The Gulf Oil Spill:
Economics and Policy Issues

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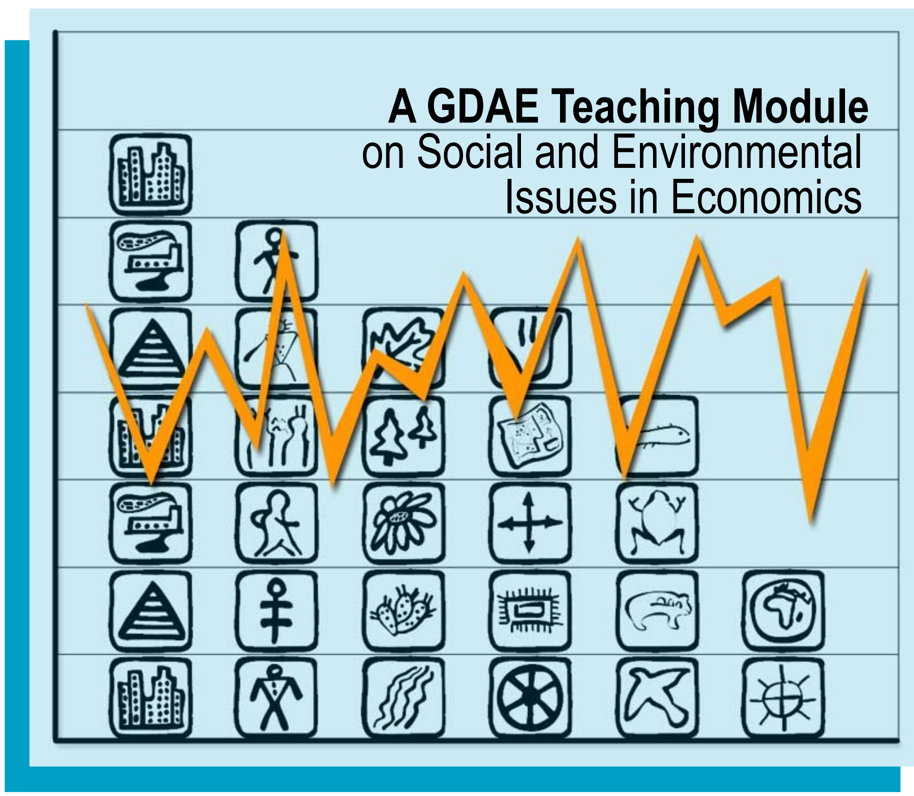

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THE GULF OIL SPILL: ECONOMICS AND POLICY ISSUES

I. INTRODUCTION

On April 20, an explosion on the *Deepwater Horizon* oil rig, located in the Gulf of Mexico about 40 miles off the Louisiana coast, killed 11 workers. The rig burned out of control and sank on April 22. Several days later it was revealed that the rig's wellhead was damaged and significant amounts of oil were leaking in to the Gulf of Mexico. The *Deepwater Horizon* soon became the largest oil spill in U.S. history, easily surpassing the 1989 *Exxon Valdez* tanker accident. In August 2010, Federal science and engineering teams estimated that the oil flow from the well was 53,000-62,000 barrels a day from April until the well was capped on July 15th. [1,2] This is equivalent to a spill the size of the 1989 *Exxon Valdez* spill – formerly the largest spill in U.S. waters -- every 4 to 5 days.[3]

The *Deepwater Horizon* spill raises numerous questions about energy, economics, and the environment. In this module we consider various aspects of the *Deepwater Horizon* spill, including its economic impacts, its implications for offshore oil development, and its lessons for national and global energy policy.

How can we evaluate the economic damages of oil spills? While some economic costs are relatively easy to estimate, such as the lost profits of the commercial fishing industry, other damages such as lost ecological and esthetic values are more difficult to quantify. The laws that apply to oil spills mandate that ecological restoration be undertaken as compensation for damages. We'll consider preliminary data on the likely economic costs of the *Deepwater Horizon* spill, noting that the ecological damages to habitats and wildlife are likely to be greater than market-based costs such as lost fishing and tourism profits.

A major issue raised by the Gulf oil spill is the economic analysis of risk. A catastrophic oil spill is an example of a low-probability, high-impact event. How should we develop policies in the presence of such risks? Is standard risk analysis the appropriate tool, or should we pursue a more cautious approach? This debate has important implications for other issues where catastrophic risk is at issue, such as global climate change and nuclear power.

Economics teaches us that the efficient price for a good or service should reflect all social costs and benefits, not just the market interaction of supply and demand. We'll review the research on what the true cost of oil should be, and how efficient pricing could benefit society. Finally, we will explore how oil dependence could be dramatically reduced. We'll assess various policy proposals that seek to provide appropriate price signals, increase energy efficiency, and encourage a transition to cleaner energy sources.

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[1] A barrel of oil is 42 gallons. Thus 35,000 barrels of oil is equivalent to 1,470,000 gallons.
[2] Gulf Spill is Largest of Its Kind, Scientists Say," *New York Times*, August 3, 2010.
[3] Calculation based on a spill size of 10.8 million gallons for the *Exxon Valdez*. See "New Estimates Double Rate of Oil Flowing Into Gulf," *New York Times*, June 10, 2010.

II. THE HISTORY AND CONTEXT OF THE *DEEPWATER HORIZON* SPILL

Deepwater Oil Drilling

While it is true that the United States is increasingly reliant on imported oil, many people don't realize that the U.S. is currently the world's third largest producer of oil, behind only Russia and Saudi Arabia.[4] In 1950, the U.S. was able to produce enough oil domestically to meet its demand.[5] But U.S. domestic oil production peaked in 1970 and has fallen by about 50% since then.[6] With rising demand, an increasing share of oil consumption has been met through imported oil – 57% of U.S. oil consumption came from imports in 2008.

Domestic oil production in the U.S. occurs both onshore and offshore. Offshore oil currently accounts for about one-third of production, with about 90% of offshore production occurring in the Gulf of Mexico. All over the world crude oil is becoming more difficult to obtain. The "easy" oil has already mostly been extracted, and supplies are increasingly obtained from sources that are deeper underground, further offshore, in areas more difficult to access, or in nontraditional forms such as tar sands and oil shale.

Deepwater oil drilling[7] has become more attractive as a result of three main factors: technological advancements, higher oil prices, and government incentives. It can cost 10 times as much to develop a deepwater oil well as opposed to a shallow-water well.[8] But as the price of crude oil increases, drilling in deeper waters becomes profitable. Ultra-deepwater drilling, in more than 5,000 feet of water, is profitable as long as crude oil prices are above $40-$45 per barrel.[9] Government incentives also encourage deepwater drilling. The Deepwater Royalty Relief Act of 1995 allowed for reduced royalty rates for deepwater leases. Although the Act officially expired in 2000, lowered royalty rates have continued to be set for deepwater development.[10] Proponents of lower rates view them as compensation for the extra risk and expense associated with deepwater drilling but opponents argue that the policy encourages risky drilling.

An increasing share of offshore oil in the U.S. comes from deepwater sources. In the mid-1990s only about 20% of oil production in the Gulf of Mexico came from deepwater wells. Now the percentage of Gulf of Mexico oil from deepwater wells is about 70%, and this percentage is likely to grow in the coming years.[11]

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[4] Energy Information Administration, U.S. Department of Energy. *International Energy Statistics*.
[5] Energy Information Administration, U.S. Department of Energy. *Energy in Brief: How Dependent Are We on Foreign Oil?*
[6] Energy Information Administration, U.S. Department of Energy. *Monthly U.S. Field Production of Crude Oil*.
[7] Deepwater drilling is defined as drilling that occurs in at least 1,000 feet of water, or at least 305 meters.
[8] "Deep Water: Where the Energy Is," Minerals Management Service. 2004.
[9] "Trend toward Deep-Water Drilling Likely to Continue," Steven Mufson, *The Washington Post*, June 22, 2010.
[10] "Overview of the Federal Offshore Royalty Relief Program," Energy Information Administration, U.S. Department of Energy.
[11] "Gulf of Mexico Oil and Gas Production Forecast: 2009-2018," Minerals Management Service, OCS Report MMS 2009-12.

The *Deepwater Horizon* Accident

The *Deepwater Horizon* oil rig was built in 2001 and was one of about 200 rigs capable of drilling in water depths of more than 5,000 feet. While the rig did receive several citations for non-compliance during routine inspections, including one citation related to the operation of its blowout preventer in 2002, its overall safety record was considered very good, even exemplary.[12] According to a *Wall Street Journal* article:

> There were few indications of any trouble with the Deepwater Horizon before the explosion. The rig won an award from the MMS for its 2008 safety record, and on the day of the disaster, BP and Transocean managers were on board to celebrate seven years without a lost-time accident. Toby Odone, a BP spokesman, said rigs hired by BP have had better safety records than the industry average for six years running, according to MMS statistics that measure the number of citations per inspection. BP has been a finalist for a national safety award from the MMS for the past two years.[13]

While the exact cause of the *Deepwater Horizon* accident is under investigation and is not yet known, it is clear that methane gas under high pressure shot out of the drilling column onto the rig at 9:45 PM on April 20, and ignited, causing a massive explosion. Despite the explosion and the sinking of the rig several days later, the rig's blowout preventer should have automatically capped the well. A blowout preventer is a large device meant to seal a wellhead if conditions indicate a potential blowout – an uncontrolled release of crude oil under high pressure into the environment. Preliminary evidence suggests that the blowout preventer had a hydraulic leak and a failed battery.[14] According to statements by workers on the rig, several safety issues were reported in the weeks leading up to the accident, including a faulty control pod on the blowout preventer.[15] But apparently BP decided to continue rig operations rather than temporarily shutting it down to repair the problems.

Initial reports indicated that the blowout preventer was operating properly and that no oil was leaking from the wellhead. However, by April 24 it became clear that the well was leaking and that the spill was "very serious."[16] Estimates of the amount of oil leaking into the Gulf were revised upwards several times, from an initial estimate of 1,000 to 5,000 barrels daily to an eventual estimate of 53,000 to 62,000 barrels per day. After several failed attempts to stop the leak, on July 15 BP reported that a tight-fitting cap had been placed on the blowout preventer and that no oil was leaking into the Gulf. In August, federal scientists estimated that a total of 4.9 million barrels, or over 200 million gallons, had leaked into the Gulf of Mexico. The *Deepwater Horizon* spill is either the second or third largest oil spill in history, and by far the largest in U.S. waters.[17]

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[12] "Review: Oil Rig Inspections Fell Short of Guidelines," Associated Press, May 16, 2010.
[13] "Rig Owner Had Rising Tally of Accidents," *Wall Street Journal*, May 10, 2010.
[14] "Deepwater Horizon Blowout Preventer Faulty – Congress," BBC News, May 13, 2010.
[15] "BP Was Told of Oil Safety Fault 'Weeks before Blast'," BBC News, June 21, 2010.
[16] "Oil Rig Wreck Leaks into Gulf of Mexico," CBC News, April 24, 2010.
[17] "Largest Oil Spills," Wikipedia.com, http://en.wikipedia.org/wiki/Largest_oil_spills. The 1991 Gulf War oil spill released 2 – 6 million barrels. Thus the *Deepwater Horizon* spill may or may not be larger than the Gulf War spill. The largest spill in history was the land-based Lakeview Gusher spill during 1910-1911 in California, at 9 million barrels.

Under pressure from the Obama administration, BP set up a $20 billion compensation fund to be paid out to those adversely impacted by the spill. According to BP, by late August nearly $400 million had been paid to claimants. BP also undertook a $50 million advertising campaign to indicate that they will take full responsibility for the spill and "make things right." But there have been some concerns about delays in the compensation process.[18] Also, the *Deepwater Horizon* spill has brought focus upon BP's past environmental safety record, which reveals this was not an isolated incident of environmental damage by the company. See Box 1 for more on this issue.

BOX 1: BP'S ENVIRONMENTAL SAFETY RECORD

The *Deepwater Horizon* spill was not the first time BP's commitment to environmental safety has been questioned. In 2001, the worst spill ever on the North Slope of Alaska occurred due to widespread corrosion in several miles of under-maintained and poorly inspected pipes[19]. BP paid more than $20 million in fines and had an independent commission review its Alaska safety practices. The report found many safety culture problems and that many workers felt that the report would not change any safety procedures.

In 2005, BP rushed the production of what was supposed to be its flagship rig, the *Thunder Horse*, in the words of a BP engineer, to "demonstrate to their shareholders that the project was on time and on schedule." However, a pump installed backwards nearly caused the rig to sink, and after extensive repairs BP soon found that the underwater pipes had been so poorly welded that they had to be replaced. There is speculation that if the *Thunder Horse* had started production without fixing these problems, an incident similar to the *Deepwater Horizon* could have occurred.

Also in 2005, an explosion at a BP oil refinery in Texas killed 15 people and wounded 170. The Telos Group, a consulting firm tasked to examine conditions at the refinery before the explosion, noted, "We have never seen a site where the notion 'I could die today' was so real."[20] After the incident, BP commissioned another independent report on safety, which came to many of the same conclusions as the 2001 report, and pointed to "systemic" safety problems.[21]

After the oil refinery explosion BP's CEO stepped down, and incoming CEO Tony Hayward promised to make safety BP's number one concern. However, in the words of OSHA administrator David Michaels, "Senior management told us they are very serious about safety, but we observed that they haven't translated their words into safe working procedures and practices."[22] Despite BP's extensive record of safety problems, federal regulators in 2007 allowed BP to write its own environmental review for a deepwater drilling project in the Arctic, an area where extreme cold temperatures make oil spills even more damaging and difficult to remediate. [23]

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[18] See http://www.foxbusiness.com/markets/2010/08/14/obama-oil-spill-payout-delays-bp-unacceptable/

[19] 2001 BP Operational Integrity Report

[20] "At BP, a History of Boldness and Costly Blunders," *New York Times,* July 13, 2010.

[21] BP, 2007 Commissioned Study on Safety Culture

[22] "At BP, a History of Boldness and Costly Blunders," *New York Times,* July 13, 2010.

[23] "BP is Pursuing Alaska Drilling Some Call Risky," *New York Times*, June 23, 2010.

III. OIL SPILL VALUATION AND OFFSHORE DRILLING POLICY

Thousands of oil spills occur every year in marine environments in the United States. The vast majority of these spills are relatively minor, less than 100 gallons, and do not cause significant economic damage.[24] Larger oil spills, such as the *Exxon Valdez* spill in 1989 and the *Deepwater Horizon* spill, result in considerable damage to both the economy and the environment. Government agencies, acting on behalf of the public, are entrusted to obtain compensation from responsible parties for the economic losses that occur as a result of a spill. To start thinking about how we might estimate the economic damages from a large oil spill, we must first consider how economists define the economic value of natural resources.

Principles of Economic Valuation

Natural resources provide numerous types of benefits to society. Some benefits are easy to observe, such as the bounty of fish supplied in oceans or the enjoyment we get from visiting a National Park. But other benefits we obtain from natural resources are less evident. Natural resources provide various **ecosystem services**, such as water purification, nutrient cycling, and erosion control, at no cost to us. Many people also derive what economists call **psychic benefits** simply from knowing that natural environments exist and will be available for future generations.

Economists classify the **total economic value** of a natural resource as the sum of use and nonuse benefits. **Use values** are the tangible benefits society obtains from the environment. **Direct use values** are obtained from a direct physical interaction with the natural environment. These values may derive from the extraction of resources and be expressed in markets, as in the case of commercial fishing or timber. Direct use values can also be non-extractive, as in the case of hiking or photography. **Indirect use values** are tangible benefits we obtain from nature – the ecosystem services mentioned above. Even though these values are not reflected in markets, ecosystem services nonetheless provide real economics benefits such as flood protection and air purification.

Nonuse values are intangible benefits that people obtain without actually using a resource. Nonuse values are further classified into option, bequest, and existence values. **Option value** is the benefit obtained for the future use of a resource. **Bequest value** is the benefit obtained by knowing a resource will be available for future generations. Finally, **existence value** is the benefit obtained by simply knowing a resource exists, even though one never plans to use or interact with it.[25]

NOTE – terms denoted in **bold face** are defined in the **KEY TERMS AND CONCEPTS** section at the end of the module.

[24] For example, in 2008 there were 3,568 documented oil spills of greater than one gallon into U.S. waters but 96% were less than 100 gallons. See "The 2010 Statistical Abstract," U.S. Census Bureau, Table 359.

[25] For a more detailed treatment of environmental valuation issues, see Harris, Jonathan M., *Environmental and Natural Resource Economics: A Contemporary Approach,* Chapter 6.

The concept of total economic value is illustrated in Figure 1, using examples of a coastal marine environment that could be damaged by an oil spill. It is important to remember that the different categories of value are additive. Also, even though some types of value are not expressed in markets, these non-market values are still "economic" in the sense that they can theoretically be estimated in monetary units.

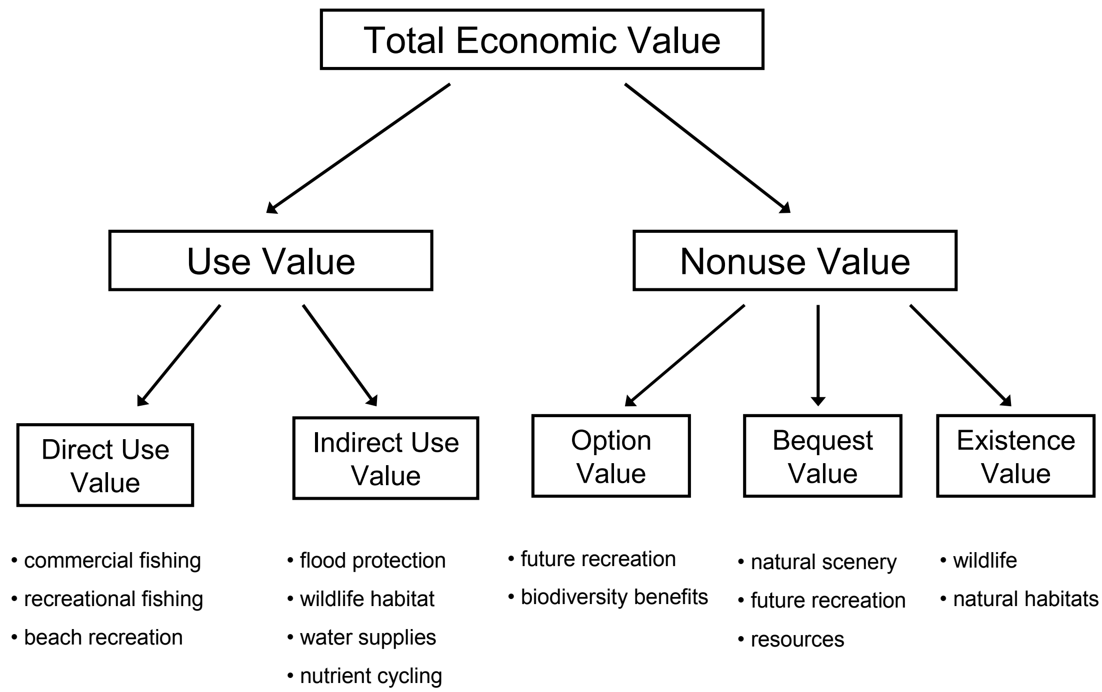

Figure 1. Total Economic Value of a Coastal Marine Ecosystem

Economists use the concept of **willingness to pay** (WTP) to express non-market values in monetary terms. For example, the existence value one obtains from knowing that the Arctic National Wildlife Refuge will remain in its undeveloped state is defined as one's maximum willingness to pay for its preservation. Willingness to pay amounts vary across individuals based on variations in preferences and incomes. The total existence benefit derived from the Refuge would simply be the sum of all individual values.

The monetization of non-market benefits is subject to debate. On one hand, some economists argue that unless we attempt to estimate non-market benefits, these benefits will implicitly have a value of zero and thus lose out to extractive market-based uses. For example, there is no market where people "buy" the existence of the Arctic National Wildlife Refuge in an undeveloped state, while the economic value of the oil under the Refuge can be expressed relatively easily in monetary terms. So without estimating the non-market benefits, it is difficult from an economic perspective to justify protection of the Refuge.

There are at least two major conceptual critiques of the monetization of non-market benefits. One is that willingness to pay is clearly a function of one's ability to pay. Imagine two individuals who are each willing to pay $100 per year for the preservation of the Arctic National Wildlife Refuge; one has an annual income of $10,000 while the other has an income of $500,000. Using the willingness to pay approach, each person would appear to value the Refuge equally. But income level is likely to be a significant constraint on willingness to pay. For this reason, the WTP of lower-income individuals may understate their real preference for environmental protection.

The other critique is that monetization fails to fully capture all values. Note that the concept of total economic value assumes that something has value only if individuals are willing to pay for it. Some ecological services may be important from an ecosystem perspective, even though willingness to pay for these services may be low. For example, willingness to pay values for the protection of an insect species may be quite low, even if it performs a critical ecological service in a habitat.

Other critiques focus on the methods of non-market valuation. In particular, nonuse values can only be estimated using **contingent valuation**. This is essentially a survey approach that attempts to elicit willingness to pay amounts for a hypothetical scenario. For example, respondents may be asked to state their willingness to pay for a policy that will reduce the risk of a large-scale oil spill by a certain probability, such as 50%. Contingent valuation is a controversial technique because respondents may not provide valid answers for various reasons. Respondents may fail to consider their real income constraints when stating willingness to pay values, because the scenario is merely hypothetical. They may also state excessively high willingness to pay values to obtain a “warm glow” effect from supporting a particular policy.

Oil Spill Damage Assessment

The economic damages from many oil spills have been estimated based on lost use values, such as commercial fishing or beach recreation. However, the possibility of significant nonuse damages first arose in the aftermath of the *Exxon Valdez* spill. An economic analysis of the nonuse losses implied that these damages comprised the majority of the losses that resulted from the spill, based on a contingent valuation study (see Box 2).

As a response to the *Exxon Valdez* spill, the Oil Pollution Act (OPA) of 1990 was passed by the U.S. Congress. Among other provisions, the OPA clarified what damages the public was entitled to receive from a responsible party as compensation for an oil spill. The OPA specifies that the natural resource damages from a spill are defined as the sum of the following three elements:

1. **Primary restoration** – the cost of restoring damaged natural resources to baseline conditions.
2. **Compensatory restoration** – the lost value of natural resources pending restoration to baseline conditions.
3. **Assessment costs** – the reasonable costs of assessing damages.

BOX 2: VALUING THE *EXXON VALDEZ* OIL SPILL

The trustees (government officials acting on behalf of the public) in the 1989 *Exxon Valdez* spill commissioned several studies to estimate the economic damages of the spill. One study focused on the recreational fishing losses, with a range of damages of $4-$51 million.[26] Another study focused on the tourism losses, finding that the spill reduced in-state tourist expenditures by $5.5 million in 1989.[27] But by far the largest economic damage category was the lost nonuse values. A contingent valuation study elicited information on respondent's willingness to pay to prevent a similar spill in the future.[28] The survey sample included U.S. households outside of Alaska, as well as Alaskans. The results found that the median household willingness to pay to prevent a similar accident was $31. Multiplying this by the number of households in the country at the time yielded a total willingness to pay of $2.8 billion.

Exxon spent about $2 billion cleaning up the spill, and the trustees reached a settlement agreement with Exxon for natural resource damages of $900 million.[29] Initially, Exxon was also hit with punitive damages of $5 billion. But through a series of appeals, this amount was reduced to $2.5 billion in 2006 and, finally, to $508 million in 2008 by the U.S. Supreme Court. The Court's majority ruled that the punitive damages should be limited by the actual damages caused. But critics contend that the court's reduction in damages was unwarranted. Senator Patrick Leahy, chairman of the Senate judiciary committee said that the ruling was "another in a line of cases where this Supreme Court has misconstrued Congressional intent to benefit large corporations." [30]

The difference between primary and compensatory restoration is illustrated in Figure 2. The wavy line across the top of the graph represents the baseline value of a resource in the absence of an accident. The baseline value includes all economic values listed in Figure 1 – i.e., it is the total economic value of the resource. Baseline values aren't necessarily constant over time, as a result of natural fluctuations and changes in external conditions.

In Figure 2, an accident occurs which significantly reduces the total value of the resource. After the accident, the resource will eventually recover to baseline conditions without any intervention. In this case, the total damages over time, relative to baseline conditions, would be areas A + B + C. Primary restoration can reduce the time to full recovery, limiting the damages over time to area A. But primary restoration is not required in all cases. Primary restoration is not to be implemented if it is technically infeasible or if the costs are "grossly disproportionate" to the benefits.[31] The benefits of primary restoration (i.e., the damages avoided by undertaking

[26] "A Preliminary Economic Analysis of Recreational Fishing Losses Related to the Exxon Valdez Oil Spill," Richard T. Carson and W. Michael Hanemann, Report to the Attorney General of the State of Alaska, December 18, 1992.
[27] "An Assessment of the Impacts of the Exxon Valdez Oil Spill on the Alaskan Tourism Industry," McDowell Group, August 1990.
[28] "A Contingent Valuation Study of Lost Passive Use Values Resulting from the Exxon Valdez Oil Spill," Carson, et al., Report to the Attorney General of the State of Alaska, November 10, 1992.
[29] "Exxon Valdez Oil Spill," Wikipedia.com, accessed August 5, 2010.
[30] "US Court Slashes Exxon Valdez Damages," Suzanne Goldenberg, *The Guardian,* June 26, 2008.
[31] Mazzota, et al.. 1994.

restoration) are equal to areas B and C in Figure 2. So primary restoration would be undertaken as long as the costs aren't disproportionate to these benefits.

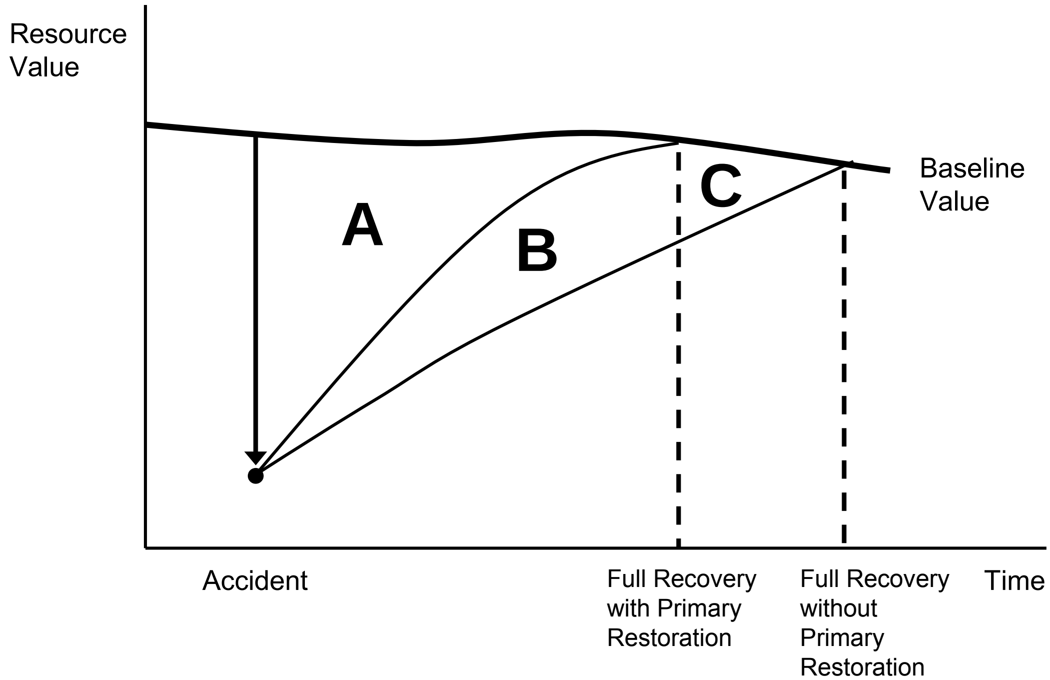

Figure 2. Damage Assessment with and without Primary Restoration

With primary restoration, the resulting loss in resource value is area A. So even if the responsible party pays for primary restoration, it must still compensate the public for the lost resource value equal to area A. While we'll explore how area A is actually measured a little later, let's first study the conceptual framework for estimating and implementing compensation.

Through the technique of **habitat equivalency analysis (HEA)**, trustees acting on behalf of the public can determine the scale of compensatory restoration that fully compensates the public for the interim losses of an oil spill. The underlying principle is that restoration projects should provide ecological services over time that substitute for the lost ecological services that accrue until an injured site recovers to baseline conditions.[32]

Habitat equivalency analysis is best described using an example from an actual oil spill. On May 16, 1997 a Texaco crude oil pipeline ruptured in Lake Barre, Louisiana, releasing an estimated 6,561 barrels of oil.[33] The spill resulted in an oil slick that impacted over 4,000 acres of marshland, caused mortality of aquatic fauna and birds, and closed the affected area to oyster harvesting for several months. The trustees classified the injured marshland into four categories, based on the degree of oiling, as shown in Table 1. The injury metric used in this case was acre-

[32] "Habitat Equivalency: An Overview," NOAA, 2006.
[33] Louisiana Oil Spill Coordinators Office, et al. 1999. "Damage Assessment and Restoration Plan, Texaco Pipeline Inc. Crude Oil Discharge, Lake Barre, Louisiana, May 16, 1997.

years – the ecological services provided by an acre of habitat for one year. Thus if ten acres of marsh were injured such that the ecological services from that habitat were reduced by 50% for a duration of three years, the lost services would be 15 acre-years of marsh services, (10*0.5*3).

Oiling Degree	Affected Acres	Percentage Service Loss	Duration to Recovery	Service Loss Estimate
Light oiling, rapid recovery	4,165	10% initially, then declining	4 months	41.9 acre-years
Heavy oiling, moderate recovery	153.6	40% initially, then declining	2 years	26.5 acre-years
Heavy oiling, slow to moderate recovery	8.1	75% initially, then declining	2 years	4.6 acre-years
Heavy oiling, slow recovery	0.28	100% initially, then declining	20 years	2.6 acre-years
TOTAL				75.6 acre-years

Table 1. Marshland Oiling, Lake Barre Oil Spill

The next step in a HEA is to estimate the compensatory restoration that would provide appropriate compensation for this injury. In this case, restoration projects must provide at least 75.6 acre-years of marsh services. Restoration projects can "create" marshland services in various ways, such as planting marsh flora, diverting water, or purchasing private land for protection. Depending upon the initial condition of the land, these actions can significantly increase the ecological services provided.

Once a HEA has determined the restoration requirements, the trustees can then locate one or more restoration projects that provide sufficient compensation. Ideally, the restoration project should involve the same kind of resource as the damaged resource. For example, a marsh restoration project would be implemented as compensation for oiled marshlands. Projects to improve recreational fishing can be implemented as compensation for lost recreational fishing benefits.[34] But resources of different types may be compared based on conversion factors determined by ecologists. In the Lake Barre case, it was determined that four acres of created marsh would compensate for the aquatic fauna and bird injuries.

[34] For example, projects to improve fish access to spawning grounds and increase public access to coastal fishing areas were implemented as compensatory restoration for the lost value of recreational fishing trips as a result of the 1996 *North Cape* oil spill in Rhode Island ("Restoration Plan and Environmental Assessment for the January 19, 1996 *North Cape* Oil Spill," National Oceanic and Atmospheric Administration, Rhode Island Department of Environmental Management, U.S. Department of the Interior, and U.S. Fish and Wildlife Service. 1999. Revised Draft.

Offshore Drilling Policy

The techniques discussed above allow public trustees to obtain appropriate compensation after an oil spill. But the possibility of future oil spills should also affect policy decisions regarding where oil development should be permitted. Offshore drilling in the United States was, until recently, managed by a federal agency called the Minerals Management Service (MMS).[35] The MMS oversees oil and gas development in the Outer Continental Shelf (OCS), an area that generally extends 200 miles from the coast. The OCS covers 1.7 billion acres, an area equal to about two-thirds of the land area of the United States. In 2009 the OCS provided 30% of the oil produced domestically in the United States.[36] The OCS is likely to provide an even greater share of domestic oil in the future, as about 60% of the undiscovered reserves in the country are estimated to be located in the OCS.

The MMS leases offshore areas for oil and gas development to private companies. These companies pay the MMS royalties for development rights, supposedly based on a fair market calculation, which totaled about $10 billion in 2009.[37] The MMS is directed to make lease decisions based on environmental factors as well as economic considerations. Specifically, the MMS seeks:

> to determine which offshore areas are acceptable for leasing, as well as to predict, assess, and manage the impact of OCS natural gas and oil activities on the human, marine, and coastal environments.[38]

To pursue this objective, the MMS maintains a model that estimates the potential environmental consequences of OCS oil and gas development. Among other factors, this model estimates the probability of oil spills as a function of oil production in different regions of the OCS, and the estimated economic damages that will occur from these spills.

The Offshore Environmental Cost Model (OECM)[39] links OCS oil production levels to oil spill damages in a four-step process as illustrated in Figure 3.

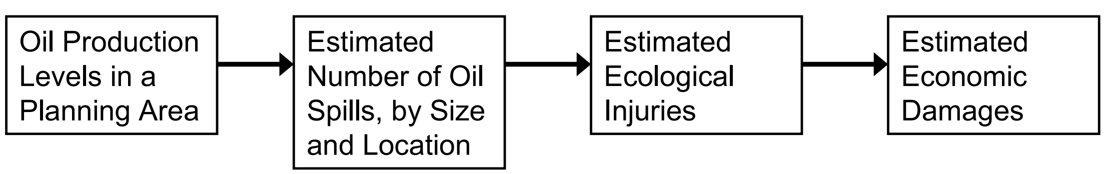

Figure 3. The Steps in the Offshore Environmental Cost Model

[35] As of June 18, 2010, the name of the Minerals Management Service was changed to the Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE). Given that the material discussed in this module covers the time when the agency was named the MMS, the older name will be used here.

[36] "Calendar Year - OCS Oil & Natural Gas Production Federal OCS vs U.S. Total, 2009," Minerals Management Service.

[37] "All Reported Royalty Revenues, Fiscal Year 2009," Minerals Management Service.

[38] "Working for America's Energy Future and a Quality Environment," Minerals Management Service.

[39] Roach, et al., 2001.

A brief investigation of this model will illustrate the strengths and limitations of economic analysis in policy planning for offshore oil development. The primary input into the model is the quantity of oil production in each of the MMS's 26 Planning Areas.[40] Based on an analysis of historical data on oil spills, the model then estimates how many spills will likely occur, classified into different size spills. The third step is to determine the ecological impacts of these spills, including estimates of coastal habitat oiling, beach closures, recreational and commercial fishing impacts, and wildlife deaths, based on the likely geographic location of spills and other model inputs such as ocean currents, wind, and season of the year. The last step is to convert these injuries to monetary damages using HEA and other economic techniques.

The OECM determined likely spill magnitudes based on oil spill data from the U.S. Coast Guard and MMS. The model differentiates between "small" and "large" spills. A small spill is defined as ranging from 1,000 gallons (24 barrels) to 1,000 barrels. Large spills are thus anything above 1,000 barrels. Historical spill data were analyzed to obtain the average size of a large oil spill – 7,000 barrels for platform or pipeline spills and 25,500 barrels for a tanker spill.

The *Deepwater Horizon* spill was clearly not an average spill – it released more than 50,000 barrels *per day*. So that raises the question of whether the OECM could have estimated the probability of such a spill. MMS data indicates that 330 spills associated with OCS production occurred over the period 1964-2009.[41] The total volume of oil released from all these spills is about 550,000 barrels. In August 2010 it was estimated that the *Deepwater Horizon* spill had released about 4.9 million barrels of oil into the Gulf of Mexico.[42] So clearly there was no historical precedent to the *Deepwater Horizon* spill in the history of OCS oil development. In fact, the largest spill that had previously occurred in the OCS was only 160,000 barrels (a 1967 pipeline rupture) and the worst drilling platform blowout had only been 80,000 barrels (a 1969 spill in California).

It is also worth noting that oil spill occurrence rates had been declining for decades, particularly platform spills. An analysis of oil spill probabilities from 2000[43] indicates that:

> The spill rates for U.S. OCS platforms in the last 15 years [1985-1999] could not be directly calculated because there were zero platform spills greater than or equal to 1,000 bbl (barrels) during that period. It is unwise to estimate a spill rate of "zero," because if used in projections of future spill occurrence, it does not allow for any platform spills occurring--something that hasn't occurred recently, but could. (p. 9)

Perhaps the historic oil spill most similar to the *Deepwater Horizon* spill was the 1979 *Ixtoc I* oil spill off the coast of Mexico. It also involved a blowout and the explosion of an oil rig, with the

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[40] The MMS's Planning Areas include 15 areas in Alaska, four along the Western coast, three in the Gulf of Mexico, and four along the Eastern coast.
[41] Summary OCS Oil Spills ≥ 50 Barrels, CY 1964 – 2009, Excel spreadsheet downloaded from MMS website, July 21, 2010, http://www.mms.gov/incidents/spills1964-1995.htm.
[42] "Oil Disaster by the Numbers," CNN.com,

http://www.cnn.com/SPECIALS/2010/gulf.coast.oil.spill/interactive/numbers.interactive/index.html
[43] Anderson and LaBelle, 2000. "Update of Comparative Occurrence Rates for Offshore Oil Spills."

release of over 3 million barrels of oil.[44] However it was widely accepted that oil development technology and safeguards had improved such that a spill of similar magnitude was very unlikely. Thus before the *Deepwater Horizon* spill, it would have been extremely difficult, if not impossible, to estimate the probability of such a spill and incorporate the results into a probabilistic model. So how should we account for the possibility of a low-probability, high-impact event in policy planning? This is an issue to which we will return in Section V.

Another result from the OECM is worth noting in considering the damages from the *Deepwater Horizon* spill. The OECM estimates the economic damages from 150 hypothetical oil spills, including six spills in the Central Gulf of Mexico Planning Area, the area where the *Deepwater Horizon* was located. The model classified economic damages from oil spills into five categories, as shown in Table 2. The table also presents the average economic damages per barrel spilled in the area.

We can see that the largest potential damages occur from wildlife deaths, with large losses also resulting from lost recreational fishing trips. Commercial fishing damages only represent 5-22% of the damage estimates. The ecological impacts of habitat degradation and wildlife deaths, which could be classified as indirect use and nonuse values, represent 58-70% of total economic damages. Of course these results are derived from hypothetical spill scenarios which may not necessarily reflect the impacts of the *Deepwater Horizon* spill. There may well be **threshold effects** of a very large oil spill, meaning that damages increase dramatically at a point where ecological systems are overwhelmed and cannot recover, or recover only very slowly. But using the estimates from Table 2 implies total damages from the *Deepwater Horizon* spill of at least $1.3-$5.6 billion based on government estimates of a total of 4.9 million barrels spilled. As we will see in the next section, most estimates of the true damages are significantly higher.

Category of Damages	**Low Estimate of Damages, per Barrel Spilled**	**High Estimate of Damages, per Barrel Spilled**
Beach Recreation	$1	$3
Recreational Fishing	$55	$283
Commercial Fishing	$59	$59
Coastal Habitat Degradation	$37	$186
Wildlife Deaths	$122	$620
TOTAL	$274	$1,151

Table 2. Offshore Environmental Cost Model Estimates of Oil Spill Damages in the Central Gulf of Mexico Planning Area

[44] "Ixtoc I Oil Spill," Wikipedia.com, http://en.wikipedia.org/wiki/Ixtoc_I_oil_spill.

IV. IMPACTS OF THE *DEEPWATER HORIZON* OIL SPILL

Understanding the full environmental impact of the *Deepwater Horizon* oil spill will require years of scientific observation. Also, some effects of the spill may not be immediately evident. Consider a cautionary tale from the *Exxon Valdez* oil spill. Four years after the 1989 *Valdez* spill, and two years after the financial settlement, the Pacific herring population in Prince William Sound crashed, and has still not recovered. Some scientists believe the collapse can be directly linked to the *Valdez* spill – that oil weakened developing herring and ultimately made them more vulnerable to disease. But this significant and lasting effect did not show up for four years after the event (see Figure 4).[45]

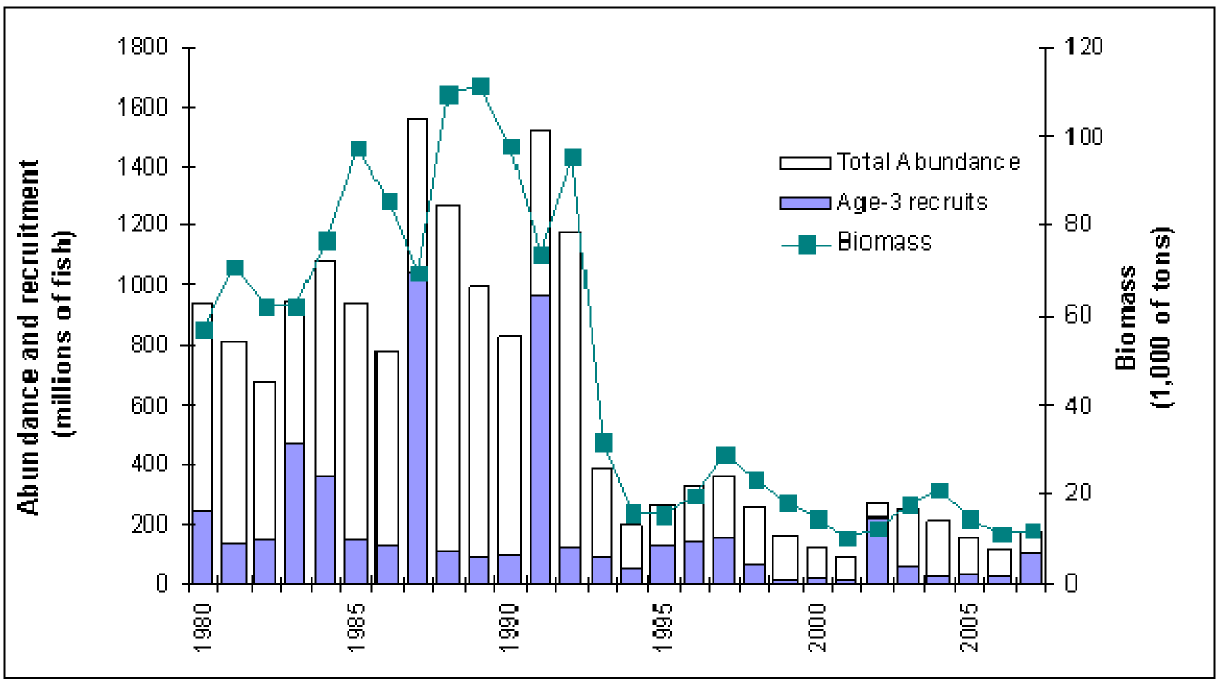

Figure 4. Collapse of Herring Stocks in Prince William Sound
Source: North Pacific Fisheries Management Council, *Ecosystem Considerations*, 2008, "Prince William Sound Pacific herring" contributed by Steve Moffitt, Alaska Department of Fish and Game

The *Deepwater Horizon* spill oiled at least 44,000 square miles in the Gulf of Mexico, an area about the size of Ohio, and hit about 600 miles of coastline. Figure 5 shows the total ocean area where surface oil slicks were observed and the coastal areas that were oiled. The affected wildlife, observed either dead or oiled, includes about 4,000 birds, 700 sea turtles, dozens of dolphins, and one whale.[46] More difficult to quantify is the spill's impact further down the food chain, on microscopic fauna and on aquatic and coastal plant life. Research is ongoing to collect data so that before-and-after comparisons can be constructed for the impacted areas.[47]

[45] "Valdez's Spill Effects on Fish Raise Concerns," *Houston Chronicle*, July 17, 2010.
[46] "Feds Work to Put a Price Tag on Oil Spill Damage," *Providence Journal,* July 22, 2010.
[47] See http://www.noaa.gov/100days/Assessing_Ecosystem_Damage.html, accessed August 4, 2010.

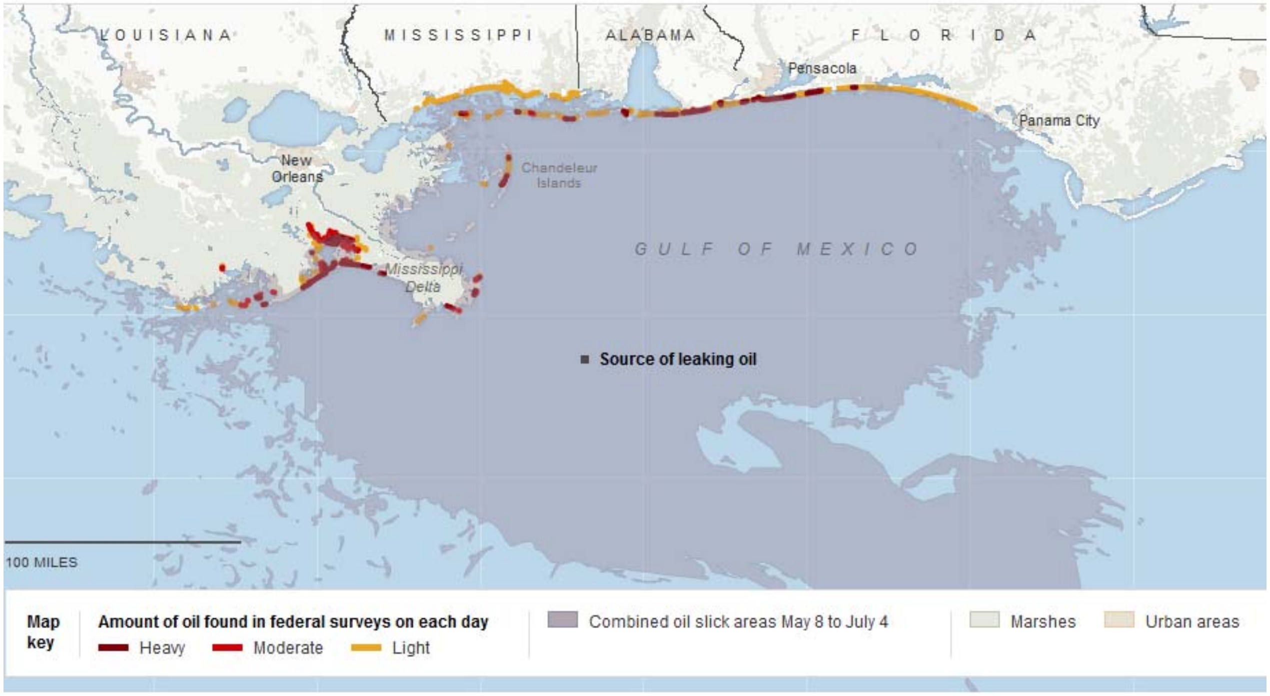

Figure 5. Oil Slick Extent and Coastal Oiling from the Deepwater Horizon Spill
Source: *New York Times*.

Preliminary Economic Estimates

Some preliminary economic estimates have attempted to quantify the spill's impacts. Most of these estimates focus on losses in terms of GDP and jobs. One estimate finds that the spill will reduce the U.S. GDP by $73 billion and that about 250,000 jobs will be lost.[48] According to a different estimate, the total damages will range from $40 to $100 billion.[49] Note that both of these estimates are considerably higher than the $20 billion compensation fund established by BP.

Three industries have been particularly impacted by the spill: commercial fishing, tourism, and the oil and gas industry. At its peak, the spill closed over one-quarter of the Gulf of Mexico to commercial fishing, an industry that contributes about $1 billion to the regional economy.[50] According to one estimate, the spill's impact on tourism in the Gulf region could be $22.7 billion over three years.[51] In considering impacts on total U.S. GDP, however, we should realize that the reduction in tourism to Gulf states will be at least partially offset by increases in tourism to

[48] "Oil Spill's Economic Damage May Not Go Beyond Gulf," Yahoo Finance, June 28, 2010.
[49] "Oil Spill Damages May Hit $100 Billion: Louisiana Treasurer," Reuters, June 17, 2010.
[50] "Gulf Coast Spill Could Wreck Region's Tourism and Fishing Industries," Peter Woriskey, *The Washington Post*, June 3, 2010.
[51] "Gulf Spill Could Cost Region $22.7 Billion in Travel Dollars," CNN.com, July 22, 2010.

other regions. The spill has also impacted the region's oil and gas industry, mainly through a temporary moratorium put in place on deepwater drilling. The oil and gas industry is particularly important in Louisiana, where it employs 58,000 people and provides 7% of the state's revenues.[52]

The spill has also significantly affected owners of BP stock. At one point the total loss in market value for BP's stock was over $100 billion.[53] The total cost of the spill to BP is estimated to range from $17 to $60 billion.[54] In addition to liability for primary restoration and compensatory damages, BP could face stiff civil fines. A provision in the Clean Water Act allows the U.S. government to collect a fine of $1,100 per barrel of oil spilled, or $4,300 per barrel if the spill is found to be a result of gross negligence.[55] With an estimated release of 4.9 million barrels, this fine would therefore be at least $5.4 billion, but perhaps as much as $21 billion. If the penalty is mitigated by an estimated 800,000 barrels of oil recovered by skimmer ships and other means, the figures would drop to $4.5 billion and $17.6 billion, respectively.[56]

Note that these damage estimates are primarily based on market economic values. But as noted above, there are also very important indirect use, non-use, and ecological values involved. How can these be estimated?

The *Deepwater Horizon* spill will leave long-term damages to marshes and other wetlands along several hundred miles of coast (see Figure 5). Experience with previous spills indicates that oil can remain in the environment for decades, with toxic effects on wildlife. The die-off of marsh vegetation after a spill contributes to erosion and possibly the permanent loss of coastal wetlands (see Box 3). This loss of ecological function and ecosystem services can at least in part be captured by a monetary valuation. A recent study estimated the total value of the ecosystem services of the Mississippi River Delta to be in the range of $12-47 billion per year.[57] Taking into account the future value of these services, the value of the Delta as a natural asset was estimated to be in the range of $330 billion to $1.3 trillion.[58]

We do not know how seriously the spill will affect the long-term functions of the Mississippi Delta and other wetlands and coastal areas in Louisiana, Mississippi, Alabama, and Florida. But if we assume a 10-20 percent loss of function for the Mississippi Delta alone, that would amount to an annual loss of $1.2 - $9.4 billion per year. Using a **present value** technique based on discounting, to estimate the total value of future services, if these losses persist for 10 years total damages would be $8 - $60 billion.[59]

In addition, there are other ecological damages from the huge volumes of oil released into the deep ocean. Due to the unprecedented use of dispersants by BP, much of the released oil

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[52] "Despite BP Spill, Louisiana Still Loves Big Oil," Bill Sasser, *The Christian Science Monitor*, May 24, 2010.
[53] "Stormy Weather: BP's Stock Hits New Low," Paul Tharp, *The New York Post*, June 26, 2010.
[54] "For BP, Oil Spill Fund Is a $20 Billion Drop in a Very Large Bucket," The Associated Press, June 18, 2010.
[55] "Special Report: Civil Fine in Gulf Spill Could Be $4,300 Barrel," Reuters, May 26, 2010.
[56] "Gulf Spill is the Largest of its Kind, Scientists Say," *The New York Times* August 3, 2010.
[57] Batker, et al., 2010.
[58] Costanza et al., 2010.
[59] For an explanation of discounting and techniques for computing present value, see Harris, 2006. Chapter 6. Calculation based on an annual discount rate of 3.5%.

remained suspended in ocean waters and never reached the shore. While the use of dispersants had the effect of lessening the visible damages on the shoreline, it may have resulted in significant damage to ocean food chains and ecosystems, since the toxicity of the dispersants is similar to the toxicity of the oil itself. In addition, large quantities of the natural gas methane were present in the spill, and dissolved methane also has a toxic effect on living organisms. It is probably impossible to get a dollar estimate, or even a good scientific measure, of these damages, but they may be considerable.

BOX 3: THE REMARKABLE PERSISTENCE OF OIL DAMAGE

In 1969, a barge hit the rocks off the coast of West Falmouth, Mass., spilling 189,000 gallons of fuel oil into Buzzards Bay. Today, the fiddler crabs at nearby Wild Harbor still act drunk, moving erratically and reacting slowly to predators. The odd behavior is consistent with a growing body of research showing how oil spills of many types have remarkably persistent effects, often at levels low enough to escape routine notice. Researchers established that the crabs were suffering from a kind of narcosis induced by hydrocarbon poisoning. Their troubles had serious implications for the marsh. Fiddler crabs normally play a crucial role in tilling the salt marsh, which helps provide oxygen to the roots of salt marsh grasses.

In Alaska, the Exxon Valdez spill dumped nearly 11 million gallons of oil into Prince William Sound, and it spread down the Alaska coast, ultimately oiling 1,200 miles of shoreline. By the late 1990s, the oil seemed to be largely gone, but liver tests on ducks and sea otters showed that they were still being exposed to hydrocarbons, chemical compounds contained in crude. At the rate the oil is breaking down, some of it could still be there a century from now.

Perhaps the greatest single hazard from the Deepwater Horizon disaster in the gulf is the long-term erosion of delicate coastal wetlands it could cause. Louisiana's coastline contains some of the most productive marshes in the world, delivering an abundance of shrimp and oysters and providing critical habitat and breeding ground for birds and fish. But even before the spill, the land was under enormous environmental stress, largely due to human activity. Dams on the Mississippi River and its tributaries have slowed the flow of sediment to the marshes, and global warming has caused sea level to rise. The Louisiana marshes are eroding at an extraordinary rate – a football field's worth sinks into the Gulf of Mexico every 38 minutes, according to the Louisiana Office of Coastal Management – and the worry now is that the oil spill will accelerate that erosion.

Source: "After Oil Spills, Hidden Damage can Last for Years," *New York Times*, July 17, 2010.

V. TECHNOLOGY, UNCERTAINY, AND PRECAUTION

As we have seen, environmental economics can provide techniques for assigning dollar values even to a disaster as massive as the *Deepwater Horizon* oil spill. But are these valuation approaches sufficient? The Gulf oil spill raises some worrisome issues that have broader implications for energy and environmental policy. If we can put a dollar value – even a very large one – on environmental damage, that implies that we can find ways to bring this event into a rational system of economic calculation, to "internalize" these costs. We will discuss the policies available to do this in the next sections of this module. Before moving to polices, though, we will consider some of these broader implications regarding our understanding of technology, uncertainty, and the possibility of unforeseen consequences.

Dealing with Risk and Uncertainty

Economists like to present things in a rational and precise form. So how can we deal with the risk of an unknown event? The standard approach is known as **expected value**. This is expressed by a simple formula:

$$\mathbf{EV[X] = p[X]\ C[X]}$$

where EV is expected value, p is the probability of event X, and C is its cost.

For example, suppose the chance of a house fire is judged to be one in a thousand per year, and the potential cost of a particular house burning down is $500,000. The expected value of fire damage for that house would then be (1/1,000)*($500,000) = $500. Despite the catastrophic nature of this event for the homeowner, it can be covered for a modest insurance premium of a little over $500 per year (say $550 to allow a profit margin for the insurance company). If 1,000 houses are covered at this cost, the expected cost of one fire per thousand houses can be paid for out of the 1,000 premiums of $550 each. This approach works out well for both the homeowner and the insurance company. On these 1,000 houses, the insurance company takes in $550,000 in premiums, pays out one claim of $500,000, and makes $50,000 profit, on average. Meanwhile the homeowner can rest assured that (provided s/he has smoke alarms and escapes personal injury) any fire damage to the house will be fully covered, even if the house is totally destroyed.

This is an economically rational way of dealing with risk. In theory, we could apply this to the oil industry by calculating the costs and probabilities associated with oil spills, and charging the resulting "premium" to the industry in the shape of a tax or other financial requirement (discussed in the next section). But for this to work, we need to have confidence in both our valuation estimates and our risk estimates. We have reviewed some of the difficulties involved in coming up with a reliable cost estimate. How about the assessment of risk? What can we say with confidence about the risk of (another) major oil spill or other catastrophic event?

Prior to the Gulf oil spill, there was a widespread assumption within the oil industry, and among most policymakers, that offshore oil drilling technology was generally safe and effective, and the chances of a major spill were treated as remote. This same confidence characterizes other industries, for example the nuclear industry. Nuclear reactors are known to be potentially subject to catastrophic meltdown, but the chances of this are assumed to be small enough that drastic measures such as shutting down operating reactors are not necessary. Should the experience of the Gulf oil spill change our attitude towards catastrophic risks that are generally presumed to be very small? Could our "rational" approach to such risks be missing something important?

One approach to analyzing events that are very significant but also very unlikely is what is called **black swan theory**[60]. According to this theory, the seemingly precise probability equation cited above is useless in dealing with highly improbable but also highly consequential events. The black swan metaphor suggests that we ordinarily assume that swans will be white, since all the swans we have ever seen are white. But black swans do exist, and the unpredicted appearance of a black swan can upset all our calculations based on previous experience. This seems appropriate for the Gulf oil spill. Oil company executives and government regulators assumed that because there was extensive experience with offshore drilling with no major incidents over a thirty year period, there was no need to take extra safety precautions or to plan for a huge drilling rig failure (see Box 4). But we know now that such a failure can, and did, occur. Indeed, in this case we should have had additional warning, since a similar blowout had occurred in 1979 with the *Ixtoc* rig off the coast of Mexico.

BOX 4: REGULATORY CAPTURE AND REGULATORY REFORM

For many years, a cozy relationship existed between the Mineral Management Service and the oil industry. "Government regulators essentially rubber-stamped potentially hazardous deepwater projects … the administration has come under sharp criticism for granting BP an exemption from environmental oversight for the Macondo [Deepwater Horizon] well."[61] This is a phenomenon known as **regulatory capture –** when government officials become subservient to the industry they are supposed to be regulating.

The Obama administration has now announced a more rigorous regulatory review process. Oil industry spokespersons complain that the new rules could "slow approval of new wells and cost jobs".[62] Since the oil industry is not well suited to weigh major risks to the public and environment against profitable production, it is critical that regulators be truly independent and take into account all possible outcomes, including potential "black swan" disasters. Whether this will be the case for offshore oil drilling in the future remains to be seen.

Technology and Unintended Consequences

In most economic models, technological progress is an unambiguous benefit: it allows labor and capital to become more productive over time, leading to greater output and increased well-being. But there can be a downside to technological progress: the possibility of unintended consequences that have a negative impact on the environment and on human well-being. Many environmental externalities arise from the negative effects of seemingly benign technologies. A prime example is ozone layer destruction caused by chlorofluorocarbons (CFCs). The invention of these chemicals, not found in nature, was hailed as providing cheap non-toxic, non-flammable

[60] See Taleb, Nassim Nicholas, *The Black Swan: The Impact of the Highly Improbable* (New York, Random House, 2007).
[61] "Drilling Permits for Deep Waters Face New Review," *New York Times*, August 16, 2010.
[62] Ibid.

coolants, aerosol propellants, and industrial solvents. Only when it was discovered that CFCs accumulate in the atmosphere and rapidly destroy the earth's essential ozone layer protection did it become necessary to reverse the growth in their use and eliminate them from production[63].

This kind of technological backlash is also an important part of the oil spill story. Modern technology has enabled oil companies to drill much deeper, go further offshore, and employ sophisticated sensing devices to exploit previously inaccessible oil fields. All this was seen by oil producers as highly advantageous. However at the same time this technological innovation increased the chances of catastrophic failures. While a warning of the potential dangers occurred with the 140-million gallon *Ixtoc* spill in 1979, the general assumption was that technological improvements had made any repeat of this unlikely. In fact, the opposite was true: the technology that enabled much deeper drilling made a large blowout much more difficult to control given the difficulties of operating 5,000 feet below the ocean surface, and the high pressures in very deep oil and methane reservoirs.

Irreversibility and Precaution

The risk of unintended consequences and "black swan" events becomes even more serious if damages are irreversible. Environmental pollution may be short or medium term in its impact. Much air and water pollution is of this nature: since the passage of the Clean Air and Water Acts, the environmental quality of many rivers has improved and urban air pollution has declined, as pollutant flows have been controlled. But some environmental damage can be permanent, or very long-lived. Large oil spills fall into this category. Decades after the Exxon Valdez and Ixtoc spills, as well as smaller spills in other coastal areas, ecological damage from remaining oil is still significant, as noted in Box 3 above[64]. We can expect this will also be true in the Gulf.

When there is a risk of irreversible damage, it often makes sense to apply the **precautionary principle**. According to this principle, when there is a risk of significant harm from a specific action or policy, and when the level of risk cannot be precisely defined, that action or policy should not be implemented. This principle overrides the logic of risk calculation through expected value analysis discussed above. While the logic of expected value works very well for specifically known risks with limited consequences, it is dangerous to apply it to situations where there is an *unknown* risk of major catastrophe.

Applied to offshore oil drilling, this principle *might* imply a complete ban on deepwater drilling. This is a very important judgment call. If we feel confident enough in our assessment of the risks, and also that effective safety measure can be put in place, then we can rely on more standard environmental policies involving regulation and perhaps taxes, fines, or other financial incentives. But if there is significant likelihood of major and irreversible damage, the more drastic approach of complete prohibition may be necessary.

There are important parallels here to other environmental issues such as nuclear power, climate change, genetically modified organisms, species loss, and ecosystem damage. All of these

[63] There are some loopholes in ozone treaties that allowed developing nations to continue to produce CFCs for a period, but the goal is complete elimination.
[64] "After Oil Spills, Hidden Damage Can last for Years," *New York Times,* July 17, 2010.

issues involve the impacts of new technology, uncertainty, and potentially catastrophic consequences.

The Limits of Market-based Policy

How do we handle situations where the potential for catastrophe exists? The standard environmental economics approach of internalizing environmental costs may be inadequate for low-probability, high-impact events. The problem, as we have seen in the case of the oil spill, is our tendency to underestimate the costs or likelihood of a major disaster, until the disaster actually occurs. Hence the importance of the precautionary principle.

The theory of **ecological economics** offers some different guidelines from those suggested by a market-based approach. Rather than starting with attempts to estimate all costs and benefits in monetary terms, then using these valuations as a basis for policy, the ecological economic approach starts with the principle of ecosystem balance and **resilience** – the idea that it is important to preserve functioning ecosystems and their capacity to "bounce back" from adverse impacts. Economic activities, in this view, should be adapted to be consistent with ecosystem preservation.

This approach implies extreme caution in dealing with technologies that can have huge and irreversible impacts on ecosystems. Certainly, drilling technology that creates the possibility of massive oil spills falls into this category. So do nuclear power, the release of genetically engineered organisms into the environment, extinction of species, or the accumulation of unprecedented amounts of global warming gases in the atmosphere. The potential for unpredictable and far-reaching impacts on complex ecosystems is very great in all of these cases.

Taking an ecologically-based approach does not mean that we cannot use valuation techniques or market-oriented policies. Rather, it implies that these approaches have their limits, and should be subject to a principle of minimal interference in ecosystems. With technological change bringing ever-increasing potential for massive environmental impact, this approach suggests a focus on **green technology** – technologies that reduce or eliminate damage to ecological systems. In the long run, such technologies may also be economically optimal, since they can avert the huge costs of unpredicted disasters. But it is unlikely that these potential costs will be adequately reflected in current markets, even with policies to internalize environmental costs.

The Gulf oil spill brings this theoretical debate into sharp relief. We can see in the oiled marshes and beaches, and in the contaminated ocean waters, the enormous damage to functioning ecosystems. Experience with earlier oil spills suggests that some impacts will last for decades. This damage is a direct result of reliance on inadequate safety and environmental controls, based in large part on market valuation. The value of oil production to our economy, the importance of the jobs and industrial development associated with it are easily measured in dollar terms. The actual and potential environmental damage is less obvious, especially before the event. Can we modify our valuation and policy techniques to take adequate account of these factors? Or are entirely different approaches needed? These questions are the focus of the next two sections.

VI. THE TRUE COST OF OIL

We often hear that we are addicted to oil. But what is the true cost of this addiction? Economists differentiate between the market price of a product and the broader social and environmental costs. The market price is determined by the interaction of consumer demand and producer supply. But the market price does not reflect social and environmental **externalities**. Externalities are defined as positive or negative effects associated with an economic transaction but impact parties outside of the transaction. So when I buy gasoline and drive my vehicle, I cause pollution which negatively impacts other people. According to economic theory, in the presence of externalities market forces will fail to produce an efficient outcome.[65]

In the presence of negative externalities, economists commonly propose instituting a tax that "internalizes" the externality. In order to maximize economic efficiency, the tax should be set at a level that equals the damaged caused by producing and consuming the product. But note that this requires the monetization of damages, which is a difficult task as we discussed in Section II. Nonetheless, various monetary estimates have been made of the social and environmental costs associated with oil production and consumption. The most obvious externalities involve the environmental damage from oil, including air pollution and climate change, but studies have also considered less obvious externalities such as the military cost of maintaining access to foreign oil and the loss of productive time from traffic congestion.

In addition to externalities, the cost of oil also includes subsidies that encourage a heavy reliance on oil. These subsidies include tax breaks and credits, pubic infrastructure, liability limitations, and public research. Another cost of oil reliance is our vulnerability to price volatility, as illustrated by the rise in gas prices from around $1.50 per gallon in early 2004 to over $4.00/gal. in mid-2008.[66] Finally, we can assume that some portion of military expenditures is needed to maintain reliable access to imported oil, and should be included in the true cost of oil.

Parry et al. (2007) review the available literature on the externalities associated with motor vehicle use. Note that not all of the motor vehicle externalities are necessarily related to oil use. For example, traffic congestion might be unchanged if all vehicles relied on electric or hydrogen power instead of oil. Table 3 presents their "best assessment" of the major externalities, or **external costs**, associated with motor vehicle use. The value for oil dependency excludes the geopolitical costs of oil dependence. It is also worth noting that their estimate of climate change externalities is based on a relatively low assumption about carbon damages, around $24 per ton of carbon. If the estimate of carbon damages from the Stern Review (Stern, 2006) were used, around $300 per ton, the climate change estimate in Table 3 would be $0.72 per gallon. See Box 5 for more discussion of the economics of climate change.

Parry, et al. estimate that the proper tax on gasoline should be $1.11/gal. – about three times the current average tax of 40 cents per gallon considering both federal and state taxes. They suggest that some externalities be addressed through policies other than gas taxes, such as congestion tolls or insurance rates based on miles traveled.

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[65] An efficient outcome is defined as one that maximizes social welfare. For a more detailed treatment of externalities, see Harris, *Environmental and Natural Resource Economics: A Contemporary Approach,* Chapter 3.

[66] Prices are national averages for regular gasoline. Data from the U.S. Energy Information Administration.

External Cost	Estimate (dollars per gallon)
Local air pollution	0.42
Climate change	0.06
Oil dependency	0.12
Traffic congestion	1.05
Traffic accidents	0.63
Total	2.28

Table 3. Externalities Associated with Motor Vehicle Use in the United States, 2005 Dollars (Parry, et al., 2007).

BOX 5: THE ECONOMICS OF CLIMATE CHANGE

There is a broad scientific consensus that human emissions of greenhouse gases, primarily carbon dioxide, are warming the Earth and resulting in other climatic changes such as droughts and more severe storms.[67] Global climate change has been called the "greatest market failure the world has seen." [68] The problem is that emissions of greenhouse gases are generally free, despite the environmental and social damage caused. Most economists advocate policies that internalize the external costs of greenhouse gas emissions, such as a carbon tax or a cap-and-trade permit system. But there is disagreement among economists over the projected damages of climate change.

Economists seek to weigh the costs and benefits of particular climate policies to determine the most efficient response. Until recently, most economists suggested a moderate policy response, with a slight reduction in emissions from the "business as usual" path and a relatively low price on carbon emissions, generally less than $50 per ton of carbon.[69] However, the widely-publicized Stern Review (Stern, 2006), commissioned by the British government, reached the conclusion that an immediate and ambitious response was needed, with a much higher price on carbon of $300 per ton of carbon (about $0.80 per gallon of gasoline). The Stern Review estimated the economic damages of climate change to be at least 5% of global economic output, and as high as 20% – every year into the indefinite future. Meanwhile, the costs of enacting policies that could avoid the worst impacts were estimated to be only 1% of global output.

Why do economists differ so significantly on climate policies? The primary reason is disagreement about how to value damages that occur in the far future by choosing a discount rate. Stern used a relatively low discount rate of 1.4%, which means that a damage of $100 that occurs 50 years from now would still be valued at around $50. Meanwhile, at a discount rate of 5% the present value would only be about $9. For more information on the economics of global climate change, see Harris and Roach (2009).

[67] See Naomi Oreskes, "The Scientific Consensus on Climate Change." 2004. *Science* 306:1686.
[68] Stern, 2006.
[69] For example, see: Nordhaus and Boyer, 2000, and Tol, 2005.

Analysis by International Center for Technology Assessment (CTA) (1998) also relied upon available research but came up with dramatically different results, as seen in Table 4. One difference is that the CTA includes estimates of the subsidies that encourage a heavy reliance on oil. These include tax subsidies, such as foreign tax credits and allowances for accelerated depreciation, as well as program subsidies such as infrastructure construction and maintenance, public research and development, and liability coverage. The CTA study also provides a more comprehensive estimate of the protection costs paid for reliable access to gasoline, including military costs. Two categories of costs that are directly comparable in the two analyses are local air pollution and climate change damages. For these two costs, we see that the Parry et al. estimates are within the range provided in the CTA study, although closer to the low estimates. The largest cost category in Table 4 is the cost of sprawl, including environmental impacts, aesthetic degradation, and increased municipal costs. For traffic congestion and accident costs, the CTA numbers are comparable to the Parry et al. values.

External Cost	**Low Estimate (dollars per gallon)**	**High Estimate (dollars per gallon)**
Tax subsidies	0.04	0.06
Program subsidies	0.32	0.95
Protection costs, including military	0.65	1.05
Local air pollution[70]	0.25	4.68
Climate change	0.03	0.24
Sprawl costs	1.41	2.12
Other social and environmental costs[71]	0.31	1.10
Traffic congestion	0.39	1.45
Traffic accidents	0.15	0.64
Other external costs[72]	1.05	1.85
Total	4.60	14.14

Table 4. The External Costs of Gasoline, 1997 dollars (CTA, 1998)

The CTA analysis concludes that the external costs of oil dependence are at least twice as high as Parry et al. found. The difference is a result of the CTA study including more categories of externalities, rather than differences in their estimates for specific categories of externalities. The CTA includes estimates for the costs of sprawl, military protection, and subsidies, while these are omitted from the Parry et al. analysis. Again it should be noted that many of these externalities aren't necessarily linked exclusively to oil use. The costs of traffic accidents, congestion, and sprawl, for example, may be similar if vehicles operated on a different fuel source.

Considering these two analyses, clearly the price we pay for a gallon of gasoline does not reflect the full cost of it. But these external costs still affect us in various ways – in terms of the taxes we pay to fund oil subsidies, poorer health, military costs, time spent stuck in traffic, and other

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[70] The very wide range in estimates of the damages from local air pollution primarily relate to the unknown impacts of particular matter on human health.
[71] Includes the costs of water pollution, oil spills, noise pollution, waste disposal, and roadway deicing and runoff.
[72] Mainly the cost of subsidized parking.

ways. These results suggest that one policy to reduce our dependence on oil would be to institute a higher gas tax, which would more fully internalize the externalities associated with gasoline use. We'll discuss this option, along with other policy options to reduce our dependence on oil, in the next section.

VII. POLICY IMPLICATIONS: GETTING OFF OIL

There is wide agreement that the United States' excessive dependence on oil is harmful to the national interest, both for security and environmental reasons. According to President Obama:

> If we refuse to take into account the full cost of our fossil fuel addiction – if we don't factor in the environmental costs and the national security costs and the true economic costs – we will have missed our best chance to seize a clean energy future.
> -- President Barack Obama, Carnegie Mellon University June 2, 2010.

As we have seen in the previous section, the measurable economic costs associated with oil use are much higher than those reflected in the price at the pumps. The same is true for other fossil fuels such as coal and (to a somewhat lesser extent) natural gas. But despite widespread concern about fossil fuel dependence, little progress seems to be made in moving towards alternative energy systems. What can be done to change this?

Probably the widest public awareness of alternative energy systems is centered on wind and solar power. These alternatives have great potential, and are rapidly expanding. But they currently constitute only a tiny portion of our energy supply, and the fossil fuel energy use that they can immediately replace is primarily in the electric power and building sectors. By contrast, the transportation sector, which uses 26% of U.S. energy, is heavily dependent on oil. How can the country – and, by extension, other countries and the world as a whole – be weaned off oil dependence?

According to a recent report by the Brooking Institution[73], key policies for moving away from oil include:

- Promotion of plug-in hybrid vehicles
- Increases in fuel economy standards
- Expanded use of biofuels such as cellulosic ethanol
- Cap-and-trade policies, carbon taxes, or gasoline taxes
- "Smart growth" and public transit
- Investment in research on advanced energy technologies

Let's examine the economic implications of these policies.

Plug-in hybrids: The advantage of allowing cars to plug into the electric grid is that electric power is more efficient than gasoline. Even with the current, primarily coal-fired electric generation system, net emissions from driving would be significantly lower. And when a

[73] Sandalow, 2007.

substantial portion of the auto fleet runs on electric power, direct substitution of efficient natural gas, wind, or solar power for coal and oil use becomes possible. According to the Brookings Institution report, plug-ins could displace one-third of the oil use in U.S. light-duty vehicles by 2025. Interestingly, tens of millions of plug-in vehicles could be operated without adding significantly to the need for electric generation capacity, since the cars would be charged largely at night, when other power demand is low. Operating costs would also be low, about 3-4 miles per KwH, equivalent to about 75 cents per gallon. Effective policies to promote plug-ins include tax credits and Federal and state purchases for fleet use.

Fuel economy standards: The Obama administration has announced new fuel economy standards that require all automakers to increase fleet fuel efficiency by 5% per year starting in 2012. The new rules will require a fleet efficiency of 35.5 miles per gallon by 2016, compared to 25 MPG in 2009 (see Box 6). Current technologies, in particular hybrid gasoline-electric engines, make the higher efficiencies specified in the new standards easily achievable.

Fuel economy standards, while generally more politically acceptable than taxes, do have the effect of raising vehicle prices. Over the lifetime of the vehicle, though, consumers save several times the added cost in reduced gas use. According to the theory of externalities, there are also significant savings in reduced external costs, so these policies are both economically and environmentally beneficial. One possible drawback to fuel economy standards is what economists call "leakage" – the tendency of car owners to drive more because driving is cheaper per mile with higher efficiency. This can be prevented by simultaneously increasing gas prices, but (as discussed below) the internalization of externalities by higher gas taxes tends to meet greater political resistance.

Biofuels have the potential to replace 25-70% of U.S. oil consumption by 2025, according to the Brookings Institution report. Currently, the dominant source of ethanol for the U.S. is corn-based ethanol. The environmental advantages of corn-based ethanol are questionable, because of the high fossil fuel inputs (energy and fertilizer) required to grow corn. Better sources of biofuels would be cellulosic ethanol made from grasses and agricultural wastes, or sugar ethanol from Central and South America. The barrier to cellulosic ethanol is currently high costs of production, and imported sugar ethanol is subject to a high tariff intended to protect the U.S. sugar industry. A tax on conventional gasoline would make biofuels more competitive.

Cap-and-trade, tax policies: In July 2010, the U.S. Senate killed a proposal, already passed by the House of Representatives, for a nationwide carbon cap-and-trade system. This proposal was attacked politically on the grounds that it would raise energy prices. Opponents labeled it "cap-and-tax". For similar reasons, proposals for a nationwide carbon tax, or an increased tax on gasoline, have generally been political non-starters. From an economics point of view, these political barriers significantly undercut the potential for successful energy policy. If we want to reduce the use of oil or other carbon-based fuels, basic externality theory tells us that it is essential to internalize the environmental costs of these fuels by a tax or some other policy, such as cap-and-trade, that effectively raises their prices. This is the most effective way to send a market signal to both consumers and producers that they should shift away from these fuels, by reduced demand for oil and other carbon-based fuels, use of more efficient technologies, or expansion of alternative energy production.

BOX 6: NEW FUEL ECONOMY STANDARDS ANNOUNCED

President Obama announced tough new rules Tuesday for fuel efficiency and emissions in the U.S. auto industry. New standards will require all automakers, including Detroit's foreign competitors, to increase fleet fuel efficiency by 5 percent per year starting in 2012.

"The status quo is no longer acceptable," Obama said, warning that the American appetite for oil comes at a "tremendous price." Flanked by auto executives and officials, the president said the proposal would simultaneously help end U.S. dependence on foreign oil, lead automakers to develop more advanced products and save consumers money in the long-term.

"This rule provides the clear certainty that will allow these companies to plan for a future in which they are building the cars of the 21st century," Obama said. "Yes, it costs money to develop these vehicles. But even as the price to build these cars and trucks goes up, the cost of driving these vehicles will go down, as drivers save money at the pump."

The standards are expected to add $1,300 on average to vehicles. But Obama said drivers would make that back within three years due to savings on gas. The new rules will require a fleet fuel efficiency standard of 35.5 miles per gallon by model year 2016, a big jump from the 2009 model year requirement of 25 mpg. A senior administration official said the changes (when compared to current pollution and vehicle use totals) will have the effect of removing 900 million metric tons of carbon dioxide from the air, taking 177 million cars off the road and shutting down 194 coal-fired power plants, with only minor modifications to vehicle and engine design.

For 2016 -- the final year the new rules will apply -- the fleet fuel efficiency standard for all domestically sold passenger cars will be 39 mpg. It will be 30 mpg for all domestically sold light trucks and sport utility vehicles. The average of these two equals a passenger car and light truck fuel efficiency standard of 35.5 mpg. The current requirements are 27.5 mpg for cars and 23.1 mpg for trucks.

“Obama Announces New Fuel Economy Standards” Fox News, May 19, 2009.

Higher prices for carbon-based fuels also complement other policies such as efficiency standards, eliminating the problem of leakage mentioned above. As a thinking exercise, imagine that the price of gas doubles, but fuel efficiency also doubles. In that case, a driver will pay the same amount per mile traveled, and will therefore have no incentive to drive more, but will use half as much fuel. Also, the total cost of fuel will remain unchanged, so there is no economic hardship involved. This simple example could provide a good goal for national energy policy – cutting oil dependence in half – but the political opposition to higher prices makes it difficult to achieve.

Smart growth and public transit: An automobile-centered infrastructure encourages development patterns that in turn make driving longer distances essential. This trend is not inevitable, but is encouraged by extensive subsidies for highway construction. In contrast to the U.S. pattern, European cities typically are more compact, have better intracity and intercity public transit, and less reliance on automobile use. A shift in public infrastructure investment can encourage more efficient modes of transit and reduce fuel use. More efficient and high-speed rail can also compete with intercity air travel, reducing consumption of aviation fuel.

R&D for efficiency and fuel alternatives: Current technologies such as fuel-electric hybrid engines can cut fuel use by up to 50%, but more advanced techniques could reduce consumption by a factor of 4, putting fuel economy into the 80-100 MPG range. According to a report by the Rocky Mountain Institute, the key factor is using ultralight materials to cut the vehicle's weight, since 2/3 to 3/4 of fuel use is weight-related.[74] Similar approaches can cut aircraft fuel use, and more efficient machinery can greatly reduce energy use in industry. A key requirement is increased expenditures for energy research and development. The Obama administration took a significant step in this direction, increasing public funding for energy R&D to about $12 billion in 2009, an increase of nearly 200% compared to 2008 funding. [75]

A Combination of Policies to Get Off Oil

No single policy will eliminate U.S. oil dependence. But a combination of the policies outlined above could shift the country – and similarly other countries – from a path of ever-growing oil use to a declining path. Figure 6 shows how a combination of end-use efficiency and supply substitution could dramatically cut U.S. oil use, and reduce oil imports almost to zero by 2030.

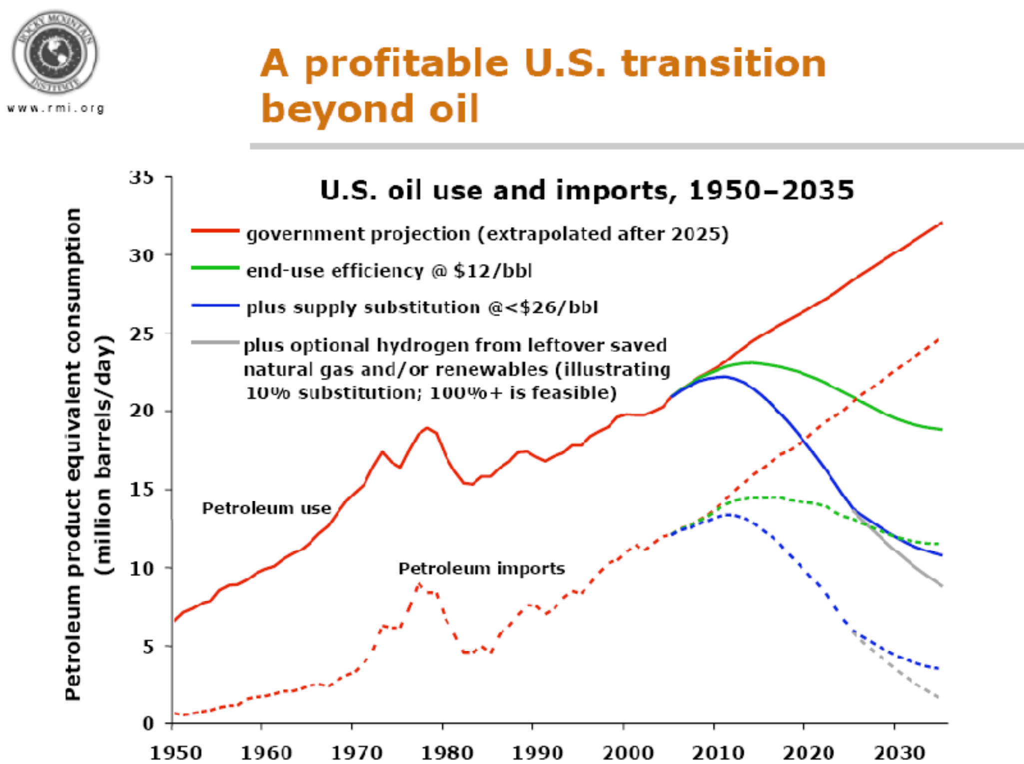

Figure 6: Moving the U.S. off oil by 2030
Source: Rocky Mountain Institute, *Winning the Oil Endgame.*

[74] Lovins et al, 2004.
[75] Data from the International Energy Agency's online database.

There are powerful economic, environmental, and national security arguments for implementing such policies. As we have seen, the external costs associated with continued oil consumption are very large. It is possible to reduce these costs with more stringent safety measures, restrictions on offshore oil drilling, and other policies to internalize the cost, such as requiring oil companies to put up "environmental bonds" to cover possible damages from oil spills.[76] But so long as U.S. oil dependence remains and increases, there will continue to be increased economic pressure for more drilling and more oil imports. The policies outlined above – all of which have very modest economic costs, or in some cases net economic benefits – could contribute to setting the U.S. on such a path over the next few decades. Perhaps the searing experience of the *Deepwater Horizon* oil spill will not fade quickly from public memory, but will remain as a spur to implementing such policies.

VII. SUMMARY AND CONCLUSIONS

Only three weeks before the *Deepwater Horizon* spill, President Obama announced plans to expand offshore oil and gas drilling in the United States, including increased development in the Gulf of Mexico and Alaska, and opening up new areas to exploration off the Atlantic Coast. Based on the recent safety of deepwater offshore drilling over the last couple of decades, standard economic risk analysis implied that this decision may have made sense. But the *Deepwater Horizon* spill illustrates the limitations of traditional economic analysis. Unexpected events, including worst-case scenarios, do happen sometimes. This module suggests that in the presence of significant uncertainty about major risks, the precautionary principle may provide a useful guide for policy making. This perspective is applicable to other environmental issues as well, such as nuclear power and global climate change.

The *Deepwater Horizon* spill had significant economic costs, including loss of jobs and income in affected industries. While these losses are clearly important, the largest economic losses may be the loss of ecosystem services provided by the habitats and wildlife in the region. Previous oil spill damage analyses, such as the OECM described earlier, suggest that these ecological damages could be several times greater than the loss of incomes. Although it may not be possible to capture the full extent of these ecological losses in monetary terms, we can obtain some estimates of their value using the methodology of habitat equivalency analysis. We also need to be aware that ecological impacts arising from the spill may occur unexpectedly several years in the future, as demonstrated by the Pacific herring crash after the *Exxon Valdez* spill.

President Obama has called the *Deepwater Horizon* spill the "greatest environmental disaster" in U.S. history.[77] The full economic and ecologic impacts of the spill will only become apparent over time. What may be most important though, is the spill's potential political impact. The *Deepwater Horizon* spill is yet another illustration of the costs associated with our heavy reliance on oil, including air pollution, military expenditures, and global climate change.

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[76] Costanza et al., 2010.
[77] See http://www.nrdc.org/media/2010/100601a.asp.

While the immediate debate has focused on whether deepwater drilling should be permitted, the larger policy question is how to reduce our addiction to oil. Numerous policy options are available that can significantly reduce oil use and are also economically efficient. Economists advocate market-based approaches such as a carbon tax or a cap-and-trade system, but these policies are currently politically unpopular. Still, some steps are being taken to reduce oil dependency, such as the higher fuel economy standards recently set by the Obama administration. Other options that hold promise include hybrid vehicles, biofuels, public transportation, and constructing vehicles with lightweight materials. There is no "magic bullet" that will solve our oil dependency – a combination of approaches will need to be pursued over an extended time period. This will require both bold political leadership and informed voters willing to move beyond the standard economy vs. the environment myth. In fact, public investments in energy efficiency and new technologies have proven to be among the best investments for promoting economic growth and creating jobs.[78] With a range of affordable energy policies, we can have a future that is both economically prosperous and environmentally sustainable.

[78] See, for example, Pollin et al., 2009.

KEY TERMS AND CONCEPTS

Assessment costs: the reasonable costs of assessing damages in a natural resource damage case such as an oil spill.

Bequest value: the value people place on the knowledge that a resource will be available for future generations.

Black swan theory: the theory that unpredictable, large-impact events often play a significant role in determining outcomes.

Compensatory restoration: the cumulative lost value of natural resources pending restoration to baseline conditions.

Contingent valuation: an economic tool that uses surveys to question people regarding their willingness to pay for a good or service such as the preservation of hiking opportunities or air quality.

Direct use values: the value one obtains by directly using a natural resource, such as visiting a National Park.

Ecological economics: an economic perspective that views the economic system as a subset of the broader ecosystem and subject to biophysical laws.

Ecosystem services: ecosystem services such as nutrient cycling, water purification, and soil stabilization; these services benefit humans and support economic production.

Existence value: the value people place on a resource that they do not intend to ever use, such as the benefit one obtains from knowing an area of rain forest is preserved even thought he or she will never visit it.

Expected value: the average value that would be obtained from a set of possible outcomes in repeated instances. Expected value is calculated as the probability of each outcome multiplied by its likelihood, summed over all possible outcomes.

Externalities: an effect of a market transaction that changes the utility, positively or negatively, of those outside of the transaction.

External costs: the costs, not necessarily monetary, that are not reflected in a market transaction

Green technology: technologies that reduce or eliminate negative environmental impacts, such as solar power, constructing products with recycled materials, and hybrid vehicles.

Habitat equivalency analysis (HEA): the process of determining the scale of compensatory restoration that fully compensates the public for the interim losses of a natural resource damage such as an oil spill.

Indirect use values: ecosystem benefits that are not valued in markets, such as flood prevention and pollution absorption.

Nonuse values: are the intangible benefits that people obtain without actually using a resource.

Option value: the value people place on the maintenance of future options for resource use.

Precautionary principle: the view that policies should account for uncertainty by taking steps to avoid low-probability but catastrophic events.

Present value: the current value of a stream of costs or benefits, calculated through the use of a discount rate.

Primary restoration: the process of acting to restore damaged natural resources to baseline conditions, such as by replanting or restocking.

Psychic benefits: a benefit derived without the actual use of a resource, such as the existence benefits of species preservation.

Regulatory capture: the phenomenon of government regulators becoming dominated by the industry they are supposed to be regulating, and making decisions that are excessively favorable to industry interests.

Resilience: the capacity of ecosystem to recover from adverse impacts.

Threshold effects: the possibility that ecological systems can withstand stresses, such as pollution, only up to a certain point, and that beyond that point damages increase dramatically and the system cannot recover, or recovers only very slowly.

Total Economic Value: the sum of use and nonuse benefits of a natural resource.

Use values: the value that people place on the use of a good or service.

Willingness to pay (WTP): the maximum amount of money people are willing to pay for a good or service that increases utility.

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DISCUSSION QUESTIONS

1. Shortly after the *Deepwater Horizon* spill, the Obama administration put in place a ban on further deepwater offshore drilling. Do you believe such a ban is justified? What safeguard do you think are required to prevent a similar incident in the future?

2. As mentioned in the module, contingent valuation was used to estimate the nonuse losses associated with the *Exxon Valdez* spill. Suppose you received a contingent valuation survey asking about your willingness to pay to prevent another spill similar to the *Deepwater Horizon* spill. About how much do you think you would be willing to pay to prevent a similar spill? Given that the U.S. population is 310 million, how much would a per capita payment of this amount yield in revenues, that might be used for example to develop alternative renewable energy supplies so that deepwater drilling would not be needed?

3. Suppose a friend of yours makes the following statement: "The real responsibility for the Deepwater Horizon spill falls upon the American people. They are the ones driving their gas-guzzling SUVs and wasting energy, which necessitates our reliance on imported oil and deepwater drilling." How would you respond to this statement? Do you agree with this logic? What economic policy measures would be appropriate in view of this?

4. How do you think policy makers should deal with possible black swan events? How might one apply the precautionary principle to different environmental issues, including nuclear power and climate change?

5. (For student with some microeconomics background.) Suppose the government decides to respond to the *Deepwater Horizon* spill by placing a tax on each barrel of oil obtained from offshore drilling, say $1 per barrel, to be paid by the oil companies. The revenues would go into a fund used to prevent future spills by developing new technologies. Would this tax simply be passed on to gasoline consumers? How would you determine the degree to which the tax would be passed on to consumers? Would oil company profits go up or down?

WEB LINKS

1. http://response.restoration.noaa.gov/dwh.php?entry_id=809 The National Oceanic and Atmospheric Administration website dedicated to the Deepwater Horizon and the oil spill response. This site provides helpful graphics, projections, and factsheets, as well as detailing and representing a large aspect of the United States government's response.

2. http://www.evostc.state.ak.us/ The website of the Exxon Valdez Oil Spill Trustee Council. This site presents detailed information on almost everything related to the Exxon Valdez oil spill, from the status of habitat and wildlife restoration, to a breakdown of the settlement, and much more.

3. http://topics.nytimes.com/top/reference/timestopics/subjects/o/oil_spills/gulf_of_mexico_2010/index.html?scp=1-spot&sq=oil%20spill&st=cse Gulf of Mexico oil spill Times Topics page. An easily navigable database of all the New York Times articles related to the Deepwater Horizon. Clicking on the graphic of the oil's distribution will bring you to another website with detailed graphics on where oil has made landfall, the many efforts to plug the well, effects on wildlife, investigating the blowout, and live video of the leak.

4. http://www.bt.cdc.gov/gulfoilspill2010/ The Centers for Disease Control and Prevention Gulf of Mexico oil spill webpage. This page is very useful for finding information almost any health issue relating the gulf oil spill.

5. http://www.boemre.gov/ The website of The Bureau of Ocean Energy Management, Regulation and Enforcement, formerly known as The Minerals Management Service. As the governmental agency responsible for monitoring offshore drilling, this website provides a variety of useful information on the oil spill, as well as developments in offshore drilling policy.