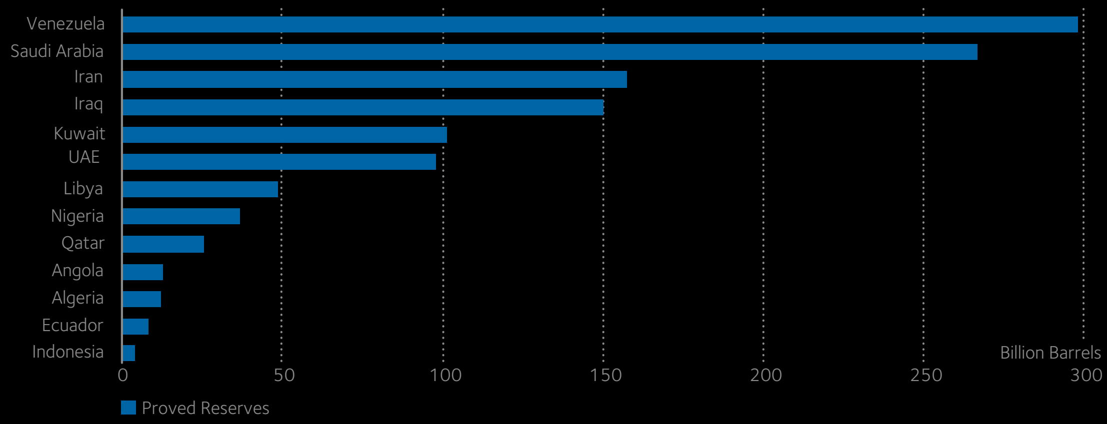
The Organization of the Petroleum Exporting Countries (OPEC) was founded in September 1960 by Iraq, Iran, Kuwait, Saudi Arabia, and Venezuela.[1] Today, OPEC also counts Qatar, Libya, the United Arab Emirates, Algeria, Nigeria, Ecuador, Angola, and Indonesia as members. Collectively, OPEC's members control more than 1.3 trillion barrels of proved oil reserves, approximately 72 percent of the global total (Figure 76).[2] The majority of this lies in Middle Eastern nations, although discoveries of extra-heavy deposits in the Orinoco Belt have given Venezuela the most proved reserves of any OPEC nation.[3]

Despite near-exclusive access to such a large share of the global oil resource base, OPEC members' combined production has historically accounted for substantially less than half of global crude oil production. In 2015, for example, total OPEC crude production amounted to roughly 40 percent of

1 OPEC, "About Us, Brief History."
2 BP, plc., *Statistical Review of World Energy 2015*.
3 EIA, "Venezuela," November 25, 2015.

FIGURE 75

OPEC Member Countries' Total Proved Reserves, 2014

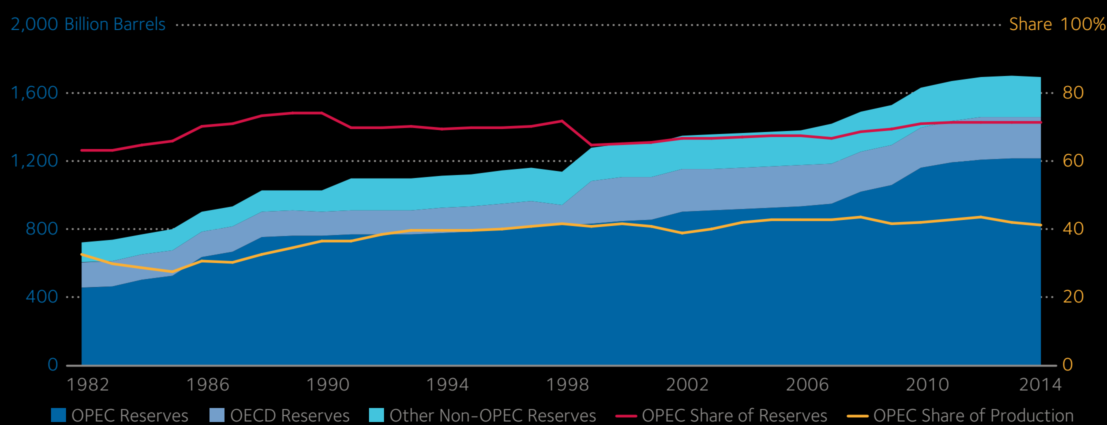


Note: Indonesia joined OPEC initially in 1962 and suspended its membership as of January 1, 2009. It reactivated its membership at the 168th Meeting of the OPEC Conference effective January 1, 2016.

Source: BP, plc., Statistical Review of World Energy 2015

FIGURE 76

Proved Oil Reserves and Production



Source: SAFE analysis based on data from BP, plc., Statistical Review of World Energy 2015

FIGURE 77

OPEC Spare Crude Oil Production Capacity

Source: SAFE analyis based on data from EIA daily global oil supplies (Figure 76).[4] From an economic perspective, this would be justifiable if resources within OPEC states were among the world's most costly. Instead, the opposite is true: resources within OPEC member states are among the least expensive to produce globally, generally requiring little incremental expenditure on exploration. Given the conventional nature of resources within most member states—with the exception of Venezuela—development expenditures are also substantially less than those outside the cartel.

Oil production in Algeria, Libya, Iran, and Qatar, for example, would remain profitable even if oil prices were below $15 per barrel, and Iraq and the United Arab Emirates have production break-even prices below $10 per barrel. Most notably, in Saudi Arabia—the leading and largest member of OPEC in terms of influence, production capacity, and output—conventional fields can be exploited for as little as $4 to $6 per barrel.[5]

OPEC's importance stems from its ability to exercise its market power. At its most effective, it has functioned as a suppliers' cartel that exerts oligopoly power over the global oil trade. It does so by setting production quotas for the bloc as a whole and for individual member states to limit global oil supply, thus artificially tightening the market. This sets higher prevailing prices for oil, ensuring greater rents for oil exporters and higher costs for net importers. This strategy has worked to sustain periods of stable high prices, and also to allow for rapid spikes such as the 1973-74 and 1979-80 oil crises.

At other times, it has had difficulties coordinating production targets, as seen in the recent low-price environment in which OPEC is operating without an official overall quota or individual country targets. But even so, in many such periods, OPEC members have contributed to dramatic oil price volatility through infighting between member countries, political instability disrupting oil supply, and, at times, deliberate actions to impact the oil market. This behavior has had dramatic effects on the global economy, including severe recessionary outcomes.

And even when OPEC collusion is imperfect or absent, its member nations and other nations with similar petroleum industry governance structures are able to act in ways that disprove the notion that oil is a free-market commodity. Some nations, like the United States, have oil industries dominated by fully or mostly privatized firms, which make investment decisions based on price and market expectations and are subject to normal economic and budget restrictions and constrained by rule of law. Not only do such free-market oriented firms base their actions on rational profit-maximizing behavior, but they can only do so effectively if their competitors act as rational independent companies in a free market would.

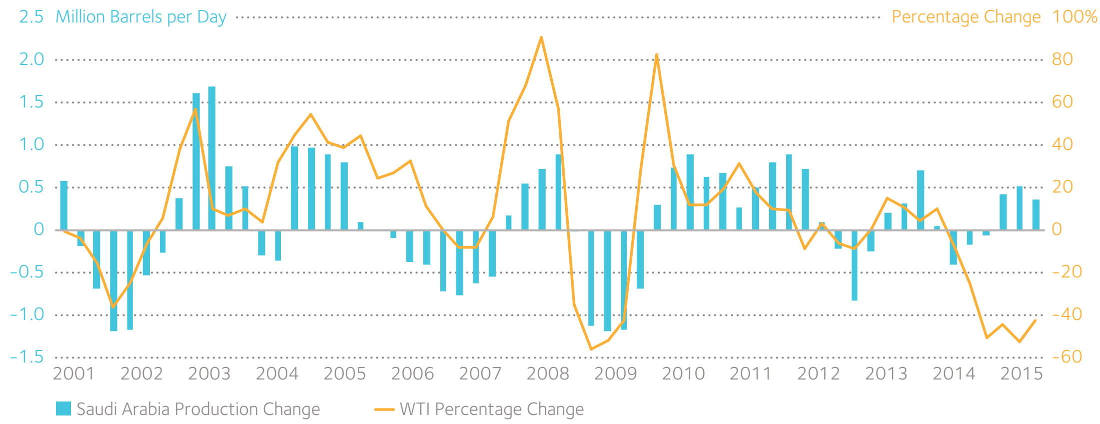
OPEC, however, is dominated by national oil companies (NOCs), which frequently operate based on political priorities rather than economically rational decision-making. OPEC nations are generally deeply dependent on oil revenue to fund government budgets and often-inefficient public spending. For example, Saudi Arabia earns 80 percent of its government revenue from oil sales; Kuwait and Angola earn 89 percent and over 70 percent of their revenue from oil respectively.[6] Nations outside of OPEC with NOCs have similar political pressure; for example, Russia's energy industry is heavily controlled by state firms, and it earns more than half of its federal budget revenue from oil and gas.[7] This direct government control of the oil industry and heavy reliance on its profits means that distributing oil revenue directly to public spending is often a higher priority than economically rational reinvestment of profits. This resulting NOC underinvestment raises the long-term prices that oil-dependent consumers must pay.

Further, countries with heavy NOC control of hydrocarbon extraction tend to operate at some distance from free market principles. With lower ease of entry, and, often, less respect for formal contracts

4 EIA, Energy and Financial Markets, "What Drives Crude Oil Prices?"
5 Reuters, "Oil production cost estimates by country," July 28, 2009.
6 Forbes, "Best Countries for Business," December 2015.
7 EIA, "Russia is world's largest producer of crude oil and lease condensate," August 6, 2015.

Year-Over-Year Change in Saudi Arabia Crude Oil Production

FIGURE 78



Source: EIA and Thomson Reuters

and rule of law, countries with NOCs prove less attractive to foreign investment. This can result in underinvestment that adds tightness to the global market and decreases overall responsiveness of supply. Even minor improvements in the business environment make great differences in enticing investments. For example, in the Middle East, nations which are by no means stable, like Egypt and Iraq, can still prove more attractive to investors than nations like Iran due to terms of and respect for contracts.

Market Manipulation Through Spare Capacity and Underinvestment

OPEC and its member states derive power from their natural endowments of petroleum, but it manifests in the short term through their maintenance of spare production capacity (Figure 77). Defined by the EIA as oil production capacity that can be restarted within 30 days and sustained for at least 90, spare capacity gives OPEC nations the ability to rapidly impart influence onto the global market when they desire. By increasing spare capacity with temporary production halts, these countries can exert upward pressure on prices while maintaining the ability to reverse that effect, and vice versa. This is particularly effective when OPEC nations collude in their use of spare capacity, but individual nations can make great impact on their own as well. In particular, Saudi Arabia, which holds the lion's share of spare production both within OPEC and globally, can quickly alter its use of spare capacity to create changes in the global market for which oil-consuming nations like the United States may be entirely unprepared.

OPEC nations' decisions are also able to create long-term distortions in the oil market that affect the United States and the global economy. By systematically underinvesting in its relatively cheap production capacity, OPEC forces investment to occur in relatively higher-cost resources in non-OPEC countries, which leads to sustained higher prices. In countries including, but not limited to, Venezuela, Iran, and Nigeria, budgetary pressure from governments in need of funding to prop up their unstable, bloated, and often corrupt oil bureaucracies have all diverted profits that would otherwise be reinvested in new production. Meanwhile, in nations with more well-functioning oil economies like Saudi Arabia, underinvestment is more likely to be a strategically planned phenomenon. While motivations for this underinvestment may vary from country to country, the effect is the same. Given their own relatively low production costs, underinvestment only ensures massive rents extracted by OPEC nations from oil-consuming countries.

The history of active manipulation of the oil market by OPEC nations is a lengthy one, replete with examples of actions that benefitted member states at the world's expense. The first, most notable instance of OPEC manipulation was the embargo that began in response to U.S. involvement in the 1973 Arab-Israeli War.[8] This embargo involved OPEC cutting production and the Arab members of OPEC, in addition to Egypt, Syria, and Tunisia, stopping oil shipments to the United States and several

8 Department of State, Office of the Historian, Milestones: 1969-1976, "Oil Embargo, 1973-1974."

other countries. At its height, the embargo caused a shortfall of 4.3 mbd, or 8 percent of the total global market.[9] This interruption resulted in a tripling of global oil prices between 1973 and 1974, from $4/bbl to more than $12/bbl, which prompted a global recession that was particularly harsh on the United States.[10]

However, such production cuts are not limited only to the high-profile crises of the 1970s. Despite talk of Saudi Arabia's response to the oil spike of 2008, in which increased production prompted relief from high prices, it is often overlooked that the road leading to prices of nearly $150 per barrel in July 2008 was paved with supply cuts from OPEC nations. In particular, Saudi Arabia cut its oil output drastically in 2006 and 2007, recording seven consecutive quarters of year-over-year decreases (Figure 78). The drastic increase in global oil prices was a contributing factor to the Great Recession that began in 2008, and any price relief instilled by renewed production increases were scant comfort as the United States lost more than 5 percent of its GDP, the worst economic crisis since the Great Depression.

Similarly, evidence of the chronic underinvestment in production by OPEC nations lies in plain sight. The drastic difference between the share of global reserves held by the bloc and its share of production bears witness to the clear discrepancy between the natural free-market level of investment that should be occurring in OPEC versus the existing level of investment. With more than 80 percent of global reserves—much of it with low production costs—nations and companies responding to economic incentives in a functioning free market would have reacted to extended periods of elevated prices, such as those that lasted for much of the first decade of this century, by investing in production that would be highly profitable at prevailing prices. Yet, OPEC has maintained a market share around 40 percent or less despite clearly having a far greater share of resources. In a free market, especially given its low production costs, OPEC oil would account for a share of production far closer to its share of resources, with investment in production rising until rents disappeared. This deliberate underinvestment further shows how OPEC action prevents the global oil trade from being a free market.

The Harmful Effects of Manipulation

The power of OPEC actions and production strategy carries important consequences for global markets, and in turn, the United States. Members' decisions on production policy, as well as politically influenced decisions by other NOCs, are both highly influential on oil market dynamics and difficult to predict, as past upward or downward shocks have shown. Each biannual regular meeting of the group is closely watched by oil market observers due to the potential for shifts that can affect concerned parties. The uncertainty and misinformation alone often create increased price volatility. The opacity of the decision-making of member nations, and other major producing nations with state-controlled oil companies like Russia, who each have their own domestic political and economic considerations, means that anyone in the market seeking to predict OPEC policy before a meeting must attempt to parse through a combination of complex financial and geopolitical factors. Price discovery, an essential element of economic planning—which in free markets is based on transparent supply and demand curves—is severely inhibited by OPEC's ability to manipulate the market. This problem is compounded by a lack of disclosed information about actual reserves and production costs.

Current market dynamics provide ample evidence of how OPEC's unpredictable manipulation of the supply curve can leave the world woefully unprepared. As prices began falling during the summer of 2014, due to factors including slower-than-anticipated global demand and increased non-OPEC production led by U.S. shale, most observers expected Saudi Arabia and its allies to react by cutting production to keep the market balanced and prices high and relatively stable. However, faced with a continued downward trend in global market share, these countries acted unexpectedly based on past precedent, and kept production levels elevated, allowing oil prices to continue their freefall. This came despite the clear understanding that such a strategy would likely push prices well below those needed to balance the Gulf states' budgets without depleting their financial reserves. Saudi Arabia, for example,

9 IEA, *Energy Supply Security 2014*, at 14.

10 Note: In real terms, prices increased from $22/bbl to $60/bbl. SAFE analysis based on data from: EIA, Real Prices Viewer.

has lost more than $100 billion of its reserve assets in less than a year.[11] The costliness of this strategy after years of relative oil price stability made it all the more unexpected, and American producers were caught off guard, but there has been ample evidence that the Saudi strategy was targeted at devastating then-growing U.S. production. Former Saudi Oil Minister Ali al-Naimi alluded to this when he explained his nation's policy in February, saying, "Inefficient, uneconomic producers will have to get out, that is tough to say, but that is a fact."[12]

In addition to unpredictable and opaque price-setting resulting from OPEC behavior, at times, prices are simply drastically elevated due to the actions of member nations. While the oil shocks of the 1970s may be most vivid in the U.S. historical memory, there have been several periods over which the group has used its partial monopoly power to extract higher prices from oil importers over many years. Enabled by low price elasticity of demand—due to the lack of alternatives to oil in global transportation—the six-year period following the oil shock of 1979 saw OPEC systematically extract higher rents from consumers around the world. After production by the current OPEC nations had risen to over 29 mbd in 1979, a series of production cuts, compounded by the effects of the Iranian Revolution and the Iran-Iraq War, dropped this level by more than half to just over 14 mbd by 1985.[13] The effect of this was to usher in a sustained era of unprecedented high oil prices. By sacrificing market share—which dropped from over 47 percent in 1979 to just under 30 percent in 1985, eventually prompting renewed production growth by Saudi Arabia—OPEC was able to keep the price of oil in real dollars higher than it had ever previously been in post-war history for seven straight years. Prices would not reach these levels again for another twenty years.[14]

Quantifying the Costs of OPEC

The costs to the United States from the market manipulation of OPEC and the actions of NOCs are substantial. It is evident that impeded price discovery and increased volatility harms the ability of U.S. businesses and consumers to efficiently maximize their utility as rational actors. But beyond that, studies have quantified the economic costs to the nation directly attributable to OPEC actions. Among them, Greene (2010) divided the costs into the categories of wealth transfers, loss of productive potential, and disruption losses. Transfers of wealth refer to the extra payments the United States sends to OPEC nations due to the elevation of oil prices above the equilibrium price that would prevail in a free market. These transfers can amount to staggering losses for the United States. Between 1974 and 2013, for example, these transfers totaled more than $3.2 trillion, almost $1.4 trillion of which came from 2005 onward. Loss of potential GDP—the lost economic production that results from the elevated cost of an essential factor of production—added more than $1.4 trillion in costs to the nation between 1974 and 2013. Dislocation losses—the costs associated with responses to unforeseen price shocks—numbered $2 trillion.[15]

These costs are not only highly significant in absolute terms but can be staggering in relative terms. In 2008, for example, they represented a combined 4 percent of GDP, and the early 1980s saw two years in which they approached 5 percent of GDP.[16] Clearly, the costs of an oil market manipulated by OPEC are devastating to the U.S. economy, and help explain why major recessions such as those of the mid-1970s, early 1980s, and late 2000s all followed an oil shock which sent massive wealth transfers from the U.S. economy to OPEC.

Conclusion

The direct results of OPEC action and the indirect results of its market power both do great damage to the economies of the United States and its allies. With today's crippling of the U.S. shale oil industry—a

11 IMF, "Saudi Arabia: International Reserves and Foreign Currency Liquidity," December 17, 2015.
12 See, e.g., CBC, "Saudi oil minister's message for high-cost crude producers: 'get out' of market," February 23, 2016.
13 Including the members for whom data was presented in the 2015 OPEC Statistical Bulletin, consisting of all current members but Indonesia; and OPEC, *Annual Statistical Bulletin 2015*.
14 David L. Greene, "Measuring energy security: Can the United States achieve oil independence?" *Energy Policy* 38, 2010, 1614-21.
15 David L. Greene, Roderick Lee, and Janet L. Hopson, and updates from Changzheng Liu, "OPEC and the Costs to the U.S. Economy of Oil Dependence: 1970-2010," Oak Ridge National Laboratory, 2011.
16 Id.

goal of Saudi Arabia's championing of high OPEC output levels that is undoubtedly showing signs of success—the potential for lasting effects on the U.S. economy from OPEC nations is now evident in additional ways. And despite the incredible impact of technological advances in drilling activities on the United States' ability to decrease its dependence on oil imports, the capacity of OPEC nations and other NOCs to keep production levels artificially elevated and drive down prices shows the uneven playing field the United States faces in the global oil market.

The clearest way to protect the U.S. economy from the havoc that OPEC actions cause is to sharply reduce the nation's near-complete dependence on oil in the transportation sector. Such efforts to ensure that oil is no longer such a strategic commodity holding the global economy hostage are an essential part of any coherent energy security strategy, but they will take time to bear fruit. Since transitioning away from oil will take decades, in addition to pursuing policies to increase domestic oil supplies, increase efficiency and the use of advanced fuels, the nation must challenge the market and regulatory structures that give OPEC and NOCs their power in the near term.

To achieve greater power in the global market, the United States should look to export shale oil production technology, especially to close allies. Rapidly rising levels of highly flexible, non-OPEC oil production in the middle of the cost curve will dilute the ability of OPEC to assert market power. Shale resources are widespread globally, and with the right mix of know-how and regulatory best practices, the shale industry will grow beyond the United States, ideally expanding the quantity of oil production in the middle of the cost curve that can withstand periods of low prices driven by OPEC.

From a regulatory perspective, the United States should find ways to press OPEC, its members, and other countries with NOCs into formally and permanently ceasing attempts at collusion and opening their markets to freer international competition. Given that many of them are WTO members and that withholding supplies is a WTO violation, the United States must explore examples of international trade law violations by OPEC and its member nations and seek enforcement.

While the market structure that would evolve from these steps would undoubtedly be advantageous over the long term, the elimination of spare capacity would leave the world reliant on inventories to manage short-term supply crises. Given that fact, it will be critical for governments to have transparent, effective means for deploying strategic stocks quickly, and the United States should play a leading role in galvanizing greater cooperation. In particular, the IEA regime should be expanded to include China, which now has a sizeable strategic petroleum reserve and is the world's second-largest consumer and largest importer.

OPEC's central position in the global oil market leaves U.S. consumers vulnerable to economic and political factors beyond American control. But, alongside serious progress on demand reduction, strong resolve from the United States to work with allies to improve the fairness and freedom of the oil market could play a key role in insulating the global economy from the volatility OPEC and NOCs can cause.

Policy Recommendations

RECOMMENDATION

Establish a commission to investigate and better understand the role of OPEC, its member states, and other national oil companies in the maintenance of the unfree global oil market.

Given the clear, outsized influence that OPEC and NOCs hold in the global oil market, the U.S. government must place a greater emphasis on understanding their role in making the global oil market less free and fair. This is made all the more urgent by the remarks made by figures including former Saudi Oil Minister Ali al-Naimi signaling that U.S. producers (and potential future investment) are among the direct targets of the current market policy of Saudi Arabia and its allies. The United States should establish a commission to enumerate and quantify the impacts that external actors have on U.S. consumers, oil producers, industries, energy security policy, and national security. The Commission would, through its investigation, identify the existing nature of U.S. government agencies' interactions with OPEC actors and countries with large NOCs, and the potential for using or leveraging these relationships to mitigate the impact of any potential activity by OPEC, its member states, or other NOC to make the global oil market less fair or competitive.

To ensure that the Commission both represents the most qualified American experts on international oil trade and domestic energy security without being hampered by partisanship, the Commission's membership should draw on established professionals from both parties with a range of expertise. These areas would include oil market dynamics, oil and gas exploration and production, crude oil refining, oil and gas pipelines, transportation-related fuel consumption, oil use efficiency, national security, foreign policy, macroeconomics, labor, environment, logistics, shipping, tourism, consumer goods, manufacturing, and tourism. To ensure balance, of the 16 members of the commission, four would be directly selected by the president, who would then appoint four members each from lists submitted by the Speaker of House and the Senate Majority Leader and two members each from lists submitted by the House and Senate Minority Leaders.

Given complete access to information held by any relevant federal agency, and aided by a support staff and external reviewers, the Commission would hold open meetings to examine and illuminate issues related to OPEC and NOC influence over U.S. energy security. The culmination would be a major report to be issued within one year of the Commission's creation, whose findings and recommendations for U.S. policy would be publicized and form the basis for measures taken by the U.S. government to help liberalize the global market and enhance the nation's energy security. The president would be required to respond to the recommendations either positively or negatively within 90 days.

Exploring Legal Action Against OPEC Member States for GATT Violations

When market conditions have allowed, OPEC has colluded to lower crude oil production and increase prices above competitive equilibrium. Likewise, market conditions are sometimes conducive to OPEC raising crude oil production and decreasing prices, sometimes sharply, to the detriment both of the global economy and the investments in advanced fuels and automotive technologies that threaten the long-term value of OPEC's oil reserves. Such deliberate actions would constitute an illegal agreement to set prices under U.S. domestic law if made by parties subject to U.S. jurisdiction, which OPEC is not.[17]

While it might be difficult to challenge OPEC's behavior directly through the WTO, as it is an international organization and not a sovereign state, many of its member states are also members of the WTO. Thus, Angola, Ecuador, Kuwait, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela are all subject to the terms of the General Agreement on Tariffs and Trade.[18] Several of these nations often produce volumes of crude oil below their available production capacity.[19] Thus, one task of the OPEC commission could be to explore the possibility of initiating a case at the WTO asserting that select members of OPEC are violating Article XI of the General Agreement on Tariffs and Trade (GATT) by imposing export quotas on crude oil and requesting that the WTO require those members of OPEC to eliminate export quotas for crude oil and make their full production capacity available for domestic or export sale.

Article XI of the GATT prohibits restrictions by any means other than tariffs on the export or sale of any product, subject to a few limitations none of which apply to crude oil.[20] There will be a question as to whether unproduced crude oil is a product subject to the terms of the GATT. A potential litigant could argue, however, that production quotas are tantamount to export quotas, and that OPEC's production quotas have the same economic effect as an export restriction in that they limit the volume of oil that one WTO member country can export to another. The commission would study the feasibility of employing this argument before the WTO. Further, it could explore the development of rebuttals to any claim that production limits might be allowed by Article XX(g), which allows restrictions on exports "relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption," provided their genuine goal is to conserve natural resources.[21]

RECOMMENDATION

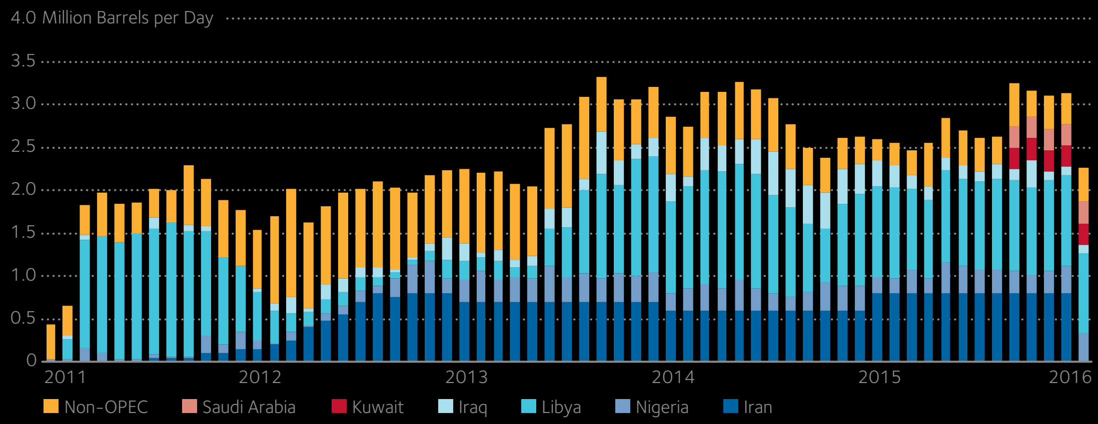
Build an international consensus among oil-consuming nations on the importance of shared responsibility and coordinated action to deal with future oil supply interruptions.

Global unplanned crude oil outages averaged 2.8 mbd over the past two years, largely due to supply disruptions in OPEC nations (Figure 79). These unexpected outages affect global oil market dynamics, including trade and prices. In February 2011, for example, clashes between protesters and security forces in Benghazi, Libya sparked a civil war. Libya's oil production was declining from 1.6 mbd—its approximate level between 2005 and 2010—before February ended, fell below 500,000 barrels per day in March, and had completely collapsed to less than 200,000 barrels per day by May.[22] Between

17 15 U.S. Code §1.
18 World Trade Organization, Understanding the WTO: The Organization Members and Observers.
19 EIA, Energy and Financial Markets, "What Drives Crude Oil Prices?"
20 General Agreement on Tariffs and Trade, Article XI.1.
21 General Agreement on Tariffs and Trade, Article XX(g).
22 IEA, *Monthly Oil Market Report*, July 2011.

Estimated Global Monthly Unplanned Crude Oil Outages

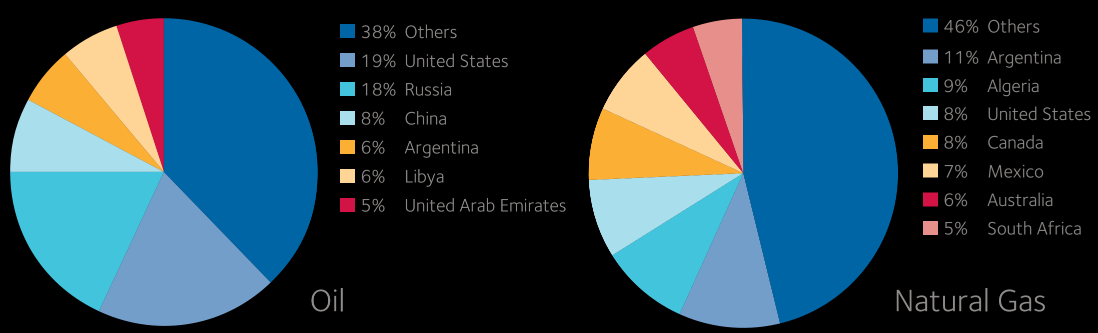
FIGURE 79



Source: SAFE analysis based on data from EIA

Global Unproved Technically Recoverable Assessed Tight Oil and Natural Gas Resources, 2015

FIGURE 80

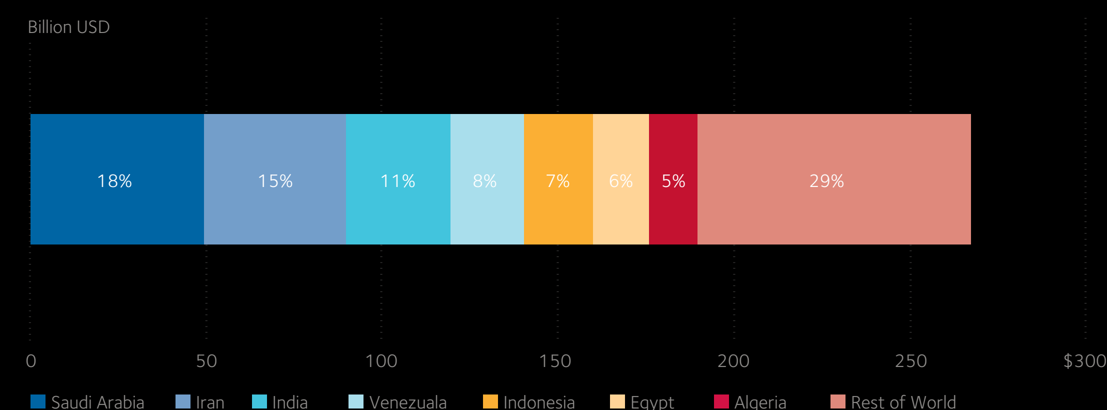


Note: Some nations' assessments last updated in 2013.

Source: EIA

Pre-Tax Consumer Oil Subsidies, 2014

FIGURE 81



Source: SAFE analysis based on data from IEA mid-February and mid-March, spot prices for Brent crude oil rose by approximately $10 per barrel. They rose another $10 per barrel by mid-April to more than $120 per barrel (for a total increase of more than 20 percent in less than two months).[23]

Despite the immediate impact that the loss of approximately 2 percent of global oil supplies had on oil prices, a coordinated oil stock release by the 28 IEA member countries was not agreed upon until June 23, 2011—more than four months after the war began.[24] In July, the IEA noted that "industry stocks looked comfortable back in March, and there was a presumption that other OPEC producers would immediately step in to boost supply to replace Libyan outages."[25] This presumption was clearly misplaced. In reality, the coordinated oil stock release was far from being the "decisive action" that the IEA framed it as.[26] It should be noted that the effect of this loss of production was not as severe as it could have been if U.S. production had not been growing at the time amid optimistic market sentiment. In the reverse scenario, had the domestic industry been hobbled like it is today, the price increase due to the loss could have been much more severe.

While major OPEC producers may or may not see reason (or monetary incentive) to "immediately step in" with higher supplies to offset disruptions, oil-consuming countries with large oil stock holdings can and should be much more willing to act in a truly decisive fashion.

While major OPEC producers may or may not see reason (or monetary incentive) to "immediately step in" with higher supplies to offset disruptions, oil-consuming countries with large oil stock holdings can and should be much more willing to act in a truly decisive fashion. As the IEA stated at the time, "Greater tightness in the oil market threatens to undermine the fragile global economic recovery."[27] Undoubtedly it did, as high oil prices persisted even after the fall of Muammar Gaddafi, contributing to the highest ever annual average oil price in 2011 and sharp reductions in both U.S. non-energy-related consumer spending and economic growth. The negative economic effects could have been mitigated by an appropriate and rapid, but still temporary, response.

Oil-consuming countries cannot always rely on major oil producers like Saudi Arabia to increase oil production immediately in the event of an outage like the one seen in Libya. They must build protocols and capacity to take action themselves. Moreover, it cannot be expected that shale oil be the swing producer in these emergency situations, as it takes longer than 90 days to begin production. The Council recommends that the United States lead a series of multilateral consultations with other major oil-consuming countries (including countries that are not currently IEA members, like China and India) to develop a set of guidelines for improved coordinated responses to oil supply disruptions. These guidelines should focus on the size of the disruption, the crude variety (or varieties) impacted, prevailing global economic conditions, the potential for establishing greater reserve capacity, and the effect of the disruption on prices.

23 SAFE analysis based on data from EIA, Spot Prices.
24 IEA, "IEA makes 60 million barrels of oil available to market to offset Libyan disruption," June 23, 2011.
25 IEA, *Monthly Oil Market Report*, July 13, 2011, at 3.
26 IEA, "IEA makes 60 million barrels of oil available to market to offset Libyan disruption," June 23, 2011.
27 Id.

RECOMMENDATION

Use the full diplomatic force of the U.S. government to push—especially through hydraulic fracturing technology—the development of oil and natural gas resources around the globe.

The development of shale oil around the world could substantially add to the productive capacity of a host of relatively stable countries and enhance the ability of global oil supplies to react more responsively to changing conditions, such as sharp price adjustments. Globally, these resources are considerable, estimated by the Department of Energy in 2013 at approximately 10 percent of all global oil resources.[28] Subsequent studies estimate unproved, technically recoverable U.S. tight oil reserves account for roughly 19 percent of the global total at 78.2 billion barrels.[29] Tight oil has been identified by the EIA in 39 countries, and more than half of the identified non-U.S. resources are concentrated in just five countries (Figure 80).[30] The development of these resources could over time help to alleviate the market's reliance on OPEC countries and the Middle East in particular. It could also have important geostrategic benefits. For example, it could help China meet more of its growing needs with domestic sources of oil, lessening the pressure to expand its search for oil in the South and East China Seas.

The United States launched the Unconventional Gas Technical Engagement Program in 2010. The program seeks to help countries identify and develop their unconventional resources safely and economically.[31] It includes shale gas resource assessments and technical guidance as well as government-to-government engagement on the environmental protection, business, and regulatory aspects of developing unconventional gas resources. The Council recommends this program be expanded to include shale and other tight oil resources or used as a model for a new program focused on these oil resources. At the same time, the intellectual property rights of U.S. companies involved in these activities must be strongly protected.

The U.S. government should provide assistance and expertise from the areas of finance (Treasury), diplomacy (State), energy (Energy), and resource development (Interior) to aid the sustainable expansion and control of the energy industry in nations with untapped potential to add flexible supply to the global oil market. In addition to providing technical know-how and resources, the United States should push nations to develop regulatory frameworks that allow for investment in hydrocarbon production, free from political encumbrance.

RECOMMENDATION

Encourage nations to cut oil subsidy programs.

On the demand side, excessive consumer fuel subsidies in both major oil-producing and oil-consuming countries distort oil consumption globally, helping to drive up prices. The IEA estimates that the cost of direct pre-tax oil product subsidies reached $267 billion in 2014, accounting for more than half of all global fossil fuel subsidies.[32] This estimate leaves aside the indirect economic costs and externalities that come from overconsumption due to this market distortion; in 2015, the IMF Fiscal Affairs

28 EIA, "Technically Recoverable Shale Oil and Shale Gas Reserves: An Assessment of 137 Shale Formations in 41 Countries Outside the United States," June 2013, at 3.
29 EIA, "World Shale Resource Assessments," September 24, 2015.
30 EIA, "Technically Recoverable Shale Oil and Shale Gas Reserves," at 8.
31 Office of the Coordinator for International Energy Affairs, Unconventional Gas Technical Engagement Program (UGTEP).
32 IEA, *World Energy Outlook 2015*.

Department estimated that the true implicit cost of energy subsidies worldwide would be $5.3 trillion for the year.[33]

For oil-producing countries, subsidies for domestic use create economically unsustainable consumption patterns and reduce potential export sales to the global oil market and earnings. The group of subsidizing oil-producing nations that supply just under half of the world's petroleum saw their share of global consumption rise 42 percent between 1992 and 2012, even as their share of production rose only 4 percent.[34] In Saudi Arabia, for example, oil consumption increased by more than 50 percent over the past eight years, owing in part to heavy subsidies and excessive—and inefficient—use of oil for power generation.[35] While many oil-producing countries use subsidies to placate often restless citizenries (Figure 81), a more sustainable approach would be to remove subsidies, export more, and use increased revenue to more efficiently address social concerns and invest to build more diversified economies. In 2014, 69 percent of global oil subsidies were paid by the 13 member states of OPEC.[36]

The most evident impact on the United States from global oil consumption subsidies is the tightening pressure they have on the global oil market by inflating demand levels. Researchers at the Federal Reserve Bank of Dallas concluded in 2014 that if oil producers cut their subsidies entirely, oil demand would drop to such an extent that the price of oil would drop by six percent, all else being equal.[37]

In addition, if companies are required by government subsidy programs to sell much of what they produce at below-market prices, their willingness to invest in expanded output is curtailed. This endures even in a scenario in which global market prices are increasing. Therefore, such companies are also likely to play a limited role in responding to any global market tightness.

In the current low-price environment, the social shock and upheaval that comes from cutting consumer subsidies is lesser, making now the ideal time for nations to act. India, Saudi Arabia, and the United Arab Emirates are among the nations that have taken some steps toward subsidy removal. They must remain committed to maintaining that progress should prices rise again. Moreover, many other U.S. allies and trade partners retain market-distorting and regressive subsidy regimes. The Council recommends the United States use its diplomatic and economic leverage to encourage the goal of decreasing fuel subsidies globally.

RECOMMENDATION

Develop a quantitative country index assessing respect for hydrocarbon production contracts.

Complex, unfavorable contract terms, often motivated by populist tendencies toward resource nationalism, have long deterred foreign direct investment in upstream projects that would otherwise be profitable. The specter of nationalist politics hanging over resource contract laws is even seen in OPEC nations seeking desperately to rejuvenate their oil industries, like Iran and Indonesia. Laws that require oil projects to be under the undue control of state entities dissuade investment that would otherwise be economically rational. Further, the enforceability and reliability of signed contracts with government partners varies to a great degree across oil-producing nations, often increasing reluctance from potential investors and thus adding to market inefficiency.

33 IMF, "How Large Are Global Energy Subsidies?" Working Paper WP/15/105, May 2015.
34 Federal Reserve Bank of Dallas, "Fuel Subsidies, the Oil Market, and the World Economy," Working Paper 1407, August 2014.
35 SAFE analysis of data from IEA.
36 IEA, *World Energy Outlook 2015*.
37 Federal Reserve Bank of Dallas, ***supra***.

While the issues inherent in respect for contracts and rule of law in oil-producing nations are myriad and complex, a comprehensive and publicized index that seeks to assess and quantify a nation's compliance with internationally accepted principles of contract law would serve to encourage nations to make progress in this area. The public diplomacy impact of a comprehensive assessment of respect for oil and gas contracts—whether done by a government agency, similar to the State Department's annual Country Reports on Human Rights Practices, or by an independent group, like Freedom House's annual Freedom in the World Index—could help encourage nations to improve their contract terms and legal protections for investors in order to avoid being seen as laggards with toxic business environments. This would promote greater transparency and rule of law in upstream investment worldwide, increasing overall market efficiency.

Conclusion

The United States remains heavily dependent on oil to power its economy. Despite an environment of abundance, this dependence acts as a double-edged sword, leaving the nation vulnerable to price shocks and crippling economic consequences, while also stifling innovation and suffocating the development of advanced technologies.

For the past two years, Saudi Arabia and its allies have orchestrated a strategy to drive down prices and undermine non-OPEC oil production. Although the efficiency, resilience, and responsiveness of U.S. shale production helps blunt the negative impact of OPEC's strategy, output is being materially affected. Moreover, investment in exploration and production is experiencing an unprecedented retreat due to lower oil prices, and the market appears certain to rebalance with very little spare production capacity available.

The global oil trends at work—rising consumption, OPEC overproduction, non-OPEC underinvestment, and high levels of instability in oil-producing countries and regions—all increase the likelihood of an oil crisis in the coming years that could, like oil shocks of the past, plunge the U.S. economy into deep recession. The odds in favor of a crisis are further heightened by the rise of terrorist movements expressly committed to targeting critical elements of the world's vulnerable oil production and delivery infrastructure and hostile state actors willing to use oil as a strategic weapon against the United States.

The innovation revolution occurring in advanced fuel technologies, as well as driverless vehicle technologies, holds the potential to wean the United States away from its oil addiction. Combined with increasing domestic oil production and measures to reduce OPEC's influence over the global oil price, this revolution can substantially improve U.S. energy security.

Many of the solutions put forth for consideration by the Council will require years to mature, but present the possibility of a radically transformed economy and society. Market forces alone will not sustain their development, especially if the world continues to experience unpredictable and volatile oil prices exacerbated by market manipulation. Government engagement will be necessary to align private interests in the service of the nation and ultimately promote fuel choice and competition in the U.S. transportation sector. The Council endorses the goal of reducing oil's share of transportation miles from 92 percent today to 50 percent by 2040 as an important national target that will help substantially strengthen the U.S. economy.

We are confident that Americans will support a bipartisan and open-minded campaign to make the nation more energy secure. Let this campaign to reduce oil dependence be the first test of this patriotic belief.

Modeling

SAFE built five unique, linked models that show how the United States can significantly reduce oil consumption in the transportation sector and the policies that will be required to achieve the 50 by '40 goal. The analysis focuses on the modes of transportation that use 92 percent of the oil in the transportation sector—light-duty vehicles, medium- and heavy-duty vehicles, and commercial aircraft.

The first model is a total cost of ownership (TCO) model that includes realistic, but aggressive, technology cost assumptions for a suite of advanced fuel vehicles (AFVs). This model uses upfront purchase cost plus projected fuel and other operational costs over the lifetime of the vehicle to calculate the full cost of ownership. It is configured to analyze a range of light-, medium-, and heavy-duty vehicles such as compact and mid-size sedans, pickup trucks, vans, and Class 8 trucks, incorporating separate analysis and simulation for carsharing vehicles in the light-duty segment. Vehicles powered by gasoline, diesel, natural gas, electricity, and hydrogen are included. The model calculates TCO for purchase years through 2040, and allows the user to test how changing underlying assumptions—for instance, changing the cost of various AFV components—will affect overall cost.

The second model, based in the Vensim modeling software and controlled via an Excel interface, is a consumer adoption model guided by the TCO results in addition to other variables such as the availability of refueling infrastructure, purchase and other monetary and non-monetary incentives, vehicle performance characteristics, energy prices, and many more. The variables are organized into a selection of connected "modules" including Car Parc, Familiarity, Infrastructure, Cost of Fuel, and Consumer Choice, each consisting of sets of independent and dependent variables. Many of the variables can be adjusted via Excel to simulate real-world policy changes. For example, the trajectory for battery costs (per kWh) through 2040 can be rendered either more or less aggressive than the model baseline. Such adjustments impact the sales rates of different vehicle platforms.

Functioning independently, but feeding into the consumer adoption model, is an autonomous vehicle adoption model. Developed in AnyLogic and controlled via a standalone Excel interface, it allows users to control dozens of variables to simulate different trajectories for carsharing and self-driving vehicle penetration in the light-duty sector. The output, projecting levels of car ownership, overall car parc, autonomous vehicle adoption for both personal and carshare vehicles, and vehicle miles traveled for different vehicle types and ownership models, feeds into the consumer adoption model. There, its results are used to illustrate the effects of different autonomous vehicle and carsharing scenarios on energy consumption, vehicle sales by technology, and oil displacement, either alone or in concert with changes to AFV technology policy inputs.

The output of the consumer adoption model includes, among other curves, a simulated set of market penetration rates and VMT shares for the suite of AFV technologies in the light-duty vehicle segment. Combined with target estimates for the medium- and heavy-duty segments informed by the TCO model, this output is fed into a petroleum scenario model to show the associated impact on oil and energy use in the transportation sector across fuels and vehicle platforms (including aviation) through 2040. This model also consolidates this impact so that oil's share of transportation VMT can be tracked from current levels to the targeted 50 percent level.

SAFE also quantifies the economic benefits of the oil displacement calculated through the petroleum scenario model in a separate Economic module, which was created alongside the consumer adoption model. It enables SAFE to present an estimated impact on GDP and oil spending by consumers based on the transportation sector's (more diversified) fuel mix, as well as to simulate the effects of oil market shocks on the economy under different AFV adoption scenarios.

As exhibited in this report, with the capacity to interactively model infinite scenarios based on adjustable assumptions, the linked models will be valuable tools to policy makers, thought leaders, media, and academics alike.

Credits and Acknowledgements

Securing America's
Future Energy

Securing America's Future Energy (SAFE) is a nonpartisan, not-for-profit organization committed to reducing America's dependence on oil and improving U.S. energy security in order to bolster national security and strengthen the economy. SAFE has an action-oriented strategy addressing politics and advocacy, business and technology, and media and public education. More information can be found at SecureEnergy.org.

1111 19th Street, NW, Suite 406 | Washington, DC 20036 | T 202-461-2360 | W SecureEnergy.org