Arnold Schwarzenegger
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# BIOMASS TO ENERGY:

# FOREST MANAGEMENT FOR WILDFIRE REDUCTION, ENERGY PRODUCTION, AND OTHER BENEFITS

# APPENDIX 11

PIER FINAL PROJECT REPORT

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# APPENDIX 11: Synthesis of Economic Valuation Studies of Forest Landscape Disturbances

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**Notice of Change in Scenario Naming Conventions**

Key assumptions, modeling structures and terminology were altered and refined to accommodate new thinking during the course of this study. The reader will observe in the appendices that the scenarios are referred to as "Scenarios 1, 2 and 3" or "S1, S2 and S3."

In both the main text of the Final Report and in the Life Cycle Assessment appendix (Appendix 4), the former Scenario 1 (S1) was renamed to the "Reference Case." Scenario 3 (S3) has been renamed the "Test Scenario." Scenario 2 (S2), focused on the relative contributions and impact of Industrial Private Forestry (IPF) has been eliminated from most of the analyses that make up the entire study. These changes better reflect the focus of the study, which is fundamentally about the landscape level changes in wildfire, habitat, and other dynamics. The modification of terminology do not substantively affect the findings or recommendations of the study.

## 2. Introduction

The Biomass to Energy (B2E) Project is developing a comprehensive forest biomass-to-electricity model to identify and analyze the economic and environmental costs and benefits of using forest biomass to generate electricity while changing fire behavior at the landscape level. The landscape level analysis allows an assessment of how forest remediation treatments (which generate material for electricity production) affect vegetation and fire behavior. Landscape scale changes in vegetation and fire behavior ultimately determine many of the benefits associated with forest-based biomass power and the costs associated with achieving these benefits.

The objectives of this white paper are to review the relevant literature on economic valuation studies of forest landscape disturbances and to compile information pertinent to constructing and performing the economic analysis model for the B2E project. Specific attention is focused on the following six research issues:

- Application typology or purpose of the analysis
- Analytical framework used to present the results of the analysis
- Breadth of coverage for the valuation of resources at risk
- Extent of spatial and temporal considerations

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- Consistency of application of benefit transfer techniques with established protocols
- Evaluation of baseline economic values and of changes to baseline conditions

The first section of this white paper reviews the relevant literature with special attention given to the research issues listed above. The second section summarizes the literature review and the third discusses anticipated challenges for the economic analysis model for the B2E project.

**Literature Review**

The literatures on fire and natural resource valuation are vast and therefore this review examines only a subset of the work that is potentially relevant for the B2E project. Studies of particular interest are those that estimate the value of resources at risk to wildland fire, the costs of fire and fire prevention efforts (forest remediation treatments), and the effects of fire and treatment efforts on resource values and fire risk.

A list of candidate studies for this review was developed by various experts who are familiar with the B2E project and the goals for the economic analysis model. A total of 25 studies were drawn from peer-reviewed journal articles, non-peer reviewed technical reports by public agencies and private consultants, and working papers that are likely to be published eventually in either of these outlets. The studies reviewed are listed below.


1. Ager, A., M. Finney and A. McMahan. 2006. "A Wildfire Modeling System for Evaluating Landscape Fuel Treatments Strategies." Working paper, USDA Forest Service Pacific Northwest Research Station, La Grande, OR.
2. California Department of Forestry and Fire Protection. 1995. California Fire Plan.
3. Calkin, D., K. Hyde, K. Gebert and G. Jones. 2005. "Comparing Resource Values at Risk from Wildfires with Forest Service Fire Suppression Expenditures: Examples form 2003 Western Montana Wildfire Season." USDA Forest Service Rocky Mountain Research Station Research Note RMRS-RN-24WWW.
4. Dunn, A.E., A. Gonzalez-Caban and K. Solari. 2005. "The Old, Grand Prix, and Padua Wildfires: How much did these Fires *Really* Cost?" Report by the USDA Forest Service Pacific Southwest Research Station, Riverside, CA.
5. Englin, J., 1997. "Review of the existing scientific literature on the effects of fire on recreation use and benefits." USDA Forest Service Report, Riverside, CA.
6. Englin, J., J. Loomis and A. Gonzalez-Caban, 2001. "The dynamic path of recreation values following a forest fire: a comparative analysis of states in the Intermountain West." *Canadian Journal of Forest Research* 31:1837-1844.
7. Gonzalez-Caban, A., and J. Loomis, 1997. "Reducing Fire Risk to California Spotted Owl and Northern Spotted Owl Habitat in Oregon: How Much Would You Pay?" Proceedings of the *Fire Effects on Rare and Endangered Species and Habitat Conference*, Nov. 13-16, Coeur d' Alene, ID.
8. Hesseln, H., J. Loomis, A. Gonzalez-Caban and S. Alexander, 2003. "Wildfire effects on hiking and biking demand in New Mexico: a travel cost study." *Journal of Environmental Management* 69:359-368.
9. Hesseln, H., J. Loomis, and A. Gonzalez-Caban, 2004. "The Effects of Fire on Recreation Demand in Montana." *Western Journal of Applied Forestry* 19(1): 47-53.

10. Hummel, S., and D.E. Calkin. 2005. "Costs of landscape silviculture for fire and habitat management." *Forest Ecology and Management* 207:385-404.

11. Loomis, J., A. Gonzalez-Caban and J. Englin, 2001. "Testing for Differential Effects of Forest Fires on Hiking and Mountain Biking Demand and Benefits." *Journal of Agricultural and Resource Economics* 26(2): 508-522.

12. Loomis, J., A. Gonzalez-Caban and R. Gregory, 1994. "Do Reminders of Substitutes and Budget Constraints Influence Contingent Valuation Estimates?" *Land Economics* 70(4): 499-506.

13. Loomis, J., H.T. Le and A. Gonzalez-Caban, 2005. "Testing transferability of willingness to pay for forest fire prevention among three states of California, Florida and Montana." *Journal of Forest Economics* 11:125-140.

14. Loomis, J., P. Wohlgemuth, A. Gonzalez-Caban, and D. English, 2003. "Economic benefits of reducing fire-related sediment in southwestern fire-prone ecosystems." *Water Resources Research* 39(9): 1260-1267.

15. Lynch, D.L. 2004. "What Do Forest Fires Really Cost?" *Journal of Forestry.*

16. MacGregor, D.G., 2003. "Accounting for Wildland Fire Costs in Wildland Fire Situation Analysis (WFSA) – Prospects and Problems." Report to the National Academy of Public Administration, Washington, DC.

17. Marose, R. 2005. "Analysis of Assets at Risk for the CDF Fire Plan Fire and Resource Assessment Program." Working paper, California Department of Forestry and Fire Protection.

18. Mason, C.L., B.R. Lippke, K.W. Zobrist, T.D. Bloxton Jr., K.R. Ceder, J.M. Comnick, J.B. McCarter and H.K. Rogers. 2006. "Investments in Fuel Removals to Avoid Forest Fires Result in Substantial Benefits." *Journal of Forestry* 104(1): 27-31.

19. Mason, C.L., K. Ceder, H. Rogers, T. Bloxton, J. Comnick, B. Lippke, J. McCarter and K. Zobrist. 2003. "Investigation of Alternative Strategies for Design, Layout and Administration of Fuel Removal Projects." Report by the Rural Technology Initiative, University of Washington, Seattle, WA.

20. Morton, D.C., M.E. Roessing, A.E. Camp and M.L. Tyrrell. 2003. "Assessing the Environmental, Social and Economic Impacts of Wildfire." Global Institute of Sustainable Forestry Research Paper 001, Yale University, New Haven, CT.

21. Rapp, V. 2004. "Reducing Fire Hazard: Balancing Costs and Outcomes." *Science Update* report by the USDA Forest Service Pacific Northwest Research Station.

22. Sullivan, J., P. Omi, A. Dyer and A. Gonzalez-Caban, 1987. "Evaluating the Economic Efficiency of Wildfire Rehabilitation Treatments." *Western Journal of Applied Forestry* 2(2): 58-61.

23. TSS Consultants. 2005. "Assessment of the Efficacy of the California Bureau of Land Management Community Assistance and Hazardous Fuels Program." Report prepared for the California Bureau of Land Management.

24. Wilson, M. and A. Troy, 2005. "Accounting for Ecosystem Service Values in a Spatially Explicit Format: Value Transfer and Geographic Information Systems." Paper presented at the *International Workshop on Benefits Transfer and Valuation Databases*, Washington, DC.

25. Youngblood, A., K.L. Metlen, E.E. Knapp, K.W. Outcalt, S.L. Stephens, T.A. Waldrop and D. Yaussy. 2005. "Implementation of the Fire and Fire Surrogate Study – A National Research Effort to Evaluate the Consequences of Fuel Reduction Treatments." Report by the USDA Forest Service Pacific Northwest Research Station, La Grande, OR.

These studies have varying degrees of relevance for the B2E project and therefore not all of them are discussed in this literature review. The studies that merit discussion are organized here into three categories: (1) estimation of forest benefits and landscape treatment costs and effects;[2] (2) suppression cost and damage accounting for specific fires; (3) estimation of changes in specific benefit flows due to fire.

***Estimation of forest benefits and landscape treatment costs and effects***

► *California Department of Forestry and Fire Protection [2].* The California Fire Plan is primarily a planning document. The purpose of the analysis is to improve wildland management in order to reduce the economic impact of fire. The most relevant parts of the Fire Plan for the B2E project are Chapter 4 and Appendix C which focus on valuation of forest assets that are at risk to wildfire. Although the analytical framework used here is simply asset valuation, the Plan suggests that remediation projects should be selected based on a benefit-cost analysis which the asset valuation results presumably would inform (p.102). And because asset valuation is the primary concern, baseline value estimates are not compared with any post-treatment estimates to establish the economic effects of potential remediation strategies.

Asset valuation in the Fire Plan is both broad and detailed in terms of its coverage. Most value estimates take the form of expected damages due to fire (expressed as $/acre), which can be interpreted as forgone benefits. Other values are only discussed qualitatively. Resources at risk include: human health and safety, air quality, rangeland, recreation, structures (housing), timber, water and watersheds, wildlife habitat and ecosystem health, cultural and historic resources, and unique scenic areas. Quantitative values are calculated for all categories except human life, wildlife habitat and ecosystem health, cultural and historic resources, and unique scenic areas.

The analysis incorporates spatial considerations by utilizing GIS data and allowing value estimates to differ based on location. However, the level of spatial disaggregation is rather coarse and differs across resources. For example, recreation and structure values are averaged across the state; air quality values are specific to air basins and fuel types; rangeland values are specific to regions within the state, land cover types, and land ownership classes. The Fire Plan states that finer spatial disaggregation should be provided by individual ranger units at a later stage of the planning process (p.99).

Temporal considerations are acknowledged and incorporated into some value estimates (e.g., timber, water) but not others (e.g., recreation). Overall, temporal considerations receive much less attention than spatial considerations and therefore asset values are expressed as constant per-acre flows rather than as functions of time.

The Fire Plan carefully documents the sources used to establish asset values and it is clear that value estimates have been borrowed from many different sources. But it is unclear whether

[2] Some studies in this group estimate only forest benefits, some examine benefits and treatment costs but not treatment effects, while others focus only on treatment costs and effects.

appropriate benefit transfer techniques were used when warranted.[3] There is little discussion of whether values were simply transferred from the study site to the policy site without accounting for differences between sites and local populations (sometimes called "fixed value transfer"), or if efforts were undertaken to account for such differences (sometimes called "value function transfer"). Given the lack of discussion, it appears that appropriate use of benefit transfer techniques was not a primary concern for the analysis.

Aside from questions about benefit transfer techniques, one estimate that is particularly problematic is the "pollution rights" component of the air quality value. The Fire Plan estimates the impact of wildfire on air quality benefits by breaking it down into components: visibility, human health, vegetation, global warming, and pollution rights. The first four are legitimate damages – social losses – caused by wildfire that should be evaluated and aggregated. But the pollution rights component should not be included in the damage assessment. The Fire Plan defines this "value" as the market value of wildfire emissions if they were traded in local air pollution markets (i.e., price multiplied by quantity). Adding this "value" to the damages would be akin to calculating the average willingness to pay (WTP) for a good, adding the market price to this WTP, and labeling the sum as the "value" of the good. This calculation actually over-states the value because it double-counts at least a portion of the real benefits (damages) generated by the good (pollution). Therefore air quality damages from wildfire could be evaluated *either* by aggregating social losses *or* by using a price surrogate but *not* by adding these quantities together.[4]

► *Marose [17].* The working paper by Marose is very similar to [2]. This paper contains updates to [2] that were made in 2005. The purpose of the analysis again is for planning but at a more local level. Marose presents an example of the "unit validation process" that follows the relatively coarse statewide analysis and that is intended to verify that analysis and ensure the accuracy of the GIS data layers at specific locations. Interestingly, the analytical framework used here moves away from the quantitative asset valuation used in [2] and instead implements qualitative valuation (i.e., indices and rankings rather than values). As in [2], baseline valuations are not compared with any post-treatment estimates to establish the economic effects of potential remediation strategies.

The asset valuation, although qualitative, is broader and more detailed in terms of its coverage than in [2]. Valuation is expanded to include infrastructure (instead of just housing structures), scenic areas, and ecosystem health. Valuation criteria for cultural and historic resources also are developed but not implemented due to lack of data. Most of this additional detail comes from the use of county-level GIS data which was not used in [2], thereby increasing the spatial detail of the analysis while reducing the spatial extent.

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[3] Although resource economists have been calling for a benefit transfer protocol – along the lines of the NOAA panel recommendations for contingent valuation studies – to be established for quite some time (Smith 1992), a consensus has not yet emerged. Therefore the term "appropriate benefit transfer techniques" is not well-defined. Freeman (2003, pp.453-456) provides a recent discussion of the relevant issues.

[4] However, a similar analysis could be used to determine the value to the currently regulated sources of increasing the emissions cap to include new and presumably low-cost sources (i.e., high risk forest land). This suggests a possible funding source for remediation treatments: if local air pollution markets were to bring high risk forest land under the cap and grant new permits, then existing high-cost industrial sources could purchase the permits (according to a trading ratio that accounts for the uncertain nature of forest fire emissions) and the revenue generated from the permit sales could be used to finance remediation treatments.

Issues related to temporal considerations and benefits transfer are the same as in [2].

► *Mason et al. [19].* The report by Mason et al. is also intended to be used for planning, but it goes well beyond a baseline evaluation of resources at risk. The main purpose of the report is to evaluate fuel reduction treatments in a benefit-cost analysis framework. To this end, the authors estimate the costs and simulate the effects of different treatment options for two sample forests (Fremont and Okanogan) in order to provide a comparison of baseline and post-treatment values.[5]

The report utilizes several existing simulation modules including the Landscape Management System (University of Washington and US Forest Service), the Forest Vegetation Simulator and the Fire and Fuels Extension (both US Forest Service). Forest growth following one of four thinning treatments, a no-treatment option, or a crown fire is simulated over a thirty year period, thereby incorporating temporal considerations to a much greater extent than in the previous two papers. Simulations for all scenarios are modeled with and without understory regeneration to mimic the effects of prescribed burns or other fuel removal treatments that might or might not occur during the thirty year period. This produces a total of twelve different simulations for each forest. Simulation results (treatment effects) are expressed in three ways: first, as a qualitative change in fire risk (e.g., from high to moderate); second, as a quantitative change in forest resource values (expressed as $/acre); and third, as qualitative changes in other forest benefits.

Coverage of resources at risk and related benefits/costs is broad. Treatment benefits include: biomass yield, foregone firefighting costs, reduced facilities losses, reduced fatalities, timber amenities (presumably recreation and scenic value), wildlife habitat, community value of fire risk reduction, carbon credits, green energy credits, electrical transmission cost reductions, foregone regeneration and rehabilitation costs, water quantity and quality, and regional economic benefits. Quantitative values are estimated for each of these except habitat, green energy credits, and electrical transmission cost reductions. Treatment costs include: out-of-pocket expenses, contracting costs, soil compaction, sedimentation, and wildlife habitat impacts. Quantitative values are estimated for each of these except soil compaction, sedimentation and habitat.

The analysis utilizes GIS data and appears to contain roughly the same level of spatial detail as in [17]. For example, the authors demonstrate that a uniform treatment strategy may produce net losses for some stands and net gains for others, implying that treatments might be spatially customized for improved efficiency.

As in [2] and [17], the authors have borrowed quantitative value estimates from several different sources that are documented and discussed in the report. Although the authors do not seem particularly concerned with ensuring that proper benefit transfer techniques are used, there is some evidence that they make a somewhat larger effort than in [2] or [17]. The authors appear inclined to use conservative estimates when faced with uncertainty.

Aside from these issues, there are again some questionable values used in the analysis. The "community value of fire reduction" relies on a stated preference survey designed to elicit WTP for "protection from wildland fire." (p.58) Including this value introduces the potential for double-counting some of the other values such as facilities/structures and timber amenities. The "green energy credit" (although not valued quantitatively) refers to producer WTP for non-fossil fuel

[5] Mason et al. [18] is very similar to [19] and therefore is not discussed here. However, [18] is much shorter and therefore more accessible to interested readers than [19].

production capacity in order to meet emission cap requirements, but it omits consumer WTP for cleaner energy. Studies have been conducted to assess this consumer WTP and could be included here. And the "regional economic benefits" estimated in this analysis are limited to changes in state and local tax receipts, which seems to be an overly conservative estimate and – depending on the scope of the analysis – might be considered a distributional effect that should not be counted as a welfare change.

► *TSS Consultants [23].* The report by TSS Consultants implements a GIS-based model (the "NaturalAssets" information system developed by Spatial Informatics Group) for valuing ecosystem services across large heterogeneous landscapes. The main purpose of the report is asset valuation, but the authors also present some very rough economic assessments of remediation treatments in two study areas (Petrolia, CA and Morongo Valley, CA) to demonstrate how the asset layer could be used in a benefit-cost analysis framework.

The coverage of assets valued is quite broad in terms of non-market values. A total of 12 ecosystem services are valued: gas and climate regulation, disturbance (storms, floods) prevention, water regulation, water supply, soil retention and formation, nutrient regulation, waste treatment, pollination, biological control (of pests and diseases), habitat refugium, aesthetic and recreational, and cultural and spiritual. Conversely, the value of structures is the only market value included in the report.

The asset valuation approach is very spatially explicit. The services mentioned above are valued for a total of 19 different land cover types including agriculture, forests, estuaries, wetlands, species habitat, urban green space, open fresh water, and others. However, temporal considerations (i.e., changes to value flows through time) are not a focus of the report.

The report relies heavily on benefit transfer (the purpose of the NaturalAssets database is to provide access to valuation results for use in benefit transfer), but there is little discussion of how values are transferred. It appears that fixed value transfer is used after the database has been searched to determine the "most similar" available values.

Although the report presents two case studies of benefit-cost analyses for remediation treatments, these studies do not provide baseline versus post-treatment value comparisons as in [19]. Rather, they simply compare the total landscape value of the study area against an estimate of a hypothetical treatment cost without accounting for the probability of fire or the change in benefit flows due to treatment.

► *Other studies.* The article by Loomis et al. [14] focuses on sediment cost savings and avoided recreation losses from prescribed burning. The authors estimate a watershed sediment generating function using multiple regression analysis and then calculate the cost savings (due to avoided debris basin clean-outs) associated with reducing the fire interval from 22 years to 10 or 5 years (to simulate prescribed burning). Outcomes are compared in a benefit-cost framework but the scope is limited to budgetary costs for debris removal (to protect the water supply) and recreation losses due to fire-induced forest closure. Fixed value transfer is used to incorporate recreation values into the assessment. Spatial and temporal considerations are minimal, aside from an adjustment made to recreation use following prescribed burns.

The paper by Ager et al. [1] ties together a number of existing simulation modules (e.g., Forest Vegetation Simulator, Parallel Processing Extension, FlamMap, RANDIG) to examine the effects of 12 different remediation treatments on fire risk and expected economic losses. The model utilizes GIS data for an area near Mt. Emily, OR to calculate burn probabilities associated

with the different treatments, and then combines these probabilities with hypothetical value schemes and loss functions (based on predicted flame length) to generate expected losses. Costs of fire suppression and fuels treatment are not considered.

The article by Hummel and Calkin [10] uses a GIS database and the Forest Vegetation Simulator to determine the effects of thinning treatments on both fire threat and owl habitat over a thirty year period in Washington's Gotchen Reserve. Optimal treatments are derived that maximize fire risk reduction given different financial objectives. Treatment costs and revenues are incorporated in a benefit-cost framework, but habitat value is not estimated. Rather, a functional relationship is derived for the trade-off between fire threat reduction and habitat provision. Actual effects of fire are not examined.

The report by Rapp [21] presents FIA BioSum, a computer model that can be used to assess the effect of various remediation treatments on fire hazard risk at the landscape scale. It can also calculate the market revenues and implementation costs associated with various treatments, but it does not account for non-market values.

The paper by Wilson and Troy [24] implements the same GIS-based model used in [23], but this application is even more focused on ecosystem service valuation. Recreation and structures are not valued and there is no mention of wildfire. Benefit transfer techniques are not discussed.

Lastly, the report by MacGregor [16] describes a framework for incorporating landscape values into the Wild Fire Situation Analysis (WFSA) process, but as a whole the other papers reviewed here are more comprehensive and informative.

***Suppression cost and damage accounting for specific fires***

► *Dunn et al. [4].* The purpose of the report by Dunn et al. is to demonstrate the true cost of a major wildfire (i.e., damage assessment) and to improve fire planning by encouraging a reassessment of anticipated future fire suppression costs. The authors focus on the out-of-pocket expenses incurred during the Old, Grand Prix and Padua fire complex. They acknowledge but do not examine non-market benefits and costs. Therefore the analytical framework is simple cost accounting and the coverage of this study is much more limited than those discussed in the previous section of this white paper. In fact, only three value categories are monetized: suppression and emergency response expenditures, post-fire recovery and water quality mitigation cost, and insurance claims and disaster relief. However, values are reported for several public, private and non-profit entities to demonstrate the reach of fire impacts across agencies. Other categories are discussed but not quantified: wildfire induced sediment loads, watershed rehabilitation, infrastructure protection, impacts on transportation and businesses due to closures, lost recreation values, and lost ecosystem services. Spatial and temporal considerations are not prominent, although the authors do emphasize that some costs are incurred far away from the fire and most expenses occur after a fire but typically are not quantified. Issues related to benefit transfer and baseline versus post-treatment value comparisons are not relevant for this study.

► *Lynch [15].* Similar to [4], the purpose of the article by Lynch is to demonstrate the true cost of catastrophic wildfire in order to improve fire planning. Therefore the analytical framework again is simple cost accounting. Several case studies of Colorado wildfires are presented with varying levels of coverage. The fires with relatively broader coverage (Bobcat Gulch and Hayman) include: suppression costs, structural damage, emergency response and disaster

relief, tourism losses, rehabilitation (erosion prevention, tree planting), water quality, water supply (sediment removal), timber losses, damage to electric transmission facilities, damages to roads, tax losses, business losses, and flood damage to structures. Costs for the Hayman fire also include fatalities, lost recreation value and lost habitat value. Other costs are acknowledged but not valued. Spatial and temporal considerations are similar to [4]. Benefit transfer is used primitively, with values borrowed directly from several fire-related non-market valuation studies (i.e., fixed value transfer). A pseudo baseline versus treatment comparison is made by comparing the per-acre costs for the large fires against a similar calculation for a fire that occurred in an area marked by a relatively natural fire cycle (Doe Canyon). This gives a rough estimate of the benefit associated with returning landscapes to more natural fire regimes.

► *Other studies.* The article by Calkin et al. [13] assesses the economic efficiency of wildfire suppression efforts by comparing the suppression costs for two fires (Black Mountain and Crazy Horse) with the likely burn areas and associated losses if suppression efforts had not been undertaken. Because the likely burn area is difficult to determine, the authors use break-even analysis; that is, they expand the fire perimeter until the total damage (lost market value) equals the suppression cost incurred. If the required expansion is large, then the economic efficiency is judged to be low; and vice versa.

### *Estimation of changes in specific benefit flows due to fire*

► *Articles co-authored by Loomis [6, 8, 9, 11].* The purpose of each of these four articles is to examine the impact of fire on wilderness recreation trips and benefits. In each case the analytical framework used is a count data travel cost model based on a primary data collection effort. The breadth of coverage is limited to recreation value: hiking in article [6] and hiking and biking in articles [8, 9, 11]. As a group, the studies allow a spatial comparison of fire effects across five states: Colorado, Wyoming, Idaho, New Mexico and Montana. Each study examines the effect of fire age on behavior and therefore each has a temporal component. Each study also compares the effects of intense crown fires with light prescribed burns, thus providing a rough comparison of baseline and post-treatment values. Although benefit transfer is not relevant for these articles, there is some discussion of how the estimated benefits might be transferred to other sites.

## Summary of Literature Review

In terms of the six research issues examined by this white paper, the preceding literature review may be summarized as follows.

- *Application typology or purpose of the analysis*. Most of the relevant literature is focused either on planning or damage assessment in order to improve policy decisions.
- *Analytical framework used to present the results of the analysis*. Most studies are motivated by the notions of benefit-cost or cost-effectiveness analysis, even if a formal analysis is not undertaken. Regional impacts typically are not accounted for, and none of the studies accounts for regional impacts with an equilibrium analysis (e.g., IMPLAN).
- *Breadth of coverage for the valuation of resources at risk*. The most commonly included non-market values are related to recreation, water, and habitat. The most commonly included market values are related to timber, structures, suppression costs and rehabilitation. Other values frequently are considered qualitatively. The issue of achieving appropriate breadth of coverage is addressed in the last section of this paper.

- *Extent of spatial and temporal considerations*. Most studies incorporate GIS data to some extent, but the level of spatial disaggregation is quite variable. The dynamic nature of forest recovery following wildfire is usually addressed but not modeled explicitly.
- *Consistency of application of benefit transfer techniques with established protocol*. Very little information is offered regarding the benefit transfer techniques used in these studies. It appears that most studies rely on very basic value transfer methods with little (if any) effort to modify the original estimates. However, as mentioned in footnote 3, there is not yet a commonly accepted protocol for benefits transfer. The issue of practicing defensible benefit transfer is discussed in the last section of this paper.
- *Evaluation of baseline economic values and of changes to baseline conditions*. Very few studies examine changes to baseline conditions. Mason et al. [19] is an exception. Loomis et al. [14] and Hummel and Calkin [10] present partial analyses. Ager et al. [1] relies on hypothetical values and treatment-response functions. The issue of obtaining adequate fire- and treatment-response functions is discussed in the last section of this paper.

From an economic standpoint, much has been accomplished with regard to valuing forest landscape disturbances but there is still room for improvement. The most spatially explicit studies with the broadest coverage tend to focus primarily on asset valuation without considering the effects of fire or remediation treatments on those values. Conversely, studies that focus on the effects of fire or remediation treatments tend to be less spatially explicit and have narrower coverage. Generally, valuation could be improved by a greater effort to practice "proper" benefit transfer, to replace qualitative discussions of uncertain values with conservative numerical estimates wherever possible, and to address the endogenous nature of landscape values. Overall, the literature contains relatively few estimates of whether fuels treatments are economically justified based on a broad accounting of both market and non-market forest resource values.

## Discussion of Anticipated Challenges

In light of these findings, it is apparent that any effort to value the resources at risk to wildland fire and/or the impact of fire or remediation treatments on wilderness resource values will face several challenges. The conclusions drawn by this white paper suggest three key issues that must be addressed.[6]

### *Lack of a benefit transfer protocol*

Barring what would be a very expensive and time-consuming effort to conduct a primary non-market valuation study for a large heterogeneous landscape, any attempt to value forest landscape disturbances will have to rely on benefit transfer. However, to date there is not a commonly accepted and practical set of standards for "proper" benefit transfer. Boyle and Bergstrom (1992) proposed the following idealistic set of criteria: 1) the non-market commodity valued at the study site must be identical to the non-market commodity to be valued at the policy site; 2) the populations affected by the non-market commodity at the study site and the policy site have identical characteristics; and 3) the assignment of property rights at both sites must lead to the same theoretically appropriate welfare measure (i.e., WTP or WTA compensation).

[6] This is not intended to be an exhaustive discussion of anticipated challenges. Clearly other challenges exist, but the issues discussed here are the most relevant to the objectives of this white paper.

In practice, judgments must be made. Most economists would agree that there must be some consideration of the differences in the resources being valued, the affected populations, the nature of the damages, and the availability of substitutes (Bingham 1993; Freeman 2003, p.454). The issue of how the values from a benefit transfer are to be used (i.e., the type of decision being made) also should be a factor. The B2E project should rationalize and document its efforts to implement a defensible set of forest resource values.

*Missing values*

It is possible and even likely that the available literature will not be able to provide transferable estimates for all values of concern. This is particularly likely for unique resources in the study area. In these cases, primary valuation studies would need to be conducted to "fill in the gaps" left by the benefit transfers.

Alternatively, if reliable estimates of some values cannot be obtained, then "break-even" analysis can be used to determine what those values would have to be in order to achieve some desired ratio of benefits to costs or some desired level of cost-effectiveness. Then a judgment then can be made regarding the magnitude of the estimated value and the likelihood that the desired criterion will be met. This type of analysis is conducted by Alaouze (2004) in the context of determining the optimal rotation for the Mountain Ash forests in Central Victoria, Australia. Rather than estimating landscape values, the author determines the minimum "conservation value" – defined as the annual flow of non-market goods and services – that would be required to make the net benefit of forest conservation greater than the net benefit of harvesting.

*Lack of well-defined response functions*

In order to quantify the effects of forest landscape disturbances, it is necessary to estimate how fire risk and forest benefit streams are affected by fire and remediation treatments. Unfortunately, such "response functions" typically are not readily available in the literature. There are some exceptions. Mason et al. [19] estimates changes in a qualitative measure of fire risk and in quantitative measures of benefit streams for various treatments. The articles co-authored by Loomis [6,8,9,11] estimate the effect of fire on recreation behavior and welfare, but they also demonstrate somewhat conflicting results and thus fail to establish a common pattern. Of the remaining articles reviewed in this white paper:

- Loomis et al. [14] calculates a fire-induced watershed sediment response function.
- Hummel and Calkin [10] estimate a functional relationship between treatment-induced fire threat reduction and habitat provision.
- Rapp [21] presents a model that assesses the effect of various remediation treatments on fire hazard risk and calculates the associated net market benefit.
- Ager et al. [1] use hypothetical values and loss functions that are based on calculated flame length.

The work by Mason et al. [19] is probably the most relevant for (and transferable to) the B2E project. The watershed sediment response function in Loomis et al. [14] also seems very useful. The results derived by Loomis and others [6,8,9,11] provide a basis for hypothesizing a generic recreation response function, but the exact nature of this function would be debatable. The relationship between fire risk and habitat in Hummel and Calkin [10] is potentially useful, but it relies in a single measure of forest structure to represent "habitat" which may not be

suitable for all species of concern. The article by Rapp [21] provides relatively little detail about the underlying model, but notably it does not consider non-market values. Lastly, Ager et al. [1] use hypothetical values and loss functions, but this approach may be useful for conducting sensitivity analyses when empirically derived relationships are not available.

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