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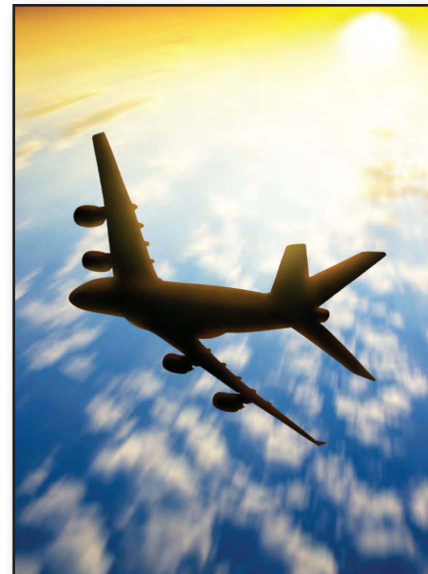

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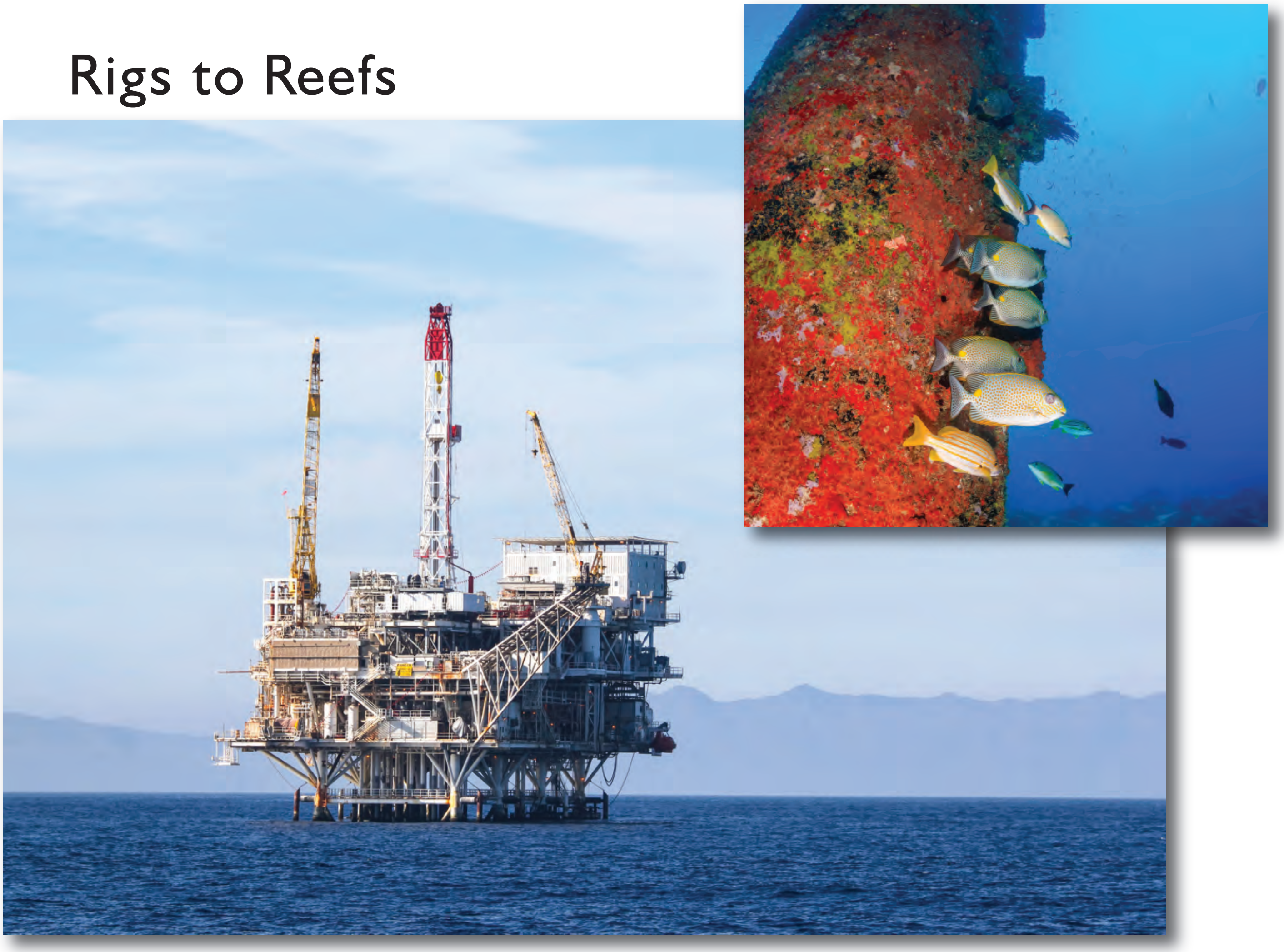
Rigs to Reefs



From controversy to consensus

A decision analysis for decommissioning California's offshore oil platforms.

By Max Henrion

The 1969 Santa Barbara oil spill was the Deepwater Horizon of its day. It was caused by a blowout during drilling operations at Platform A, six miles off the coast of Southern California. Images of dying seabirds and beaches fouled with crude oil are credited with jump-starting the modern U.S. environmental movement. Certainly, memories of this disaster help make offshore oil drilling a controversial issue in California to this day.

The 27 oil and gas platforms off the coast of Southern California are now reaching the end of their productive lives. The leases require the owners to decommission the platforms by removing them entirely. The visible platforms are massive structures, but are only the tip of the iceberg: Platform Harmony, the largest of the

(opposite page)
Platform: Oil and gas platforms off the coast of Southern California are now reaching the end of their productive lives and need to be decommissioned. But how?

Image © Henrik Lehnerer | 123rf.com

Fish (inset): The oil and gas platforms' supporting structures are encrusted with shells and other marine organisms, and are an attractive breeding ground for fish.

Image © Richard Whitcombe | 123rf.com

27, including its underwater supports, is taller than the Empire State Building. The supporting structures are encrusted with up to a foot thick of shells and other marine organisms. Many fish, such as commercially valuable rockfish, breed on them, attracting sea lions and other marine mammals, including recreational human divers.

Complete removal of all platforms is estimated to cost more than $1 billion. It is unclear that any site in the United States would be willing to accept the materials for disposal. The platforms total more than 375,000 tons of steel along with their encrustations. They might need to be shipped to Central America or across the Pacific to Asia. At the same time, conservationists, fishermen and divers have become concerned about the effect on the marine life that has grown up around these structures. Other stakeholders include the oil companies that own and operate the platforms, environmental advocacy groups and state and federal agencies concerned with air quality, wildlife and other natural resources.

Given the many stakeholders and sensitive environmental issues, even the question of how best to decommission the platforms became a matter of public controversy. To clarify the options, the California Natural Resources Agency requested the California Ocean Science Trust (OST) to commission a comprehensive study. [OST is a non-profit whose mission is to provide credible, unbiased science and analysis to support public policy affecting the oceans.] OST hired a multidisciplinary team, led by Brock Bernstein, including a platform engineer, marine biologists, economists, legal experts and two decision analysts (including the author and Surya Swamy of Lumina Decision Systems) to analyze and help compare potential solutions.

Building and Pruning the Decision Tree

A wide variety of decommissioning options were suggested. As with most decision analyses, a key initial step was to identify the most promising strategies for more detailed evaluation, and to prune away those that initial research finds to be impractical. The team identified the main branches of the decision tree shown in Figure 1 as: 1) complete removal, 2) partial removal, and 3) leaving the platforms in place for reuse.

It might seem fitting to repurpose these monuments to the extraction of fossil fuel as platforms for renewable energy – for wind turbines, wave power or solar arrays. Sadly, it turns out that the platforms location, construction and the cost of grid connection makes such uses unviable. Other proposals for reuse included liquefied natural gas (LNG) terminals, aquaculture and offshore hotels. But, after more detailed investigation of technical, legal, regulatory and economic issues, these also turned out to be impractical or not applicable to more than one platform. Any reuse that retains the platform in place is, of course, postponing rather than addressing the question of eventual removal.

Thus, it appeared that the main alternative to complete removal was partial removal, also known as the "rigs to reefs" option: remove the topside of each platform, cut the "jacket" (the supporting steel structure) off at 85 feet below sea level, and leave the rest of the jacket as an artificial reef.

This option preserves most of the marine life that flourishes around the structure, saves about half the

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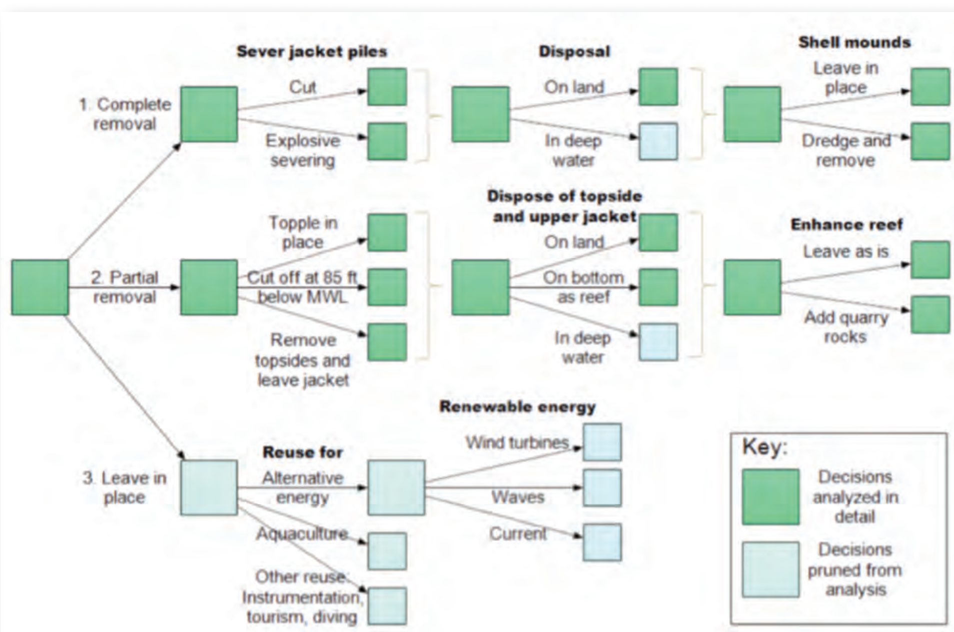

Figure 1: Decision tree of decommissioning options.

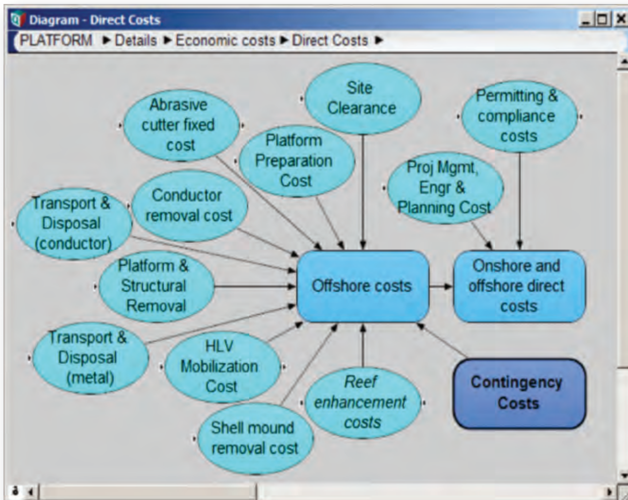

Figure 2: Influence diagram showing uncertainties affecting the decommissioning costs.

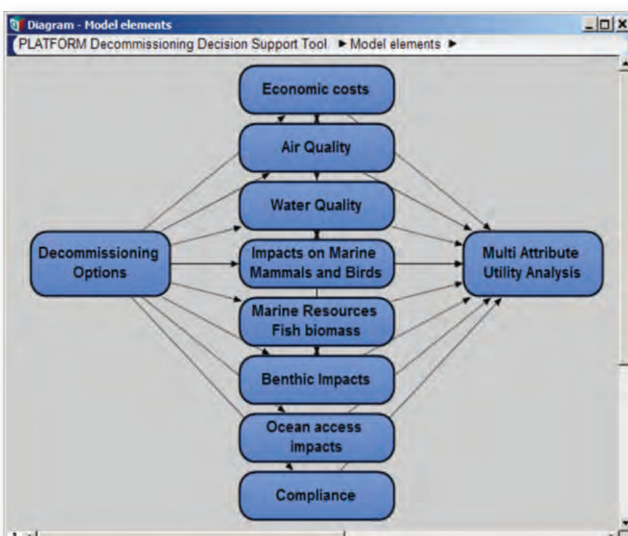

Figure 3: Influence diagram showing the eight attributes in the multi-attribute utility analysis of the decommissioning options.

Attribute: Impacts on Marine Mammals			
Level	**Description**	**Decisions**	**Score**
Best	Status quo, no effect	No action	100
Good			
Medium	Slight effect son movement or migration of marine mammals	Partial removal	70%
Poor	Some disturbance or disorientation	Complete removal without explosive severing	50%
Worst	Disturbance, disorientation, and possible mortality	Complete removal with explosive severing	0

Figure 4: User interface to score each level of impact on marine mammals.

decommissioning cost (depending on depth) and avoids hazard to shipping. Marine biologists found that most of the biological production, including breeding areas for commercially valuable rockfish, occurs below this depth.

Subsidiary options occurred further down the decision tree. The piles supporting the jacket could be severed using explosives, which costs less than conventional cutting, but at greater risk to marine mammals. The shell mounds on the seabed beneath each platform include rock and mud from drilling operations and old shells fallen from the jacket. These may be left in place or dredged to restore the seabed to its pristine state but at the risk of dispersing potentially toxic materials from early drilling operations. Partial removal may leave the jacket standing, after cutting off the top, or toppled to rest on its side. Either way, the jacket may be enhanced as an artificial reef by the addition of quarry rocks. The darker green decision nodes in the tree represent paths included in a detailed quantitative analysis. The light green ones show a few of those that were pruned away after preliminary qualitative analysis found them unpromising, to make the model simpler and more tractable.

An Interactive Decision Model

The Lumina team developed the decision analysis as an interactive computer model named PLATFORM, implemented in Analytica ([1] Lumina 2014). PLATFORM is designed to enable stakeholders to evaluate decision strategies and changing assumptions against a comprehensive list of objectives, using a multi-attribute decision framework. Like most Analytica models, it is organized as a hierarchy of influence diagrams to enable team members and stakeholders to navigate and examine model structure and assumptions.

Figure 2 shows an example influence diagram on the economic costs of decommissioning, along with a tornado chart showing the sensitivity of total cost to uncertainty in each of the input assumptions. The Lumina team worked with a platform engineer to develop this influence diagram and the underlying cost model ([2] Bressler and Bernstein 2015). Uncertainty in the cost estimates was expressed by probability distributions with a bias of 12 percent and relative standard deviation of 23 percent, based on experience of errors in cost estimates from platform decommissioning in the Gulf of Mexico. (No platforms have yet been decommissioned off the coast of California.) The Lumina team collaborated with other domain experts to create influence diagrams and quantitative models of other key attributes, including biological productivity of fish ([3] Pondella et al. 2015), air emissions ([4] Cantle and Bernstein 2015) and ocean access.

A Multi-Attribute Model of Stakeholder Objectives

PLATFORM was designed to help stakeholders explore the implications of their varying views. Lumina worked with domain experts and stakeholders to develop a multi-attribute utility framework to cover the full range of preferences. The influence diagram in Figure 3 shows in the middle column the eight attributes that identify the key objectives against which to evaluate decision strategies. Users can click each attribute node to open up the influence diagram showing how to evaluate each option against attribute, as in the economic cost model in Figure 2. Economic costs, fish biomass and ocean access attributes contain quantitative models.

The other attributes were modeled by two to five possible outcomes. For example, Figure 4 shows a user interface table of levels of impact on marine mammals. Users can select a numerical score for each intermediate outcome – poor and medium in this case – between 0 for worst and 100 for best outcome. In this way, the framework evaluates scores performance on each attribute, quantitative or qualitative, on a scale from 0 to 100.

To combine scores on the eight attributes into a single utility for each option, PLATFORM uses SMARTS (simple multi-attribute rating tool with swing weights), a widely used method developed by Ward Edwards and Hutton Baron ([5] 1994). Swing weights define the relative importance of each attribute based on the value to the stakeholder of changing the outcome from its worst to

Assessing swing weights by attribute

Attributes	Type	Best outcome	Worst outcome	Swing weight
Costs	Quantitative	Status quo: $0	Complete removal: $250 million	100
Air quality	Qualitative	Status quo: Zero emissions.	Complete removal: Emissions from 4400 ton HLV onsite for 113 service days for complete removal.	40
Water quality	Qualitative	Status quo: No impact	Complete removal: Accidental discharge of contaminated material at surface, or shell mound removal with toxic sediment contaminates water column.	15
Marine mammals	Qualitative	Status quo: No impact	Complete removal: Explosive severing for complete removal causes disturbance, disorientation, and some mortality to marine mammals.	20
Birds	Qualitative	Deck removal: Reduced mortality from flight collisions. Loss of offshore roosting replaced by new	Deck removal: Loss of offshore roosting reduces fitness and survival, which outweighs reduced flight collisions.	10
Benthic impacts	Qualitative	Status quo: No impact	Complete removal: Anchoring or shell mound removal leads to widespread impact and spreading contaminants.	10
Fish production	Quantitative	Status quo: 10,000 Kg/y	Complete removal: Zero fish production	25
Ocean access	Quantitative	Removal: Adds 2 Sq N Mi	Status quo: Limits access	20
Strict compliance	Qualitative	Complete removal complies with lease	Partial or no removal violates lease.	50

Figure 5: Setting swing weights for each attribute.

best level for this problem relative to the range of most important attribute (cost in this case). Swing weights are more meaningful than abstract "importance weights" that ignore the actual range of outcomes. Rather than rate the importance of impacts on fish production relative to costs in the abstract, a swing weight rates the relative importance of reducing fish production from 10,000 Kg/year to zero relative to increasing the costs from zero to $250 million.

Users employ the screen in Figure 5 to specify a swing weight for each attribute. With SMARTS, they first identify the attribute range whose range from worst and best outcome has the highest value to them – cost in this example. Then they order the other attributes from most to least important. Finally, they use the pull-down menus to assign a value between 0 and 100 for each intermediate attribute. The model calculates the overall utility for each decision strategy as the sum of the individual attribute scores multiplied by their swing weights.

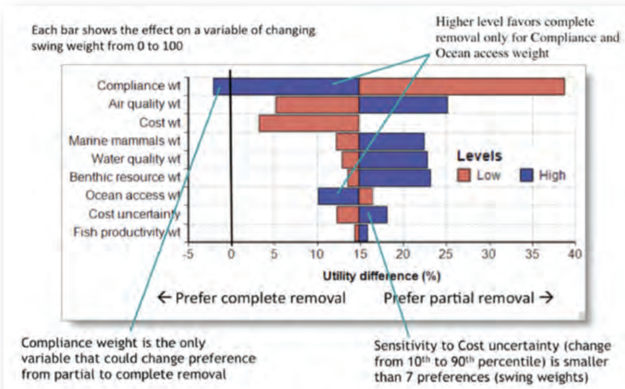

Figure 6: Tornado chart showing sensitivity of preferred decision to changes in swing weights.

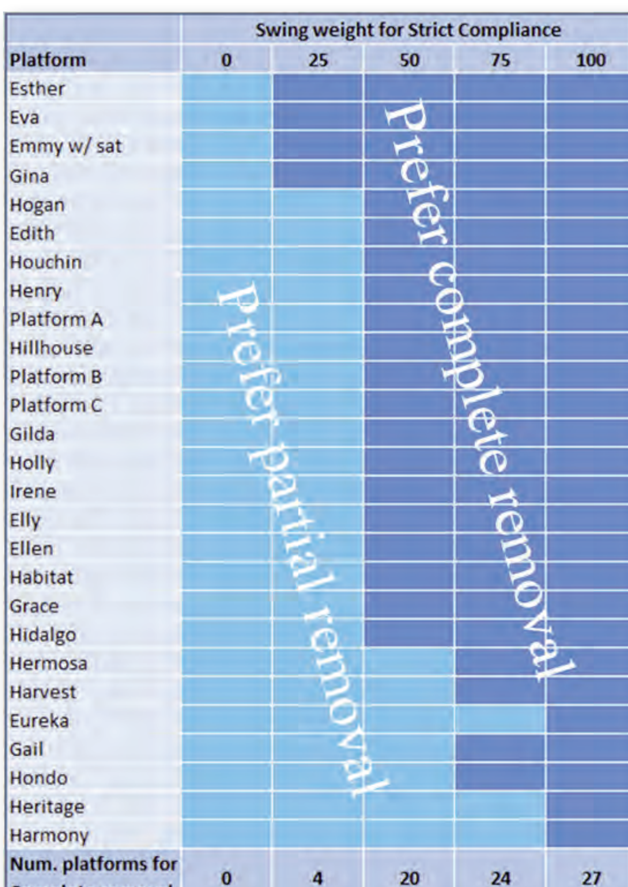

Figure 7: How changing the swing weight for "strict compliance" changes the preferred decision for each platform, from shallowest to deepest.

Insights from Sensitivity Analysis

No method of quantifying preferences can be precise, and stakeholders differed substantially in their views on the importance of the eight attributes. So, the Lumina team performed a series of sensitivity analyses to explore the effects of stakeholder imprecision and disagreement. Figure 6 shows a tornado diagram. Each bar shows the effect of varying one swing weight from 0 to 100, holding the others at their nominal values (given in Figure 5). The horizontal axis is the percent utility difference between partial removal and full removal for Platform Harmony. For the nominal values, the center line of the bars is positive at 15 percent, meaning partial removal ("rigs to reefs") is the preferred option. For most bars, the blue bar (higher weight) is on the right, meaning greater importance for that attribute favors partial removal. An interesting insight is that – unusual for environmental decisions – there is no conflict between reducing costs and reducing environment impacts; partial removal reduces both costs and (most) environmental impacts relative to complete removal.

The main conflicting attribute is "strict compliance" with the leases that call for complete removal. If you think this attribute is critical, you naturally favor complete removal, so the blue bar goes left. In fact, compliance is the only attribute for which changing its weight to an extreme (100, the same as cost) is sufficient by itself to make the score negative; i.e., to make complete removal the preferred decision for this platform.

The "cost uncertainty" bar, near the bottom of Figure 5, shows sensitivity to not a swing weight but to technical uncertainty in decommissioning costs – changing it from its 10th to 90th percentile of the expert probability distribution. Interestingly, sensitivity to this, the largest technical uncertainty, is dominated by the sensitivity to seven of the eight swing weights. Thus, potential differences between stakeholder preferences have a much larger effect on recommendations than does technical uncertainty – not an uncommon finding in decision analysis on environmental issues.

So far we have been evaluating strategies for a single platform. These platforms vary substantially in their size, removal cost and the amount of marine life that they support. Therefore, the recommended option may differ from one to another, even with the same multi-attribute preferences. To dismantle a platform, one needs a heavy lift vessel (HLV), a huge crane mounted on a ship and capable of lifting up to 4,000 tons. Most HLVs are in the North Sea installing wind turbines and may need to voyage around Cape Horn to reach California. (They don't fit through the Panama Canal.) So, it's economic to share the huge cost of renting and shipping an HLV over several platforms to be decommissioned as a group.

As a result, the model needed to analyze strategies with decisions for all 27 platforms. Figure 7 shows PLATFORM's recommended options, complete or partial removal, from the most shallow, Platform Esther, down to the deepest, Platform Harmony. As we increase the swing weight on strict compliance from 0 to 100, the number of platforms for which it prefers complete removal increases from zero to all 27.

Recommendations and Outcomes

After seeing the team's 263-page report to California Ocean Science Trust ([6] Bernstein et al. 2010), one stakeholder asked if we could provide a single-slide summary of our recommendations – a good idea for any decision analysis! Figure 8 is a refined version of the summary page. It identifies the two primary decision options, complete removal and partial removal ("rigs to reefs"), and summarizes the most salient differences between them. Most stakeholders tended to support the "rigs to reefs" option once it became clear that it could both reduce environmental impacts, preserving much of the rich marine life around the platforms, and save more than half a billion dollars if applied to all 27 platforms.

The partial removal option may be sweetened further for environmental advocates (bottom of Figure 8) by splitting the savings between the platform operators and 55+ percent going to an ocean conservation fund to be administered by the California Department of Natural Resources.

Some stakeholders, including an oil company and the Sportfishing Conservancy, ran PLATFORM directly to explore assumptions and scenarios. Others examined and discussed results in a series of workshops with stakeholders and the public. Skyli McAfee, executive director of the California OST, the direct client for the project, said, "By clearly identifying the issues, synthesizing the best multi-disciplinary science, daylighting the uncertainty and providing for unbiased review, the tool created by Bernstein et al. was successful in distilling the rhetoric to meaningful discussion of tradeoffs and values."

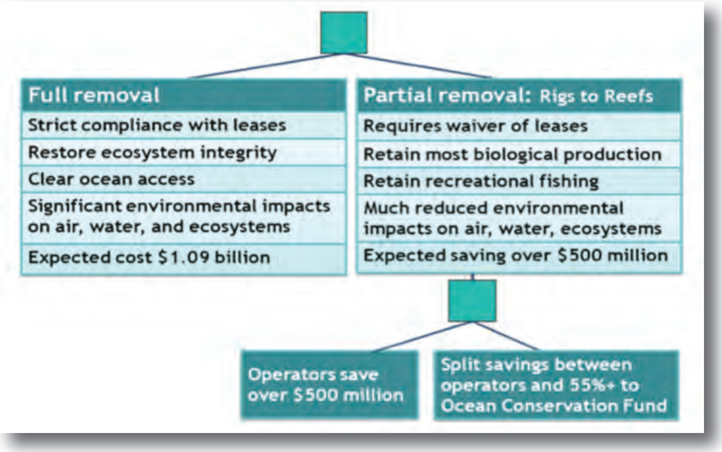

Figure 8: Single slide summary of the decommissioning decision.

The findings contributed to ongoing policy discussions in California, as well as legislation to waive the lease requirement for complete removal and transfer ownership of the artificial reefs to the state of California. [It proposed putting 55 percent of savings from partial removal to an ocean conservation fund until 2017 and higher percentage thereafter to incentivize earlier action on decommissioning.] The resulting bill, AB 2503, was adopted by the California legislature almost unanimously and signed into law by then-Gov. Arnold Schwarzenegger in September 2010. Decommissioning on the first platforms is expected to start in the next year. ORMS

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The PLATFORM decision model, and a free version of Analytica to run it, are available for download from http://www.lumina.com/case-studies/a-win-win-solution-for-californias-offshore-oil-rigs/

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