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## **Marine Hydrocarbon Seep Capture: Feasibility and Potential Impacts, Santa Barbara, California**

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### **Significance**

Just off of Coal Oil Point near Santa Barbara, California lie the world's most active and most studied marine hydrocarbon (oil and gas) seeps (Figure 1) (1).



**Figure 1: Map of Southern California Showing Study Area**  
Source: UCSB Hydrocarbon Seep Project (2001).

The recent energy crisis in California has renewed interest in capturing this seepage as a potential "green" source of natural gas. The Santa Barbara County Air Pollution Control District (SBCAPCD) believes that capturing natural hydrocarbons may reduce local air pollution.

### **Background**

ARCO Oil and Gas Company installed the world's first seep gas capture devices in 1982 (2). The two tents currently capture enough natural gas to provide energy to 190 households per year (3).

Capturing the seep gas and routing it to commercial pipelines provides an exciting alternative to more traditional natural gas development. The seeps are also one of the most unique sources of air pollution in the

region because the seep hydrocarbons contribute to ground level ozone (smog).

### **Problem Statement**

In this study we analyze the environmental consequences, political feasibility, and economic practicality of installing additional seep tents in the Santa Barbara Channel.

### **Research Approach**

We take an interdisciplinary approach to evaluating a proposed project by estimating the:

- Water quality and marine ecologic impacts
- Effects on air quality
- Regulatory obstacles and requirements
- Economic costs and benefits of installing additional seep capture tents.

Below, we outline the key findings of our integrated analysis, concluding with the economic criteria necessary to make a seep tents project practical. We list recommendations for further research, potential seep tents projects, and policy regarding their use in the Santa Barbara Channel.

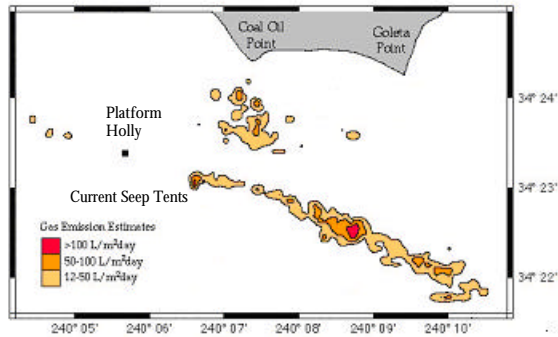
### **Environmental Impact**

A seep tents project will likely have a minimal long-term impact on water quality and marine ecosystems, and will generate small improvements in air quality, as outlined below.

#### ***Effect of Seep Tents on the Marine Environment***

In order to estimate the effects of seep tents on the marine environment, information on the biogeochemistry and marine ecology of the Coal Oil Point seeps are synthesized. Figure 2 shows the most recent mapping of the seep field's hydrocarbon flux. Most of the hydrocarbons released by the seeps dissolve, disperse and/or biodegrade before they have a detectable impact on water quality and marine ecosystems. A unique benthic community is adapted to the seep sediments where toxicity-tolerant bacteria decompose and use seep hydrocarbons. These hydrocarbons then enter the food chain through organisms that prey on the bacteria, resulting in increased biomass in the seep community (4).

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**Figure 2. Hydrocarbon Seep Area Map. Source: UCSB Hydrocarbon Seep Project (2001).**

There will be little impact to benthic organisms if the seep tents are raised off the sea floor. Most of the environmental impacts from tent installation would be short term, one-time impacts to the seafloor communities; however, laying pipeline could cause long-term ecosystem level impacts if not placed sufficiently far from critical habitats such as kelp beds.

Overall, we estimate no benefits or significant impacts on the water quality and marine ecology from installing additional seep tents off Coal Oil Point.

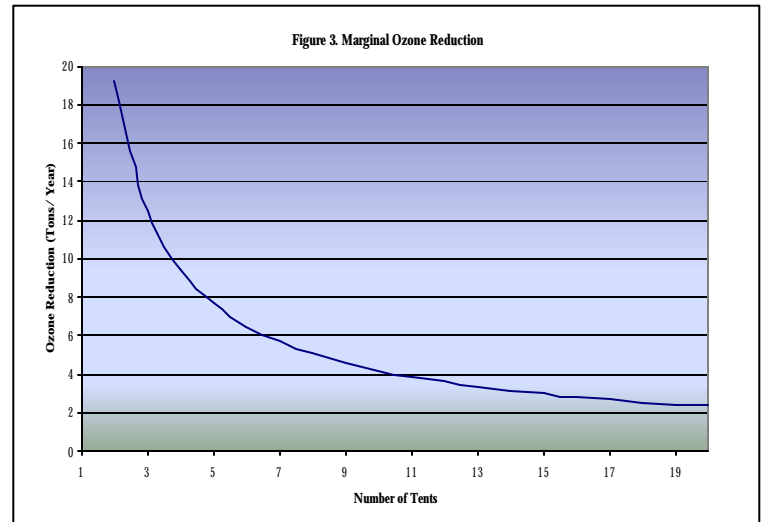
### ***Effect of Seep Tents on Air Quality***

We develop an air quality model that relates seep gas emissions to ozone formation and estimates the change in ozone associated with seep gas capture (5). This links to a health impacts model that monetizes the benefits of improved air quality from seep tents installation.

The seeps release reactive organic gases (ROGs) into the atmosphere that react with oxides of nitrogen and sunlight to form tropospheric ozone (smog). Ozone is a serious health concern, yet the seeps' contribution to ozone formation is small compared to other sources. Because of the complex chemistry of ozone formation, the magnitude of the seeps' contribution depends on the climate and the spatial and temporal levels of ROGs and nitrogen oxides in Santa Barbara's airshed, and can vary considerably.

The first seep tent will reduce about 0.4% of total ozone produced annually in Santa Barbara County, averaged over 20 years, as opposed to 41% produced by man-made sources (6). Statistical analysis of spatial heterogeneity of seep flux shows that additional tents reduce less ozone on the margin (Figure 3).

Methane, the primary component of seep gas, is a potent global warming agent; methane from the seeps accounts for roughly 0.004% of global emissions (7). One seep tent would reduce approximately 0.0003% of global methane emissions.



### **Regulatory Requirements**

Aside from the required development permits, the major regulatory obstacles are permitting the infrastructure to process the gas and acquiring emission reduction credits.

### **Permits and Gas Processing**

Permits and approval for installing tents and infrastructure are required from the California EPA, Army Corps of Engineers, State Lands Commission, Coast Guard, Minerals Management Service, S.B. County Planning and Development, and SBCAPCD (8). Gas processing will most likely require an onshore facility. Current regulations under the Santa Barbara County Coastal Plan make it unlikely that seep gas be sent to a new facility or an existing onshore facility.

### **Emission Reduction Credits**

Emission reduction credits (ERCs) may be allocated to polluting firms in agreement with the SBCAPCD, allowing the firm to emit certain amounts of polluting substances in return for reducing polluting emissions elsewhere. ERCs were critical to the economic success of the 1982 ARCO project and are currently valued at about \$5,000 per ton of ROGs (9).

For two primary reasons, it is unlikely that the project will receive emission reduction credits: (1) an applicant



must show the reductions are permanent, yet the seepage varies over space and time, and (2) as a natural emitter of ROG<sub>s</sub>, the seeps are not currently eligible for credits. Credits are also contingent on whether Santa Barbara County is in non-attainment for ozone, and currently the county is in non-attainment status for state ozone standards but in attainment status of federal standards. Given these factors, it would be a rare exception to issue credits for a seep tents project.

**Cost-Benefit Analysis**

A formal accounting of the costs and benefits of a seep tent project will guide regulators in decisions regarding the project. Thus, two views are taken in evaluating the economic results: that of the entrepreneur and that of the policymaker. The entrepreneur needs to know the project profit, which equals the revenues from natural gas sales and ERCs, less the capital, installation, and maintenance costs over a 20-year planning horizon. In addition to considering entrepreneurs incentives the policymaker must also consider the value of improved air quality. If the project is acceptable, the policymaker must also determine the appropriate amount of ERCs required to create an incentive for seep tent installation.

An integrated analytical model is developed to simulate over 17,000 different project scenarios and determine their viability from the entrepreneurial and social perspectives. The cost-benefit analysis model integrates the ozone reduction model, health benefit valuation model, emission reduction credits, gas price forecast and project cost estimates. Four methods of forecasting natural gas prices are used. The most likely forecast is an annual average generated by an ARIMA time series model, valued at \$2.45 per 1000 cubic feet (MCF). The value of improved health from ozone reduction is determined using a range of studies from the economic literature, and results in three scenarios. The most likely scenario values health benefits at \$2.1 million for the first tent averaged over 20 years.

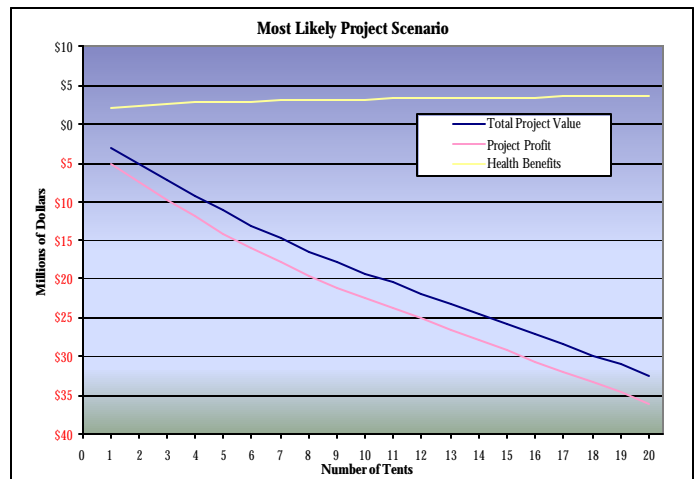
**Most-Likely Project Scenario**

A most likely project scenario is constructed of conservative parameters based on the best available data (shown in Table 1).

**Table 1. Most likely project scenario parameter values and source of values.**

| Input Parameter                             | Value                             | Source                     |
|---|-----------------------------------|----------------------------|
| Starting Tent Flux Capture                  | 220,000 MCF/tent/year             | ARCO starting tent Capture |
| Decrease in Flux Over Time                  | 7.4%                              | Historic ARCO Capture      |
| Discount Rate                               | 5%                                | Intermediate Estimate      |
| Gas Sales Scenario                          | Conservative                      | ARIMA Time Series Model    |
| Health Benefit Scenario                     | Conservative                      | Benefits-Transfer Approach |
| Air Regime (NO <sub>x</sub> or ROG limited) | Co-limited (NO <sub>x</sub> -ROG) | Ozone Production Model     |
| Emission Reduction Credits                  | No                                | SBAPCD Judgment            |

Under the “most likely scenario” we project present value costs of \$7.5 million, monetary health benefits of \$2.1 million, and gas sales revenue of \$2.2 million resulting in a total project loss of \$3.1 million over a 20-year planning horizon (Figure 4). Health benefits and emission reduction credits are the model’s most influential parameters based on a sensitivity analysis of the project’s value and profit.



Five other project scenarios (Table 2) show that:

- No seep tents should be installed even with the maximum effect of the tents on ozone reduction
- Both high and scarcity-driven gas pricing suggest that one tent should be installed
- Five tents are optimal under the least conservative health benefits valuation method
- Three tents are optimal if emission reduction credits are acquired



**Table 2. Summary of results: optimal number of tents, project value, health benefit, and project profit for six project scenarios (Millions of dollars).**

| Scenario    | Description                       | Optimal Tents | Project Value | Health Benefit | Project Profit |
|-------------|-----------------------------------|---------------|---------------|----------------|----------------|
| Most-likely | Most-likely                       | 0             | \$0           | \$0            | \$0            |
|             |                                   | (1)           | (\$3.1)       | (\$2.1)        | (\$5.2)        |
| 1           | ROG-limitation                    | 0             | \$0           | \$0            | \$0            |
|             |                                   | (1)           | (\$1)         | (\$4.2)        | (\$5.2)        |
| 2           | High Gas Pricing                  | 1             | \$4.3         | \$4.2          | \$0.1          |
| 3           | High Gas Pricing/ Health Benefits | 5             | \$41.3        | \$48.2         | -\$6.9         |
| 4           | ERC                               | 3             | \$32.6        | \$2.6          | \$30           |
| 5           | Hotelling Gas Pricing             | 1             | \$0.2         | \$2.1          | -\$1.9         |

Under likely project conditions, installing new seep tents is not practical from either a social (public policy) or an entrepreneurial viewpoint. From a business' point of view, unless emission reduction credits are issued or unlikely high market gas pricing conditions are sustained, the project will not be attractive. From society's point of view, the most likely scenario is not valuable because costs to the private firm are greater than society's benefits.

If a potential project's value were positive, however, a policy could be devised to motivate installing seep tents. ERCs could be issued to compensate an entrepreneur for their losses on the project. For example, in a low-cost version of the most likely scenario, the project loses \$1.7 million (without credits). For a credit of only 5% of this project's ROG reduction (the 1982 ARCO project used 80%), the owners of the tents would be compensated \$2 million for this loss and would achieve an industry standard 10% rate of return. This suggests that a policymaker could create an incentive to produce an air quality improvement valued at \$2.1 million for \$2 million in emission reduction credits.

Before issuing credits it is prudent to compare the cost effectiveness of installing seep tents to other abatement technology. Results suggest that seep tents are a cost effective technology for ROG abatement (\$8,000 with seep tents vs. \$14,000/ton using other abatement technologies) (10). However, the seep tent's potential to abate methane emission is not sufficient to justify the project (\$500/ton with seep tents vs. \$ 3.80 /ton on the global trading market) (11).

### Recommendations

#### Further Research

Research should be conducted to better understand the chemistry of the Santa Barbara airshed as well the marine ecology of the seep field. We recommend the use of Santa Barbara County hospital data to derive the exact relationship between illness and ozone in place of using a benefits transfer method.

#### Project Recommendations

If a seep tents project is proposed in the future, we recommend that an entrepreneur consider the following points: (1) permitting associated with onshore gas processing, (2) acquisition of ERCs.

#### Policy Recommendations

A policymaker should evaluate the following four issues in light of a new seep tents project: (1) the precise amount of ozone reduced by seep tents should be calculated to accurately determine the value of health benefits and amount of emission reduction credit; (2) permit conditions should account for the seeps' spatial and temporal variability; (3) a socially responsible value for the credits should be instituted that is equal to or less than the health and other possible external benefits of ozone reduction by seep tents; (4) the cost effectiveness of seep tents should be compared with other methods of abating tropospheric ozone.

#### References and Notes

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