Changing Oil:

Emerging Environmental Risks and Shareholder Value in the Oil and Gas Industry

Details of the methodology, assumptions, and results

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CONTENTS

I. Introduction

This information accompanies the World Resources Institute report, *Changing Oil: Emerging Environmental Risks and Implications for Shareholder Value* and should be read in conjunction with that report (Austin and Sauer, 2002). It is intended primarily for those interested in the details of the methodology and assumptions used in *Changing Oil*. This addendum also provides more complete information on scenario-specific results than appears in the main report.

Besides wishing to be transparent about our work, one of the purposes of this paper is to encourage comment in order to facilitate the further development of the methodology. We are aware of a number of aspects where improvements could readily be made.

First, results could be enhanced through access to more accurate and more recent data than was available to us. In particular, the use of more detailed information on distribution of reserves, international trading patterns and other data that companies and financial institutions might have access to would improve the accuracy of results. Here we describe the data sources that were used, highlighting some of the limitations of that data.

Second, there inevitably will be much to agree and disagree on regarding the assumptions made about the impact of environmental policies on the industry's performance. Even forecasts for the future price of crude oil—the most closely watched variable in the industry—vary widely. The range of forecasts for many other parameters, including the impact of unprecedented environmental challenges, is inevitably broad. The aim here is to clarify the important assumptions that we made and the rationale for doing so.

In reviewing the methodology, we hope that readers will provide comment and feedback to permit improvement over time. Any comments or further questions should be directed via email to Duncan Austin at duncan@wri.org.

II. Overview of the Methodology

The *Changing Oil* report uses a methodology previously developed by WRI (Repetto and Austin, 2000). The methodology has much in common with traditional shareholder valuation frameworks in that it is explicitly forward-looking and uses scenarios to frame future possibilities. The methodology traces a link between external environmental influences and fundamental business drivers, such as sales volumes or asset values, and expresses final impacts in terms of percentage changes in shareholder value. To account for the subjective nature of predicting the future, uncertainties are handled in a systematic and transparent way so that investors can come to different conclusions if they have different opinions about how future uncertainties may be resolved or wish to alter forecasts on the basis of new information.

Unlike some other approaches, we do not attempt to place a value on overall management positioning and statements with regard to the issues we are examining.[1] We also do not attempt to value the reputational effects—positive or negative—that companies incur by responding differently to these environmental challenges, though we recognize that these may be important. Instead, the approach focuses on the core elements of shareholder value in these companies, such as reserves, acreage, and refining assets—the traditional foundations for company valuation in this sector. The goal is to predict how environmental issues could affect these major components of industry value. Investors could use this information as a complement to other assessments and screens of company performance.

The steps in the methodology are as follows:

1. Identify salient future environmental issues
2. Build scenarios around each salient issue
3. Assign probabilities to scenarios
4. Assess company exposures for each scenario
5. Estimate financial impacts contingent on scenarios
6. Construct overall measures of expected impact and risk

Steps 2 to 5 were repeated for both of the environmental issues examined. Steps 1 and 6 frame the overall analysis. We discuss below how this approach was applied in general. Sections III and IV contain specific detail about how the approach was applied to analyze the climate and access issues.

Steps 1 to 3: Identifying Issues, Developing Scenarios, and Applying Probabilities

The first 3 steps were achieved with assistance from industry experts. In conjunction with Forum for the Future, we conducted a workshop to identify pending environmental issues facing the sector over the next 5 to10 years. The workshop, held in June 2001, was attended by company

[1] See for example CERES (2002) and Mansley (2002).

representatives and other industry experts.[2] We examined trends facing both upstream and downstream parts of the sector.

The workshop findings were supplemented by conversations with government officials, academics, and members of environmental groups. We also conducted an extensive literature review of government documents, academic papers, trade publications, and materials produced by industry associations such as the American Petroleum Institute (API), National Petroleum Refiners Association, and International Petroleum Industry Environmental Conservation Association.

The workshop and supplementary research identified many environmental issues confronting the industry, including pending clean air and clean fuel regulations, risks associated with the marine transportation of fuels, and growing constraints on industry infrastructure development. Although many environmental issues were identified, the report focuses on two key issues: (1) pending climate policies and (2) constraints on access to reserves. Other issues were eliminated either because they were deemed less financially significant or because the publicly available data with which to determine company-specific exposure were insufficient.

Following the workshop, the authors developed the issue-specific scenarios as outlined in the following sections. These were sent to workshop attendees and others we had consulted with for review and comment, and were then adjusted to reflect that input.

Similarly, in assigning probabilities, we sent the final scenarios to a broader group consisting of workshop attendees, individuals we had consulted with, other oil and gas company representatives, and members of environmental groups. Unfortunately, the response rate was quite limited (more so on the access issue than for the climate issue). Accordingly, we assigned probabilities on the basis of the limited responses and using our best judgment. In order to be transparent, the scenario-specific results were separately illustrated in the main report, and are tabulated here. (A series of tables appears in the Appendix). We comment on the scenario-specific probabilities in the following sections.

Step 4: Assessing Company Exposure

In order to ascertain companies' exposures to the two pending environmental issues, we compiled a database of company-specific information. As the project progressed, we gathered financial, operational, and environmental information from many sources, including Herold, IHS/Energy Group, API, *Oil and Gas Journal* (OGJ), the U.S. Environmental Protection Agency (EPA), and the U.S. Department of Energy (DoE). We also derived information from companies' annual reports, environmental reports, and websites. This database was used to form an initial assessment of companies' exposure to pending environmental issues, as described in the following sections.
For our final analysis, the most important data sources were Herold and IHS/Energy.

All data used in the report is publicly available.[3] However, it is worth noting that resources did constrain data used in some parts of the study. Most notably, while we were able to obtain a

[2] The workshop was attended by representatives from Amerada Hess, BP, Chevron, Shell, Texaco, TotalFinaElf, in addition to energy and environment consultants and members of non-governmental organizations.

comprehensive database of company reserves outside of the United States, the comparable dataset for the United States is disaggregated to the well level, as opposed to the field level, and is consequently considerably larger (and more expensive). Clearly, the results of the study could be enhanced through access to proprietary data held by companies or to more costly industry data sources beyond the reach of this research effort.

Table 1 summarizes just some of the key data collected on the companies. It shows the composition of company value and the exposure of each company's reserves to environmentally sensitive areas. Combined, these factors give each company a different profile with regard to climate and access issues. As a result, these issues will affect companies differently in financial terms.

Step 5: Estimating Scenario-Specific Financial Impacts

These assessments are explained in detail in Sections III and IV. We note here that Steps 5 and 6 require a benchmark of company value against which environmentally induced changes can be measured. We use Herold's Appraised Net Worth (ANW) estimates as our baseline for shareholder value (Herold, 2001a). Herold applies a proprietary valuation methodology to the latest available information on companies to determine the value of separate segments of each company, as well as the company's overall net worth. Herold's ANW estimates are generally comparable to market capitalization of the same period. For our sample of companies, Herold's ANW was on average 3.5 percent higher than recent market capitalization values. In some cases, however, Herold's ANW was as much as 30 percent higher or lower than recent market values. The Herold's reports used data from Autumn 2001 and are generally based on company financial figures reported at the end of 2000.

Step 6: Aggregate Measures of Impact and Risk

Having examined the two main environmental issues separately, we combined the financial results for each issue to obtain an overall assessment. Developments on climate and access issues were assumed to be independent. Accordingly, the ranges of values from the climate and access results can be combined to assess each company's overall range of outcomes.

To come up with the final range of results (Figure 11 in *Changing Oil)* we calculated the financial impacts for each company of each possible combination of climate and access scenarios (15 combinations in all). Each 'combined scenario' was weighted by multiplying the probabilities of the climate and access scenarios occurring independently. This provided a probability distribution for each company. To summarize that distribution we took the mean value and the 90th percentile range, thereby excluding those outcomes on either tail of the distribution that had less than a 5 percent chance of occurring.

[3] Most of the data in this report is also available free of charge from such sources as company annual reports. Other information, such as Herold's Comparative Appraisal Reports and IHS/Energy data on companies' oil and gas operations is available for a fee.

III. Estimating the Financial Implications of Climate Policies

This section describes the application of the methodology to determine the financial impacts of pending climate policies for the 16 companies in our sample. It details how Steps 2 to 5 of the overall approach were applied for this issue.

Steps 2 and 3: Identifying Possible Climate Scenarios and Assigning Probabilities

Through consultation and research, we identified a wide spectrum of possible climate-related futures, ranging from near-term implementation of the Kyoto Protocol to continued international stalemate that prevents meaningful action to reduce GHG emissions. Figure 1 illustrates the relationships among some of these admittedly complex developments, while Table 2 provides details on the scenarios used here. The probabilities assigned to each scenario were informed by a limited poll of company representatives and other industry experts. Final judgments, however, were made by the authors.

In addition to these high-level scenarios, for Scenarios A, B, and C we developed sub-scenarios to capture different possibilities for the scope of GHG permit trading programs and the initial allocation of valuable permits. For Scenario D, we explored sub-scenarios for different rates of uptake of more efficient vehicles. Detailed description of these sub-scenarios were omitted from the main report to avoid complexity, but are spelled out with their probabilities in Table 3.

Step 4: Assessing Company Exposure

For this analysis, a company's relative exposure to potential climate policies depended mainly on

- the oil and gas mix of its production, proven reserves, and acreage;
- the relative focus on upstream or downstream activities; and
- the regional spread of its operations.

To determine company exposure, we relied on the composition of value for each company as determined by Herold's Comparative Appraisal Reports (Herold, 2001a). These reports provided information on the composition of corporate value by fuel type, stage of the value chain, and geographic region that formed the baseline for our assessment of shareholder value for each company.

Step 5: Calculating the Impact of Climate Policies for Shareholder Value

The methodology compares baseline estimates of shareholder value for three core business segments with new estimates of shareholder value under each of the separate climate scenarios. Baseline estimates of shareholder value were taken from Herold's ANW estimates, made in 2001 (Herold, 2001a). The business segments evaluated were (a) proven developed reserves, (b) undeveloped reserves and acreage, and (c) refining (and other downstream) operations. Calculations included three separate steps to assess changes in value for the separate segments. These were then combined to estimate an overall financial impact for each company.

(a) Changes in the Value of Proven Developed Reserves

(i) Overview

Proven developed reserves were valued as conventional depletable resources. The net present value (NPV) of an oilfield (or gas field) is a function of when the resource is extracted, the prevailing market price for the resource, the extraction cost, and the discount rate applied. The value of a company's overall proven developed reserves is the sum of the NPVs for all oil and gas fields across different regions, where market price, extraction cost, and extraction profile over time can all differ by region and fuel type.

To assess the shareholder value impacts of climate policies, we compared a reference NPV calculation for reserve value with NPV calculations reflecting alternative climate scenarios. The climate scenarios differed from the reference case through changes to some or all of the following variables:

- producer price of oil and gas
- market demand for oil and gas
- extraction costs for oil and gas
- introduction of rents from grandfathered tradable carbon permits (zero in the reference case in the absence of an existing carbon market)

Our analysis allowed for different regional impacts in three major regions: (1) the United States, (2) non-U.S. developed countries, and (3) developing countries—the most important blocs to emerge with regard to the Kyoto Protocol. We also explored different possibilities for grandfathering carbon permits to upstream producers.[4] Policy introduction was assumed for 2004, with a gradual phase-in to 2010 to meet appropriate targets. The analysis extended out to 2015, although outlying years contributed significantly less because of discounting. Following Herold, we used a base discount rate of 8 percent.

Climate policy scenarios were assumed to alter producer prices for gas and oil markets.[5] Oil and gas prices are, of course, volatile and hard to predict. The assumption made here was that climate-induced changes would represent additional price movements not reflected in conventional forecasts. Companies faced different market demand for their products (mainly decreases), particularly for oil, but also experienced increases in demand for natural gas under certain scenarios. Operating costs increased slightly to reflect the energy component of extraction processes, but these effects tended to be small. In certain regions under certain scenarios, permits were grandfathered to upstream or downstream businesses, enhancing shareholder value, all other things being equal.

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[4] Although permits could also be introduced at the downstream segments of the business, we did not explore that possibility in our analysis.
[5] Producer prices are the consumer price net of the value of a carbon permit, or carbon tax rate.

With policies introduced incrementally from 2004 on, the price for carbon permits increases gradually to the levels indicated in the scenario descriptions below. These price trends are consistent with both low prices established through recent market trades–generally less than $20 per metric ton of carbon–and the higher prices projected by economic models to reach eventual targets in a decade's time–anywhere from $50 to $200 per metric ton of carbon. In this study, we conservatively use values at the low end of the range forecasted by economic models for carbon prices in 2010. The highest value used, in Scenario A, is $50. This assumption favors companies in scenarios where it is assumed they would have to bid for permits in an auction. However, it disfavors companies in scenarios where it is assumed they would be granted some of these permits for free.

In grandfathering scenarios, companies received windfalls from the allocation of permits in proportion to 2001 sales in participating countries (non-U.S. developed countries, and the United States in scenarios where that country took action). In practice, these might be set at levels reflecting earlier sales levels but, lacking the data, we have used 2001 as a baseline year. In addition, permits are grandfathered at a level that covers only half of a company's needs in 2001 to avoid granting companies an excessive windfall that might not stand up to political scrutiny.

Changes in the NPV of reserves under each scenario were then expressed in terms of percentage changes to companies' ANW as estimated by Herold. This allowed the companies to be compared with each other.

(ii) Establishing a Reference Case

The starting point was information from Herold's Comparative Appraisal Reports on quantities of proven reserves, reserve/production ratios, expected sales prices, and operating costs for both the company as a whole and its major regional operations (Herold, 2001a). Separate information is provided for oil and gas reserves. Geographic breakdown typically extends to the two or three largest countries and one or two larger regional blocks (e.g. “North Africa” and “Other Europe”) in which a company operates. For our purposes, we assigned reserves into three geographical areas: United States, Other Developed Countries, and the Rest of the World. These are the three most important blocs to have emerged with regard to discussions on the Kyoto Protocol.

In some cases, attributing reserves from Herold's reported regions to the three regions analyzed here required exercising some judgement (e.g., allocating “Other Western Hemisphere” reserves between Other Developed and Rest of the World categories). In these cases, we consulted annual reports and other sources of information to guide our allocation of reserves into the three main regions. On the whole, though, the share of company reserves reported under the more ambiguous geographical headings was relatively small.

Using this information, a reference case asset value for reserves was derived for each company with the following assumptions:

Oil Price
Future oil prices followed Herold’s 2001 forecast, as indicated in Table 4a. The companies' region-specific sales prices in 2001 showed some variation around the $25 per barrel figure, largely reflecting small regional differences in price (company averages ranged from $25.53 to $22.06 per barrel). To establish future sales prices in the reference case, we applied Herold’s expected annual percentage change in Table 4a to company- and region-specific 2001 prices. The implication is that future oil prices for all companies and all regions move proportionately over time, albeit from slightly different starting points.

Gas Price
Future gas prices were determined in the same way using Herold's 2001 gas price. Table 4b is a forecast for U.S. gas prices only. Because of limited transportation of natural gas, there is greater price variation across different regions. Companies' average 2001 prices ranged from $2.95 to $6.20 per million cubic feet. In the absence of region-specific price projections, we have applied the implied annual growth rate in U.S. prices to non-U.S. production as well. The effect is that, although gas reserves in other countries are valued differently from those in the United States, future price changes are assumed to be proportional across regions.

Quantity of Oil and Gas Produced
Companies were assumed to continue producing indefinitely at the same decline rate (inverse of the reserve/production ratio) reported by Herold for each of the company’s identified regions. This implies homogeneity of company reserves within regions, and invariance of decline rate to price. Companies' decline rates varied across regions and, of course, by fuel type.

Lifting Costs
Herold gives fuel- and region-specific lifting costs for 2001. In projecting future extraction costs, we start by noting that the Energy Information Administration reports real lifting costs per unit for oil and gas combined falling by 2 to 3 percent per year from 1981 to 1999 (EIA, 2001). In nominal terms, average costs per unit for U.S. extraction have just risen, while average costs per unit for foreign extraction have just fallen. We have assumed constant nominal lifting costs in the baseline. The methodology uses average costs, not marginal costs, which is not too damaging an assumption for relatively small increases or decreases in overall company output.

Development Costs
Herold also reports a one-time cost for developing the remaining reported reserves. Without further information, we assumed that this cost was paid out in equal nominal installments from 2001 to 2005. This was not altered in the climate scenario cases.

Discount Rate
Following Herold, we used an 8 percent discount rate.

Comparing WRI's and Herold's NPV projections
Applying these factors over a 15-year time period from 2002 to 2015 provides separate NPVs for companies' oil and gas reserves. Inevitably, there is some difference between our NPV estimates and those made by Herold, (reported in Table 1). For proprietary reasons, Herold does not disclose its precise assumptions regarding future costs, prices, and the variation of these among companies

and regions. Nor is it clear how aggregate development costs will be spread out over future years. Our projected NPV for companies proven oil reserves in the reference case tended to be slightly higher than Herold's estimates, while our estimates for gas reserves tended to be slightly lower.

(iii) Developing Climate Policy Scenarios

Reference reserve values were compared with NPVs of reserves under different climate scenarios. Changes in key parameters were informed by results from a number of economic models used to evaluate the Kyoto Protocol.

Changes in Oil Price and Demand
In a competitive oil market, the introduction of a broad climate policy (through a permit or tax system) would lead to a reduced quantity of oil sold at a higher retail (or consumer) price. However, some of the permit (or tax) “incidence” would likely fall on companies in the form of lower producer prices. The scale of the impact for oil companies will depend on the elasticities of supply and demand. OPEC's price-setting role complicates matters as the cartel would likely attempt to keep producer prices within established bounds by controlling production levels.

Table 5 reports price and quantity impacts in oil (and gas) markets under different climate policies as predicted by some of the more prominent U.S.-based economic models. As models differ in the predictions they make for absolute oil and gas prices, we have normalized impacts by expressing changes in terms of percentage increase or decrease relative to each model's reference case values. Models differ regarding their views on the competitive nature of the world oil market. Energy Information Administration (EIA), for example, assumes a competitive oil market in which world oil (producer) price falls by up to 16 percent. In contrast, the Second Generation Model (SGM) makes the exact opposite assumption and holds producer prices constant, perhaps reflecting OPEC efforts to control prices.[6]

The parameters used in this analysis for oil price and demand changes in different scenarios are shown in Table 6. These were informed by results in Table 5. Note, though, that settling on final parameters for the scenarios requires significant exercise of judgment in applying output parameters from economic models assessing certain scenarios to the specific scenarios explored here. In particular, there is a need for further economic research exploring how the economy would fare under the most recent policy developments regarding climate change. While many models have examined the full Kyoto Protocol, there are many fewer assessments of the implications of US non-action or partial action.

Deciding on parameters for scenarios in which Kyoto was implemented without US participation (Scenarios B and C) was informed by a review of several European economic models which have explored this question (Carraro, undated; Hagem and Holtsmark, 2001). Model results generally indicated that US non-participation would lead to higher emissions levels observed in other developed countries than under the full Kyoto Protocol, and would result in an average permit price a third to two-thirds less than the full Kyoto case. Consequently we derived parameters for

[6] Note that this is still consistent with an increase in the consumer price of oil and gas caused by the "wedge" introduced by tradable permits or carbon taxes.

Scenarios B and C by adjusting the parameters for the Full Kyoto case in the direction, and by the magnitude, indicated by these results.

Hence, for scenarios B and C–the Kyoto Protocol without U.S. participation–it was assumed that demand reductions in participating countries would be lower than in Scenario A and that recourse to developing country reductions through the Clean Development Mechanism would be lower, as developed countries could count on lower permit prices without the United States acting as a major buyer. For Scenario D, there was no change in price, only a fall in demand for oil.

For individual climate scenarios, we assumed that prices and quantities would begin changing in 2004 to reach percentage differentials from reference values in 2010 (see Table 6). The production levels projected from applying Herold's reserve decline factors in the reference case were adjusted downward by a factor that ensured that 2010 production was a certain percentage below reference case values.

Changes to Gas Price and Gas Demand

This was basically similar to treatment of oil prices and demand with one important difference. Because oil is globally traded, restrictions in just one region (e.g., Other Developed Countries) led to changes in the single global oil price and thus affected other regions. However, given limited trading of natural gas, regional prices for natural gas were not linked.

Operating Costs

Operating costs will increase with the increase in price to consumers of energy. This increase will depend on the share of energy in overall production costs. The U.S. Census Bureau shows costs of purchased fuels and electricity making up only 12 percent of total cost of supplies for the oil and gas industry in 1997 (U.S. Census Bureau, 1999). Other cost components would also likely change in price reflecting embodied carbon in provision of supplies and in equipment. However, lacking further detail, we disregard these. Because operating cost increases were applied to only 12 percent of base operating costs, changes in overall operating costs were relatively minor.

Introduction of Permits (or Taxes)[7]

The introduction of a carbon permit creates a price wedge between the price paid by a consumer for a barrel of oil (or cubic foot of natural gas) and the price received by the producer.[8] The final consumer price would reflect the production price of fuel and a scarcity value for carbon embodied in the permit price.

Most models focus on estimating the permit value required to attain specific carbon reduction goals. For a given reduction target, the permit price will vary with the elasticity of supply and demand for oil. The impact for an oil and gas producer will be dependent on the producer price (consumer price net of the permit value) that arises from the introduction of the policy, and whether permits are grandfathered.

[7] Discussion is in terms of tradable permits, though equivalent impacts would be true of a tax system, though "grandfathering" under a tax system would be achieved through different means.

[8] Note that existing taxation of oil and gas means that some price differential often already exists. If so, the introduction of a carbon permit or tax merely increases it.

In our model, the permit price is delinked from the separate producer price assumptions. The rationale is that many different estimates of permit value have been found to achieve the same degree of reduction in oil output. This allowed us to experiment with different face values of permits to achieve different reductions. The prices used are shown in Table 6.

Where permits were grandfathered, they were assumed to go to upstream producers only. For oil producers, permits were grandfathered on the basis of historical sales in participating regions (e.g., all developed countries in Scenarios A and C, and non-U.S. developed countries in Scenario B). Herold's only provides figures on the location of production, not the location of sales. In order to calculate companies' location of sales, we calculated sales distribution from production location by applying the export ratios for large regions reported in BP's *Statistical Energy Review* (BP, 2001). So, for example, the Statistical Energy Review reports that 60 percent of Canadian oil is exported to the United States. Without knowing company-specific transportation patterns, we applied these national, or regional, averages to data on companies' production locations. Finally, of sales volumes assumed to be eligible for grandfathering, it was assumed that grandfathering only applied to half of volumes to reflect the political unlikelihood of excessive windfalls being granted to companies.

The NPV of individual climate scenarios was then compared with our reference case NPV and a percentage difference calculated. This percentage difference was then applied to Herold's baseline NPV for oil and gas reserves before being expressed as a percentage change in the company's overall appraised net worth.

(b) Changes in the Value of Undeveloped Reserves

The value attributed by investors to undeveloped reserves and acreage for exploration is considerably less than that for proven developed reserves. This discrepancy reflects the time lapse before these reserves are realized and the less precise information available on unproven reserve quantities. Indeed, valuation of unexplored acreage is necessarily somewhat speculative. Even in the upstream-only sample companies, the value placed on these possible future reserves never exceeds 12 percent of the total assets reported by Herold. (See Table 1).

To model policy-induced changes in acreage value, we adjusted Herold's baseline value for acreage by the same company-specific percentage increase or decrease calculated for proven reserve value. We also took account of differences in the oil-gas ratio between proven reserves and unproven reserves, with information on the latter derived by comparing the proven reserve figures against the known physical reserves owned by the company and reported in the IHS/Energy database. This was computed for all of the scenarios above. Because of the small initial value of the acreage component, these effects were very modest–rarely reaching 1 percent of ANW–and in some cases negligible.

(c) Changes in the Value of Refining Operations

In climate scenarios where oil demand is reduced, it is assumed that refinery throughput will also be reduced with subsequent reduction in profits for downstream operations (refining, marketing, and transport). Climate policies would result in reduced throughput for refineries as demand for petroleum products fell, as well as in higher feedstock and energy costs. The exact nature of refinery exposure will depend on its crude oil input, the carbon intensity of its product slate, the degree to which it could reconfigure to produce a less carbon-intensive fuel mix, and the plant's overall efficiency. Refineries would be able to respond to climate policies with several process modifications, including use of power-recovery systems, improved catalysts, intermediate reboilers and condensers, and air and crude preheating. Unfortunately, because data on specific refinery energy use and product mix are generally not publicly available, a refinery-by-refinery assessment of opportunities to change fuels or processes to meet new demands cannot be done.[9]

Without sufficient data to adequately distinguish one refinery's product mix from another, our approach was to apply discount factors to the value of refining and downstream segments of each of the companies for the three main regions.

This is unsatisfactory on several levels. First, it contradicts one of the stronger general findings from a previous WRI study that environmental issues constitute sources of competitive advantage within the industry, precisely because no two plants or companies are equally positioned to respond to new regulatory challenges (Repetto and Austin, 2000). Nonetheless, for purposes of establishing a likely financial impact for refining, we have adopted this uniform approach. Second, Herold's often aggregates the value of refining, marketing, and transport into one category, effectively implying that our discount factor is applied to all of the downstream components of the business. This may not be too damaging an assumption, given that throughput in these sectors will be proportionally affected, and that throughput will be the largest influence on changing profitability. Companies are still differentiated to the degree to which they are wholly or partially located in the refining part of the value chain. With more information on the profit margins associated with the separate segments of the downstream business, a more accurate analysis could be done.

To explore different regional uptake of climate policies, we have applied discount factors to three separate regions: the United States, other developed countries, and the rest of the world. In different scenarios, different combinations of these regions may be impacted.

The value of each companies' refining operations was taken from Herold's Comparative Appraisal Reports. This value was then divided across the three separate regions used in this analysis on the basis of refining capacity in each region. Figures on refining capacity were available from the *Oil and Gas Journal* (Oil and Gas Journal, 2001). This implies that equal capacity refineries are of equal value irrespective of location.

In determining how refineries might be impacted, the starting point was a recent study by Bovenberg and Goulder that finds that the equity value of the U.S. petroleum refining sector could fall by 4.7 percent under a $25 per ton carbon tax (Bovenberg and Goulder, 2001). Bovenberg and Goulder also explore sensitivity to tax levels of $12.50 and $50, finding equity losses for the sector of 2.7 and 8.9 percent, respectively.

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[9] The Energy Information Administration's Financial Reporting Service collects the information, but it is not made publicly available.

Bovenberg and Goulder's study shows that percentage loss in company value was slightly less than percentage decrease in oil demanded. For example, under a permit price of $25 per ton of carbon, U.S. refinery output falls by 6 percent relative to business as usual (e.g., a slightly larger percentage than the equity value). Hence, we set percentage loss in region-specific asset value of refineries equal to 0.8 times the percentage reduction in oil demand for that region. These values were then summed up across 3 regions, and restated as a percentage decline in overall ANW.

We made one exception in Scenario D, where we assumed that there would be some offsetting growth opportunity for refineries to produce new fuel types for a new generation of vehicles. In that scenario, we halved the discount factor applied.

(d) Combining Value Changes for Different Business Segments

The value impacts for the different business segments were aggregated to come up with company-specific values for each climate scenario. The aggregate results for each scenario are given in Table 7. To summarize company exposure to climate pressures as a whole the results for each scenario were weighted by the probabilities given in Table 2.

One's view of the financial impacts facing companies is of course sensitive to the weight given to the individual scenarios. In addition, some factors within the model are more important than others in determining the final results.

Several factors probably lead us to underestimate the generally adverse impact on companies. First, we have used conservative values for carbon prices in 2010. Many models estimate that prices for carbon may reach or exceed $200 per metric ton of carbon by that date. In contrast, the highest value we use is $50 per ton, mainly to reflect political pressure that may prevent such high prices emerging. If prices were higher and companies had to bid for permits, negative financial impacts could be greater. Second, we assume no action takes place before 2004 and that permit prices are implemented gradually, increasing at a steady rate until the final price in 2010 is reached. Starting sooner or pursuing a more rapid plan of implementation could result in bigger financial impacts. Finally, we have only raised operating costs to reflect direct use of energy by companies. In practice, rising energy costs would increase the price of other supplies and equipment used in extraction virtue of the energy embodied in those input factors.

In contrast, some factors probably lead us to overstate the impact on companies. First, we have followed Herold in using an 8 percent discount rate. Applying a higher cost of capital diminishes the importance of later years in NPV calculations. This lowers overall financial impacts and contracts the differences observed between companies. Second, in scenarios, where companies might receive permits for free, the implication of assuming a low permit price ($50 as opposed to $200) is to diminish the financial value of the property rights that companies might be assigned.

What We Do Not Estimate

In focusing our attention on quantifying the changes in value of companies' core assets, we ignore several other channels through which climate pressures might affect shareholder value.

- We do not analyze the beneficial impact of companies' incremental activities, such as investing in renewable energy sources and reducing operational emissions. Unfortunately, even in companies that have made the largest steps in these areas, the asset value of such business segments remains trivial relative to core activities.

- We ignore the potential impacts on companies' reputations—positive or negative—that may result from the fact that companies handle climate issues differently.

- We do not attempt to measure the degree to which companies are exposing themselves, as some have suggested, to longer-term product liabilities similar to those recently faced by the tobacco industry.

- Finally, we do not explicitly consider climate-related policies or pressures that may emerge after the 2008–2012 window of the Kyoto Protocol targets and timetables. Though the discount rate reduces the relevance of longer-term pressures for today's shareholder value determinations, the industry may well face greater pressure for change then than it does now. This ought to be of concern to management, though it is unlikely to interest financial markets.

Though harder to quantify, other studies have explored the financial impacts associated with some of these factors.[10]

[10] See, for example, CERES (2002) and Mansley (2002).

IV. Estimating the Financial Implications of Access Constraints

This section describes the application of the methodology to determine the financial impacts of potential access constraints for the 16 companies in our sample. It details how Steps 2 to 5 of the approach were applied to the access issue.

Steps 2 and 3: Identifying Possible Access Scenarios and Assigning Probabilities

How access issues play out will depend on region-specific developments and trends in customer and investor preferences. Environmental preferences often compete with other concerns. For example, general momentum to protect ecosystems and biodiversity is at odds with meeting increasing demand. Desire for plentiful energy may lead consumers to care less about disruption of far-off ecosystems. Alternatively, recent world events may renew energy security concerns that trump preferences to prohibit drilling in protected areas or near heavily populated coastlines. Other factors may be relevant as well. Technological advances in autos or power generation may permit more vigorous insistence on stringent environmental protection. Alternatively, advances in drilling technologies could earn the industry access to pristine areas through the promise of reduced intrusion.

To help frame future possibilities, we consulted with industry representatives and experts to define and assign probabilities to the scenarios described in Table 8. As with climate scenarios, we had only a limited response to a polling exercise, and so final judgments on probabilities were made by the authors.

Step 4: Assessing Company Exposure to Access Constraints

Access constraints will be site- and company-specific. Nonetheless, an overview of company exposure emerges from comparing the location of reserves and operations to the location of ecosystems at risk documented by global maps.

To conduct this assessment, Geographic Information System (GIS) data were obtained for company fields and contract areas around the world and for several global maps of environmentally important areas. Information on company interests comes from IHS Energy Group's database of fields and reserves, which does not include interests in the United States (IHS Energy, 2001).[11] The global maps of environmentally sensitive areas are from the World Wildlife Fund, which brings together several other smaller mapping efforts such as WRI's mapping of reefs at risk and frontier forests (WWF, 1999). The map of protected areas is produced by the World Conservation Monitoring Centre (WCMC), an extension of the United Nation's Environment Programme (WCMC, 1999).

Exposure to restricted access scenarios is primarily a function of the geographic location of each company's reserves and acreage. To determine exposure, we mapped the location of oil and gas reserves and acreage with respect to existing protected areas (IUCN classes I-IV) and

[11] IHS Energy does produce data on U.S. fields, but the cost for the data is beyond the scope of this research effort.

environmentally sensitive regions (WWF Global 200 Hotspots) to see where overlap occurred for each company.

BOX 1. MAP LAYERS

- **WWF Global 200 Ecoregions (Terrestrial and Marine):** A science-based global ranking of biologically important habitats. Ecoregions are used as the unit of scale for comparison, with the most important type of habitat for each region included in the final list (e.g., the most important coral reef from each ocean). The intent is to identify regions at the broadest scale at which natural systems operate.

- **WCMC Protected Areas:** The World Conservation Monitoring Centre, under the auspices of the United Nations Environmental Programme, has identified at a global level all areas of land and sea that are especially dedicated to the protection and maintenance of biological diversity and managed through legal or other effective means (based on IUCN classes I–IV).

- **IHS Energy Group:** Data were extracted from the International Exploration and Production Activity Database, which includes data on location, contracts, ownership, reserves, field development status, reservoir characteristics, hydrocarbon composition, and annual production. The database has global coverage except for fields and contracts located in the United States. We included all fields and contracts in which our companies had interests. Where held by more than one company, reserves and contracted areas were allocated to companies on the basis of equity share.

Table 9 shows the percentage of each company's oil and gas reserves that falls within the boundaries of WWF Global 200 terrestrial or marine ecoregions or within protected areas. There are differences in both overall company exposure and exposure to different types of areas.

Higher exposure of a company's reserves to areas deemed environmentally significant may not in itself imply greater financial exposure. Companies with high exposure may be operating to higher environmental standards that minimize or dispel risk within these areas. Alternatively, companies with low exposure to environmentally sensitive areas may nonetheless be susceptible to environmental risks in other regions through poor performance or processes, which could create liabilities or other adverse effects. However, the analysis is a first-level assessment of potential risk, indicating which companies might be more exposed to increased pressure to maintain pristine and biodiverse areas based on assessments conducted by environmental experts. In addition, such assessments are proving relevant for practices in other extractive industries (e.g., forestry).

Step 5: Assessing the Financial Impacts of Emerging Access Risks

(i) Overview

To assess the shareholder value impacts of access scenarios we compared a reference NPV for reserves and acreage with new estimates of NPV reflecting alternative access scenarios listed in Table 8. Baseline estimates of the value of reserves and acreage were derived from Herold's Appraised Net Worth estimates, made in 2001 (Herold, 2001a).

Access scenarios differed from the reference case through changes to some or all of the following factors:

- the quantity of reserves and acreage available for production;
- the production rate; and
- operating costs.

The degree to which companies were affected by our assessment of access constraints was dependent mainly upon the distribution of the company's reserves relative to environmentally sensitive areas.

(ii) Establishing a Reference Case

Establishing a baseline required attributing a financial value to all of a companies' physical reserves and acreage interests. This required reconciling information on the financial value of reserves (reported by companies and by Herold) with information on the physical location and volume of reserves (reported by IHS Energy).

To accomplish this, we assumed that all physical reserves that had commenced production as of 2000 correlated with proven reserves reported financially by companies. These physical reserves were then attributed a financial value on the basis of dividing Herold's estimate of the value of proven reserves across all physical producing reserves separately for two regions: (1) the United States and (2) the Rest of the World. We classified all reserves that had not yet commenced production as acreage. These were assigned a baseline financial value on a similar basis by dividing up Herold's estimate of acreage value across non-producing reserves, again for the United States and the Rest of the World. This led to four separately valued components of company reserves:

1. Producing reserves in the United States
2. Non-producing reserves (or acreage) in the United States
3. Producing reserves in the Rest of the World
4. Non-producing reserves (or acreage) in the Rest of the World

The implication is that all reserves within these categories are equally valued, when in reality different fields will be valued differently on a barrel of oil equivalent basis. With proprietary field information, a more sophisticated analysis could be done at field-level to determine whether reserves in environmentally sensitive areas are valued higher or lower than the regional averages.

In addition, there may be some discrepancy between our division of reserves and acreage on the basis of production having commenced by 2000, and the reporting of proven and unproven reserves, and acreage interests by companies. The definition of reserves used by most companies includes an economic component reflecting viability of extraction, which is not captured by the purely physical data available from IHS Energy. Again, with company-specific information on reserves, a more accurate analysis would be possible.

(iii) Evaluating Scenarios

Under different scenarios, access pressures were reflected by different combinations of increased production costs, reduced production capacity, and shares of reserves being placed “off-limits.” (e.g., effectively becoming worthless to the company). Reserves were treated differently depending on whether production had commenced or not. We assumed that fields that were already producing would be more resilient to access pressures than fields that had not yet commenced production. Offsetting that, non-producing fields were given a considerably lower financial value than producing fields.

Of course, companies draw from reserves in any time period unequally, and have some capacity to shift production between fields to maximize production efficiency. In contrast, our assumption is that all reserves contribute in proportion to their size and their decline rate to the company’s overall production. In some cases, assuming that some reserves are ruled “off-limits” may overstate the impact to a company because they had no plans to produce from it in the near future. Of course, in other cases, reserves that overlap with environmentally sensitive areas may be precisely those reserves which the company was planning to develop or produce heavily from in the near future.

Different impacts from access constraints were calculated as follows:

Producing Reserves Being Placed “Off-Limits”
Where developed reserves were located in regions deemed sensitive, a percentage of these reserves (depending on the scenario) were deemed off-limits and subtracted from the baseline quantity of proven reserves in each company's portfolio. These percentage reductions in different countries were then aggregated to reduce the NPV of producing reserves in the Rest of the World region, and consequently the company’s appraised net worth or shareholder value. The overall reduction for the Rest of the World region was then used to inform the treatment of reserves in the United States for which field-specific data was unavailable (see below).

Non-producing Reserves being placed “off-limits”
Where non-producing reserves (unproven and/or undeveloped reserves and acreage) are located in regions deemed sensitive, a percentage of these reserves (depending on the scenario) were deemed off-limits and subtracted from the baseline quantity of non-producing reserves in the Rest of the World. These percentage reductions in many different countries were then aggregated to reduce the NPV of producing reserves in the Rest of the World region, and consequently the company’s appraised net worth or shareholder value.

In general, it was assumed that non-producing reserves had a higher chance of being ruled off-limits because of the fact that production had not yet commenced. Against that, non-producing reserves were accorded a much smaller financial value than producing reserves, so that their loss was considerably less important in financial terms.

Constrained Production

Where producing reserves were considered susceptible to opposition from local communities (Scenario B) we reduced the current production rate by 15 percent for each year going forward. This reflects the effects of sabotage on production equipment, labor strikes, or other means of protest that could effectively reduce production. We then adjusted the NPV of the reserves to reflect the decreased volume of production.

To determine the effect of a production constraint on the NPV of a reserve, we modeled the production of a typical reserve out to 2020 using an average decline rate of 9 percent and a discount rate of 8 percent. Data on the nominal price of oil and the nominal extraction costs came from Herold's, and were essentially the averages seen across the company sample. From this simple model we determined that a 15 percent reduction in production of a reserve resulted in an 8 percent decline in NPV for the reserve. This latter factor was then applied to reserves which might face production constraints.

Increase in Operating Costs

For one scenario, we assumed that operating costs would increase due to factors such as project delays, increased expenditures on social and community investments, and on site protection. We then adjusted the NPV of the reserves to reflect such increases.

Using the same simple reserve model described above we determined that a 15 percent increase in operating costs would result in a 4 percent decline in NPV for the reserve. This figure was then applied to the relevant reserves.

(iv) Scenario Descriptions

Scenario A: Global Support for Conservation

Scenario A, representing increased global support for conservation and the protection of biodiversity, examines a case where a small percentage of worldwide reserves in ecologically important areas will become off-limits from formal intervention by international, state, and regulatory agencies or by a formal commitment from companies not to explore and produce in sensitive areas. The value of these off-limits reserves is deducted from a company's asset base and total appraised net worth.

For countries outside of the United States, it was assumed that between 15 percent and 30 percent of reserves located in ecologically important areas, and between 30 percent and 45 percent of reserves located in protected areas, were put off-limits (see Table 10). Though these percentages appear high, they are applied to relatively small fractions of companies' overall reserve base. On average, the non-U.S. reserves placed off-limits were about 5 percent of total reserve holdings.

Due to a lack of field-specific data, reserves in the United States were treated differently for this analysis. We made a conservative assumption that 2.5 percent of U.S. reserves and acreage would be placed off-limits (i.e., approximately half the level seen in other countries). This reflects potential constraints in areas such as Alaska, the Rockies, and in offshore California and Florida. We recognize that companies are invested to different degrees in sensitive regions in the United States, yet without standardized reserve data for the United States we must apply the exposure uniformly across companies. There is a need for further research of company exposure to U.S. access issues. The results of this scenario are sensitive to this assumption, both because reserves in the United States make up a large share of overall reserves and because U.S. reserves are highly valued.

This assumption has the greatest implications for Apache, Burlington, ConocoPhillips, Occidental, and Unocal. Depending on whether their reserves are more or less exposed to environmentally sensitive areas, results for these companies will be affected accordingly. Hence, in Table 11, the scenario results are broken down into United States and Rest of the World components.

Scenario B: Local Opposition to Oil and Gas Development

In Scenario B, we assumed that informal pressures such as NIMBY ("Not In My Backyard") in the industrial world and community opposition in the developing world continue to create complications and restrictions on companies' access to reserves.

In the industrial world, as a result of NIMBY concerns, a small percentage of reserves in environmentally sensitive and protected areas became off-limits in Australia, Canada, France, Germany, the Netherlands, Norway, and the United Kingdom. Again, the United States was treated slightly differently by reducing the U.S. value of proven reserves and acreage by 2.5 percent (as in Scenario A).

In Scenario B, we also assumed that community opposition in some developing countries would raise extraction costs by 15 percent by 2006 and reduce overall production by 15 percent a year for the life of the reserve. This scenario was applied to reserves in Bolivia, Chad, Cameroon, Colombia, Ecuador, Equatorial Guinea, Indonesia, Nigeria, and Papua–New Guinea. We chose these countries based on comments from the Scenarios Workshop that we held in London with industry representatives and on research on past and current areas of community opposition.[12] The scenario is partly informed by Shell's experience in Nigeria, where production has at times been constrained by 40 percent. We chose a more conservative value.

Scenario C: Weak Environmental Sentiment

National security and global oil supply concerns suppress environmental and biodiversity issues, and access to most areas is granted under current terms. Scenario C, reflecting no change in effects from access issues in the future, does not involve any changes in the current appraised net worth of our companies.

[12] The countries were chosen on the basis of historical evidence of conflict between local people and international oil companies. This evidence was accumulated through a workshop of oil industry professionals, an extensive literature review, conversations with peers in the NGO community, and regular reviews of updates from grassroots organizations such as Oil Watch.

(v) Aggregate Financial Impacts of Access Scenarios

The different scenarios were given different probabilities, as indicated in Table 8. The weighted impact of restricted access using those probabilities is indicated in Table 11.

It bears repeating that some company's results are sensitive to assumptions made about the exposure of US reserves to access pressures. Depending on the specific distribution of company's fields with regards to sensitive areas in the United States, companies may be more or less exposed than indicated here. In addition, there is very little publicly available information on the cost and production consequences for oil and gas companies operating in areas where conservation pressures are high. There is a need for further research, or increased company disclosure, on the scale of additional costs or on the production difficulties faced by companies operating in such areas.

V. Calculating Overall Impacts for Companies

In Step 6 of the methodology, we combined the separate findings from the climate and access analyses into summary statistics that captured companies' overall exposure to these two environmental issues. In doing so, we assumed that developments on climate and access issues were assumed to be independent, though there are certainly many interesting ways in which these issues might be intertwined. The assumption of independence, however, permits an overall exposure to be calculated more easily.

To come up with the final range of results (Figure 11 in *Changing Oil)* we calculated the financial impacts for each company of each possible combination of climate and access scenarios (15 combinations in all). Each "combined scenario" was weighted by multiplying the probabilities of the climate and access scenarios occurring independently. This provided a probability distribution for each company. To summarize that distribution we took the mean value and the 90th percentile range, thereby excluding those outcomes on either tail of the distribution, which had less than a 5 percent chance of occurring.

Values summarizing the probability distribution for each company are given in Table 12.

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APPENDIX:

Company Data, Assumptions and Results Tables

Table 1. Composition of Company Assets as of December 31, 2000, and Exposure of Reserves to Environmentally Sensitive Areas

	Amerada Hess	Apache	BP	Burlington	Chevron Texaco	Conoco Phillips	Eni	Enterprise
Appraised Net Worth (thousands of dollars)	**9,456**	**7,485**	**143,045**	**12,632**	**60,709**	**19,951**	**56,133**	**5,314**
Total Value of Assets (thousands of dollars)	**11,799**	**11,202**	**174,853**	**15,364**	**69,466**	**26,352**	**69,365**	**7,273**
I. Value of Business Segment as Percentage of Total Assets								
Total Proven Reserves	**65**	**83**	**52**	**86**	**57**	**64**	**37**	**79**
Proven Oil Reserves	**48**	**38**	**27**	**13**	**42**	**35**	**22**	**69**
U.S.	11	22	12	9	10	7	2	
Other Developed Countries	37	12	11	2	4	14	7	69
Rest of World		3	5	2	28	14	14	
Value of Proven Gas Reserves	**17**	**45**	**25**	**74**	**15**	**29**	**15**	**10**
U.S.	8	32	14	59	9	13		
Other Developed Countries	10	11	5	12	5	14	11	10
Rest of World		3	5	3	1	2	3	
Acreage	**5**	**6**	**5**	**8**	**3**	**5**	**3**	**11**
Attributed to Oil[a]	2	3	3		2	4	1	8
Attributed to Gas[a]	3	3	2	8	1	1	1	3
Refining, Marketing and Transport	**18**		**18**		**16**	**21**	**9**	
Attributed to U.S.[a]	18		1		13	13		
Attributed to Other Developed[a]			8		3	7	9	
Attributed to Rest of World[a]			8		1	1		
Other Assets[b]	**13**	**11**	**25**	**6**	**24**	**10**	**51**	**11**
II. Percentage of Total Reserves in Environmentally Sensitive Areas								
Non-U.S. reserves in ecologically important areas (WWF Global 200)	15	31	24	2	29	33	7	
Non-U.S. reserves in protected areas (IUCN I-IV)	2		4		5		2	

Table 1 (continued)

	ExxonMobil	Occidental	Repsol	Royal Dutch/Shell	Sunoco	TotalFinaElf	Valero	Unocal
Appraised Net Worth (thousands of dollars)	**192,653**	**12,451**	**24,057**	**150,287**	**3,886**	**95,341**	**5,778**	**8,567**
Total Value of Assets (thousands of dollars)	**219,876**	**23,071**	**45,315**	**169,415**	**5,714**	**118,135**	**9,339**	**13,631**
I. Value of Business Segment as Percentage of Total Assets								
Total Proven Reserves	**41**	**62**	**39**	**46**		**36**		**64**
Proven Oil Reserves	**24**	**44**	**30**	**23**		**20**		**22**
U.S.	8	33		4				8
Other Developed Countries	8			6		7		2
Rest of World	8	12	30	13		13		11
Value of Proven Gas Reserves	**17**	**18**	**9**	**22**		**16**		**43**
U.S.	10	18		4		1		20
Other Developed Countries	8			14		8		3
Rest of World			9	4		7		20
Acreage	**4**	**5**	**3**	**4**		**3**		**12**
Attributed to Oil[a]	1	1	2	2		2		2
Attributed to Gas[a]	3	4	1	3		1		9
Refining, Marketing and Transport	**20**		**28**	**21**	**53**	**14**	**89**	
Attributed to U.S.[a]	3			5	53	1	82	
Attributed to Other Developed[a]	7		17	12		11	7	
Attributed to Rest of World[a]	10		11	4		2		
Other Assets[b]	**35**	**33**	**30**	**29**	**47**	**47**	**11**	**24**
II. Percentage of Total Reserves in Environmentally Sensitive Areas								
Non-U.S. reserves in ecologically important areas (WWF Global 200)	11	22	27	26	na	28	na	45
Non-U.S. reserves in protected areas (IUCN I-IV)	1	14		2	na	1	na	

[a] Calculated by WRI from information in company annual reports.
[b] Includes chemicals, utilities, renewables, coal, and other assets.

Source: Financial information comes from *Herold Comparative Appraisal Reports* (various dates, 2001). Exposure of reserves to environmentally sensitive areas calculated by WRI using information from IHS/Energy, International Exploration and Production Activity Database (Englewood, Colorado: IHS Energy Group, 2001); World Wildlife Fund, *The Global 200 Ecoregions* (Washington, D.C.: WWF, 1999); and WCMC, *United Nations List of National Parks and Protected Areas* (London: WCMC, 1993).

Figure 1. Scenarios for Future Pressures to Reduce GHG Emissions

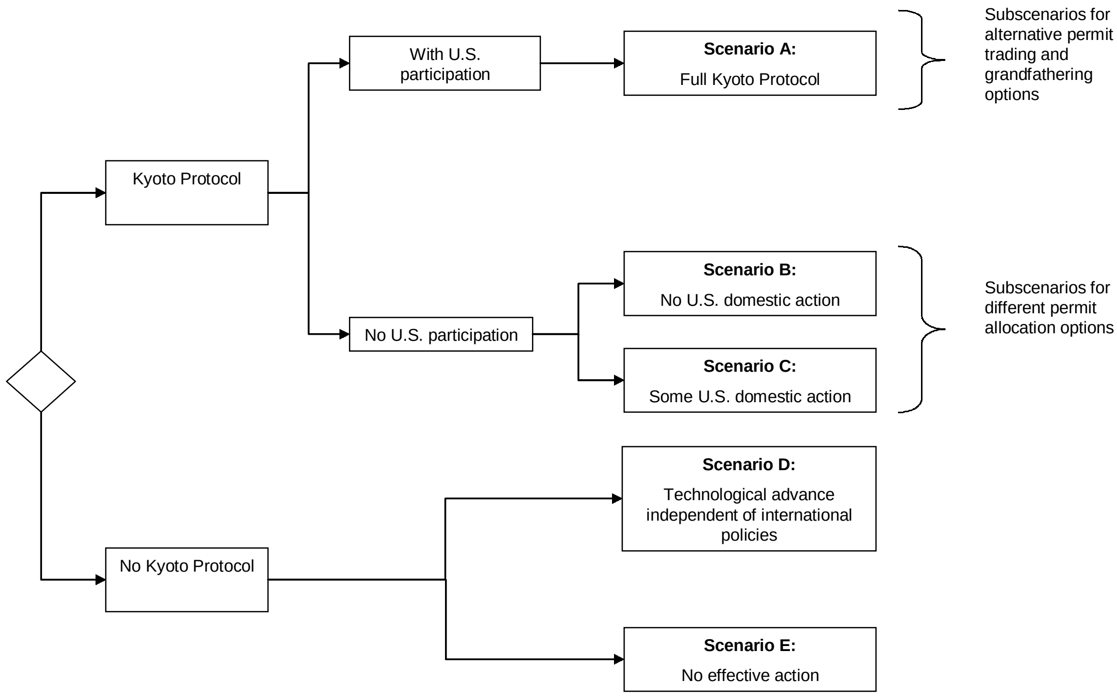

Table 2. Scenarios for Future Pressures to Reduce GHG Emissions

Scenario	Description	Probability
A. Full Kyoto Protocol	The United States reverses its position and adopts the Kyoto Protocol, along with all other developed nations. Impetus for change in U.S. stance may reflect several possibilities: a reaction to a "surprise" climate event, a response to compelling new scientific evidence, or a part of a broader effort of international engagement by the United States, perhaps to bolster support for the war on terrorism.	10%
B. Kyoto Protocol without the United States	The Kyoto Protocol goes into force without U.S. participation, effectively putting in place a Kyoto framework for all other developed countries. No significant emissions reduction occurs in the United States; voluntary programs prove ineffective.	30%
C. Kyoto Protocol without the United States, but with some U.S. domestic Action	As in Scenario B, the United States does not participate in Kyoto Protocol, but a series of effective domestic policies leads to some reduction in GHG emissions. U.S. reductions are less than would have been achieved under Kyoto Protocol.	40%
D. Independent Technological Advance	Kyoto Protocol fails to move forward. However, technological advance, either independent or prompted by targeted policies, reduces demand for oil and leads to some emissions reductions.	10%
E. No Effective Action	Continued international stalemate prevents adoption of Kyoto Protocol, and there are no major technological breakthroughs. This scenario implies no change in a company's near-term financial performance.	10%

Table 3. Sub-scenarios for Climate Issue

Scenario	Description	Probability
A. Full Kyoto Protocol		**10%**
A1	Developed country trading; no grandfathering of permits	2.5%
A2	Global trading; no grandfathering of permits	2.5%
A3	Developed country trading; permits grandfathered to upstream producers	2.5%
A4	Global trading; permits grandfathered to upstream producers	2.5%
B. Kyoto Protocol without the United States		**30%**
B1	No grandfathering of permits	15%
B2	Permits grandfathered to upstream producers	15%
C. Kyoto Protocol without the United States, but with some U.S. domestic action		**40%**
C1	No grandfathering of permits	20%
C2	Permits grandfathered to upstream producers	20%
D. Independent Technological Advance		**10%**
D1	Mild penetration of efficient vehicles	7.5%
D2	Accelerated penetration of efficient vehicles	2.5%

Table 4a. Herold Forecast for WTI Spot Oil Price ($/bbl)

	Projected Oil Price ($/bbl)	Annual Percentage Change
2001	$25.00	
2002	$23.00	-8
2003	$22.00	-4.5
2004	$22.50	2.3
2005	$23.00	2.2
Annual Escalation		2.0
2015	$28.00	

Source: Herold, 2001b

Table 4b. Herold Forecast for U.S. Spot Gas Price ($/MMbtu)

	US Spot Gas Price ($/Mmbtu)	Annual Percentage Change
2001	$4.50	
2002	$4.00	-11
2003	$3.75	-6.3
2004	$3.75	0
2005	$3.75	0
Annual Escalation		0.6
2015	$4.00	

Source: Herold , 2001b

Table 5. Parameters from Economics Estimates of Climate Policy

			Percentage Change from Model-Specific Baseline Value in 2010			
Models	**Country**	**Scenario for Emissions Levels in 2010**	**Producer Oil Price**	**Oil Quantity Demanded**	**Producer Natural Gas Price**	**Natural Gas Quantity Demanded**
EIA	**United States**	24% above 1990 levels	–4	–2	2	2
		9% above 1990 levels	–10	–6	19	10
		3% above 1990 levels	–14	–11	29	12
		7% below 1990 levels	–16	–13	30	11
WEFA	**United States**	7% below 1990 levels	–11	–13	5	1
CRA	**United States**	7% below 1990 levels (no international trading)		–25		–31
		7% below 1990 levels (trading amongst Annex I countries)		–12		–16
EPRI	**United States**	7% below 1990 levels (no international trading)	–15	–15		1
		7% below 1990 levels (trading amongst Annex I countries)	–10	–8		1
DRI	**United States**	1% above 1990 levels		–9		–11
		9% above 1990 levels		–6		–8
		19% above 1990 levels		–1		2
SGM	**United States**	Kyoto with no trading		–15		1
		Kyoto with Annex I Trading		–8		1
		Kyoto with Global Trading		–2		0
		5% increase in Annex I emissions allocations, no trading		–12		1
	Non-U.S. Developed Countries	Kyoto with no trading		–16		–18
		Kyoto with Annex I Trading		–9		–19
		Kyoto with Global Trading		–3		–7
		5% increase in Annex I emissions allocations, no trading		–13		–17
	Developing Countries	Kyoto with no trading				
		Kyoto with Annex I Trading				
		Kyoto with Global Trading		–9		–8
		5% increase in Annex I emissions allocations, no trading				
	Global Total	Kyoto with no trading		–9		–9
		Kyoto with Annex I Trading		–5		–9
		Kyoto with Global Trading		–5		–5
		5% increase in Annex I emissions allocations, no trading		–8		–8

Sources: EIA (1998); SGM (2002). Model results from WEFA, CRA, EPRI and DRI are reported in EIA (1998).

Table 6a. Parameters Used for Scenario A

Scenarios	**Units**	**Scenario A**					
		Trading Between Developed Countries			**Global Trading**		
		U.S.	Other Developed Countries	Rest of World	U.S.	Other Developed Countries	Rest of World
Producer Oil Price	percentage change from baseline in 2010	-8.3			-8.3		
Oil Demand		-8	-8	0	-3	-3	-9
Gas Price (High)		20	20	0	2	2	0
Gas Price (Low)		2.5	2.5	0	2	2	0
Gas Demand (High)		10	5	0	2	3	0
Gas Demand (Low)		-10	-20	0	0	-7	-8
Operating Costs		17	17	0	9	9	0
Permit Price	$ per metric ton of carbon in 2010	50			25		

Table 6b. Parameters Used for Climate Scenarios B and C

Scenarios	**Units**	**Scenario B**			**Scenario C**		
		Kyoto without the United States and with no effective U.S. domestic action			**Kyoto without the United States and with some U.S. domestic action**		
		U.S.	Other Developed Countries	Rest of World	U.S.	Other Developed Countries	Rest of World
Producer Oil Price	percentage change from baseline in 2010	-4			-5		
Oil Demand		0	-2	-4.5	-2.6	-2	-4.5
Gas Price (High)		0	1.3	0	6.6	1.3	0
Gas Price (Low)		0	1.3	0	0.8	1.3	0
Gas Demand (High)		0	4.7	0	3.1	4.7	0
Gas Demand (Low)		0	2	-4	-3.1	2	-4
Operating Costs		0	5	0	5	5	0
Permit Price	$ per metric ton of carbon in 2010	0	15	15	0	15	15

Table 7. Results of Climate Scenarios and Sub-Scenarios

			AHC	APA	BP	BR	CVX	COP	E	ETP
Main Scenarios	Sub-Scenarios	**Probability Weightings**	Percentage Change in Shareholder Value							
A		**10%**	**-4.3**	**-1.7**	**-3.1**	**2.1**	**-3.3**	**-5.5**	**-2.8**	**-7.2**
	A1	2.5%	-6.7	-3.7	-4.1	1.5	-4.5	-8.3	-3.9	-10.3
	A2	2.5%	-5.6	-5.3	-4.9	-1.8	-4.7	-7.3	-3.7	-9.6
	A3	2.5%	-1.6	3.6	-0.4	7.4	-0.9	-2.2	-1.1	-2.9
	A4	2.5%	-3.1	-1.6	-3.0	1.2	-2.9	-4.3	-2.3	-5.9
B		**30%**	**-1.6**	**-1.7**	**-1.9**	**-0.4**	**-1.8**	**-2.4**	**-1.2**	**-3.4**
	B1	15%	-2.2	-2.1	-2.2	-0.6	-2.1	-2.7	-1.5	-4.4
	B2	15%	-1.1	-1.4	-1.7	-0.3	-1.6	-2.1	-0.9	-2.4
C		**40%**	**-2.6**	**-1.9**	**-2.3**	**0.4**	**-2.4**	**-3.8**	**-1.6**	**-4.4**
	C1	20%	-3.1	-2.2	-2.5	0.2	-2.6	-4.1	-1.9	-5.4
	C2	20%	-2.0	-1.6	-2.1	0.5	-2.2	-3.5	-1.3	-3.3
D		**10%**	**-5.0**	**-5.1**	**-4.0**	**-1.7**	**-4.8**	**-6.8**	**-3.6**	**-9.2**
	D1	7.5%	-2.4	-2.4	-1.9	-0.8	-2.3	-3.2	-1.7	-4.4
	D2	2.5%	-13	-13.1	-10.2	-4.3	-12.3	-17.5	-9.4	-23.7
E		**10%**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
		Weighted Average	**-2.4**	**-2.0**	**-2.2**	**0.1**	**-2.3**	**-3.5**	**-1.6**	**-4.4**

Table 7 (continued)

			XOM	OXY	REP	RDS	SUN	TOT	UCL	VLO
Main Scenarios	Sub-Scenarios	**Probability Weightings**	Percentage Change in Shareholder Value							
A		**10%**	**-2.7**	**-5.3**	**-7.2**	**-2.6**	**-3.5**	**-2.9**	**-3.3**	**-6.3**
	A1	2.5%	-3.5	-7.5	-8.1	-3.5	-5.0	-3.8	-4.0	-9.2
	A2	2.5%	-4.2	-8.0	-8.5	-3.7	-1.9	-3.6	-5.6	-3.5
	A3	2.5%	-0.4	-1.0	-5.1	-0.8	-5.0	-1.8	0.1	-9.2
	A4	2.5%	-2.6	-4.7	-7.1	-2.3	-1.9	-2.6	-3.6	-3.5
B		**30%**	**-1.6**	**-3.4**	**-4.2**	**-1.1**	**0.0**	**-1.4**	**-2.4**	**-0.2**
	B1	15%	-1.9	-3.5	-4.4	-1.5	0	-1.6	-2.6	-0.2
	B2	15%	-1.4	-3.3	-4.1	-0.8	0	-1.2	-2.2	-0.2
C		**40%**	**-2.0**	**-4.3**	**-5.0**	**-1.5**	**-1.6**	**-1.7**	**-2.7**	**-2.9**
	C1	20%	-2.2	-4.4	-5.1	-1.8	-1.6	-2.0	-2.9	-2.9
	C2	20%	-1.8	-4.2	-4.8	-1.2	-1.6	-1.5	-2.5	-2.9
D		**10%**	**-3.5**	**-7.8**	**-7.9**	**-3.3**	**-1.8**	**-3.4**	**-4.9**	**-3.3**
	D1	7.5%	-1.6	-3.7	-3.7	-1.6	-0.8	-1.6	-2.3	-1.5
	D2	2.5%	-9.0	-20.0	-20.5	-8.6	-4.8	-8.7	-12.6	-8.9
E		**10%**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
		Weighted Average	**-1.9**	**-4.0**	**-4.8**	**-1.5**	**-1.2**	**-1.8**	**-2.6**	**-2.2**

Table 8. Scenarios for Future Pressures to Restrict Access to Reserves

Scenario	Description	Probability
A. Global Support for Conservation	International biodiversity initiatives, such as the Convention on Biological Diversity, gain global support, resulting in formal efforts to protect biodiversity worldwide. In developed countries, widespread preference to protect biodiversity and endangered ecosystems restricts access to more regions within their own borders. Desire to protect ecologically valuable and diverse areas extends into developing regions where more and more reserves are formally placed off-limits.	20%
B. Local Opposition to Oil and Gas Development	Consumer preferences and environmental concerns restrict access in developed countries. In this scenario, access to protected areas in the United States, Europe, and other developed countries is limited. Increasing exposure of indigenous groups and local communities to international NGOs and media increases ability of developing regions to deter or hinder oil and gas projects they see as harmful to their livelihoods. Protests, sabotage, or other disruptions increase costs and constrain production in developing regions.	60%
C. Weak Environmental Sentiment	National security and global oil supply concerns suppress environmental and biodiversity issues, and access to most areas is granted under current terms. This scenario implies no change in a company's near-term financial performance.	20%

Table 9. Share of Company Reserves Exposed to Ecologically Sensitive or Protected Areas

Percentage of company's total reserves

	Terrestrial Ecoregions	Marine Ecoregions	Protected Areas
AHC	13	1	2
APA	0	31	0
BP	3	21	4
BUR	1	1	0
CVX	12	17	5
COC	12	17	0
ENI	2	5	2
ENT	0	0	0
XOM	4	7	1
OXY	3	19	14
P	0	27	0
REP	21	6	2
RDS	2	8	1
SUN	NA	NA	NA
TOT	20	9	1
UCL	1	44	0
VLO	NA	NA	NA

Source: see text for explanation of calculations

Table 10. Parameters Used for Access Scenarios

Scenario	Probability	Parameters	
A. Global Support for Conservation	20%	***Percentage of category assumed off-limits for reserves outside the U.S.:***	
		- Reserves with production in ecologically important regions	15%
		- Reserves that have not commenced production in ecologically important regions	30%
		- Reserves with production in protected areas	30%
		- Reserves that have not commenced production in formally protected areas	45%
		All U.S. proved reserves and acreage:	
		- Percent off-limits:	2.5%
B. Local Opposition to Oil and Gas Development	60%	*Percent off-limits for reserves in United Kingdom, the Netherlands, Norway, Germany, France, Denmark, Canada and Australia:*	
		- Reserves with production in ecologically important regions and protected areas	20%
		- Reserves that have not commenced production in ecologically important regions and protected areas	45%
		All U.S. proved reserves and acreage:	
		- Percent off-limits:	2.5%
		For all producing reserves in Nigeria, Chad, Cameroon, Equatorial Guinea, Papua New Guinea, Indonesia, Ecuador, Colombia, and Bolivia:	
		- Increase in extraction costs:	15%
		- Constraint in production:	15%
C. Weak environmental sentiment	20%	- Business as Usual. No changes from reference case	

Table 11. Results of Access Scenarios

Percentage Change in Shareholder Value									
		AHC	APA	BP	BR	CHX	COP	E	ETP
Scenario A	**TOTAL**	**-1.4**	**-3.3**	**-1.7**	**-2.3**	**-2.5**	**-3.0**	**-0.5**	**0.0**
	United States	-0.6	-2.0	-0.9	-2.2	-0.7	-1.5	-0.1	0.0
	Rest of World	-0.8	-1.3	-0.8	0.0	-1.7	-1.5	-0.4	0.0
Scenario B	**TOTAL**	**-1.5**	**-3.5**	**-1.3**	**-2.3**	**-2.1**	**-1.9**	**-0.9**	**0.0**
	United States	-0.6	-2.0	-0.9	-2.2	-0.7	-1.5	-0.1	0.0
	Rest of World	-0.9	-1.5	-0.4	0.0	-1.4	-0.4	-0.8	0.0
Scenario C		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Weighted Average		**-1.2**	**-2.8**	**-1.1**	**-1.8**	**-1.8**	**-1.7**	**-0.6**	**0.0**

Table 11 (continued)

Percentage Change in Shareholder Value									
		XOM	OXY	REP	RD	SUN	TOT	UCL	VLO
Scenario A	**TOTAL**	**-1.0**	**-3.1**	**-2.5**	**-0.8**	**0.0**	**-1.7**	**-3.9**	**0.0**
	United States	-0.5	-2.4	0.0	-0.3	0.0	0.0	-1.3	0.0
	Rest of World	-0.5	-0.7	-2.5	-0.5	0.0	-1.7	-2.5	0.0
Scenario B	**TOTAL**	**-2.2**	**-3.3**	**-2.1**	**-1.6**	**0.0**	**-1.0**	**-5.3**	**0.0**
	United States	-0.5	-2.4	0.0	-0.3	0.0	0.0	-1.3	0.0
	Rest of World	-1.7	-0.9	-2.1	-1.3	0.0	-1.0	-3.9	0.0
Scenario C		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Weighted Average		**-1.5**	**-2.6**	**-1.8**	**-1.1**	**0.0**	**-1.0**	**-3.9**	**0.0**

Table 12. Aggregated Results – Percentage Change in Shareholder Value from Access and Climate Scenarios Combined

Company	Average	Variance	95th percentile	5th Percentile
AHC	-3.6%	2.2%	-1.5%	-6.6%
APA	-4.7%	3.4%	-1.7%	-8.6%
BP	-3.3%	1.3%	-1.3%	-5.3%
BR	-1.8%	1.7%	0.4%	-4.0%
CHX	-4.1%	2.1%	-1.8%	-6.9%
COP	-5.2%	4.1%	-1.9%	-8.7%
E	-2.3%	1.0%	-0.9%	-4.5%
ETP	-4.4%	5.4%	0.0%	-9.2%
XOM	-3.4%	1.5%	-1.6%	-5.7%
OXY	-6.6%	5.1%	-3.3%	-11.1%
RD	-2.6%	1.1%	-1.1%	-4.9%
REP	-6.5%	4.8%	-2.1%	-10.0%
SUN	-1.2%	1.2%	0.0%	-3.5%
TOT	-2.7%	1.1%	-1.0%	-4.4%
UCL	-6.5%	5.5%	-2.4%	-10.1%
VLO	-2.2%	3.8%	0.0%	-6.3%