Breaking the Habit:

Eliminating Our Dependence on Oil from the Gulf of Mexico by 2020, the Persian Gulf by 2023, and All Other Nations by 2033

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April 2011

Executive Summary

Optimizing our energy supply in a way that maximizes our nation's security, economic competitiveness and environmental health is one of the greatest challenges we face. The majority of the oil we consume is either imported from unstable regions like the Persian Gulf or extracted domestically offshore, jeopardizing both our national security and coastal ecosystems and the economies that depend on them. At the same time, our use of oil pumps billions of tons of pollutants, including particulate matter and CO_2, into the atmosphere, which makes people sick and contributes to climate change. On top of that, the continuing cost of subsidizing oil production at the expense of renewable energy development reduces our competiveness in the fast-growing clean energy sector.

On the other hand, reducing our consumption of oil, especially by eliminating the need to drill in the Gulf of Mexico and import oil from the Persian Gulf, would be a huge step towards a safer, healthier and more prosperous nation.

This is a step that we can now take thanks to technological advances in four key petroleum-consuming sectors: shipping, residential and commercial heating, electricity generation and light-duty vehicle transportation. By making improvements in each of these sectors, we could alleviate U.S. dependence on Gulf of Mexico oil by 2020 without increasing oil imports. Further improvements could free our nation from needing to import oil from the Persian Gulf by 2023, and ultimately, we could eliminate all other oil imports by 2033. In this paper, Oceana presents a vision of how we could achieve these crucial goals.

Notably, it is not necessary to make these cuts in the order suggested (i.e. Gulf of Mexico oil, then Persian Gulf oil, then all imported oil). Instead, imports from the Persian Gulf could be eliminated by 2020 and oil from Gulf of Mexico waters by 2023. Or we could aim to alleviate both at the same time, and achieve that goal by 2023. Rather, the key message of this vision is that we, as a nation, have the very real opportunity to fundamentally change our relationship with oil. By making the changes discussed below as soon and as aggressively as possible, we can eliminate the need for offshore drilling and oil imports in just over 20 years – which would be a momentous and valuable accomplishment.

How much change we need in each sector depends of course on how much we make in the others. This paper presents just one scenario, or one set of targets, that, if met, would achieve our three goals (Table 1; Fig. 1, 2). Ultimately, though, many other formulas could be created by either increasing or decreasing the amount of change made in the four sectors; by tackling other sectors, such as commercial trucking; or by adopting energy conservation practices. **Regardless of the path we choose, it is clear that we could eliminate our dependence on oil from Gulf of Mexico waters by the end of this decade, the Persian Gulf just three years later, and all other imports by 2033.**

Table 1: Making Oil Drilling and Imports Unnecessary:
We can save 1.9 million barrels per day by 2020, and 7.3 million barrels per day (bpd) by 2030.

Sector	2020		2030	
	Reduction in Oil Consumption (thousand bpd)	Percent Reduction in Sector's Oil Consumption (%)	Reduction in Oil Consumption (thousand bpd)	Percent Reduction in Sector's Oil Consumption (%)
Commercial Shipping	105	23	107	30
Residential and Commercial Heating	228	25	632	100
Electricity Generation	200	100	N/A	N/A
Light-Duty Vehicle Transportation	1,380	16*	6,540	81*
Electric Vehicles	190	2	2,660	33
Cellulosic Ethanol	1,190	13	1,110	14
Algal Biofuel	0	0	2,770	35
Total	**1,913**	**9**	**7,279**	**38**

**Percent reductions for light-duty vehicle technologies may not sum to sector's total percent reduction due to rounding.*

Figure 1: Achievable Reductions in Oil Use Would Eliminate Need for Gulf of Mexico Oil Drilling in 2020 and Make 80% of Imports Unnecessary in 2030.

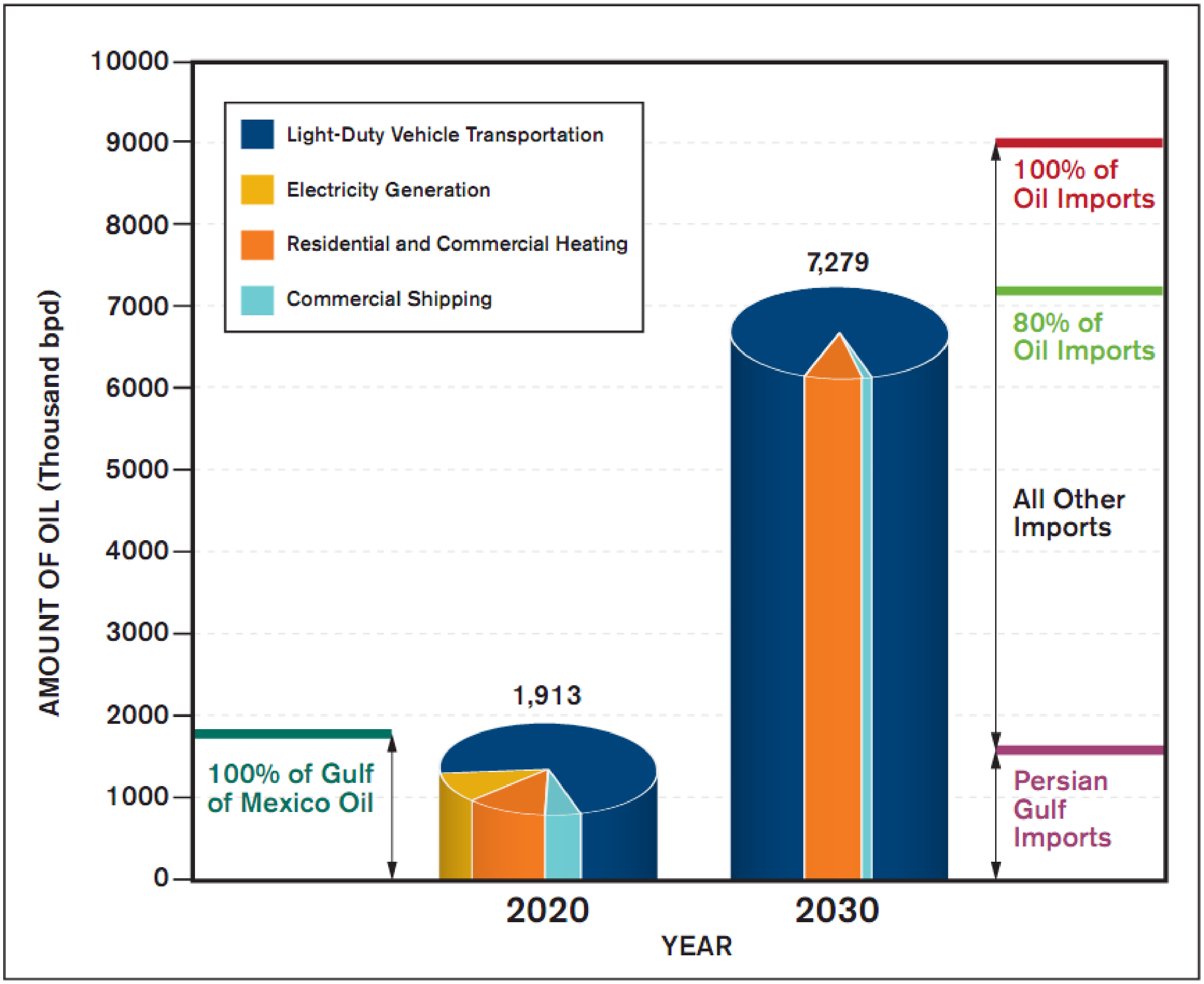
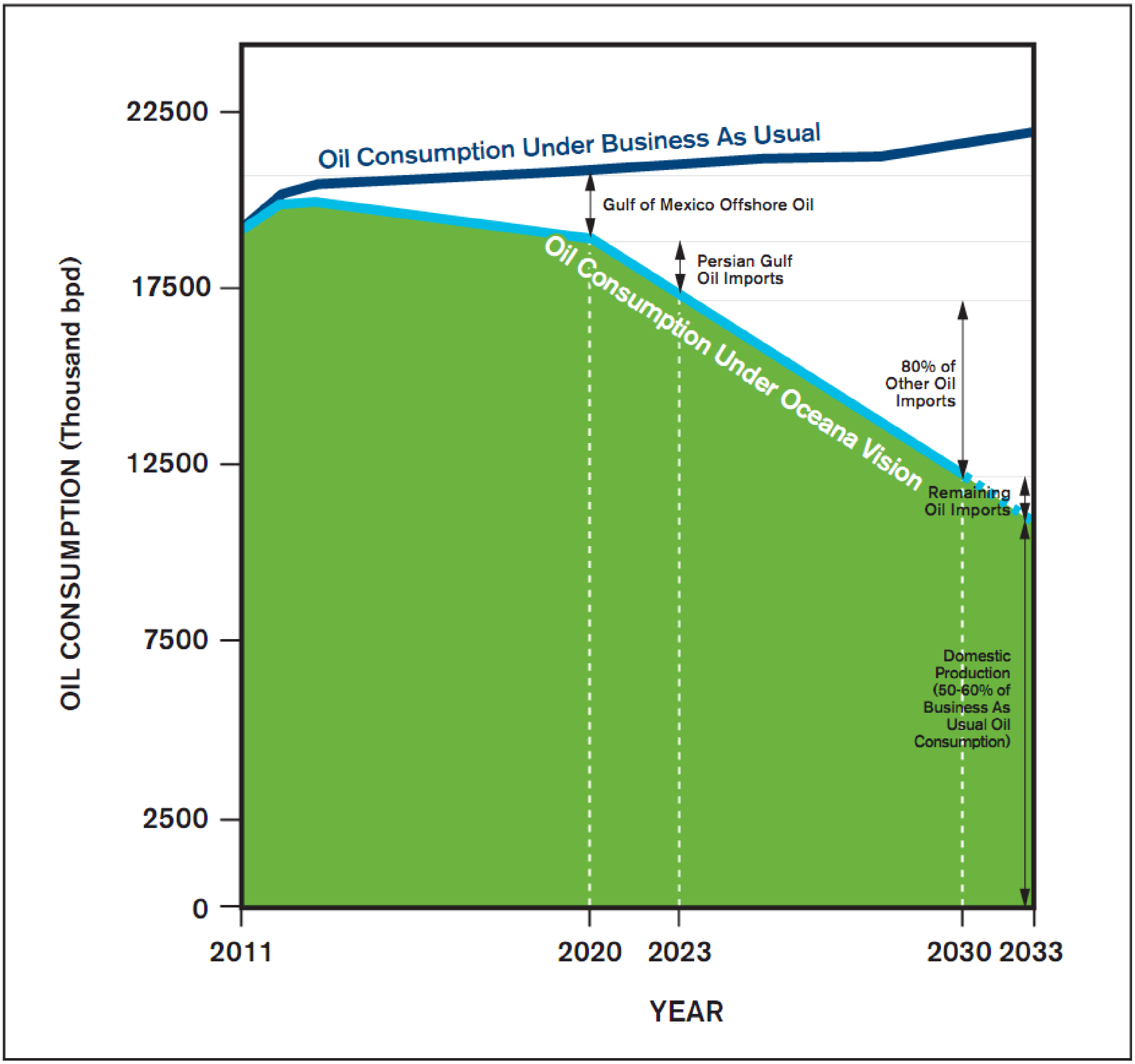


Figure 2: Achievable Reductions in Oil Use Could Eliminate Need for Gulf of Mexico Offshore Oil Drilling by 2020, Persian Gulf Oil Imports by 2023 and 80% of Other Oil Imports by 2030.



ELIMINATING OFFSHORE OIL DRILLING IN THE GULF OF MEXICO – THE 2020 VISION

The risks associated with offshore drilling in the Gulf of Mexico have never been made more clear than they were in the spring and summer of 2010. Fortunately, we can alleviate the need for these risky practices. Currently, we get about 9% of the oil we use or about 1.6 million barrels per day from offshore drilling in the Gulf of Mexico. In 2020, the U.S. Energy Information Administration projects this number will grow slightly to 1.79 million barrels per day, although it will account for about 9% of total consumption. The following changes could alleviate the need for more than that amount of oil. Some of them require a shift to electric power, in which case clean energy generation will be needed to fulfill the additional demand. However, as described in this paper, we have the capability to generate enough clean electricity to fulfill those needs.

Improve Efficiency in Commercial Ocean-Going Ships

Tremendous efficiencies can be achieved in the shipping sector. One notable example is the practice of "slow-steaming." By simply slowing down, ships can increase efficiency and reduce fuel use. In fact, by slowing down just 10%, ships can cut their fuel use by 23%, according to the International Maritime Organization. A variety of other measures could be taken as well. Assuming a simple slowing of steaming speed by 10% and a corresponding savings of 23% on fuel, the need for 105,000 barrels of oil per day would be alleviated. While there may be additional trips added to make up for the slower speed, there are also additional operational and technical measures ships could employ. According to studies by the IMO, a reduction of much more than 23% is achievable now with existing technology. The envisioned reduction of 105,000 barrels of oil per day is approximately 6% of the amount of oil forecasted to be produced by offshore drilling in the Gulf of Mexico in 2020.

Shift Residential and Commercial Heating from Oil to Electricity

Electric heat is more efficient than oil heat. Shifting just 25% of the homes and businesses that still use oil for heating to electricity would not only make them more efficient, it would also alleviate the need for about 228,000 barrels of oil each day. This is about 13% of the amount of oil we will get each day from the Gulf of Mexico in 2020. Making this shift will require additional electricity to be generated. This need could be met with just 2.3 gigawatts (GW) of offshore wind power or similar amounts of onshore wind, solar, and geothermal power.

Stop Using Oil to Generate Electricity

While we use relatively little oil to generate electricity, stopping this practice would alleviate the need for 200,000 barrels of oil per day. This is 11% of the amount of oil we will get from the Gulf of Mexico in 2020. To replace the electricity generated by oil, we would need 11.7 GW of offshore wind power. Onshore wind, solar, and geothermal energy could also be used to fill this electricity demand.

Power Light-Duty Vehicles with Electricity and Cellulosic Ethanol

Our cars and other light-duty vehicles are the primary users of oil. To make the transition to clean energy and to achieve energy independence, this must change. We won't achieve it overnight, but by 2020, we could eliminate the need for about 1.4 million barrels of oil per day, or roughly 80% of offshore oil from the Gulf of Mexico, by using cellulosic ethanol and beginning to electrify our automobile fleet. Under this scenario, nearly 1.2 million barrels of oil per day would be replaced by cellulosic ethanol fuel and by electrifying just 5% of our automobile fleet, we could eliminate the need for the remaining 200,000 barrels of oil per day. The adoption of electric vehicles would create an additional electricity demand which could be fulfilled by adding about 3.4 GW of offshore wind or comparable amounts of onshore wind.

ELIMINATING 80% OF OUR OIL IMPORTS BY 2030 – THE 2030 VISION

Instability in the Middle East and subsequent surges in gasoline prices have brought our nation’s dependence on foreign oil into sharp focus. Many politicians and experts alike have suggested increasing domestic production to break this dependency. However, U.S. offshore oil deposits are not sufficient to make us energy independent. An alternative that doesn’t endanger our environment or health exists: eliminating the need for oil imports in the first place. The U.S. Energy Information Administration projects oil imports will decrease slightly from current levels to about 9 million barrels of oil per day in 2030, accounting for about 50% of the nation’s oil consumption. Of these 9 million barrels of imported oil, about 1.6 million barrels will come from the Persian Gulf. Further advances in the above four sectors would allow us to reduce all oil imports by 80% by 2030 and entirely eliminate Persian Gulf imports as early as 2023. Continued reductions beyond 2030 in the above sectors would also allow the nation to eliminate all oil imports.

Improve Efficiency in Commercial Ocean-Going Ships

Although we assume all ships have already slowed speeds by 10%, many other options exist that, if implemented, would increase fuel efficiency by an additional 30%. Some could further reduce speeds and save even more fuel at no expense. Technological and operational modifications, including special hull coatings and just-in-time arrival, could also be adopted. Combined, these changes could reduce oil consumption by between 30% and 69%. And these figures do not even include technological innovations or improvements made between now and 2030 that would provide even greater opportunities for fuel savings. Thus, oil consumption in the commercial shipping sector could be further reduced by 30%, or 107,000 barrels of oil per day, between 2020 and 2030.

Shift Residential and Commercial Heating from Oil to Electricity

Converting the remaining residential and commercial buildings using oil-fired heating systems to electric ones would save 632,000 barrels of oil per day by 2030. By doing so, these homes would not only save money with more efficient heating systems, but also avoid price spikes caused by volatility in the international oil markets. To provide the electricity for these new heating systems, roughly 6.4 GW of offshore wind or other renewable energies would need to be installed.

Power Light-Duty Vehicles with Electricity, Cellulosic Ethanol, and Algal Biofuels

By 2030, the U.S. Energy Information Administration projects that light-duty vehicles will account for 8 million barrels of oil per day, or 60% of our nation's total oil consumption. Electric vehicles, cellulosic ethanol, and algal biofuels could all put a significant dent in this number, alleviating the need to consume 6.5 million barrels of oil per day by 2030. About 41% of this reduction would be due to increased adoption of electric vehicles, which could account for 40% of the light-duty vehicle fleet by 2030. Another 17% of the envisioned reduction would be due to ramped up production of cellulosic ethanol. The balance of the reduction, roughly 42%, would occur as algal biofuel production is commercialized. As before, the expansion in the electric vehicle fleet would need to be accompanied by an increase in renewable energy generating capacity, specifically about 54 GW of offshore and onshore wind.

Introduction

Optimizing our energy supply in a way that maximizes our nation's security, economic competitiveness, and environmental health is one of the greatest challenges we face. Right now, the majority of oil we consume is either imported from unstable regions like the Persian Gulf or extracted domestically offshore. Without action, this situation is unlikely to change, leaving our national security and coastal ecosystems and economies at risk. On the other hand, reducing our consumption of oil, especially by eliminating the need to drill in the Gulf of Mexico and import from the Persian Gulf, would be a huge step towards a safer, healthier, and more prosperous nation.

In this report, we draw from the results of a broad range of studies to show how reasonable actions over the next two decades in four sectors – commercial shipping, residential and commercial heating, electricity generation, and light-duty vehicle transportation (Table 2) – could eliminate the need for offshore drilling and oil imports. Importantly, none of the projections in this report depend upon the passage of major legislation. Consequently, our vision presents an achievable roadmap for breaking our nation's oil habit.

Our vision would eliminate the need for offshore drilling in the Gulf of Mexico by 2020 without increasing oil imports. It would eliminate the need for oil imports from the Persian Gulf by 2023. By 2030, we could do without 80% of our imports and we could phase out the rest of oil imports by 2033. Oceana's plan allows for considerable flexibility. Persian Gulf imports could be eliminated in 2020, for instance, and Gulf of Mexico imports in 2023. Regardless of what source is eliminated when, the overarching message is clear: we, as a nation, have a real opportunity to fundamentally change our relationship with oil.

Table 2: Making Oil Drilling and Imports Unnecessary:
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Vision to 2020

Eliminating all offshore drilling in the Gulf of Mexico by 2020 would not only ensure another disaster like the Deepwater Horizon oil spill does not occur, but also catalyze a shift in investments from a fading industry to emerging industries.[1] To eliminate drilling in the Gulf of Mexico, 1.79 million barrels per day (bpd) of crude oil consumption - about 9% of total consumption - must be cut by 2020 according to the U.S. Energy Information Administration (EIA),[2] a target that projections based on reasonable action show can be reached. Specifically, with reasonable policies and incentives, oil consumption in 2020 can be reduced by nearly 2 million bpd beyond business as usual levels.

COMMERCIAL SHIPPING: CUT 105,000 BARRELS PER DAY OF OIL BY SAVING 23.3% OF FUEL VIA EFFICIENCY

Domestic and international shipping by U.S. ships is projected by EIA to consume roughly 450,000 bpd in 2020, an increase of 20,000 bpd from current levels.[3] While it represents only a small percentage of total U.S. oil demand, this sector presents low-hanging fruit for cutting petroleum consumption and so provides a good starting point. Multiple studies and demonstrations, for instance, have shown that reducing speed by only 10% can net improvements in fuel efficiency of between 19% and 27%.[4] Assuming a median value of 23.3%, the fuel savings estimated by the International Maritime Organization,[5] reducing speed by 10% would reduce petroleum consumption in 2020 by 105,000 bpd, a small fraction of the distillate and residual fuel oil produced in the Gulf of Mexico.[6]

In fact, many companies are already slowing their ships to cut their fuel costs. Maersk Lines, one of the largest global shipping companies, has committed to super slow steaming, reducing speeds up to 50% in pursuit of fuel savings and emissions reductions.[7] Maersk's example proves a speed reduction target of 10% is achievable.

RESIDENTIAL AND COMMERCIAL HEATING: CUT 228,000 BARRELS PER DAY OF OIL BY ELECTRIFYING 25% OF OIL-FUELED HEATERS

Oil is widely used for heating in the United States and will continue to be in the coming decade under a business as usual scenario, according to EIA. Specifically, oil heating will account for roughly 910,000 bpd of oil use in 2020, down by only 90,000 bpd from 2010.[8] One reason heating oil is so popular is the high cost of switching from oil-fueled systems, like furnaces and boilers, to alternatives, like electric or geothermal heaters. In the case of electric heat, though, great increases in efficiency can compensate for upgrade expenses,[9] making the transition economically viable, especially as oil prices continue to rise. Supplanting a quarter of the oil consumption in heating with electric systems would save 228,000 bpd by 2020, and would require the electrification of about 4 million homes.

Although this proposal is the most ambitious part of the vision to 2020, achieving the entire 228,000 bpd reduction is not necessary in order to achieve the vision's 2020 goal of eliminating the need for offshore oil production in the Gulf of Mexico. Rather, a reduction in the use of oil for heating as small as 100,000 bpd, or roughly 10% of total consumption in this sector, would be sufficient assuming all other proposed reductions are achieved.

To accommodate the increase in electricity demand resulting from the electrification of heating systems, a number of renewable energy options are available. Expanding renewable energies rather than conventional sources of energy, e.g. coal or natural gas, ensures that the combustion of one fossil fuel is not substituted for that of another, which would still contribute to local pollution and climate change, albeit to a lesser extent. There are a variety of scenarios in which clean energy could more than account for this additional demand.

Offshore wind, a nascent industry with vast potential, offers one option for meeting the demand for more electricity. To meet 100% of the demand, 2.3 GW of offshore wind would need to be constructed[10] - an increase from today's dearth of offshore wind but a very reasonable goal given the vast economically-recoverable wind resources of the Atlantic coast alone, which are rated at over 100 GW,[11] and current proposed offshore wind farms. Cape Wind, for instance, would generate 450 MW of power, while other farms would generate as much as 1 GW of power.

In non-coastal areas, distributed solar photovoltaics could satisfy electricity needs at the point of consumption, i.e. at each building, largely avoiding grid and transmission complications. Alternatively, onshore wind could be installed, particularly in the gusty Midwest, to meet electricity demands at a regional level. In reality, a combination of these sources would fill the demand. These options are discussed further below.

ELECTRICITY GENERATION: CUT 200,000 BARRELS PER DAY OF OIL BY REPLACING 100% OF THE GENERATORS WITH RENEWABLE ENERGY

Oil consumption in electricity generation is predicted by EIA to remain flat at 200,000 bpd between 2010 and 2020.[12] Combined, petroleum-based generators in 2009 had a nameplate capacity of 63 GW,[13] but generated far less electricity than they could have, as indicated by their paltry 0.078 capacity factor.[14] Their low electricity output makes it rather easy to replace 100% of the power they generate by 2020. To replace all electricity generated using petroleum, 11.7 GW of offshore wind would be required.[15] Again, there are many potential alternatives, and again, offshore wind is particularly promising: half of the power generated by these oil-fired power generators feeds coastal states with superb offshore wind resources and where offshore wind farms are currently being developed.[16]

LIGHT-DUTY VEHICLE TRANSPORTATION: CUT 1,380,000 BARRELS PER DAY OF OIL BY ELECTRIFYING 5% OF THE FLEET AND SATISFYING 13% OF THE FLEET'S FUEL DEMAND WITH CELLULOSIC ETHANOL

Over the next decade, light-duty vehicles will continue to comprise the lion's share of petroleum consumption – about 60% - in the United States, accounting for 8.89 million bpd in 2020.[17] As a result, they also provide the greatest opportunity for reducing petroleum use. To this end, two technologies hold particular promise over the next decade: electric vehicles and cellulosic ethanol. The combined effect of accelerated deployment of these two technologies could be 1,380,000 bpd less of oil consumed, reducing the light-duty sector's consumption of oil by a modest 16%.

Electric Vehicles: Cut 190,000 barrels per day of oil by electrifying 5% of the fleet

The replacement of conventional vehicles with electric ones can greatly reduce petroleum consumption, while also spurring economic growth and decreasing local and global pollution. Under business as usual, EIA projects there to be roughly 314,000 full electric vehicles (EVs); 500,000 plug-in hybrids (PHEVs), equally divided between those with 10- and 40-mile all-electric ranges; and 7.2 million hybrid electrics (HEVs) on the roads in 2020.[18] These projections assume there are no additional policy changes to spur adoption of electric vehicle use, a very conservative scenario that can be exceeded with simple changes in national policy. Other studies based on reasonable, and still rather conservative, projections have shown the adoption of electric vehicles could be much greater.

A study by Deutsche Bank estimates that, assuming only the continuation of current regulations and incentives, the U.S. fleet of all types of electric vehicles will reach nearly four million by 2020, with HEVs numbering 2 million and PHEVs and EVs constituting the balance.[19] Not surprisingly given its underlying assumption, Deutsche Bank's projection more or less agrees with EIA's business as usual projection. Other studies, though, have looked at electric vehicle adoption rates under accelerated deployment.

A 2008 Morgan Stanley paper[20] reported that base case consumer demand was sufficient to allow for a fleet of 12 million hybrids in 2020, 3.8 million of which would be PHEVs[21] – about triple the figures projected by Deutsche Bank and EIA. Morgan Stanley's report has been widely cited in subsequent papers and reports, so we utilize its projections of PHEV and HEV adoption in lieu of those from Deutsche Bank. In total, then, 8.2 million HEVs, 3.8 million PHEVs, and 0.7 million EVs could be on the road in 2020. Combined, these electric vehicles would make up roughly 5% of the entire light-duty vehicle fleet,[22] a similar 2020 target as put forth by Google in its "Clean Energy 2030" proposal.[23] The calculated oil savings from the 12.7 million electric vehicles: 190,000 bpd.[24]

Although such a fleet size may seem overly-optimistic, it is dwarfed by the estimations contained in a fourth report from The Center for Entrepreneurship and Technology (CET) at U.C. Berkeley. The report found that the adoption of switchable batteries and pay-per-mile service contracts[25] could lead to as many as 9 million EVs and 25 million HEVs on the road in 2020. CET estimates these vehicles would reduce oil consumption by roughly 600,000 bpd.[26] For the 2020 vision, we used the more conservative figure of 190,000 bpd, where roughly 5% of the fleet, or 12.7 million vehicles, would be some type of electric vehicle.

As electric vehicles become more widespread, their effect on the electricity grid must be considered. Because the majority of recharging would occur overnight when electricity demand is lowest, even an electric vehicle market penetration of 50% would not necessitate extensive additions to electricity generating capacities.[27] However, most of the electricity demand from electric vehicles under these scenarios would be met by conventional sources of energy, e.g. coal or natural gas, that are associated with a variety of deleterious health and environmental effects. Thus, rather than relying on existing infrastructure, this vision foresees the expansion of renewable energies, particularly wind, to satisfy the electricity demand from electric vehicles.

Since most electric vehicles would charge at night, without better storage capabilities, solar power could not satisfy this demand. Wind power, though, is well-suited to satisfying this demand because winds are strongest at night.[28] The results of a study from Oak Ridge National Laboratory shed light onto how much wind would be required. The study projected the electricity demand from 20 and 50 million PHEVs in 2020 and 2030, respectively, and found that (neglecting capacity factors) roughly 0.32 GW of electricity must be generated for every million EVs.[29] Therefore, to provide the electricity for a combined PHEV and EV fleet of 4.5 million (both of which must be charged), roughly 3.4 GW[30] of offshore or onshore wind power must be installed.

Cellulosic Ethanol: Cut 1,190,000 barrels per day of oil by satisfying 13% of the fuel demand

Considerable controversy has surrounded the use of ethanol in transportation, particularly when derived from sugar or corn, due to concerns over sustainability and the depletion of already-stressed food stocks.[31] Cellulosic ethanol, which is produced by breaking down cellulose into sugar that is then processed into ethanol, avoids many of these issues.

Cellulosic ethanol can be produced from agricultural and forestry wastes, circumventing food supply and land-use concerns. Additionally, even when cellulosic ethanol is created from energy feedstocks like switchgrass, which would require the expansion of agricultural land or the conversion of food to energy crops, the feedstocks grow quickly, require relatively few inputs, and can be cultivated in marginal areas. Thus, although less sustainable than residues, energy feedstocks still offer a viable route to sustainable cellulosic ethanol production that would deliver net carbon reductions.

Despite the promise of cellulosic ethanol, progress in the industry has failed to meet expectations. In the second half of 2010, for instance, the Environmental Protection Agency estimates no cellulosic ethanol was blended with gasoline. Furthermore, in all of 2010, only 1 million gallons were produced when the Energy Independence and Security Act called for 250 million gallons.[32]

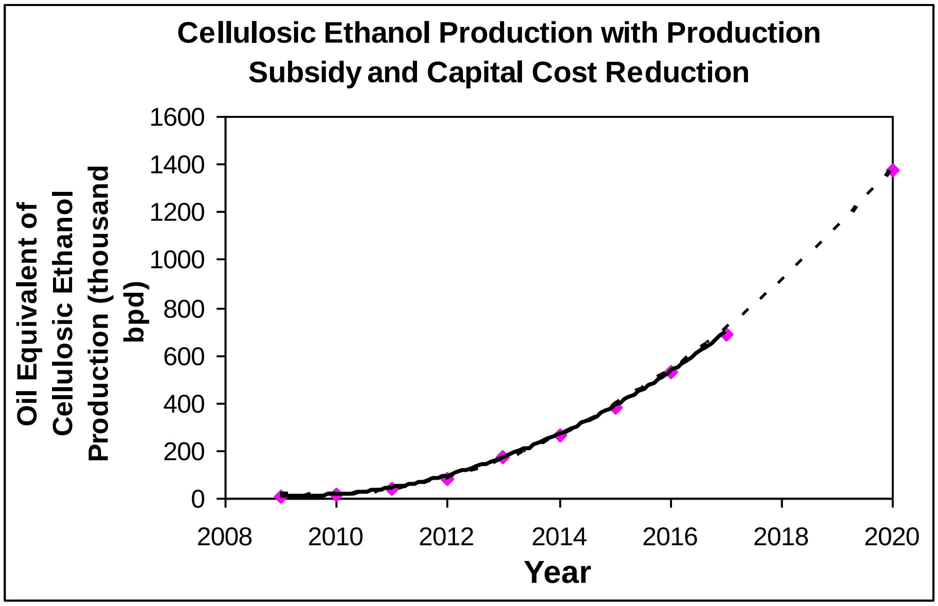
Even so, the scale of pilot facilities continues to increase thanks to public and private investments. Even under business as usual, EIA in its 2011 Annual Energy Outlook predicts cellulosic ethanol production will reach 190,000 bpd in 2020.[33] Similarly, a 2008 National Renewable Energy Laboratory (NREL) report estimated that, given the state of the industry and existing incentives at the time of its publication, cellulosic ethanol production would reach 500 million gallons in 2017,[34] or the oil equivalent of 48,000 bpd.[35] Unlike EIA, though, NREL's study further modeled the effect five policies and incentives would have on production levels in the same time frame. It concluded that if a capital cost reduction policy and a production subsidy were put in place, cellulosic ethanol production could increase more than tenfold to 692,000 bpd oil equivalent by 2017.[36]

While NREL doesn't give a specific 2020 estimate needed for the vision calculation, NREL does project that cellulosic ethanol production would grow exponentially between 2008 and 2017, nearly doubling in two years between 2015 and 2017 alone. Under such growth conditions, at least another doubling would be expected between 2017 and 2020, although continued exponential growth would yield much more than a doubling. Nonetheless, to err on the conservative side, we assume a doubling occurs, which would result in the equivalent of 1.38 million bpd of oil being produced in 2020 (Fig. 3). For comparison, over the same period of 2017 to 2020, EIA's business as usual scenario projects cellulosic ethanol production quadrupling.

Further justification for our assumed growth in the cellulosic ethanol industry from 2017 to 2020 can be drawn from the annual growth rate of the industry under NREL's projection. The industry exhibits a compounded annual growth rate (CAGR) of 70% from 2009 to 2017, which, if continued, would result in cellulosic ethanol production of 3.4 million bpd oil equivalent in 2020 – far more than our assumed 2020 production. Even assuming the continuation of the industry's growth rate between 2016 and 2017 of 30% would yield 1.5 million bpd oil equivalent of cellulosic ethanol in 2020 – again more than our assumed 2020 production. Notably, a continued 30% growth rate from 2017 to 2020 would not be unprecedented: the solar and wind industries grew at a CAGR of 39.8% and 29.7%, respectively, between 2000 and 2010.[37]

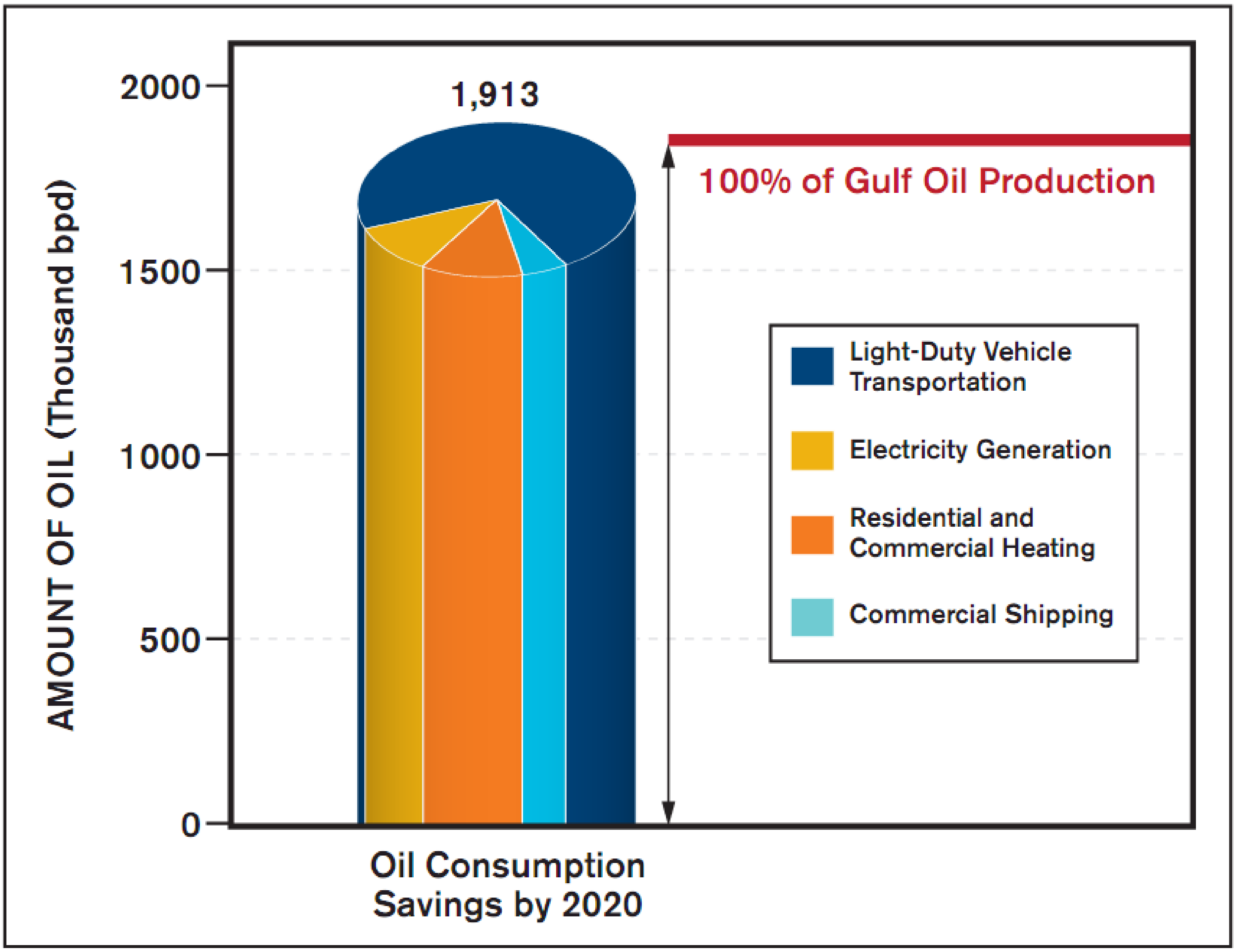
Thus, this vision assumes that production of cellulosic ethanol will reach 1.38 million bpd oil equivalent by 2020, which is a net increase from business as usual (0.19 million bpd) of 1.19 million bpd. This amount of cellulosic ethanol could supplant roughly 13% of the demand for liquid fuel for light-duty vehicles.

Figure 3: Cellulosic ethanol production as estimated by the NREL (solid line) and extrapolated to 2020 (dashed line). The extrapolated 2020 value (1.38 million bpd), minus EIA's projected 2020 production under business as usual (0.19 million bpd), was used in this report.



TOTAL OIL SAVINGS BY 2020: 1,913,000 BARRELS PER DAY

Figure 4: Oil Consumption Savings Achieved by 2020 Would Make Offshore Oil Production in the Gulf of Mexico Unnecessary.



In total, conservative estimates from a diverse array of studies show that realistic and feasible reductions in oil consumption in commercial shipping, electricity generation, heating, and light-duty vehicle transportation could save a combined 1,913,000 bpd of oil beyond business as usual by 2020. About 70% of this reduction occurs via changes in light-duty vehicle transportation, specifically enhanced adoption of electric vehicles and cellulosic ethanol, while residential and commercial heating make up most of the remainder (Fig. 4). Overall, a savings of about 1.9 million bpd accounts for roughly 9% of total U.S. oil demand in 2020[38] and would negate the need to drill for oil in the waters of the Gulf of Mexico. It would also allow us to cut imports from the Persian Gulf by 9% by 2020.[39]

MEETING ADDITIONAL ENERGY DEMAND

As stated above, displacing oil in heating, automobile use and electricity generation would increase electricity demand, which must be met by an equivalent increase in generation capacity. To provide a climate change benefit, this capacity must be met with clean energy.

One potential source of this replacement capacity is offshore wind, a nascent industry that has significant potential. To power the new demand created by this vision purely with offshore wind, 17.4 GW would need to be installed by 2020. Although a daunting objective considering the nation's current lack of offshore wind turbines, numerous studies have highlighted the exceptional offshore wind resources of the United States. One of the most conservative reports estimates the East Coast alone has 127 GW of economically recoverable offshore wind capacity.[40] Using less conservative variables, NREL estimates the eastern seaboard has enough wind to generate in excess of 500 GW of power,[41] while based on the same dataset another study estimates economically recoverable wind power to be around 212 GW.[42] Thus, the resource potential clearly exists for offshore development.

The technology exists, too; one needs to simply consider Europe, which added 883 MW of offshore wind in 2010 to reach a cumulative 3 GW of capacity.[43] Even here in the U.S. roughly 9 GW of offshore wind projects are in development, predominantly off the East Coast. While permitting and construction will take multiple years, most of these projects – as well as others - could be completed by 2020, particularly if the Department of the Interior's "Smart from the Start" initiative and similar efforts succeed. For these reasons, installing 17.4 GW of offshore wind by 2020, while ambitious, is feasible. However, offshore wind does not have to bear the full burden.

Many other renewable energies would be well suited to this task. Distributed photovoltaic solar panels, for one, are ideal for supplying electricity to heating systems because they can be located at the point of consumption, i.e. on the roofs of buildings that install electric heaters. Such a distributed approach circumvents the need for additional transmission lines, a considerable hurdle in current efforts in expanding renewable energy. Regional power generation for inland regions can be provided by geothermal or wind power, particularly in the wind-rich Midwest. Wind power already competes economically with conventional power sources in resource-rich areas;[44] by 2020, technological advances will have skewed this inequality even further towards wind power.

According to the Department of Energy's landmark *20% Wind Energy by 2030* report,[45] 150 GW of wind power could be installed in 2020, a 110 GW increase over current wind power capacity and 100 GW more than the EIA anticipates will be installed by 2020.[46] Thus, onshore wind alone could easily provide the required 17.4 GW of additional electricity.

Vision to 2020 to 2030

Besides securing the health of our coastal economies and ecosystems in the Gulf of Mexico, we also need to safeguard our nation's national and energy security by reducing oil imports. We can do this by following a similar vision to make further reductions in petroleum consumption. Net imports of crude oil and other petroleum supplies are projected by EIA to be roughly 9 million bpd in 2030 and subsequent years,[47] or 50% of our total oil supply.[48] Of this 9 million bpd, 1.6 million bpd are projected to be from the Persian Gulf.[49] Studies suggest that across the same sectors as analyzed in the previous section (except petroleum-fueled electricity generation, all of which was eliminated), moderate actions could reduce oil consumption by 7.2 million bpd by 2030 beyond business as usual. Under such a scenario, Persian Gulf imports could be completely eliminated as soon as 2023 and, assuming reductions in oil consumption continue at a steady pace, all other imports a decade after that - an immense boost towards national security and energy independence.

COMMERCIAL SHIPPING: CUT 107,000 BARRELS PER DAY OF OIL BY SAVING 30% OF FUEL VIA EFFICIENCY

EIA predicts that shipping will continue growing through 2030, consuming 10,000 bpd more than in 2020 for a total of 355,000 bpd.[50] Under our vision, all vessels have already reduced their speed by 10% by 2020, but slowing by an additional 5% or 10% would further increase fuel efficiency and reduce oil consumption. Beyond slow steaming, many other technological and operational modifications exist that could increase fuel efficiency. Currently available options include: special hull coatings, which can reduce fuel use by 8-10%; propellers, 5-10%; kites, 10-35%; weather routing, 2-4%; just-in-time arrival, 1-5%; propeller maintenance, 3%; and engine tuning, 1-2%.[51] Combined, these readily-available technologies alone could reduce oil consumption by 30-69% - and that does not even include increased efficiencies from new strategies that may be developed in the interim. Thus, via a combination of further reductions in speed and the implementation of currently available and soon-to-be developed technological and operational improvements, oil consumption in the commercial shipping sector could be reduced by at least 30%, or 107,000 bpd, by 2030.

RESIDENTIAL AND COMMERCIAL HEATING: CUT AT LEAST 632,000 BARRELS PER DAY OF OIL BY ELECTRIFYING 100% OF REMAINING OIL-FUELED HEATERS

The EIA predicts that under business as usual from 2020 to 2030, petroleum use for heating falls by just 50,000 bpd to 632,000 bpd.[52] As previously explained, current electric heating technology is more efficient than oil heating systems and will become increasingly cost effective as oil prices rise and renewable energy advances lower electricity generation prices. Thus, the remaining oil heating units in the United States could be phased out by 2030 without great expense, saving 632,000 bpd of oil, or more if the 2020 target is not met. As before, the electricity for these heaters could be supplied by offshore wind, specifically 6.4 GW of additional capacity,[53] or by other renewable energies.

LIGHT DUTY VEHICLE TRANSPORTATION: CUT 6,540,000 BARRELS PER DAY OF OIL BY ELECTRIFYING 40% OF THE FLEET AND SATISFYING 14% AND 35% OF THE FLEET'S FUEL DEMAND WITH CELLULOSIC ETHANOL AND ALGAL BIOFUELS, RESPECTIVELY

EIA projects that light duty vehicles will account for 8.0 million bpd of crude oil consumption in 2030, roughly the same proportion (60%) of total oil consumption as in 2020.[54] Unlike in 2020, though, algal biofuels contribute significantly to reducing oil consumption by 2030, which, in conjunction with growth in electric vehicles and cellulosic ethanol, net an aggregate reduction of 6.5 million bpd.

Table 3: Envisioned reductions in oil consumption by the light-duty vehicle sector from electric vehicles, cellulosic ethanol, and algal biofuel.

Technology	Reduction in Oil Consumption (thousand bpd)	Percent Reduction in Oil Consumption by Light-Duty Vehicles (%)
Electric vehicles	2,660	33
Cellulosic ethanol	1,110	14
Algal biofuel	2,770	35

Electric Vehicles – 2,660,000 barrels per day of oil by electrifying 40% of the fleet

Based on existing policies and incentives, the National Academy of Sciences (NAS) calculated plug-in hybrid electric vehicles (PHEVs) would number 13 million in 2030 and save roughly 7 billion gallons of oil per year,[55] or 1 million bpd.[56] NAS assumed these PHEVs would have an all-electric range of 40 miles, which is similar to that of the Chevy Volt. Further analysis by NAS found that if aggressive policies and incentives were implemented, PHEV-40 adoption would increase significantly to 40 million vehicles or 14% of the light-duty fleet by 2030,[57] reducing oil consumption by 2.2 million bpd. Other publications have reported similar potential levels of PHEV fleet size given aggressive policies.[58] Notably, NAS's report considered only PHEVs, meaning combined fuel savings from all electric vehicles, i.e. hybrids, plug-in hybrids, and full electrics, would be much greater.

In fact, the previously-cited Center for Entrepreneurship and Technology report found that, assuming the adoption of switchable batteries and pay-per-mile contracts, 75 million EVs and 35 million HEVs could be on the road in 2030, accounting for about 40% of the light-duty vehicle fleet.[59] These projections dwarf the business as usual estimates of EIA, which suggest that there could be 1.2 million EVs, 15 million HEVs, and 1 million PHEVs on the road in 2030,[60] but the CET projections are similar to targets put forth by Google.[61]

With respect to oil, CET estimated its projected fleet of 75 million EVs and 35 million HEVs would reduce oil consumption by between 2 million bpd (if oil prices follow EIA's predictions) and 3.7 million bpd (if oil prices increase further than predicted by EIA and if operator subsidies[62] are adopted by governments). The middle of this spread, less the 190,000 bpd reduction achieved under the 2020 vision, was taken in this paper to be the best estimate for achievable reductions by 2030: 2,660,000 bpd.[63] This would eliminate about 33% of oil consumption by light-duty vehicles in 2030.

As previously discussed, the electricity required for charging the PHEVs and EVs could be provided via offshore or onshore wind. Satisfying 100% of the electricity demand via offshore wind would require the installation of 54 GW.[64]

Cellulosic Ethanol – 1,110,000 barrels per day of oil by satisfying 14% of fuel demand
According to EIA, under current policies and incentives cellulosic ethanol production could hit 6.2 billion gallons, or 600,000 bpd oil equivalent, by 2030.[65] Significant opportunity for even greater expansion in this sector exists, though, according to a report from Sandia National Laboratory. The Sandia report[66] found that 75 billion gallons of cellulosic ethanol could be produced in 2030, but this would require substantial investment in energy feedstocks, which would lower the alternative fuel's sustainability. Conversely, utilizing only agricultural and forestry residues (the most sustainable feedstock for cellulosic ethanol production) would yield 30 billion gallons of cellulosic ethanol, or 2.9 million bpd oil equivalent.[67] A similar picture of cellulosic ethanol production in 2030 was drawn by the International Energy Agency, which projected 10% and 25% of agricultural and

forestry residues would net 1.6 and 4 million bpd oil equivalent, respectively, across all of the Americas.[68] Given the extent of agricultural and forestry lands in the United States, the nation would most likely generate a substantial portion of the Americas' cellulosic ethanol, lending credence to Sandia's estimate of 2.9 million bpd. Subtracting the 1.19 million bpd production level achieved in the 2020 projection and EIA's business as usual projected production of 600,000 bpd in 2030 results in a predicted displacement of an additional 1.11 million bpd oil by cellulosic ethanol in 2030 from 2020 levels.

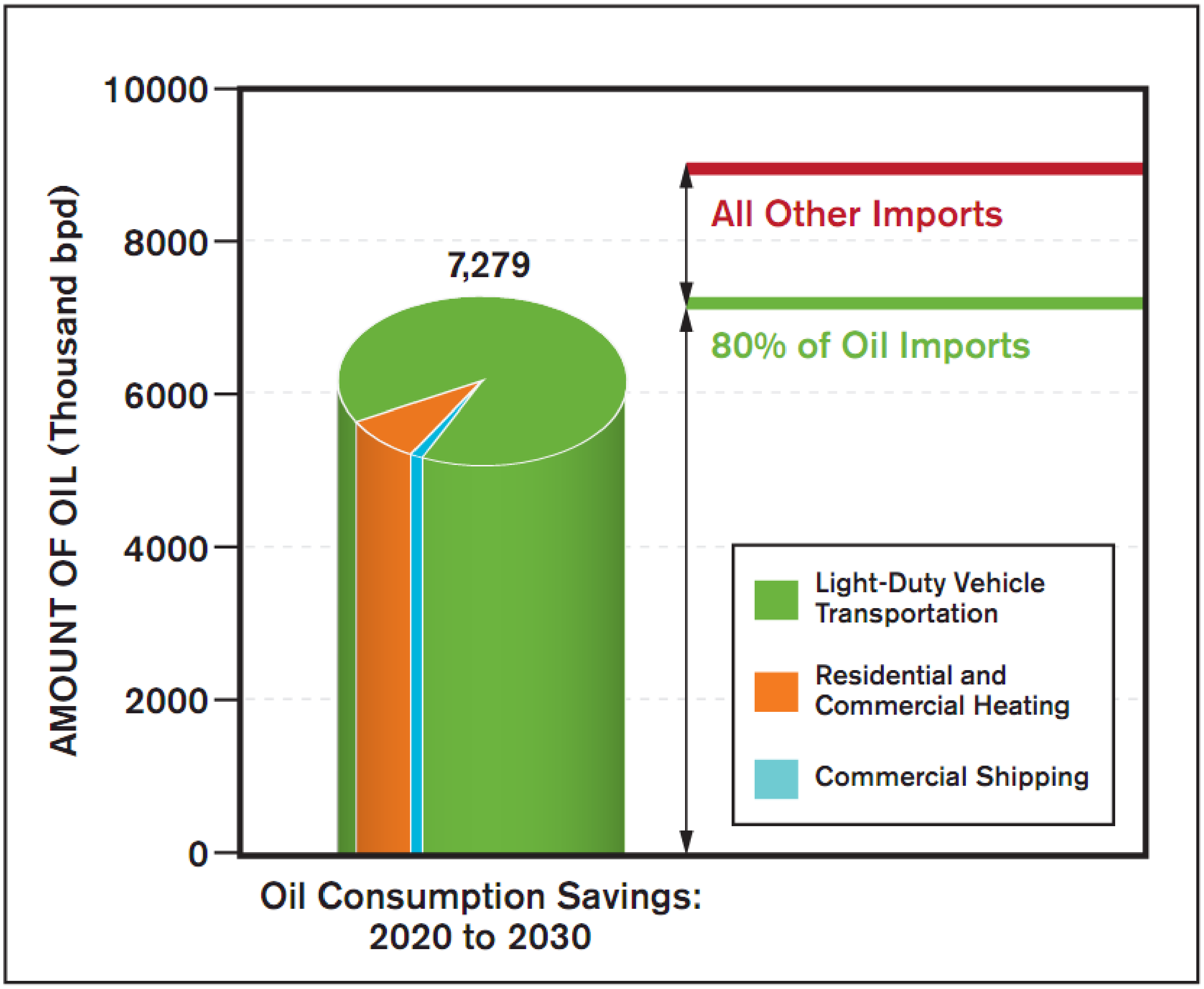
Algal Biofuel – 2,770,000 barrels per day of oil by satisfying 35% of fuel demand

Because the algal biofuel industry remains in its infancy, predictions of its size in 2030 are scarce. NREL has published one of the only reports to this end, finding that worldwide production of 17 gigaliters per year of algal biofuel, or 5.9 million bpd oil equivalent, by 2030 is conceivable and would furthermore be in line with the current rate of ethanol adoption in the U.S. and Brazil.[69] On the other hand, global production of 170 gigaliters per year, or 11.8 million bpd oil equivalent, would require "very concerted effort" by industry and government alike. Erring on the side of conservatism, we assume "very concerted effort" is not achieved and global production would consequently reach 5.9 million bpd oil in 2030.

Pike Research reported that 47% of global production of algal biofuel could occur in the United States.[70] This suggests that 2.77 million bpd oil equivalent of algal biofuel would be produced within the United States in 2030.

TOTAL OIL SAVINGS FROM 2020 TO 2030: 7,279,000 BARRELS PER DAY

Figure 5: Oil Consumption Savings Achieved by 2030 Would Make 80% of Imports Unnecessary.



Following the 9% reduction in total oil consumption that we demonstrated could be achieved by 2020, an additional 7.3 million bpd oil could be displaced by 2030 with emerging technologies like algal biofuels and existing technologies spurred by moderate policies and incentives (Fig. 5). This would account for 80% of all oil imports in 2030,[71] which more than displaces the need for oil from the Persian Gulf. In fact, if this vision were achieved, Persian Gulf imports could be phased out as soon as 2023, greatly enhancing our national security, and the remaining imports could be phased out in total by 2033, assuming reductions in oil consumption continue at a rate similar to that in the prior decade.

While it may seem that these goals are difficult, if not impossible, to achieve, and that the framework presented in this report would require drastic and ultimately unrealistic action, the opposite is actually true; this report relies on projections from credible sources, it emphasizes conservative estimates, and uses realistic policy and investment scenarios.

MEETING ADDITIONAL ELECTRICITY DEMAND

Additional electricity capacity must be installed by 2030 in order to power newly-installed electric heating systems and the burgeoning electric vehicle fleet. The electric heating systems account for a small percentage of the increased demand and could be powered by solar or wind power. The majority of the increased electricity demand is generated by the surge in electric vehicle adoption that, as previously discussed, can be satisfied via onshore or offshore wind.

In the case of offshore wind, 60.4 GW of additional capacity would need to be installed. While daunting, a number of factors make this target more achievable than it may seem. For one, construction in the previous decade would have established the necessary supply chains and streamlined the licensing and permitting process. Additionally, the US has sufficient economically-recoverable offshore wind resources to accommodate the 60.4 GW of capacity on top of any capacity installed by 2020. Finally, deeper waters in the Atlantic, the Great Lakes, and even the Pacific offer additional sites for offshore wind that could supply electricity to nearby regions at economical prices as offshore wind technology progresses.

Beyond offshore wind, further advances in solar panel technology would continue to drive costs down, facilitating their distributed deployment. Onshore wind, too, could continue to grow well beyond the 55 GW of capacity predicted by EIA under business as usual implementation. The Department of Energy, for instance, found wind power could feasibly reach 300 GW by 2030.[72] Together these sources will easily be able to generate the necessary power to replace the oil previously used for transportation and electric heating.

Conclusion

While the dream of securing energy independence and eliminating domestic offshore drilling has been deferred for decades, a variety of current technologies could make this dream a reality in the near future. Our analysis shows that offshore drilling in the Gulf of Mexico, Persian Gulf imports, and all other imports could be eliminated as soon as 2020, 2023, and 2033, respectively, although Persian Gulf imports could just as easily be eliminated in 2020 and offshore Gulf of Mexico oil in 2023. Importantly, our analysis further shows that achieving these milestones can be achieved using reasonable, moderate policies and incentives. At the same time, business as usual will not suffice; more aggressive action must be taken to ensure a successful transition away from dangerous, polluting oil and towards alternatives that will promote the health, safety, and economy of our nation.

The vision outlined above, which draws from an array of aggressive but practical projections, provides just one of many possible frameworks for this transition. Other currently available and reasonable methods that could significantly reduce oil consumption include increasing CAFE standards, mitigating fuel consumption in the commercial truck fleet, and augmenting public transportation systems like high-speed rail or buses. Regardless of the road taken, it is imperative that action not be delayed. The future of our nation depends on it.

Methodology

Business as usual estimates of oil consumption and penetration of technologies that reduce oil consumption, e.g. electric vehicles, in given years (i.e. 2020 and 2030) were taken from the Reference Case[73] of the Energy Information Administration's (EIA) Annual Energy Outlook 2011.[74] Potential reductions in oil consumption given augmented deployment of various technologies were estimated by compiling the projections of a variety of reports from public and private institutions. We did not include projections that assumed the existence of improbable policies, such as a carbon price, in our analysis, and we further utilized more conservative projections where possible. Each of our figures also takes into account projected growth in energy use over time, as estimated by EIA.

In the case of the light-duty vehicle sector, EIA's Reference Case already incorporates business-as-usual adoption of electric vehicles and cellulosic ethanol into its estimate of the sector's oil consumption. Consequently, the quantity of electric vehicles and cellulosic ethanol projected by EIA was subtracted from the quantity of these two technologies under the accelerated deployment scenario in order to calculate the reduction in oil consumption provided by these technologies beyond reductions that would be part of the business as usual (BAU) scenario. Those BAU reductions were already taken into account by EIA as offsetting some oil use, so including them would have caused us to double count the resulting oil reductions.

[1] As evidenced by the predicted declines in oil consumption as percent of market share in BP's *Energy Outlook 2030* and Exxon-Mobil's *The Outlook for Energy: A View to 2030*. This decline in oil market share coincides with rapid growth in renewable energies in the next two decades. Even now, events hint at lessening oil supplies; Exxon-Mobil, for instance, missed replacement rate for its oil reserves over the past decade ("Exxon Struggles to Find New Oil." *The Wall Street Journal*. 16 Feb. 2011.).
[2] "AEO2011 Early Release Overview – Table 132." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
[3] "AEO2011 Early Release Overview – Table 7." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
[4]Harrould-Kolieb, E., and J. Savitz. "Shipping Solutions: Technological and Operational Methods Available to Reduce CO_2." *Oceana*. Oct 2010.
[5] "Study of Greenhouse Gas Emissions from Ships." *International Maritime Organization*. March 2000.
[6] "Petroleum & Other Liquids: Product Supplied." *EIA*. 29 Jul 2010. 3 Mar 2011 <http://www.eia.doe.gov/dnav/pet/pet_cons_psup_dc_r30_mbblpd_a.htm>.
[7] Rosenthal, Elizabeth. "Slow Trip Across Sea Aids Profit and Environment." *The New York Times*. 16 Feb 2010.
[8] "AEO2011 Early Release Overview – Table 11." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
[9] This includes efficiency losses at the point of electricity generation and from transmission. Sources:
(1) "Selecting Heating Fuel and System Types." *DOE*. 20 Oct 2010. 3 Feb 2011 <http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12330>.
(2) Jacobson, M.Z. and M.A. Delucchi. "Providing All Global Energy." *Energy Policy*. Jan 2011.
[10] Calculated with data from the following publications: (1) "2005 Residential Energy Consumption Survey." *EIA*. 5 Feb 2011 <http://www.eia.doe.gov/emeu/recs/>. (2) "2003 Commercial Buildings Energy Consumption Survey." *EIA*. 5 Feb 2011 <http://www.eia.doe.gov/emeu/cbecs/>. (3) Simon, Mahan. "Untapped Wealth: Technical Methodology." *Oceana*. 4 Feb 2011 <http://na.oceana.org/sites/default/files/Technical_Notes_0.pdf>.
[11] Mahan, S., I. Pearlman, and J. Savitz. "Untapped Wealth." *Oceana*. Sept 2010.
[12] "AEO2011 Early Release Overview – Table 11." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
[13] "Electric Power Annual 2009 – Table 1.2." *EIA*. 4 Jan 2011. 4 Feb 2011 <http://www.eia.doe.gov/cneaf/electricity/epa/epat1p2.html>.
[14] "Electric Power Annual 2009 – Table 5.2." *EIA*. 4 Jan 2011. 4 Feb 2011 <http://www.eia.doe.gov/cneaf/electricity/epa/epat1p2.html>.
[15] 11.7 GW is calculated by multiplying 63 GW by the quotient of 0.078, the capacity factor of petroleum-based generators, divided by 0.42, the capacity factor of offshore wind. Source for offshore wind capacity factor: Simon, Mahan. "Untapped Wealth: Technical Methodology." *Oceana*. 4 Feb 2011 <http://na.oceana.org/sites/default/files/Technical_Notes_0.pdf>.
[16] Petroleum liquid use by state: "Electric Power Monthly – Table 1.8B." *EIA*. 14 Feb 2011. 22 Feb 2011 <http://www.eia.gov/cneaf/electricity/epm/table1_8_b.html>.
Petroleum coke use by state: "Electric Power Monthly – Table 1.9B." *EIA*. 14 Feb 2011. 22 Feb 2011 <http://www.eia.gov/cneaf/electricity/epm/table1_9_b.html>.
[17] "AEO2011 Early Release Overview – Table 7." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.

[18] Projected sales from 2011 to 2020 for all three vehicle types taken from: "AEO2011 Early Release Overview – Table 57." *EIA*. 16 Dec 2010. 28 Feb 2011 <http://www.eia.doe.gov/forecasts/aeo/tables_ref.cfm>. Fleet sizes as of 2010 (zero for EVs and PHEVs, 1.6 million for HEVs) were taken from: "Alternative Fuels & Advanced Vehicles Data Center: HEV Sales by Model." *DOE*. 3 Feb 2011. 28 Feb 2011 <http://www.afdc.energy.gov/afdc/data/vehicles.html>.
[19] Specifically, Deutsche Bank predicts there to be 1.2 million PHEVs and 0.7 million EVs on the road in 2020. Source: "Electric Cars: Plugged In 2." *Deutsche Bank*. 3 Nov 2009.
[20] Steinmetz, J., and R. Shanker. "Plug-in Hybrids: The Next Automotive Revolution." *Morgan Stanley*. 11 Mar 2008.
[21] Morgan Stanley does not distinguish between PHEVs with different all-electric ranges in its projections. However, the report does stipulate the PHEVs it considers have all-electric ranges of between 20 and 40 miles. Given current trends in the automotive sector, such as the 40-mile electric ranges of the Chevy Volt and China's BYD F3DM, we assume that all of the PHEVs projected to be demanded by Morgan Stanley have a 40 mile all-electric range.
[22] EIA projects the entire light-duty vehicle fleet to reach 251 million vehicles in 2020 under business as usual. Source: "AEO2011 Early Release Overview – Table 58." *EIA*. 16 Dec 2010. 26 Feb 2011 <http://www.eia.doe.gov/forecasts/aeo/tables_ref.cfm>.
[23] Greenblatt, Jeffery. "Clean Energy 2030." *Google*. 14 July 2009. 14 Mar 2011 <http://knol.google.com/k/clean-energy-2030#>.
[24] In calculating this value, business as usual electric vehicle fleet size (see previous endnote) was first subtracted from the vision's fleet size. PHEVs were divided into HEV or full EV for purposes of calculation, using the assumption that 65% of consumers drive less than 35 miles per day. We also assumed average annual vehicle mileage would be 14,000 miles in 2020; average fuel efficiency of light-duty vehicles would be 35.5 mpg in 2020 (per the existing 2016 CAFE standard); and HEV fuel efficiency would be 32.5% greater than conventional vehicles. Sources: (1) "Electric Cars: Plugged In 2." *Deutsche Bank*. 3 Nov 2009. (2) "Gasoline and the American People – Selected Media Coverage." *Cambridge Energy Research Associates*. 21 Dec 2006.
[25] Under a pay-per-mile contract, EV buyers don't have to buy a battery and pay for electricity. Rather, they sign contracts with companies that finance charging infrastructure, electricity, and the battery in the EV, which the EV buyer essentially rents. This allows for the existence of stations where a depleted battery can be instantly exchanged for a fully-charged battery at no additional cost (since it is already factored into your contract, which is based on mileage), allowing for trips to last more than the range of a battery.
[26] Becker, T., I. Sidhu, and B. Tenderich. "Electric Vehicles in the United States: A New Model with Forecasts to 2030." *Center for Entrepreneurship and Technology, UC Berkeley*. 24 Aug 2009. There is a large discrepancy between the ratio of EVs to reduced oil consumption as reported in CET's report and as calculated in this paper based on Deutsche Bank's report. Communication with author Tom Becker revealed this is likely due to CET's use of a 1:1 ratio between reduced gasoline and oil consumption. In other words, to reduce oil consumption by 1 barrel, Becker et al. assumed electric vehicles would have to offset 42 gallons of gasoline; conversely, this paper's calculations use a ratio of 19 gallons gasoline to 1 barrel oil, the actual yield of a barrel of oil after refining. This approach is justified mainly due to one reason: gasoline is the most important product of crude oil. Oil refining and production is generally sensitive to gasoline consumption, but not to other products such as jet fuel. Without a market for gasoline, refining of crude would not be economically viable because 19 of the 42 gallons yielded would not be sold. Alternatively, a decrease in demand of, for instance, jet fuel does not necessarily mean the number of barrels of crude oil will decrease, because jet fuel is a small part of the products. Thus, decreasing gasoline consumption by 19 gallons would most likely reduce crude oil consumption, i.e. refining, by 1 barrel. Clearly, this relationship breaks down as a higher percentage of consumption of crude oil is eliminated because products other than gasoline must be supplied. However, at low percentages such as those discussed in this report, the 1 barrel oil to 19 gallons gasoline ratio would most likely hold. As a final point, it's possible that as gasoline consumption decreases and crude oil

refining becomes less profitable, consumers of other refining products could substitute away from those products, decreasing the demand for them as well.

[27] (1) Denholm, P. and W. Short. “An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles.” *NREL*. July 2006. (2) “Economic Impact of the *Electrification Roadmap*.” *Electrification Coalition*. Apr 2010.

[28] “Accommodating High Levels of Variable Generation.” *North American Electric Reliability Corporation*. April 2009.

[29] The study (Hadley, S.W., and A. Tsvetkova. “Potential Impacts of Plug-In Hybrid Electric Vehicles on Regional Power Generation.” *Oak Ridge National Laboratory.* January 2008) specifically determined that 19.58M PHEVs in 2020 and 50.39M PHEVs in 2030 would require about 56 TWh and 140 TWh, respectively, of electricity. Notably, other studies, such as by the Electrification Coalition (see “Economic Impact of the *Electrification Roadmap*”, April 2010), estimate less gigawatts would be necessary per million PHEVs.

[30] At 0.32 GW per million electric vehicles and 4.5 million electric vehicles (excluding HEVs, which do not need to be charged), 1.44 GW of power would be required. This value of 1.44 GW, though, assumes a 100% capacity factor. To calculate how much offshore wind capacity must be installed to generate this amount of power, the capacity factor of offshore wind, 0.42 (see previous footnotes), must be taken into account. Thus, dividing 1.44 GW by 0.42 yields 3.4 GW, the amount of offshore wind that must be installed.

[31] E.g., Kemp, L., and J.M. Sibbing. “Growing a Green Energy Future: A Primer and Vision for Sustainable Biomass Energy.” *National Wildlife Federation*. Mar 2010.

[32] Maron, Dina Fine. “Much-touted Cellulosic Ethanol is Late in Making Mandated Appearance.” *ClimateWire*. 11 Jan 2011. 3 Feb 2011 <http://www.eenews.net/public/climatewire/2011/01/11/1>.

[33] “AEO2011 Early Release Overview – Table 17: Renewable Energy Consumption by Sector and Source.” *EIA*. 16 Dec 2010. 28 Feb 2011 <http://www.eia.doe.gov/forecasts/aeo/tables_ref.cfm>.
EIA predicts 2020 production of cellulosic ethanol will be 0.15 quadrillion Btu. To convert this value to barrels oil, we assumed 1 gallon ethanol contains 75,700 Btu; ethanol has two-thirds of the energy content of gasoline; and 1 barrel crude oil generates 19 gallons gasoline.

[34] Sandor, D. R. Wallace, and S. Peterson. “Understanding the Growth of the Cellulosic Ethanol Industry.” *NREL*. Apr 2008.

[35] To convert gallons cellulosic ethanol to barrels oil equivalent, we assumed ethanol has 2/3 of the energy content of gasoline and crude oil generates 19 gallons of gasoline.

[36] The study calculates total cellulosic ethanol production would be 7.2 billion gallons per year by 2017. See previous endnote for conversion methodology.

[37] “Solar, Wind, and Biofuels Global Markets Surge 35 Percent to $188.1 Billion in 2010.” *CleanEdge*. <http://www.cleanedge.com/about/pr/Clean_Energy_Trends2011_Press_Release.pdf>.

[38] EIA estimates oil consumption in the U.S. in 2020 under business as usual would be 20.59 million bpd. Source: “AEO2011 Early Release Overview – Table 11.” *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.

[39] EIA estimates imported oil (including crude oil and heavy and light petroleum products) from the Persian Gulf under business as usual will amount to 1.3 million bpd in 2020. Source: “AEO2011 Early Release Overview – Table 146.” *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.

[40] Mahan, S., I. Pearlman, and J. Savitz. “Untapped Wealth.” *Oceana*. Sept 2010.

[41] Schwartz, Marc, et al. “Assessment of Offshore Wind Energy Resources for the United States.” *National Renewable Energy Laboratory*. Jun 2010. 24 Jan 2011 <http://www.nrel.gov/docs/fy10osti/45889.pdf>.

[42] Fisher, Curtis, et al. “Offshore Wind in the Atlantic.” *National Wildlife Federation*. 2010. 24 Jan 2011 <http://www.nwf.org/offshorewind>.

[43] “The European Offshore Wind Industry: Key Trends and Statistics 2010.” *European Wind Energy Association*. Jan 2011. 24 Jan 2011

<http://www.windkraft-journal.de/bilder/10_01/offshore%20stats%2020092.pdf>.
[44] "America's Energy Future." *The National Academy of Science*s. Washington, D.C.: National Academies Press, 2009.
[45] "20% Wind Energy by 2030." *U.S. DOE*. Jul 2008.
[46] "AEO2011 Early Release Overview – Table 16." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
[47] "AEO2011 Early Release Overview – Table 11." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>. Net imports of crude oil are projected to be 8.29M bpd and other petroleum supplies 0.77M bpd, which combined equal roughly 9M bpd.
[48] Total crude oil consumption in 2030 was calculated as that projected by EIA in the Annual Energy Outlook 2011 (21.36 million bpd) minus the reductions in consumption achieved under the 2020 framework (1.91 million bpd), equaling 19.45 million bpd.
[49] This includes imports of crude oil and heavy and light refined products. Source: "AEO2011 Early Release Overview – Table 146." *EIA*. 16 Dec 2010. 3 Mar 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
[50] The value for petroleum consumption in 2030 given here, and in all subsequent sections, is calculated by subtracting this vision's 2020 reductions from the sector's business as usual oil consumption in 2030 per EIA's Annual Energy Outlook 2011. For instance, Table 7 of EIA's Annual Energy Outlook 2011 predicts shipping consumption of crude oil will increase from 450,000 bpd in 2020 to 460,000 bpd in 2030. Taking into account reductions achieved under Vision 2020 (105,000 bpd), oil consumption in 2030 would therefore be 355,000 bpd.
[51] (1) Harrould-Kolieb, E., and J. Savitz. "Shipping Solutions: Technological and Operational Methods Available to Reduce CO_2." *Oceana*. Oct 2010. (2) "Low Carbon Commercial Shipping." *AEA Energy & Environment*. Mar 2007.
[52] See previous footnote for methodology. EIA projects 2030 consumption of oil for residential and commercial heating to be 860,000 bpd under business as usual. Source for EIA data: "AEO2011 Early Release Overview – Table 11." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
[53] To calculate the electricity demand from replacing oil-fired heating systems between 2020 and 2030, the ratio of required electricity to reduction in oil consumption in heating systems previously calculated for 2020 was used (4.28 MW per thousand bpd). Offshore wind was assumed to have a 42% capacity factor (see previous endnotes).
[54] The AEO2011 projects light-duty vehicle oil consumption will reach 9.42 million bpd in 2030 ("AEO2011 Early Release Overview – Table 7." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>). The achieved reductions in 2020, 1.42 million bpd, were subtracted from this value to arrive at 8.0 million bpd consumption in 2030.
[55] "Transitions to Alternative Transportation Technologies – Plug-in Hybrid Electric Vehicles." *National Research Council*. 2010. 22 Feb 2011 < http://www.nap.edu/openbook.php?record_id=12826&page=R1>.
[56] To convert gallons per year to barrels per day, two equivalencies were used: 19 gallons gasoline per barrel crude oil, and 365 days per year.
[57] EIA, in its Annual Energy Outlook 2011, predicts light-duty vehicle fleet size to be 283 million in 2030. Source: "AEO2011 Early Release Overview – Table 58." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
[58] E.g., Sandalow, David B., ed. *Plug-in Electric Vehicles: What Role for Washington?* Washington D.C.: The Brookings Institution, 2009.
[59] Becker, T., I. Sidhu, and B. Tenderich. "Electric Vehicles in the United States: A New Model with Forecasts to 2030." *Center for Entrepreneurship and Technology, UC Berkeley*. 24 Aug 2009.
[60] Projected sales from 2011 to 2020 for all three vehicle types taken from: "AEO2011 Early Release Overview – Table 57: United States Light Duty Vehicle Sales by Technology Type." *EIA*. 16 Dec 2010. 28 Feb 2011 <http://www.eia.doe.gov/forecasts/aeo/tables_ref.cfm>. Fleet sizes as of 2010 (zero for EVs and PHEVs, 1.6 million for

HEVs) was taken from: "Alternative Fuels & Advanced Vehicles Data Center: HEV Sales by Model." *DOE*. 3 Feb 2011. 28 Feb 2011 <http://www.afdc.energy.gov/afdc/data/vehicles.html>.
[61] Greenblatt, Jeffery. "Clean Energy 2030." *Google*. 2009 Jul 14. 14 Mar 2011 < http://knol.google.com/k/clean-energy-2030#>.
[62] An operator subsidy in this case means that the operator of the contract would subsidize consumers to purchase electric vehicles, much in the same way that cell phones are subsidized with the additional purchase of a phone network contract.
[63] The reduction in oil consumption associated with EIA's business as usual projection of the electric fleet was not factored into this calculation because EIA's projected fleet size of electric vehicles was insignificant compared to CET's projected electric fleet size.
[64] The increase in full EVs from 2020 to 2030 (70.5 M) was multiplied by the ratio 0.32 GW per million EVs. Offshore wind was assumed to have a capacity factor of 0.42 (see previous endnotes).
[65] "AEO2011 Early Release Overview – Table 17: Renewable Energy Consumption by Sector and Source." *EIA*. 16 Dec 2010. 28 Feb 2011 <http://www.eia.doe.gov/forecasts/aeo/tables_ref.cfm>.
EIA predicts 2030 production of cellulosic ethanol will be 0.47 quadrillion Btu. To convert this value to barrels oil, we assumed 1 gallon ethanol contains 75,700 Btu; ethanol has two-thirds the energy content of gasoline; and 1 barrel crude oil can be refined into 19 gallons gasoline.
[66] West, Todd, et al. "Feasibility, Economics, and Environmental Impact of Producing 90 Billion Gallons of Ethanol Per Year by 2030." *Sandia National Laboratory*. 6 Aug 2009.
[67] To convert gallons cellulosic ethanol to barrels oil equivalent, we assumed ethanol has 2/3 of the energy content of gasoline and crude oil generates 19 gallons of gasoline.
[68] Eisentraut, Anselm. "Sustainable Production of Second-Generation Biofuels." *IEA*. Feb 2010.
[69] Darzins, A., P. Pienkos, and L. Edye. "Current Status and Potential for Algal Biofuels Production." *NREL*. 6 Aug 2010. 14 Feb 2011 < http://www.fao.org/uploads/media/1008_IEA_Bioenergy_-_Current_status_and_potential_for_algal_biofuels_production.pdf>.
[70] "Algae-Based Biofuels Production to Reach 61 Million Gallons per Year by 2020." *Pike Research*. 27 Oct 2010. 14 Feb 2011 < http://www.pikeresearch.com/newsroom/algae-based-biofuels-production-to-reach-61-million-gallons-per-year-by-2020>.
[71] Total oil imports in 2030 were calculated by subtracting this vision's projected reduction in oil consumption in 2020 beyond that required to eliminate offshore Gulf of Mexico oil (123,000 bpd) from EIA's forecast of business as usual total oil imports (9.06 million bpd) in 2030. Source for EIA business as usual projection: "AEO2011 Early Release Overview – Table 11." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.
[72] "20% Wind Energy by 2030." *U.S. DOE*. July 2008.
[73] The Reference Case assumes that no new legislation is passed from the time of the completion of the Annual Energy Outlook, and that existing legislation sunsets as planned.
[74] "AEO2011 Early Release Overview." *EIA*. 16 Dec 2010. 3 Feb 2011 <http://www.eia.gov/forecasts/aeo/tables_ref.cfm>.

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