Appendix V

Assessment of Costs and Environmental Benefits

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Cost-benefit assessment for selected recommendations

Sangwon Suh
Dept. Bioproducts and Biosystems Engineering
University of Minnesota

Laura Schmitt Olabisi
Ecosystem Science and Sustainability Initiative
University of Minnesota

Kris Johnson
Ecosystem Science and Sustainability Initiative
University of Minnesota

Haochi Zheng
Dept. Applied Economics
University of Minnesota

With comments and advice from:

Steven J. Taff
Dept. Applied Economics
University of Minnesota

Stephen Polasky
Dept. Applied Economics
University of Minnesota

Introduction

An assessment of costs and benefits is an important part of policy development and implementation. Some of the costs and benefits of the recommendations presented in the Minnesota Statewide Conservation and Preservation Plan (SCPP) are fairly readily quantified—for example, the cost of a specified subsidy for electric vehicles. Many of the recommendations in this report do not lend themselves easily to a quantification of costs and benefits. What price tag do we attach to the runoff-cleansing capabilities of a wetland? How much do we gain when we save a woodpecker's nesting site, or a place to spend a day outdoors? What is the value of a bike trail or a brook trout? Nevertheless, a sincere attempt to identify, estimate, and compare costs and benefits can provide a general sense of the relative merit of alternative choices, create valuable context for decisions, and offer an indication of how we can best configure resulting policies to maximize benefits and minimize costs.

This report presents the results of cost-benefit assessment of selected SCPP recommendations. Because of time and funding constraints, the assessment was limited to seven recommendations and based on values obtained from other studies carried out previously around the United States rather than conducting original research to quantify costs and benefits. The following recommendations were chosen based on the advice of the habitat, land use, and energy team leaders and on the quantifiable nature of the parameters involved:

- ***Habitat Recommendation 2a:*** Acquire high-priority shorelands
- ***Habitat Recommendation 5:*** Restore land, wetlands, and wetland-associated watersheds
- ***Land Use Recommendation 8:*** Protect large blocks of forested land
- ***Energy Recommendation 3:*** Invest in perennial biofuel and energy crop research and demonstration projects on a landscape scale *and* ***Land Use Recommendation 4:*** As much as possible, transition renewable fuel feedstocks to perennial crops
- ***Energy Recommendation 4:*** Develop policies and incentives to encourage perennial crop production for biofuels in critical environmental areas
- ***Energy Recommendation 16:*** Provide incentives to transition a portion of Minnesota's vehicle fleet to electrical power, while simultaneously increasing renewable electricity production for transportation

The following process was used to assess costs and benefits for each of the selected recommendations:

1. ***Brainstorming:*** The team held brainstorming sessions with the resource teams that generated the recommendation to identify key costs and benefits of implementing the recommendation.

2. ***Survey:*** Cost benefit analysis team members surveyed habitat, energy, and land use team members to gather information on various aspects of each cost or benefit item, including its geographical and temporal scales. Habitat, energy, and land use team members were given the opportunity to rank costs and benefits according to their expert knowledge.

3. ***Literature Review:*** Cost benefit analysis team members reviewed relevant scientific papers and reports to estimate the potential magnitude of costs and benefits of the recommendation.

Because the analyses are based on scientific studies of similar but not identical settings and involve the application of approximation and informed judgment, the results are presented as ranges and estimates. The findings understandably should not be used as hard-and-fast indicators of the economic merits of individual recommendations. They are, however, useful for:

- Identifying costs and benefits of the recommendation
- Indicating the likely order of magnitude of the costs and benefits
- Providing ideas for how implementation might be fine-tuned to maximize benefits and minimize costs

This report is organized as follows:

- The recommendation under study is shown in bold font.
- Key benefits and costs are listed and elaborated upon in the context of relevant literature to yield a best-approximation range of values for each.
- Key benefits and costs are summarized in a table.
- Summary figures are based on a five-year period unless otherwise noted. All prices are adjusted to 2008 price unless otherwise noted.

Acquire High-Priority Shorelands

Habitat Recommendation 2a: Acquire high-priority shorelands

Natural shorelands provide multiple benefits, including recreation opportunity, public access to water, protection of wildlife species, and reduction of nutrient and solid loading into surface waters. Minnesota's water legacy features 5,508 miles of cold-water stream shoreland and more than 64,000 miles of lake and warm-water stream shorelands. Currently 46% of cold-water stream shoreland and 34% lake and warm-water stream shorelands are under public ownership. The Aquatic Management Area (AMA) acquisition planning committee recently published a report outlining the need to increase public ownership of cold-water stream shoreland to 72% and that of lake and warm-water stream shorelands to 39% by 2032 (AMA 2007). This analysis follows the plan outlined by the AMA report.

General conclusions we can draw from this analysis include:

1. Wildlife benefits are difficult to quantify but expected to be significant.
2. Recreation-related benefits and water quality–related benefits are estimated to be significant and likely larger than the numbers we use here.
3. Site selection is important to the overall cost-effectiveness of the recommendation.

Key Benefits

Acquisition of critical shorelands in Minnesota is expected to realize the following benefits:

1. Provision of recreation-related industrial production
2. Fishing- and wildlife watching–related tax revenue
3. Benefits through hunting opportunities
4. Benefits through additional public access to water bodies
5. Additional education opportunities from publicly accessible shoreland
6. Protection of species of greatest conservation need, such as common loon, black tern, and Blanding's turtle
7. Reduction of nutrient and solid loading into surface water
8. Protection of habitat for fish and wetland-dependent species, such as waterfowl and wild rice

1. Provision of recreation-related industrial production

The DNR estimates that outdoor recreation–related industries in Minnesota represent $4.25 billion per year of annual production (in fiscal year 2000) and tax revenue related to Minnesota's outdoor recreation economy amounts to $127 million per year for fishing and $32 million per year for wildlife watching (DNR 2008). According to the DNR, 29% of Minnesotans fish, and Minnesotans spend $1.46 billion for fishing-related activities (DNR 2008). Given that Minnesota's fishing and wildlife-watching activities are closely related to accessible shorelands, the recommendation is expected to increase production of related industries.

According to the AMA Report, 500 miles of cold-water stream shoreland (CSS) and 375 miles of lake and warm-water stream shoreland (LWSS) will need to be acquired for the next five years (AMA 2007). This represents about 9.1% and 0.6% of CSS and LWSS, respectively, or 1.3% of the total shoreland in Minnesota. Although the exact relationship between increased shoreland accessibility and industrial production is not found in the literature, it is considered to be reasonably conservative to assume that a 10% increase in accessible shoreland will result in a 1% increase in fishing and wildlife-watching. Assuming the 10:1 ratio, shoreland acquisition for the next five years is expected to have recreational benefits of $5.35 million per year for related industrial production.

2. Fishing- and wildlife watching–related tax revenue

Using the estimates and assumptions listed for the first benefit above, shoreland acquisition for the next five years is expected to have recreational benefits of $150,000 per year at the fifth year for fishing-related tax revenue and $40,000 for wildlife watching–related tax revenue for a total of **$190,000** per year.

3. Benefits through hunting opportunities

A study in North Dakota analyzed the recreational benefits of CRP, and annual hunter expenditures attributable to waterfowl hunting due to CRP were calculated as $6.7 million. For comparison, North Dakota's hunting-related economic activities were about one-fifth of Minnesota's in 2001 (IAFWA 2002). Thus, benefits through hunting opportunities would be **$6.7 million** per year at the fifth year.

4. Benefits through additional public access to water bodies

Benefits through additional public access to water bodies are **unquantified**.

5. Additional education opportunities from publicly accessible shoreland

Benefits through additional education opportunities via publicly accessible shoreland are **unquantified**.

6. Protection of species of greatest conservation need, such as common loon, black tern, and Blanding's turtle

Natural or well-managed shoreland provides critical habitat for multiple wildlife species. The benefits of protecting wildlife species such as common loon, black tern, and Blanding's turtle is expected to be significant. However, literature that estimates monetized benefits of protecting wildlife species was unavailable, so this benefit remains **unquantified**.

7. Reduction of nutrient and solid loading into surface water

Nutrient concentration and water clarity have an important nonlinear relationship (Radomski, 2008). According to Radomski (2008), most of the Minnesota's water bodies maintain good clarity, while water bodies with total phosphorus over 20 to 25 parts per billion quickly lose their clarity. Creating riparian buffer zones and managing shorelands can be effective ways to reduce nutrient and solid loading to surface water.

According Carson and Mitchell (1993), the average U.S. household is willing to spend \$310 to \$422 per year (adjusted to 2008 dollars) for boatable, fishable, and swimmable water. Assuming that increase in protected shoreland will reduce nutrient and solid loading and thus protect the water body from degrading proportionally, water quality benefits by shoreland acquisition per year for the next five years is calculated as **\$7.8 million** to **\$10.6 million** for 2 million households in Minnesota.

8. Protection of habitat for fish and wetland-dependent species, such as waterfowl and wild rice

Protected and well-managed shorelands are expected to provide habitats for fish and other wildlife species, and provision of such habitats is expected to have significant benefits. Literature review, however, failed to locate a published study that shows monetized benefits of protected shoreland through provision of habitats for Minnesota wetland-dependent species, including waterfowl and wild rice. As a result, this benefit remains **unquantified**.

Key Cost

We anticipate one key cost:

1. Acquisition of critical shorelands

AMA (2007) estimates that $10 million per year would be required for CSS acquisition between 2008 and 2017, and $25 million per year for LWSS acquisition between 2008 and 2017. From 2018 to 2032, estimated costs are $3.3 million and $7.7 million per year for CSS and LWSS acquisition, respectively. Overall acquisition cost per year, 2008–17, would be $35 million.

Summary of Key Benefits and Costs

Two important benefits to wildlife could not be quantified through the literature survey, although those benefits are expected to be significant when quantified. Both recreation-related benefits and water quality–related benefits are estimated to be significant. These estimates are conservative given the uncertainties associated with the data and method. For instance, for water-quality benefits, it is assumed that protected shoreland would reduce nutrient and soil erosion and thus water quality of surface water proportional to the length of protected shoreland. In reality, the water-quality benefits accruing from protecting shoreland depend on many factors, including the criticality of the shoreland in the watershed and nutrient and solid loading and hydrology of the area. Therefore, protecting 1% of the shoreland would be able to achieve much more than a 1% water-quality improvement, while the reverse can be true as well depending on the site to be acquired. This sheds light on the importance of site selection and its sensitivity on overall cost-effectiveness of the recommendation.

Benefits	**Amount (annually @ 5th year)**	**Party receiving benefit**
1. Recreation-related commercial production	$5.35 million	Local industry
2. Fishing- and wildlife watching–related tax revenue	$190,000	State and local governments
3. Benefits through hunting opportunities	$6.7 million	Citizens of region & state, hunters
4. Additional public access to water body	Unquantified	Citizens, anglers, wildlife-watchers
5. Additional education opportunities via publicly accessible shoreland	Unquantified	Citizens, anglers, wildlife-watchers
6. Protection of species of greatest conservation need	Unquantified	
7. Reduction of nutrient and solid loading	$7.8 million–$10.6 million	Citizens, anglers, wildlife/fish
8. Protect habitat for fish and wetland-dependent species	Unquantified	Wildlife, anglers
Costs	**Amount (annually @ 5th year)**	**Party incurring cost**
1. Acquisition of critical shorelands	$35 million	State and local governments

Table 1. Summary of potential costs and benefits from acquisition of high-priority shoreland. For assumptions and references, please see text.

Restore Wetlands

Habitat Recommendation 5: Restore land, wetlands, and wetland-associated watersheds

Wetland ecosystems provide multiple and essential services that benefit society. They regulate peak flows and recharge surface and ground water, store and process nutrients and sediment, and provide critical habitat to aquatic species, waterfowl, and migratory birds (Mitsch and Gosselink 2000). However, more than half of the original wetlands in the coterminous United States have been drained, filled in, and plowed under for agricultural use and expanding urban development (Mitsch and Gosselink 2000). Nearly 35 million acres of wetlands have been lost in the Upper Mississippi River basin (Dahl 1990), and more than 90% of wetlands have been converted in the former prairie of Minnesota.

A key recommendation of the SCPP is the restoration of wetlands in Minnesota and their associated uplands, particularly in the western prairie region of the state, which has lost nearly all of its original wetlands and grasslands to agriculture. This section focuses on wetland restoration in particular, and does not specifically address benefits associated with upland restoration.[1] It discusses key benefits likely to be generated through wetland restoration and evaluates the range of potential economic value that could be realized through implementation of this recommendation. These benefits are presented alongside the anticipated costs of restoring wetlands, and the overall cost effectiveness of this proposed action is discussed.

Overall, the costs and benefits of wetland restoration are highly variable and context-dependent, and it is not possible to provide simple analysis of the cost effectiveness of this action. Land acquisition and restoration costs vary widely, as will the value of benefits derived from wetland restoration. The monetary estimates included in this assessment are imperfect and include valuations for very different ecosystems not intended to apply directly to Minnesota. Wetland restoration projects should be guided by real data, and local information should be used to evaluate the ecosystem service benefits likely to accrue from any restoration effort.

Nevertheless, three broad conclusions can be derived from this assessment and used to inform potential wetland restoration in Minnesota:

1. Intact wetlands provide significant value, likely $300 to $10,000 per acre, and investment in targeted restoration would yield significant benefits.
2. Not all wetlands are created equal. Restoration of sites where multiple benefits of flood mitigation, water quality, and wildlife support can be realized likely would provide greater benefit per dollar than wetlands restored to provide a single ecosystem service.
3. The most benefits are likely to be realized from restoration of wetlands in areas with the least remaining original wetland cover. Restoration of wetlands on 3% to 7% of the land area of Upper Mississippi River basin (at most only half of the original wetland area) likely would be sufficient to significantly reduce damage from flooding and greatly enhance water quality (Hey and Phillipi 1995; Mitsch and Gosselink 2000).

[1]See the cost-benefit analysis for energy recommendation 3 for benefits associated with restored grasslands.

Key Benefits

Wetlands perform a range of critical hydrological and ecological functions that in turn provide a variety of direct and indirect benefits to society. Intact wetlands decrease the risk of damaging floods, maintain water quality for drinking and recreation, nurture healthy populations of wildlife and fish, and provide other important services such as climate regulation and ground-water recharge (Brauman et al. 2007).

Restoration of wetlands in Minnesota, particularly where low percentages of original wetlands remain intact, would generate multiple significant benefits, including the following three critical benefits:

1. Mitigation of potential flooding
2. Nutrient removal and improvement of water quality
3. Provision of wildlife habitat and unique recreational and hunting opportunities

1. Mitigation of potential flooding

Wetlands perform an important hydrological function by regulating the flow of water across landscapes and reducing peak flood levels (Mitch and Gosselink 2000; Zedler and Kercher 2005). The loss of millions of acres of wetlands in the latter half of the 20th century corresponded with a six-fold increase in the number of floods and an increase in property damage by nearly a factor of 10 (Hazards & Vulnerability Research Institute 2007). Restoration of degraded or removed wetlands could reduce significantly the incidence and impact of flood events, particularly in regions where significant portions of original wetlands have been lost. For example, analysis of the Des Plaines River in Illinois concluded that a 5.7-acre wetland could retain runoff from a 410-acre watershed (Godschalk et al. 1999), and the U.S. Army Corps of Engineers determined that decreasing runoff within a watershed by 10% might reduce the flood peaks with a two- to five-year return period by 25% to 50%, and might reduce a 100-year flood by as much as 10% (USACE 1995). Also, it has been estimated that restoration of between 5 million acres (Hey and Philippi 1995) and 13 million acres (Godschalk et al. 1999) of wetland in the Upper Mississippi River basin would have greatly diminished the catastrophic flooding in 1993.

Efforts to monetize the benefit of flood mitigation have generated a wide range of potential values. Reviewing dozens of wetland valuation studies, Woodward and Wui (2001) calculated the mean flood mitigation values (in inflation-adjusted 2007 dollars) of wetlands to be $650 per acre, within a very broad range of between $147 and $2,887. Flood control by Mud Lake, on the border between Minnesota and South Dakota, was estimated to be worth $576 per acre (Roberts and Leitch 1997). The value of wetlands for reducing flooding in the Red River basin was estimated between $341 and $507 per acre (Schultz and Leitch 2003); however, this value is likely too low because subsequent study suggested higher-than-anticipated water storage capacity by wetlands in this region (Apfelbaum et al. 2004).

The value of wetlands for flood mitigation is context dependent. Wetlands in watersheds that have lost much of their original wetland cover are more valuable than others, as are wetlands that reduce the risk of floods in highly populated areas with expensive property. For example, the flood mitigation benefit of intact wetlands within the Charles River that flows into Boston Harbor in Massachusetts was calculated to be $12,350 per acre (Mitsch & Gosselink 2000).

Using the entire range of values presented above between $147 and $12,350 per acre of wetland, flood mitigation benefits for Minnesota statewide[2] **would be between $1.8 million and $148 million per year**.

2. Nutrient removal and improvement of water quality

Agricultural runoff and urban wastewater deliver excess nutrients to associated rivers, streams, wells, and aquifers, and this nonpoint source pollution is a significant problem (Carpenter et al. 1998). Nutrient enrichment contaminates drinking water and endangers human health (Weyer et al. 2001; Townsend et al. 2003) and creates coastal hypoxic zones where these waterways flow into the ocean (Turner and Rabalais 2003). In Minnesota, although only a small portion of the state's waters have been assessed, more than 40% of rivers, lakes, and streams have been classified as impaired. Wetlands can buffer the delivery of nutrients to surface and ground water, removing significant proportions of contaminants such as nitrogen and phosphorus and improving water quality (Woltemade 2000). Wetland restoration may be a cost-effective means of improving water quality compared to conventional drinking water treatment facilities. For example, in Gotland, Sweden, nitrogen abatement using wetlands was four times more effective than abatement using sewage treatment plants (Gren 1995). In the upper Illinois River watershed, nutrient abatement through wetland restoration achieved a 50% to 70% cost savings over conventional wastewater treatment facilities (Hey et al. 2005). At a larger scale, an estimated 5 million to 13 million hectares of restored wetlands in the Mississippi River Basin (only 0.7% to 1.8% of total area) would achieve a significant reduction of nitrogen to the Gulf of Mexico and reduce the size of the hypoxic zone (Mitsch et al. 2001).

Clearly, wetlands have well-demonstrated capacity to catch runoff and process nutrients, with significant benefits for water quality. However, economic valuation of this ecosystem service is, like flood mitigation, difficult and very context dependent. One review of multiple wetland valuation studies calculated that benefits range from $208 to $2,277 per acre, with a mean value of $689 (Woodward & Wui 2001). This corresponds to **$2.5 million** to **$27.3 million** per year statewide using projections of the DNR Long Range Duck Plan, which proposed a target of 2 million acres over 50 years, with 600,000 (12,000 acres annually) being wetlands.

3. Wildlife habitat and unique recreational and hunting opportunities

Wetlands are unique ecosystems that support significant biodiversity and provide critical habitat for a wealth of species (Gibbs 2000). Despite more than a century of land use change, the northern Great Plains remain important for migratory birds, wildlife, and wetland species. In particular, the wetlands of this region support 50% to 80% of the nation's ducks (Guntenspergen et al. 2002). Not surprisingly, the loss of more than half of the nation's wetlands has seriously impacted wetland species, many of which have been listed as federally endangered in response to their precipitous declines (Wilcove et al. 1993).

Restoration of wetlands could provide significant benefits to wetland biodiversity and increase populations of species valued for bird-watching, hunting, and fishing. Restored wetlands have provided valuable habitat for amphibians in Minnesota (Lehtinen & Galatowisch 2001); increased populations of teal and other ducks in Prince Edward Island, Canada (Stevens et al. 2003), and supported a fourfold increase in the number of wa-

[2]All statewide per-year calculations used the projections of the DNR Long Range Duck Recovery Plan (2006), which proposed a target of 2 million acres restored in the next 50 years. Of this total, approximately 600,000 acres would be wetlands, with 12,000 acres of new wetland restored annually.

terfowl species in Illinois (Hickman 1994). The DNR's Long Range Duck Recovery Plan (2006) emphasizes the need to restore wetlands and their associated grasslands to support significant increases in the duck population. The plan targets a 58% increase in the breeding population to a total of 1 million ducks, and anticipates a nearly 50% rise in associated duck hunting and waterfowl watching. Assuming expenditures and tax receipts remain proportionate, future revenue associated with a larger duck population and increased recreation would total $361 million (2007 dollars) per year by 2056.

Again, the benefits of increased wildlife from wetland restoration are difficult to monetize. Evidence suggests even citizens who will not directly use or benefit from enhanced wildlife associated with wetlands are willing to pay for their existence, particularly for wetlands that support significant and rare biodiversity (Stevens, Benin, and Larson 1995). Woodward and Wui (2001) determined an average nonuse value of wetland "habitat" to be $505 per acre. Since wetlands support ducks and other species of interest for recreational use, the economic value of hunting, fishing, and bird-watching are important as well. Bergstrom et al. (1990) surveyed several thousand recreational hunters and anglers in Louisiana and calculated an average annual gross economic value of $83 per acre. Woodward and Wui (2001) found much higher values through their review of dozens of valuation studies; mean recreational fishing values were $590 but ranged as high as $2,217 per acre, and mean value of bird-watching was calculated to be $2,000 per acre, though it ranged as high as nearly $4,600 per acre. These values lead to a benefit of **$1 million** to **$55.2 million** per year statewide using the DNR Long Range Duck Plan projections as noted above.

Key Costs

Although several key benefits would be realized through restoration of wetlands in Minnesota, implementation of this action requires investment from state and local governments as well as individuals. These costs include, but may not be limited to:

1. Restoration, construction, and management of wetlands
2. Opportunity cost of alternate uses (e.g., forgone income from crop production)
3. Acquisition cost of private lands acquired for public wetlands
4. Costs of state easements, tax incentives, etc., to promote altered land use practices
5. Potential loss in local tax revenue when productive lands are restored to wetlands

1. Restoration, construction, and management of wetlands

Restoration of drained and converted wetlands is a costly, complicated, and time-consuming endeavor, and varies widely depending upon the landscape context and the size, type, and intended function of the restored wetland. For example, a 2001 U.S. Fish and Wildlife Service estimate for restoration of drained wetlands in Minnesota ranged between $235 and $360 per acre (USFW 2001) for private landowners (this and all following costs adjusted to 2007 dollars). A more recent Minnesota Board of Water and Soil Resources estimate derived a cost of approximately $3,500 per acre (Lines 2008). Large projects would likely realize some economies of scale benefits and achieve a lower per-acre restoration cost; for example, restoration of 1,800 acres of wetlands in the prairie pothole region of northwestern Minnesota in 2003 cost approximately $1,700 per acre

(Jacobson 2004), and Schultz and Leitsch (2003) suggested the cost for a "medium-sized" wetland restoration project to be approximately $1,150 per acre. The DNR Long Range Duck Recovery Plan (2006) anticipates an annual cost of approximately $67 million for restoration and management of wetlands and associated uplands. The plan suggests that 30% of the 2 million acres restored should be wetlands, totaling 600,000 acres or 12,000 acres per year. Assuming restoration costs can be divided equally between wetlands and uplands (determining the actual split would be much more complicated), the annual cost of wetland restoration needed to achieve the duck population goals would be approximately $20 million, equivalent to about $1,600 per acre. Based on this range for wetland restoration costs of $235 to $3,500 per acre and a restoration rate of 12,000 acres per year, we estimate the costs of wetland restoration statewide to be **$2.8 million** to **$42 million** per year.

2. Opportunity cost of alternate uses (e.g., forgone income from crop production)

A second significant cost associated with restoration or re-creation of lost wetlands is the forgone income that would have been realized from continued crop production or from development of land for urban or industrial uses. Since the recommendation emphasizes wetlands in the predominantly agricultural regions of the state, we will focus on profits lost from forfeited commodity production. We use corn production for the purposes of this simple calculation, and assume that all forfeited agricultural income would come from converting productive corn land to wetlands. The estimates of productivity, income, and average cost are taken from Lazarus, Taff, and Zou (2008).

Assumptions: average productivity = 158 bushels/acre
average price = $4–$8/bushel
average subsidies/other income = $53/acre
average input cost = $509/acre

Based on these assumptions, the average cost of not producing corn is $176 to $808/acre, or, applied across 12,000 acres, **$2.1 million** to **$9.7 million** per year.

3. Acquisition cost of private lands acquired for public wetlands

A recent University of Minnesota report analyzed farm real estate prices across the state. Prices vary across regions; the median price in the west-central region was determined to be $2,081, while median price in the southwest was $2,850. The price varies considerably within each region according to the location and productive capacity of the land, so individual acquisitions for wetland restoration will vary widely in cost. Using the statewide median price of $2,461 per acre (Taff 2008), we calculate the cost of acquiring 12,000 acres[3] at **$11.8 million.**

[3]The DNR Long Range Duck Plan estimates 60% of restored wetlands and grasslands will remain privately owned and 40% will become public land. For this calculation: 12,000 acres wetland restored annually x 0.4 (% acquired) x price per acre. Similarly, for annual incentive costs statewide: 12,000 acres wetland restored annually x 0.6 (% private) x incentive per acre.

4. Costs of state easements, tax incentives, etc., to promote altered land use practices
5. Potential loss in local tax revenue when productive lands are restored to wetlands

Wetland restoration on private land not acquired by the state will be possible through the use of conservation easements and tax incentives. Ideally, the level of these incentives should be commensurate with the opportunity cost of income forfeited from other uses of the land, and should provide significant reimbursement for restoration and management activities. However, current policy instruments such as CRP payments have been unable to keep up with rising commodity prices. This analysis uses the most recent cropland rental rates calculated by Hachfeld et al. (2008). Rental rates range from less than $30 per acre for Mille Lacs County to more than $130 per acre for Mower, Nicollet, and Faribault Counties. Costs are estimated at $30 to $150 per acre, with the context that cheaper land has increased in value proportionately less than more expensive land. Taxes and easements are assumed to have identical costs. Corresponding costs of incentives statewide would be **$216,000** to **$1.08 million** per year based on DNR Long Range Duck Plan projections as noted. Lost tax revenue was not calculated (that level of detail was beyond the purview of this analysis).

Summary of Key Benefits and Costs

Overall, multiple potentially very significant benefits could be realized from restoration of converted or degraded wetlands in Minnesota. Restored wetlands could reduce or prevent floods, improve local water quality, and enhance wildlife habitat to support biodiversity and increase recreational opportunities. Although valuation of ecosystem services is highly uncertain, a number of recent economic studies have estimated intact wetlands to be of considerable monetary value. Estimates (all adjusted to 2007 dollars) include $337 to $886 per acre of Louisiana wetland (Costanza, Farber, and Maxwell 1989); $1,512 to $1,630 per acre (Woodward and Wui 2001); and $1,925 per acre of wetland in the Illinois River watershed (Prato and Hey 2006). Hey and Philippi (2004) calculated an adjusted 2007 value of more than $10,000 per acre of restored wetland within the 100-year flood zone in Minnesota, and argue that conversion of all farmland within this zone is economically justified because of the overwhelming benefits that would be realized from flood mitigation.

Furthermore, existing wetlands, particularly those dependent upon direct precipitation or rain-fed streams, are vulnerable to climate change, and may provide reduced benefits as temperatures and precipitation patterns continue to change (Winter 2000; Murdoch, Baron, and Miller, 2000). Restoration of these and other wetlands and reestablishment of more natural hydrologic regimes will be critical to enhancing the resilience of Minnesota's landscape to a changing climate.

Clearly, even the lower valuations of benefits derived from wetlands are nontrivial. However, there are significant costs involved in wetland restoration, and these costs, compared to estimates of potential benefits, are well understood and more easily quantified. Substantial investment would be required on the part of the state. Costs include outright acquisition of critical wetlands, easements and other payments to individuals, ongoing management of restored wetlands, and lost income from agriculture and other land uses.

Benefits	**Annual amount**	**Party receiving benefit**
1. Flood mitigation	$1.8 million–$148 million	Communities and farms downstream
2. Water quality	$2.5 million–$27.3 million	Public water in cities and towns, landowners with wells, local streams
3. Wildlife habitat and recreational/hunting opportunities	$1 million–$55.2 million	Citizens of region and state, hunters, bird-watchers, anglers
Costs	**Annual amount**	**Party incurring cost**
1. Restoration. construction, and management	$2.8 million–$42 million	State and local governments, land owners
2. Opportunity cost	$2.1 million–$9.7 million	Farmers, developers
3. Acquisition cost	$11.8 million	State and local governments
4. Easements, incentives	$216,000–$1.08 million	State and local governments
5. Lost tax revenue	Not calculated	Counties and local municipalities

Table 2. Summary of potential costs and benefits from wetland and wetland-associated restoration. For assumptions and references, please see text.

Protect Forested Land

Land Use Recommendation 8: Protect large blocks of forested land

Large blocks of forestland provide many benefits. Ecosystem services from intact natural environments include watershed protection, carbon storage, climate regulation, and wildlife habitat. Trees add recreational value, too: A study in the Rocky Mountains, Colorado, of the effect of tree density on recreational demand and benefits suggested that increasing trees per acre 1 percent would increase willingness to pay or benefits per day in dollars by 8 percent (Walsh, Ward, and Olienyk 1989).

Of course, maintaining large blocks of forestland has costs as well, including (as elaborated upon below) the cost of acquiring and monitoring easements and the opportunity cost of forgoing development.

This cost-benefit assessment we perform here based on information gathered in studies around the country leads to the following general conclusions:

1. Because the price of forestland in Minnesota is overwhelmingly high, the benefits we were able to quantify may not be sufficient to counterbalance them. Decisions should also take into account benefits such as air purification and soil stabilization that we were unable to quantify.
2. The ecosystem services provided by large blocks of forested land influence each other and are influenced by the setting. As a result, the numbers we derive here based on information pieced together from a

number of studies carried out around the country provide only a rough approximation of the true value of services provided by large blocks of forested land in Minnesota.

An important consideration that is not easy to quantify is the impact global warming will have on the costs and benefits associated with protecting large blocks of forested land. How will the value of forests altered by climate change compare with the value we place on forests as we know them today? The answer to that will clearly make a difference in how the balance of costs and benefits plays out over time.

Key Benefits

1. Carbon sequestration
2. Air purification
3. Watershed services
4. Soil stabilization and erosion control
5. Wildlife habitat
6. Diverse recreational opportunities
7. Timber
8. Nontimber products
9. Housing prices

1. Carbon sequestration

Birdsey and Heath (1995) estimated that an average acre of public forestland sequesters about 31.45 tons of carbon per acre just in the trees. Applying this number to total acres of roadless lands in the United States that have been designated as wilderness (with some adjustments for tree density and dominant vegetation type), Loomis and Richardson (2000) came up with an estimated of $490 million to $1 billion annually for the carbon sequestration service performed by the 42 million acres of roadless areas on national forests in the United States. Applying the 31.45 tons of carbon sequestered per acre with a 2007 price base, the current estimated value is $35.7 billion. Therefore, the annual carbon sequestration benefit per acre is $14.05 to $28.67. Multiplying this by the 270,000 to 520,000 acres of large, roadless blocks of forest the forest subcommittee considered over five years, we estimate a total $18.95 million to $74.5 million carbon sequestration benefit[4].

2. Air purification

Trees trap airborne pollutants and thus improve air quality and human health. In Chicago, Illinois, in one year, trees removed air pollutants providing $9 million in air quality (McPherson et al. 1997 via Bolund and Hunhammar 1999). McPherson (1991) determined that planting half a million trees in Tucson, Arizona, would reduce airborne particulates by 6,500 tons per year. The annual value of this pollution control mea-

[4]This is the carbon benefit stored in standing trees, compared to no trees; note this benefit does not take into account the carbon sequestration value of soil.

sure was estimated to exceed $1.5 million. Therefore, the air quality value of each tree equals $4.16. Because this monetized benefit very likely varies across tree species and regions[5], we find it is difficult to determine an exact number by applying existent results for this benefit. Thus, in this assessment this benefit remains **unquantified**.

3. Watershed services

Forested watersheds capture and store water, thus contributing to the quantity of water available and the seasonal flow of water. Forests also help purify water by stabilizing soils and filtering contaminants.

Some studies using contingent valuation estimated residents' willingness to pay for the water quality in Minnesota. Residents living near the Minnesota River were willing to annually pay $14.07 via taxes or $19.64 via water bills for a 40% decrease in phosphorus in the river (Mathews, Homans, and Easter 1999). In southwestern Minnesota, communities were willing to pay $2.4 million, $2.0 million, $6.6 million, and $2.6 million annually for water quality improvement in the levels of iron, sulfate, hardness and copper respectively (Cho 1990). In Lake Bemidji, willingness to pay for water quality improvements was $88 per household (Henry, Ley, and Welle 1988 via Wilson and Carpenter 1999). Although these numbers provide useful context, we chose not to use them to estimate the watershed service benefit in this analysis.

More than half of roadless areas intersect watersheds that provide drinking water to local communities. In particular, roadless forests safeguard clean water from watersheds nationwide. Thus, protecting roadless lands would yield cost savings to water treatment plants and highway departments from avoiding sedimentation associated with logging and roads. This benefit was estimated to range from $130,000 to $260,000 annually for one town located adjacent to a relatively small national forest of 631,000 acres (Loomis 1988). Applying the benefit transfer method by assuming that the average distance between town and adjacent forest is similar in Minnesota and the study area in the literature, preserving roadless forest on national forests in Minnesota would yield a per-acre watershed services benefit of $0.36 to $0.72 ($130,000–$260,000 divided by 631,000 acres and converted to 2007 dollars), a statewide annual benefit of $97,200 to $374,400 (2007 price base), and a five-year benefit of **$490,000** to **$1.87 million**.

4. Soil stabilization and erosion control

Forest vegetation helps stabilize soils and reduce erosion and sedimentation. Estimated values associated with soil stabilization primarily reflect the ecosystem service benefit the forest can provide. In the United States, on- and off-site costs of soil erosion are $44 billion per year (Daily et al. 1997). Values range from $1.94 per ton in Tennessee to $5.5 million annually in Oregon's Willamette Valley (Krieger 2001). In Tucson, Arizona, one mature mesquite tree is expected to reduce storm-water runoff by 9 cubic feet per year. Based on the cost of constructing detention ponds to control runoff, the value of a tree for runoff control is $0.18 annually (McPherson 1992, Dwyer et al. 1992 via Krieger 2001). The statewide estimated average annual sheet and rill erosion rate on cultivated cropland in Minnesota is 2.1 tons/acre/year in 1997. However, without information on how much of the cropland can be stabilized by the forest, it is difficult to quantify this part of the benefit, so for the purposes of this analysis it remains **unquantified**.

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[5]The estimated result from other literature is based on the study of mesquite trees, which are rarely found in Minnesota.

5. Wildlife habitat

Roadless forests preserve critical habitat for fish and wildlife, including more than 1,600 threatened, endangered, or sensitive plant and animal species in the United States. Moskowitz and Talberth (1998) report that the costs to U.S. agriculture of replacing natural pest control services with chemical pesticides would be about $54 billion annually. The U.S. Forest Service also estimates that it would cost more than $7 per acre per year to replace the pest-control services of birds in forests with chemical pesticides. In addition, the pollination services of natural ecosystems provide U.S. agriculture benefits of $4 billion to $7 billion per year (Krieger 2001). By assuming the forest natural ecosystems in Minnesota can provide similar services, after adjusting for inflation to 2007 prices the average benefit per acre is estimated as at least $8.20 per year and the benefit over the acreage under consideration here would be $2.21 million to $4.26 million annually, and **$11.05 million** to **$21.3 million** over five years.

6. Diverse recreational opportunities

Wild, unroaded lands offer a unique form of outdoor recreation, and many studies have estimated the value of wilderness-related recreation. Based on an average value of $41.87 per visitor day, the economic value of recreation on the 42 million acres of roadless areas in U.S. national forests is $600 million annually (Loomis and Richardson 2000). Forest ecosystems are also important destinations for hunters and anglers. The economic impact of these activities leads to a $1.3 billion to $2.1 billion revenue for hunting and $2.9 billion for fishing nationwide. In Montana, anglers were willing to pay $2.07 million to protect high-quality recreational fishing in just one roadless area (Krieger 2001).

If we took an average of the recreational benefit measure across the United States, which is $16.73 per acre in 2007 ($600 million divided by 42 million acres, converted to 2007 dollars), and apply to the recommendation cover area of 270,000 to 520,000 acres in Minnesota, we get a potential recreation benefit from protecting large blocks of forests of $4.52 million to $8.87 million annually and **$22.6 million** to **$44.35 million** over the five-year period.

7. Timber

According to the Minnesota Department of Natural Resources (DNR)'s annual report of forest resource, the estimated value of forest products manufacturing shipments in 2006 was $6.93 billion. Value-added impact attributable to Minnesota timber equals $41.60 per dollar of timber sold, and $4.3 billion is the total that stays in Minnesota.

8. Nontimber products

Forests produce many commercially valuable products other than timber, including mushrooms, floral greens, medicinal plants, and edible plants and animals. A previous study shows the nontimber value of forest was about $50 to $20 /ha/year among different ownership types in Wisconsin. The nontimber values range from 10 times to 4 times timber revenues. The hedonic pricing model showed that stands with the same tree distribution had significantly higher nontimber values for national forests (Scarpa, 2000). Therefore, a total benefit of $25.35 million to $32.87 million/year and **$126.75 million** to **$164.35 million** for five years can be expected applying this standard in Minnesota if we assume the forest generates similar value across different ownerships.

9. Housing prices

Protecting natural environments such as roadless areas can increase the property values of adjacent private lands. One case study indicated an increase of 13% in the value of private property adjacent to the Green Mountains in Vermont using a hedonic pricing model (Phillips 1999). Other examples: In Massachusetts, trees add $2,686, or 6%, to house values (Morales 1980 via Garrod and Willis 1993); In Athens, Georgia, using hedonic pricing method, one study estimated landscaping with trees increases sale prices by 3.5% to 4.5%, with an average increase of $1,475 to $1,750 (Anderson and Cordell 1988 via Garrod and Willis 1993). However, hedonic methodology assumes a market-based homogenous preference across different individuals with regard to the same object, which rarely happens in reality. Furthermore, all these housing price changes probably reflect the private benefits and costs of a home, but not the public benefits/costs to have any alternations. Therefore, without knowing the benefit/cost from the public side, the direct market price approach would underestimate/overestimate true values, and so we leave this benefit **unquantified**.

Key Costs

We identified three key costs for this recommendation:

1. Easement acquisition
2. Easement monitoring
3. Opportunity cost of maintaining forestland

1. Easement acquisition

Easement costs would be $500[6] per acre in northern Minnesota and $2,000 per acre in southern Minnesota for a total of $165 million to $310 million for easement acquisition of 270,000 to 530,000 acres in today's dollars over the next 10 to 25 years.

2. Easement monitoring

Easement monitoring would cost $80,000 to $127,000 per year (**$400,000** to **$630,000** for the five-year period) once (and if) 270,000-acre and 520,000-acre targets are reached. However these estimates are varied across different types and locations of land.

3. Opportunity cost of maintaining forestland

The opportunity cost for maintaining forested land is defined as the additional value that could be obtained with the most highly favorable/valued alternatives. It can be calculated by multiplying the total land area that could be developed by the price of the land. However, it is difficult and almost not possible to predict how much of the land would be developed. Here, the total amount of timberland sold in Minnesota and median residential land sales prices are used to approximate the forested land opportunity cost. In 2007, the total sale

[6]The cost estimates are directly taken from forest subcommittee recommendation

of timberland was 15,759 acres, and the predicted median sales price per acre for forestland without structures was $12,000/acre (Figure 1). Thus, an estimated opportunity cost for recommended forest area converting to housing in 2007 is $189.1 million, assuming all the forestland goes to housing use.

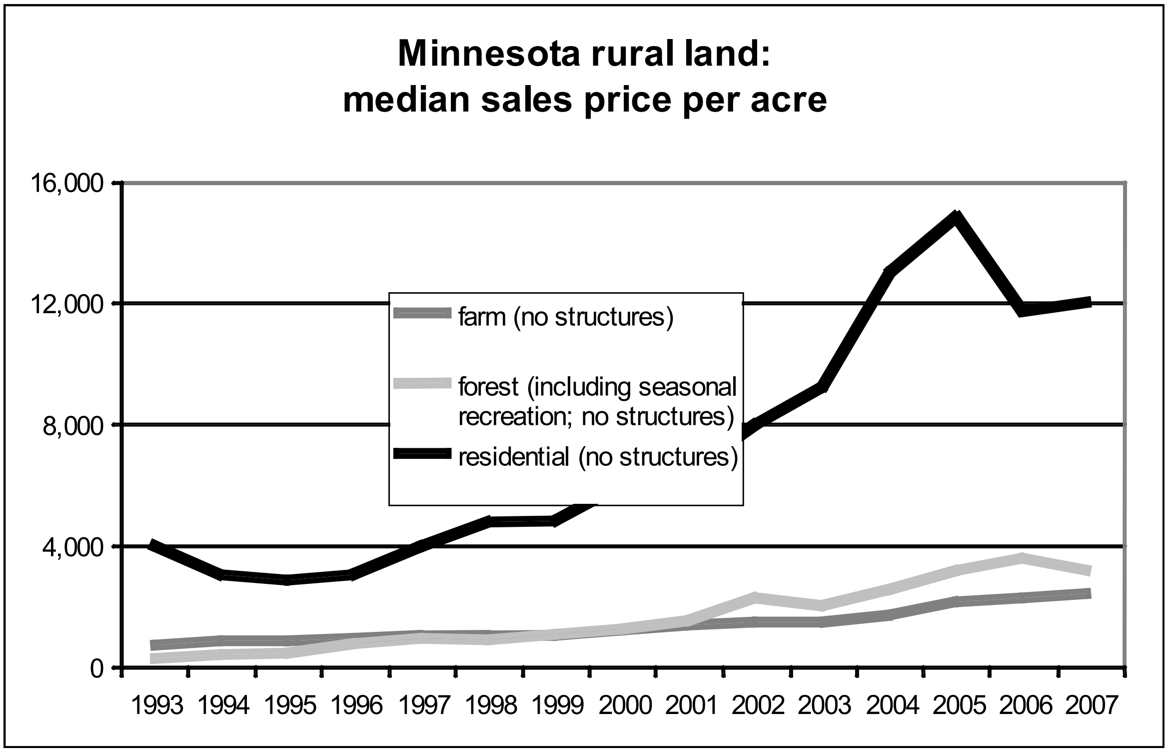

Figure 1. Data and chart are provided by Minnesota Land Economics.

Summary of Key Benefits and Costs

Estimated benefits and costs are summarized in Table 3. For the benefit side, timber and nontimber value contribute the major part of the monetary values. In addition, the forest ecosystem services provide substantial benefits on: climate regulation and carbon sequestration; watershed service; biodiversity and recreational opportunities and so on. On the other hand, as the forestland price is overwhelmingly high, there is a great chance for the cost go beyond the benefit. However, some of the benefit cannot be quantified in the table, such as: air purification and soil stabilization, the overall results could be underestimated for the benefit side.

However, there are couple issues that need to be noticed. All the services and benefits we discussed above depend on a good understanding of those services. More than often, services interact with and depend on each other. Classifications are arbitrary and useful for discussion, but in reality these services are not independent and could not operate alone (Hawkins 2003, Daily 1997b). Furthermore, the values are not necessarily comparable across regions because they often correspond to different aspects of a forest ecosystem service, were arrived at using different methods and are expressed in different units. This means that finding a total value of all services in an area is not as simple as valuing each category and adding them up.

Benefits	**Amount* (5 years over 270,000–520,000 acres)**	**Party receiving benefit**
1. Carbon sequestration	$18.95 million–$74.5 million	Citizens, society, future generations
2. Air purification	Unquantified	Citizens
3. Watershed service	$490,000–$1.87 million	Citizens, town, landowners
4. Soil stabilization	Unquantified	
5. Wildlife habitat and species	$11.05 million–$21.3 million	Citizens, business
6. Recreation	$22.6 million–$44.35 million	Citizens, communities, government
7. Timber value	$636.68 million–$1.25 billion**	Business
8. Nontimber value	$126.75 million–$164.35 million	Citizens, business
9. Housing price	Unquantified	Property owner
Costs	**Amount* (5 years over 270,000–520,000 acres)**	**Party incurring cost**
(1. Easement acquisition costs)	($165 million–$310 million)***	State, local government
(2. Easement monitoring costs)	($400,000–$630,000)	State, local government
(3. Opportunity costs)	($1.004 billion)****	Developers

Table 3. Summary of potential costs and benefits protecting large blocks of forested land in the first five years of project implementation. For assumptions and references, please see text.

*All dollar values are adjusted to 2007 price base. **Total timber sale is $6.93 billion in 2006 over 15,112,700 acres. ***Easement acquisition costs are estimated over 10–25 years ****Opportunity costs are calculated with a 3% interest rate over 5 years.

Produce Perennial Biofuel Crops

Energy Recommendation 3: Invest in perennial biofuel and energy crop research and demonstration projects on a landscape scale

Land Use Recommendation 4: As much as possible, transition renewable fuel feedstocks to perennial crops

These two recommendations share the goal of transitioning part of the Minnesota landscape to perennial energy crop production. For the purpose of this assessment, the costs and benefits of the end goal were analyzed, rather than the steps necessary to reach that goal. Therefore, this is not a cost-benefit assessment of the recommendations, which are oriented towards research. Rather, it is an assessment of the benefits and costs associated with the implementation of that research on the landscape. This assessment is also related to several other recommendations:

Habitat Recommendation 7: Keep water on the landscape

Energy Recommendation 4: Develop policies and incentives to encourage perennial crop production for biofuels in critical environmental areas

Energy Recommendation 11: Invest in research and enact policies to protect existing native prairies from genetic contamination by buffering them with neighboring plantings of perennial energy crops

Energy Recommendation 12: Invest in efforts to develop sufficient seed or seedling stocks for large-scale plantings of native prairie grasses and other perennial crops

Energy Recommendation 13: Invest in research and policies regarding "green payments"

The benefits and costs identified by each team were consolidated and are listed below. The energy team assumed an implementation scale of 2 million acres, mainly affecting counties in the Red and Lower Mississippi River basins, so that figure was used in this assessment. As with the other recommendations, the time frame for assessment was five years of implementation. However, we allowed four years for the cellulosic ethanol program to ramp up, meaning that ethanol is actually produced only in the last year of the program. The "recommendation implemented" scenario was compared with a scenario in which these 2 million acres remain in annual crops, likely a corn/soybean rotation in the Lower Mississippi basin and a wheat/soybean rotation in the Red River basin. In the "no implementation" scenario, the assumption is that no progress would be made toward the production of cellulosic ethanol in the five-year period. This recommendation is therefore designed to jump-start cellulosic ethanol production from perennial crops in Minnesota.

Several SCPP recommendations (listed above) are oriented toward the production of cellulosic ethanol using perennial crops. Cellulosic ethanol is not yet commercially viable on a large scale, but Minnesota's ethanol production industry is expected to grow in the coming decades, given state and national production mandates. The costs and benefits associated with the cellulosic ethanol industry should be periodically reevaluated as technology and industry parameters change.

Keeping in mind the inherent uncertainties, the following broad conclusions can be drawn from this assessment:

1. The benefits of carbon sequestration vary dramatically depending on crop type
2. The opportunity cost for not using land for an annual crop also shows a tremendous range, depending on commodity prices
3. Implementing the recommendations could result in a net economic loss or gain over the five-year assessment period, depending on how reality tracks our estimates and on the value associated with unquantified benefits
4. Many of the costs associated with this recommendation are startup costs and so would become less significant over time

Key Benefits

We identified nine key benefits:

1. Increased biofuel production due to better yields
2. Payments to farmers through the state perennial program
3. Secondary economic benefits of biofuel production
4. Improved water quality and reduced soil erosion
5. Reduced water runoff
6. Increased carbon sequestration and reduced greenhouse gas (GHG) emission
7. Improved wildlife and aquatic habitat
8. Improved landscape aesthetics

1. Increased biofuel production due to better yields

Assuming that the cellulosic ethanol produced from perennial crops will add to, rather than replace, the state's corn ethanol sector, eventually Minnesota would be able to use all of the land referenced in this recommendation (2 million acres) to produce feedstock for cellulosic ethanol. At an annual yield of 2 tons per acre (a conservative estimate suggested by the energy team), and 75 gallons of ethanol production per ton of material, these lands have the potential to produce 300 million gallons of ethanol annually. The gross profit to farmers is estimated at $80 to $120 per ton for sale of their cellulosic crop (Tiffany 2008). However, these profits would not be realized right away—the cellulosic ethanol industry must first develop. We therefore assume revenue from sale of cellulosic feedstock for only the fifth year of the program, allowing four years for an ethanol sector ramp-up. Gross farmer gain from biofuel production is therefore:

2,000,000 acres x 2 tons/acre x $80/ton x 1 year = **$320 million**
2,000,000 acres x 2 tons/acre x $120/ton x 1 year = **$480 million**

2. Payments to farmers through the state perennial program

Payments to farmers as recommended by the energy team are $600/acre over a four-year period, allowing time for ethanol production to ramp up. This amounts to:

$600/acre x 2,000,000 acres x 4 years = **$4.8 billion**

3. Secondary economic benefits of biofuel production

This includes the larger economic benefits of producing ethanol from the perennial crops. In 2006, the Minnesota Department of Agriculture (MDA) estimated the total economic impact of producing corn ethanol as $2.77 billion, or approximately $5 per gallon of ethanol. We assume this economic benefit for only the last year of the first five years of project implementation, allowing time for ramp-up of the ethanol industry. This results in a benefit of:

300,000,000 gallons ethanol x $5 x 1 year = **$1.5 billion**

4. Improved water quality and reduced soil erosion

Perennial landscapes provide both improved water quality and reduced soil erosion compared with annual row crop landscapes. This is because they provide year-round ground cover, which reduces the erosive impact of wind and rain, and provide root structure to hold the soil year-round. The current literature demonstrates that conversion from row to perennial crops results in improved water quality, including reduced stream sedimentation (Babcock et al. 2007). However, this benefit is highly dependent on the location of a given field in relation to a waterway, in addition to other factors such as slope and soil type. The type of perennial crop being planted is also a factor. The team assumed that for every 1% conversion of land use to perennial crops, sedimentation in rivers would also reduce by 1%.

The 2008 budget for water quality restoration projects under the Clean Water Legacy program was $4,374,000. Assuming a reduction in the amount needed for restoration activities corresponding to the amount of sedimentation reduction, over five years the benefit of perennial plantings would be:

2,000,000 acres converted/27,400,000 acres in farms in 2007 x $4,374,000 x 5 = **$1.596 million**

Sedimentation reduction would be the major benefit of the decreased soil erosion resulting from a transition from annual crops to perennials. Many soil erosion cost studies also address the cost of soil erosion incurred by farmers, who must compensate for nutrient loss with added fertilizer. However, in our example of comparing a perennial landscape with an annual crop, the fertilizer regimes would be sufficiently different that calculating a benefit to farmers of avoiding soil erosion resulting from this recommendation would not be appropriate.

5. Reduced water runoff

The specific benefit of decreased runoff from perennial landscapes identified by the land use team is reduced stream-bank erosion. This benefit remains unquantified, and would differ according to the type of perennial crops planted so this remains **unquantified**.

6. Reduced greenhouse gas (GHG) emissions and carbon sequestration

It is unquestionable that making progress toward the state goal of 80% GHG reduction by 2050 is valuable to Minnesota. Because of the global nature of climate change, Minnesota's contribution to the problem and the magnitude of the benefits incurred by reducing this contribution are nebulous. However, Minnesota's leadership could generate markets for low-carbon fuels and catalyze national progress toward a renewable energy economy. This would have large ecological and economic benefits for the state and the nation. Quantifying these indirect GHG reduction benefits is not possible given the limited scope of this assessment, so the proxy we have chosen to represent them is the price of carbon dioxide (CO2) futures sold on the European Climate Exchange (ECX). Regardless of whether the carbon credits for producing low-carbon fuels in Minnesota would actually be sold on the ECX, the price of CO2 futures is a good indication of the market value of reducing GHG emissions.

An extensive literature survey reveals that carbon sequestration increases in land that has been transitioned from annual crops to perennial grasslands, and in land transitioned from annual crops to short-rotation woody crops (Anderson et al. 2008). Increased sequestration is taken into account by life-cycle studies of GHG emissions from cellulosic ethanol production and use. Displacing motor gasoline with cellulosic ethanol made from switchgrass is believed to reduce total GHG emissions by 60% (Groode and Heywood 2007). Given that Minnesota is an ethanol exporter, some of the avoided emissions from cellulosic ethanol production would take place outside the state borders. Nevertheless, Minnesota may be able to sell carbon credits from a cellulosic ethanol program or charge a premium for its low-carbon ethanol. The current price of carbon on the ECX is $40.8 per metric ton. Applying this price to be applicable to cellulosic ethanol production using switchgrass, and assuming (as above) that ethanol production ramps up in the fifth year of the program, the value of reduced GHG emissions would be:

$40.8/metric ton CO_2e x 300,000,000 gallons ethanol/year x 1 gallon gasoline/1.52 gallon ethanol [due to lower energy content of ethanol] x 0.6 [reduction represented by replacing gasoline with cellulosic ethanol]) x (0.0093 tons CO_2e/gallon gasoline [EPA figure]) x 1 year = **$44.8 million**

A life cycle GHG analysis of ethanol produced from short-rotation woody crops has not yet been produced.

During the first three years of the program, grasslands or lands in short-rotation woody crops would be sequestering carbon at a mean rate of 1.6 metric tons CO_2/acre/year and 7.0 metric tons CO_2/acre/year, respectively (Anderson et al. 2008). However, these values are uncertain given the wide variation in carbon sequestration rates gathered from the literature. For perennial grassland, sequestration rates could vary between 0 and 3.2 metric tons CO_2/acre/year, and for short-rotation woody plantings they could vary between 4.4 and 9.6 metric tons CO_2/acre/year.

The value of sequestered carbon for grassland during the first four years of the program is therefore between **$0** and 3.2 metric tons CO_2/acre/year x 4 years x 2,000,000 acres x $40.8/metric ton CO_2 = **$1 billion**

The value of sequestered carbon for short-rotation woody cropland during the first four years of the program is between 4.4 metric tons CO_2/acre/year x 4 years x 2 million acres x $40.8/metric ton CO_2 = **$1.4 billion** and 9.6 metric tons CO_2/acre/year x 4 years x 2 million acres x $40.8/metric ton CO_2 = **$3.1 billion**

7. Improved wildlife and aquatic habitats

Perennial grasslands and short-rotation woody crops both harbor more diverse bird species than do annual row crop landscapes (Dhondt and Sydenstricker 2001, Murray et al. 2003). However, the monetary benefit of this increased biodiversity is unclear. A study in North Dakota evaluated total revenue from pheasant, waterfowl, and deer hunting attributed to conservation reserve program (CRP) lands, and found this value to be $9.45/acre in 2000 (Bangsund et al. 2004). Assuming that perennial bioenergy cropland provides similar benefits, this totals $9.45 x 2,000,000 acres = **$18.9 million**.

Also, reduced sedimentation of waterways in a perennial landscape has beneficial impacts on fish communities, reducing fish kills in some watersheds (Westra et al. 2005). The monetary value of this reduction has not been evaluated.

8. Improved landscape aesthetics

This benefit remains **unquantified**, because no studies have been conducted on aesthetic preference for perennial landscapes compared with annual crop landscapes.

Key Costs

We identified four key costs associated with this recommendation:

1. Cost of farm subsidies
2. Opportunity costs of not using land for annual crops
3. Production costs of perennial crops
4. Production costs of cellulosic ethanol

1. Cost of farm subsidies

These subsidies are payments to farmers designed to encourage them to transition to perennial crops. They are equivalent to the benefit listed above: **$4.8 billion**.

2. Opportunity costs of not using land for annual crops

Without implementation of the recommendation, the 2 million acres would presumably be planted in corn in the Lower Mississippi basin and wheat in the Red River basin. Farmers would receive some revenue from these crops, but would also incur costs associated with producing them. The opportunity cost per acre is equal to the net return to the farmer for these crops. For the sake of this exercise, we assume production costs per acre are fixed, although in reality they would fluctuate depending on the cost of chemical inputs, labor, land rent, etc. Because of this assumption, the net profit for the farmer (and therefore the opportunity cost for taking land out of production) more than doubles when grain prices double. This is most likely an overestimation of opportunity costs, and makes this analysis conservative. Assuming five years of corn/wheat production at a high and low price point for each crop, using the most recent average yields for Minnesota from Lazarus et al. (2008), this cost is equivalent to:

(corn, $4/bushel): $175.50/acre x 1,000,000 acres x 5 years = **$877.5 million**
(wheat, $8/bushel) : $100.40/acre x 1,000,000 acres x 5 years = **$502 million**
(corn, $8/bushel): $807.50/acre x 1,000,000 acres x 5 years = **$4.04 billion**
(wheat, $12/bushel): $300.43/acre x 1,000,000 acres x 5 years = **$1.5 billion**
= $1.38 billion to $5.54 billion

3. Production costs of perennial crops

The per-acre costs of perennial crop production must be weighed against the gross income accruing to farmers after selling their crop to ethanol producers (calculated above in the benefits section). Lazarus et al. (2008) estimate these total costs for switchgrass to be $460/acre, including seed, fertilizer, land rent, equipment, and labor. Assuming other perennial crops would have a similar cost profile, total costs for all land planted in perennials would be:

$460/acre x 2,000,000 acres x 5 years = **$4.6 billion**

4. Production costs of cellulosic ethanol

University of Minnesota applied economics research fellow Doug Tiffany derived the costs summarized below from several sources, including Aden et al. (2002) and Perrin et al. (2008).

Besides the cost of raw biomass (equal to the price paid to the farmer), other costs of ethanol production include transportation of material to the plant, operating costs at the plant, and the plant's start-up capital. Some electricity may be sold by the plant back to the grid, and the revenue from this activity is also considered. Total costs per gallon for a lignocellulosic ethanol process are estimated at $1.12/gallon (minus the cost of feedstock). For the one year of ethanol production we are assuming, the total costs of ethanol production are:

Price for feedstock paid to farmers (from farmer benefits above): **$320 million** to **$480 million**
Other ethanol costs: 300,000,000 gallons x $1.12/gallon = **$336 million**
Total: **$656 million** to **$816 million**

There are also critical implications for food prices and indirect land use effects of using productive land to produce energy crops. While the magnitude of these effects remains unclear, displacing commodity production in Minnesota could potentially shift corn and soybean farming to more sensitive environments in other parts of the world, with negative implications for carbon emissions, erosion, and deforestation (Fargione et al. 2008). Alternatively, removing land from soybean and corn production in Minnesota could push up food prices. One of the reasons the energy team recommended promoting electrical power for the transportation sector in Minnesota (Energy Recommendation 16) was to avoid some of these potentially negative impacts of converting land to energy crop production. However, as mentioned in the cost-benefit assessment for that recommendation, transitioning the Minnesota fleet to electric power would not necessarily replace cellulosic ethanol production for the out-of-state market. The most up-to-date scientific and economic information on ethanol production and land displacement should be used to inform discussion of this policy recommendation.

Summary of Key Benefits and Costs

The large range in potential costs and benefits for this assessment reflects the uncertainty in assigning monetary value to ecosystem benefits, particularly carbon sequestration. Several ecosystem benefits—including improved nongame wildlife habitat, landscape aesthetics, and reduced peak flows due to lower runoff rates—were too difficult to quantify to be included here.

This assessment only covers the first five years. If the changes created a landscape with dramatically lower ecosystem impacts and GHG emissions in the long term, the relative benefit would increase because many of the costs in the table represent one-time start-up costs (for example, ethanol plant construction and equipment costs), and would not be repeated annually.

This recommendation primarily involves monetary exchanges between the state government and farmers, and these are the two groups most heavily represented in the third column of the table (below). Depending on commodity prices, state programs may have to invest more or less money in subsidy payments to farmers to encourage them to transition to perennial crops.

Benefits	**Amount**	**Party receiving benefit**
1. Biofuel production	$320 million– $480 million	Farmers
2. Payments to farmers	$4.8 billion	Farmers
3. Secondary economic effects of biofuel production	$1.5 billion	Business owners, citizens, local and state governments (through taxes)
4. Improved water quality/reduce erosion	$1.6 million	State government, ecosystems/wildlife
5. Reduced water runoff	Unquantified	
6. Reduced GHG emissions	$44.8 million	State government, ecosystems/wildlife, citizens
7. Carbon sequestration	$0–$3.1 billion	State government, ecosystems/wildlife, citizens
8. Improved wildlife and aquatic habitats	$18.9 million	Citizens, businesses, ecosystems/wildlife
9. Improved landscape aesthetics	Unquantified	
Costs	**Amount**	**Party incurring cost**
1. Farm subsidies	$4.8 billion	State government
2. Opportunity cost of not using land for annual crops	$1.38 billion– $5.54 billion	Farmers
3. Production costs of perennial crops	$4.6 billion	Farmers, possibly state government
4. Production costs of cellulosic ethanol	$656 million– $816 million	Businesses

Table 4. Summary of potential costs and benefits from a perennial crop payment program in the first five years of project implementation, all adjusted to 2007 values. For assumptions and references, please see text.

Encourage Biofuel Production on Expiring CRP Lands

Energy Recommendation 4: Develop policies and incentives to encourage perennial crop production for biofuels in critical environmental areas

The outcome of this recommendation was considered by the energy team to be very similar to the outcome of the recommendation to encourage perennial biofuel production on agricultural land (Energy Recommendation 3, discussed above). The costs and benefits are therefore nearly identical, except that this recommendation was expected to apply to only 1 million acres of expiring Conservation Reserve Program (CRP) lands. The energy team considered this to be the area of land in Minnesota likely to be converted to annual row crop (corn or wheat) production when CRP contracts expire. Please refer to the cost-benefit assessment of the perennial biofuels recommendations for a full discussion of the costs and benefits and a list of references. The following table is a summary of these costs and benefits (most are half the value of the costs and benefits for the perennial biofuel recommendation, because they take place on half the land area).

Benefits	**Amount**	**Party receiving benefit**
1. Biofuel production	$160 million– $240 million	Farmers
2. Payments to farmers	$2.4 billion	Farmers
3. Secondary economic effects of biofuel production	$790 million	Business owners, citizens, local and state governments (through taxes)
4. Improved water quality/reduced erosion	$1.258 million	State government, ecosystems/wildlife
5. Reduced water runoff	Unquantified	
6. Reduced GHG emissions	$23.9 million	State government, ecosystems/wildlife, citizens
7. Carbon sequestration	$0-$1.55 billion	State government, ecosystems/wildlife, citizens
8. Improved wildlife and aquatic habitats	$11.65 million	Citizens, businesses, ecosystems/wildlife
Costs	**Amount**	**Party incurring cost**
1. Farm subsidies	$2.4 billion	State government
2. Opportunity cost of not using land for annual crops	$690 million– $2.77 billion	Farmers
3. Production costs of perennial crops	$2.3 billion	Farmers, possibly state government
4. Production costs of cellulosic ethanol	$328 million–$408 million	Businesses

Table 5. Summary of potential costs and benefits from a perennial crop payment program for expiring CRP land in the first five years of project implementation. For assumptions and references, please see text.

Encourage Electric Vehicles

Energy Recommendation 16: Provide incentives to transition a portion of Minnesota's vehicle fleet to electrical power, while simultaneously increasing renewable electricity production for transportation

Several states use incentives to promote adoption of low-emission and zero-emission vehicles. For example, California offers a tax rebate for electric vehicles (EVs) of between $1,000 and $1,500 per newly purchased vehicle. Colorado offers an income tax credit for alternative vehicles based on their emissions reduction factor compared with a traditional gas-powered car (a 2007 Toyota Prius with an estimated cost of $22,500 receives a $3,013 income tax credit under this program).

Several hybrid electric vehicles (HEVs) are expected to be offered on the market within the next several years. For this exercise, we used information for the forthcoming Chevrolet Volt offered by General Motors at an estimated cost of $40,000, which is an HEV with a battery range of 40 miles, after which the battery is recharged using the gasoline engine. The Volt may be plugged into a standard 120-volt outlet for recharging.

We analyzed an implemented tax rebate of $3,000 for an HEV similar to the Volt over a five-year period. This rebate would be designed to encourage adoption of HEVs, as stated in the recommendation. Renewable energy would be added to the grid to supplement the additional electrical power requirements imposed by the hybrid electric fleet. We assumed in this analysis that this would be wind power.

As in all cost-benefit analyses, this analysis is based on a number of uncertainties. Nevertheless, we draw the following general conclusions that may be helpful in guiding policy:

1. Benefits would likely be on the order of millions to tens of millions of dollars over the five-year assessment period
2. Costs would likely be on the order of tens of millions of dollars over the five-year assessment period
3. This recommendation should be assessed in the context of other programs to reduce GHG emissions and gasoline/ethanol consumption and in the context of the latest scientific and economic information on the impacts of alternative fuel production

Key Benefits

We identified four key benefits:

1. Reduced CO2 emissions leading to reduced state contribution to GHG emissions
2. Reduced emissions of particulates, ground-level ozone, nitrogen dioxide, carbon monoxide, and toxics leading to human health and ecosystem health benefits
3. New labor markets and business opportunities associated with wind electricity production for the transportation sector
4. New labor markets and business opportunities associated with HEV production

In addition, the team that formulated this recommendation suggested that HEVs could reduce pressure on the land resource and stabilize commodity prices, by reducing the need to produce ethanol. Given current concern about energy crop production in the developed world leading to increased land clearing for food crops in environmentally sensitive regions of the developing world, an HEV fleet could be seen as one method of combating this trend (see the cost-benefit assessment for Energy Recommendation 3). However, these complex national and global land use dynamics are well beyond the reach of this assessment. We recommend that Minnesota legislators and citizens carefully consider the latest scientific and economic information on the impacts of alternative fuel production when drafting or revising state energy policy.

A first step in identifying benefits is to estimate the adoption rate of HEVs with and without the incentive program. Several studies suggest that consumers like the fuel flexibility, at-home recharging convenience, and environmental responsibility that HEVs offer, and may be willing to pay more for them (Golub et al. 1994, Kurani et al. 1996, Ewing & Sarigöllü 1998). A study from California that evaluated household demand for alternative vehicles found that up to 18% of households would choose an EV for their next car purchase when the price of the EV was held within $4,000 of a conventional vehicle (Kurani et al. 1996). Another study using a discrete choice model found that household choice of vehicle responded to price difference with an odds ratio of 0.8. This means that for a price difference of $1,000, 80% as many households would choose an EV over a cheaper, gasoline-burning vehicle, after the effects of other criteria on vehicle choice were removed (Ewing & Sarigöllü 1998). In the same study, for a price differential of $1,300, 24% of respondents reported that they would choose an EV as their next purchase, while 25% would choose a conventional gas-powered vehicle similar to their current vehicle (the remaining 51% would choose a more fuel efficient gasoline vehicle than the vehicle they currently own, postulated to cost $1,300 less in the study). This indicates that consumers would be *more* willing to choose an EV than purchase price alone would predict. The authors of the study explain that this is likely due to the convenience and performance features of an EV that are superior to a gasoline vehicle.

The purchase price of the Volt is expected to be $40,000 (this cost may come down over time). A comparable gasoline vehicle is expected to cost $22,500; therefore, the price differential between a gasoline vehicle and an HEV would be $17,500. If 80% as many car consumers would choose an HEV over a conventional vehicle in a given year when the price difference is between $1,300 and $4,000, as referenced in the literature above, and if the odds ratio sensitivity to price differential is 0.8, the percentage of consumers choosing an HEV in a given year would be (0.8)17.5 x 25% = 0.5%.

For the sake of simplicity, we are assuming that the only difference between the HEV and the gasoline-powered vehicle is price, although realistically this is clearly not the case. As a result, this is likely an underestimation of HEV adopters, given the performance and convenience features of HEVs that would be attractive to consumers. Other assumptions include (1) Minnesota consumers behave similarly to California consumers; and (2) HEV choice is similar to EV choice.

If the state of Minnesota were to offer tax rebates of $3,000 to offset the purchase price of an HEV, the percentage adopting this technology in a given year would be (0.8)14.5 x 25% = 0.98%.

Minnesota consumers currently purchase about 68,700 cars and light trucks per year, according to Minnesota Pollution Control Agency (MPCA) data. Presumably, all of these consumers would consider an HEV choice. Therefore, without the tax rebate, 344 HEV cars would be adopted annually, and with the rebate 673 HEV cars would be adopted annually.

1. Reduced CO2 emissions leading to reduced state contribution to GHG emissions

Without the recommendation being implemented, any HEVs added to the fleet would use electricity from Minnesota's current grid. Minnesota's GHG emissions per kilowatt hour (kWh) electricity in 2004 were 0.84 kg CO2e (Minnesota Department of Commerce 2005). In 2004, GHG emissions from gasoline vehicles were 0.000554 metric tons CO2e per vehicle mile traveled (Ciborowski 2007). An average personal vehicle in the state traveled 10,308 miles per year in 2004 (MPCA). This is approximately 28.2 miles per day; the Volt is designed to run 40 miles on the battery alone before recharging either electrically or with the gasoline motor. Therefore, the average Minnesota consumer could use the Volt as an entirely electric car, with an efficiency of 3 miles/kWh.

If the recommendation were not adopted, *avoided* emissions in the transportation sector in a given year would equal the emissions of gasoline vehicles replaced by HEVs minus emissions from adopted HEVs:

(344 cars x 10,308 miles x 0.000554 metric tons CO2e/mile) – (0.84 kg/kWh x 10,308 miles/3 miles/kWh x 1 metric ton/1,000 kg x 344 cars) = 972 metric tons CO2e.

If the recommendation were adopted, and gasoline vehicles were replaced by HEVs using entirely renewable (zero-emission) electricity, avoided emissions in a given year would equal the emissions of gasoline vehicles replaced by HEVs:

673 cars x 0.000554 metric tons CO2e emissions/mile x 10,308 miles = 3,843 metric tons CO2e

Please see the cost-benefit assessment for Energy Recommendation 3 above for a more detailed discussion of the value to Minnesota of reducing carbon emissions. For this recommendation, we used the price per ton of ECX carbon futures set for December, 2008 as a proxy for the value of Minnesota reducing its GHG emissions. This price is currently 26 euros ($40.80) per metric ton. If the carbon reduction merits of the HEV subsidy/renewable electricity program could be demonstrated, the carbon savings could presumably be sold under "Certified Emissions Reductions" trading on the ECX. This means that the value of yearly carbon savings compared with a "no adoption" scenario could be:

(3,843 metric tons – 972 metric tons) x $40.80/metric ton = $117,137

As more cars are adopted each year of the program, the value of this carbon savings compounds to **$1,757,000** over five years.

2. Reduced emissions of particulates, ground-level ozone, nitrogen dioxide, carbon monoxide, and toxics leading to human health and ecosystem health benefits

Numerous studies have dealt with the human health effects of particulate and ground-level ozone emissions from gasoline-powered vehicles (Cifuentes et al. 2001). A survey of human health impact studies from California puts the direct and indirect costs of motor vehicle emissions at between $9.4 billion and $240.3 billion annually (Plenys 2004). This value includes health-care costs, lost workdays, and the costs of restricted activity days caused by exposure to vehicle emissions. This amounts to between $266 and $6,793 per person, based on California's total population in 2003. California's CO2 emissions in 2003 from the transportation sector were 233,875,458 metric tons (USDOE 2008). Assuming a linear relation between health-care costs and emissions for the purpose of applying these numbers to Minnesota, the health-related costs of vehicle emissions are $0.00114 and $0.02905 per person per 1,000 metric tons CO2 emitted (with CO2 serving as a proxy for emissions hazardous to human health).

If we apply these parameters to the avoided CO2 emissions attributed to the HEV program, annual savings for the baseline year 2003 would be between:

$0.00114 x (5,088,006 Minnesotans) x (3,843 – 972) metric tons/1,000 = $16,653
$0.02905 x (5,088,006 Minnesotans) x (3,843 – 972) metric tons/1,000 = $424,353

These costs would obviously be higher in the first year of the HEV program (assumed to begin in 2010), due to Minnesota's higher population at that time. However, all other costs are calibrated for year 2003–04, and there is no information on emissions beyond 2004, so we will simply consider these costs to be conservative.

For all five years of the program, cumulative savings would therefore be between **$250,000** and **$6,365,000**

Ground-level ozone emissions also negatively affect vegetation (Ollinger et al. 1997). The beneficial impact on plant and animal health incurred by reducing these emissions through replacement of gasoline-powered vehicles is unfortunately too complex to quantify here.

3. New labor markets and business opportunities associated with wind electricity production for the transportation sector

The assumption we make here is that additional wind capacity would be needed to fuel an HEV fleet. It is possible that base load power management could be introduced to fuel the fleet, but that was not considered here.

Kildegaard and Myers-Kuykindall (2006) indicate that community-based wind projects offer more benefits to local economies than large-scale corporate projects. These benefits are estimated as $18,889 per megawatt (MW) of installed wind capacity. Minnesota is currently using nearly 100% of its available wind capacity, so more wind systems would need to be built to power an HEV fleet. Assuming that community-based wind projects could be mobilized, benefits of a wind-powered HEV fleet would be:

10,308 miles x (1 kWh/3 miles) x (1 MWh/1,000 kWh) x (1 MW/8,760 MWh) x 3 (ratio of installed capacity to operational capacity for wind systems) x 673 cars = 0.79 MW annually x ($18,889/MW) = $14,959 or **$75,000** compounded over 5 years.

4. New labor markets and business opportunities associated with HEV production

An analysis of the impacts of EV production on the U.S. economy generated a net positive output of $1.33 billion for a market penetration of 684,000 vehicles, compared to economic output without EV manufacture (Meade 1995). This includes the employment and economic benefits of manufacturing EVs, parts and electricity, as well as the negative effects of displacing gasoline vehicle manufacture and gasoline production. Applying these findings to the Minnesota economy is somewhat problematic because the state does not contain all of the relevant economic sectors. However, we believe applying the national figures to Minnesota will yield a conservative estimate of benefits because more vehicle parts and fuel manufacturing for EVs than for gasoline vehicles would take place in the state. Therefore, the benefits of HEV penetration in Minnesota under the tax rebate program are estimated to be:

($1,330,000,000)/(684,000 vehicles) x (673 – 344 vehicles per year) x 5 years = **$3,199,000**

Key Costs

We identified four key costs for this recommendation:

1. Cost of subsidizing HEV purchases borne by state
2. Cost of transitioning to HEVs borne by consumers
3. Opportunity costs associated with government spending on this program and with lost revenue from gasoline/ethanol-powered vehicle production
4. Cost of adding additional wind power to the grid

1. Cost of subsidizing HEV purchases borne by state

This calculation is fairly straightforward:

$3,000/vehicle x 673 vehicles x 5 years = **$10,095,000**

2. Cost of transitioning to HEVs borne by consumers

The cost for consumers of transitioning from a gasoline vehicle to an HEV includes the price differential between HEV and gasoline vehicles minus the tax rebate payments, minus the difference in operation and maintenance costs between HEVs and gas vehicles. Essentially, it is the cost of ownership of an HEV compared with that of a conventional vehicle. This cost depends on several parameters, including the price of gasoline and the price of electricity. Because these parameters are notoriously difficult to model or predict with any accuracy, in this assessment current values are used.

The cost of wind electricity in the upper Midwest is taken to be $0.052/kWh (Jones et al. 2006). With the HEV's electric engine efficiency of 3 miles/kWh, an HEV will travel 58 miles for $1.00. A gasoline-powered vehicle will go about 5.5 miles for $1.00 with gasoline prices at $4.00/gallon and a vehicle efficiency of 22 mpg.

For a Minnesotan driving the average 10,308 miles per year in an HEV, fueling costs would total $252/year. A gas-powered car would take $1,874/year to fuel. Maintenance costs for an EV at low market penetration are estimated at 5.1¢ per mile, due to the EV engine's relatively few moving parts (Cuenca et al. 1999), while for a gasoline-powered car they are 13.2¢ per mile. This totals $529 annually for HEV maintenance and $1,358 annually for gasoline vehicle maintenance. Fueling and maintenance costs together are therefore $781/year for the HEV and $3,232/year for the gasoline vehicle.

The recommendation would put 673 – 344 = 329 more HEVs on the road compared with the "no implementation" situation, so total costs to consumers break down as follows:

Purchase price difference of HEV compared w/gasoline vehicle, with tax rebate:
5 years x $14,500 x 329 cars = $23,852,500

Operation cost difference for HEVs compared with gas vehicles:
15 years of operation (5 for cars adopted in first year; 4 for cars adopted in second year, and so on) x ($3,232 – $781) x 329 cars = –$12,095,685

Total cost to HEV consumers = **$11,757,000**

Note that, under these assumptions, an HEV would pay for its additional purchase price through reduced operating costs (compared with a gasoline vehicle) within six years.

3. Opportunity costs associated with government spending on this program and with lost revenue from gasoline/ethanol-powered vehicle production

The opportunity costs associated with no longer producing gasoline vehicles are included in the economic effects described by Meade (1995). Opportunity costs of the tax rebate program would require determining whether this program is the most effective investment of resources to achieve its stated goal. This recommendation should therefore be compared with other recommendations designed to reduce Minnesota's GHG emissions and shift the state's vehicle fleet away from gasoline and ethanol, both of which have more negative impacts on natural resources than renewable electrical power. Given that GHG emissions from the transportation sector are a large and growing portion of Minnesota's GHG budget, if the tax rebate program were to advance widespread adoption of HEVs, the effect could be extremely positive. The market penetration of HEVs would be determined by at least the following, all of which are very difficult to project into the long-term future:

- Future price of the vehicles
- Maintenance and battery replacement policies of vehicle manufacturers
- Future fuel efficiency of gasoline vehicles
- Future price of electricity and gasoline
- State transportation and development policies
- Alternative transportation availability (e.g., mass transit)

The opportunity costs associated with government spending and lost revenue are **unquantified**.

4. Cost of adding additional wind power to the grid

The cost of installing new wind projects has been estimated at $1,091,000 per MW (Jones et al. 2006). Given the electricity requirements outlined in the business opportunities section above, new installed wind capacity for the five year HEV introduction period would cost **$4,309,000**.

Summary of Key Benefits and Costs

The results of the five-year cost-benefit assessment are summarized in the table below, after being adjusted to 2007 values. However, some key costs and benefits of the program were not quantified—for example, some health benefits of gasoline vehicle reduction and opportunity costs of implementing tax rebates. With a lower purchase price for HEVs and higher gasoline prices relative to electricity prices, the benefits of a tax rebate program would rise relative to the costs. It is important to assess this recommendation in the context of other programs designed to achieve lower GHG emissions and reduced gasoline/ethanol consumption.

Benefits	**Amount**	**Party receiving benefit**
1. Reduced CO2 emissions	$1,757,000	State—credit received through ECX
2. Reduced particulate, ground-level ozone, NO2, CO, and toxics emissions	Human health benefits: $250,000–$6,365,000 Ecosystem health benefits: unquantified	Citizens, ecosystems/ wildlife, businesses
3. New labor/business opportunities associated with wind electricity production	$75,000	Business community, citizens, state and local governments through taxes
4. New labor/business opportunities associated with HEV production	$3,199,000	Business community, citizens, state and local governments through taxes
Costs	**Amount**	**Party incurring cost**
1. Subsidies for HEVs	$10,095,000	State government
2. Cost of transitioning to HEVs borne by consumers	$11,757,000	Citizens
3. Opportunity costs of government spending and lost revenues from vehicle production	Unquantified	
4. Cost of adding wind power to grid	$4,309,000	Business community

Table 6. Summary of potential costs and benefits from an HEV tax rebate program in the first five years of project implementation. For assumptions and references, please see text.

Literature Cited

Aden, A., M. Ruth, K. Ibsen, J. Jechura, K. Neeves, J. Sheehan, B. Wallace, L. Montague, A. Slayton, and J. Lukas. 2002. *Lignocellulosic biomass to ethanol process design and economics utilizing co-current dilute acid prehydrolysis and enzymatic hydrolysis for corn stover*. NREL Technical Report No. NREL/TP-510-32438, Golden Colo.

Anderson J., R. Beduhn, D. Current, J. Espeleta, C. Fissore, B. Gangeness, J. Harting, S. Hobbie, E. Nater, and P. Reich. 2008. *The potential for terrestrial carbon sequestration in Minnesota*. Report to the MNDNR from the Minnesota Terrestrial Carbon Sequestration Initiative. Available at: http://wrc.umn.edu/outreach/carbon/pdfs/andersonetal2008.pdf

Apfelbaum, S., D. Eppich, and J. Solstad. 2004. *Wetland hydrology and biodiversity in the Red River Basin*, Minnesota. Technical Paper No. 12, Technical and Scientific Advisory Committee of the Red River Basin Flood Damage Reduction Workgroup.

Aquatic Management Area (AMA). 2007. Minnesota's Aquatic Management Area Acquisition Plan 2008–2033: Shoreline Habitat, Angling, and Clean Water For Our Future, Acquisition Planning Committee.

Babcock B., P. Gassman, M. Jha, and C. Kling. 2007. *Adoption subsidies and environmental impacts of alternative energy crops*. Briefing Paper 2007. Center for Agricultural and Rural Development, Iowa State University.

Bangsund, D. A., N. M. Hodur, and F. L. Leistritz. 2004. Agricultural and recreational impacts of the conservation reserve program in rural North Dakota, USA. *Journal of Environmental Management* 71:293–303.

Bergstrom, J.C., J. R. Stoll, J. P. Titre, and V. L. Wright. 1990. Economic value of wetlands-based recreation. *Ecological Economics* 2:129–47.

Birdsey, R. A., and L. S. Heath. 1995. Carbon changes in U.S. forests. In *Productivity of America's forests and climate change*, ed. L. Joyce. General Technical Report, RM GTR-271. Fort Collins, Colo.: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Bolund, P., and S. Hunhammar. 1999. Ecosystem services in urban area. *Ecological Economics* 29.

Brauman, K. A., G. C. Daily, T. K. Duarte, and H. A. Mooney. 2007. The nature and value of ecosystem services: An overview highlighting hydrologic services. *Annu. Rev. Environ. Resour.* 32:67–98.

Carpenter, S. R., N. F. Caraco, D. L. Correll, R. W. Howarth, A. N. Sharepley, and V. H. Smith. 1998. Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications* 8:559–68.

Carson, R. T., and R. C. Mitchell. 1993. The value of clean water: The public's willingness to pay for boatable, fishable, and swimmable quality water. *Water Resources Research* 29 (7): 2445–54.

Census Bureau, 2001. *National survey of fishing, hunting, and wildlife-associated recreation*. U.S. Dept. of Interior, FWS; and U.S. Dept. of Commerce, Census Bureau.

Cho, Y. 1990. Willingness to pay for drinking water quality improvements: A contingent valuation study for southwestern Minnesota. University of Minnesota graduate thesis.

Ciborowski, P. 2007. Personal communication. Minnesota Pollution Control Agency.

Cifuentes, L., V. H. Borja-Aburto, N. Gouveia, G. Thurston, and D. L. Davis. 2001. Hidden health benefits of greenhouse gas mitigation. *Science* 293:1257–59.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387.

Costanza, R., S. C. Farber, and J. Maxwell. 1989. Valuation and management of wetland ecosystems. *Ecological Economics* 1: 335–61.

Cuenca, R. M., Gaines, L. L., and A. D. Vyas. 1999. *Evaluation of EV production and operating costs*. Center for Transportation Research Report # ANL/ESD 41, Energy Systems Division, Argonne National Laboratory.

Dahl, T. E. 1990. *Wetland losses in the United States: 1780–1980s.* Washington, D.C.: U.S. Department of the Interior.

Daily, G. C., S. Alexander, P. R. Ehrlich, L. Goulder, J. Lubchenco, P. A. Matson, H. A. Mooney, S. Postel, S. H. Schneider, D. Tilman, and G. M. Woodwell. 1997. Ecosystem services: Benefits supplied to human societies by natural ecosystems. *Issues in Ecology 2*.

Dhondt, A. A., and K. V. Sydenstricker. 2001. *Avian biodiversity studies in short rotation woody crops*. Ithaca, N.Y.: Cornell University Laboratory of Ornithology.

Dwyer, J. F., E. G. McPherson, H. W. Schroeder, and R. A. Rowntree. 1992. Assessing the benefits and costs of the urban forests. *Journal of Arboriculture* 18(5).

Ewing, G., and E. Sarigöllü. 1998. Car fuel-type choice under travel demand management and economic incentives. *Transpn Res.*-D 3(6): 429–44.

Fargione, J., J. Hill, D. Tilman, S. Polasky, and P. Hawthorne. 2008. Land clearing and the biofuel carbon debt. *Science* 319 (5867): 1235–38.

Gibbs, J.P. 2000. Wetland loss and biodiversity conservation. *Conservation Biology* 14: 314–17.

Godschalk, D. R., T. Beatley, P. Burke, D. J. Brower, and E. J. Kaiser. 1999. *Natural hazard mitigation: Recasting disaster policy and planning*. Washington, D.C.: Island Press.

Golub, T. F., J. Torous, and S. Crane. 1994. *Precursors of demand for alternative-fuel vehicles: Results from a survey of 2,000 fleet sites in California*. Institute of Transportation Studies # UCI-ITS-WP-94-11, U.C. Irvine.

Goulder, L. H. and D. Kennedy. 1997. Valuing ecosystem services: philosophical bases and empirical methods. In *Nature's services: Societal dependence on natural ecosystems*, ed. G. C. Daily. Washington, D.C.: Island Press.

Gren, I. 1995. The value of investing in wetlands for nitrogen abatement. *European Review of Agricultural Economics* 22:157–72.

Groode, T. A., and J. B. Heywood. 2007. *Ethanol: A look ahead*. Cambridge, Mass.: MIT Laboratory for Energy and the Environment.

Guntenspergen, G. R., S. A. Peterson, S. G. Leibowitz,, and L. M. Cowardin. 2002. Indicators of wetland condition for the Prairie Pothole Region of the United States. *Environmental Monitoring and Assessment* 78:229–52.

Hachfeld, G., W. Lazarus, D. Nordquist, and R. Loppnow. 2008. *Cropland rental rates for Minnesota counties*. University of Minnesota.

Hazards & Vulnerability Research Institute. 2007. *The spatial hazard events and losses database for the United States, Version 5.1* Online database. Columbia, S.C.: University of South Carolina. Available from http://www.sheldus.org.

Henry, R., R. Ley, and P. Welle. 1988. The economic value of water resources: The lake Bemidji survey." *J. Minnesota Academy of Science* 53 (3).

Hey, D. L., and N. S. Philippi. 1995. Flood reduction through wetland restoration: The Upper Mississippi River Basin as a case study, *Restor*. Ecol. 3:4–17.

Hey, D.L., L.S. Urban, and J.A. Kostel. 2005. Nutrient farming: The business of environmental management. *Ecol. Eng*. 24:279–87.

Hickman, S. 1994. Improvement of habitat quality for nesting and migrating birds at the Des Plaines River Wetlands Demonstration Project. *Ecol. Eng.* 3:485–94.

IAFWA. 2002. Economic importance of hunting in America. Washington, D.C.: International Association of Fish and Wildlife Agencies.

Jacobson R.L. 2004. Restoration of an 1,800 acre prairie pothole wetland complex in Northwestern Minnesota. In: *Proceedings of the 2003 International Conference on Ecology and Transportation*, ed. C. L. Irwin, P. Garrett, and K. P. McDermott, 115–28. Raleigh, N.C: Center for Transportation and the Environment, North Carolina State University.

Jones, K. A., B. Jordan, K. H. Keller, and S. J. Taff. 2006. *Reducing CO2 emissions in the upper Midwest: Technology, resources, economics, and policy*. Staff paper P06-10, Department of Applied Economics, University of Minnesota.

Kildegaard, A., and J. Myers-Kuykindall. 2006. *Community vs. corporate wind: Does it matter who develops the wind in Big Stone County, MN?* University of Minnesota Morris.

Krieger, D. G. 2001. *Economic value of forest ecosystem services: A review.* Washington, D.C.: The Wilderness Society.

Kurani, K., T. Turrentine, and D. Sperling. 1996. Testing EV demand in 'hybrid households' using a reflexive survey. *Transpn Res.*-D 1(2): 131–50.

Lazarus, B., S. Taff, and T. Zou. 2008. *Minnesota crop cost and return guide 2008* [DRAFT]. St. Paul: University of Minnesota.

Lehtinen, R.M, and S.M. Galatowisch. 2001. Colonization of restored wetlands by amphibians in Minnesota. *The American Midland Naturalist* 145:388–96.

Lines, Kevin. 2008. Personal communication (conservation easement program administrator, Board of Water and Soil Resources).

Loomis, J. 1988. *Economic benefit of pristine watersheds.* Denver: American Wilderness Alliance.

Loomis, J., and R. Richardson. 2000. *Economic values of protecting roadless areas in the United States.* Washington, D.C.: The Wilderness Society.

Mathews, L. G., F. R. Homans, and K. W. Easter. 1999. *Reducing phosphorus pollution in the Minnesota River: How much is it worth?* St. Paul: Department of Applied Economics, University of Minnesota.

McPherson, E. G. 1992. Accounting for benefits and costs of urban green space. *Landscape and Urban Planning* 22.

McPherson, E. G., D. Nowak, G. Heisler, S. Grimmond, C. Souch, R. Grant, and R. Rowntree. 1997. Quantifying urban forest structure, function, and value: the Chicago Urban Forest Climate Project. *Urban Ecosystems* 1.

Meade, D. 1995. The impact of the electric car on the U.S. economy: 1998–2005. *Econ. Systems Res.* 7(4): 413-38.

Minnesota Department of Commerce. 2005. *The Minnesota utility data book: A reference guide to Minnesota electric and natural-gas utilities 1965–2005.*

Minnesota Department of Natural Resources. 2006. *Long Range Duck Recovery Plan.*

Minnesota Department of Natural Resources. 2008. Natural resources, recreation & the economy. http://www.dnr.state.mn.us/faq/mnfacts/economy.html (July 2008).

Minnesota Land Economics. http://www.landeconomics.umn.edu.

Mitsch, W. J., J. W. Day Jr., J. W. Gilliam, P. M. Groffman, D. L. Hey, G. W. Randall, and N. Wang. 2001. Reducing nitrogen loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to counter a persistent ecological problem. *Bioscience* 51:373–88.

Mitsch, W. J., and J. G. Gosselink. 2000. *Wetlands*. 3rd ed. New York: Wiley.

Morales, D. J. 1980. The contribution of trees to residential property value. J. *Arboriculture* 6.

Moskowitz, K., and J. Talberth. 1998. *The economic case against logging our national forests*. Santa Fe, N.M.: Forest Guardians.

Murdoch, P. S., J. S. Baron, and T. L. Miller. 2000. Potential effects of climate change on surface-water quality in North America. *Jour. Am. Water Res. Assoc.* 36: 347–66.

Murray, L. D., L. B. Best, T. J. Jacobsen, and M. L. Braster. 2003. Potential effects on grassland birds of converting marginal cropland to switchgrass biomass production. *Biomass & Bioenergy* 25: 167–75.

Ollinger, S. V., J. D. Aber, and P. B. Reich. 1997. Simulating ozone effects on forest productivity: Interactions among leaf-, canopy-, and stand-level processes. *Ecol. App.* 7(4): 1237–51.

Perrin, R., K. Vogel, M. Schmer, and R. Mitchell, R. 2008. Farm-scale production cost of switchgrass for biomass. *BioEnergy Research* 1(1): 91–97.

Phillips, S. 1999. Windfalls for wilderness: Land protection and land use in the Green Mountains. Craftsbury Common, Vt.: Ecology and Economic Research Group, Wilderness Society.

Plenys, T. 2004. *Health care costs in California due to petroleum related processes and byproducts.* Environment Now draft report available at http://www.hydrogenhighway.ca.gov/topicteams/Economy/task5/draft_health_costs.doc

Polasky, S. 2008. Why conservation planning needs socioeconomic data. *Proc. Nat. Acad. Sciences* 105(18): 6505–06.

Prato, T., and D. Hey. 2006. Economic analysis of wetland restoration along the Illinois River. *Jour. Am. Water Res. Assoc.* 42:125–31.

Radomski, P. J. 2008. *Shoreland - present and future: A presentation to statewide external advisory committee to the Minnesota shoreland rule update project*.

Roberts, L.A., and J. A. Leitch. 1997. *Economic valuation of some wetland outputs of Mud Lake, Minnesota-South Dakota*. Department of Agricultural Economics, Agricultural Economics Report No. 381. North Dakota State University.

Scarpa, R., J. Buongiorno, J. S. Hseu, and K. S. Abt. 2000. "Assessing the nontimber value of forests: A revealed-preference, hedonic model. *Journal of Forest Economics* 6(2).

Schmitt J., T. Smith, and S. Suh. 2008. *Environmental and economic assessment of ethanol production systems.* Report to the Minnesota Pollution Control Agency.

Schultz, S. D. and J. A. Leitch. 2003. The feasibility of restoring previously drained wetlands to reduce flood damage. *J. Soil Water Conserv.* 58:21–29.

Stern, N. 2007. *The economics of climate change: The Stern review*. U.K.: Cambridge University Press.

Stevens, C. E., T. S. Gabor, and A. W. Diamond. 2003. Use of restored small wetlands by breeding waterfowl in Prince Edward Island, Canada. *Restoration Ecology* 11: 3–12.

Stevens, T. H., S. Benin, and J. S. Larson. 1995. Public attitudes and economic values for wetland preservation in New England. *Wetlands* 15:226–31.

Taff, S. J. 2008. *Minnesota farm real estate sales: 1990–2007*. Department of Applied Economics, Staff Paper P08-5. University of Minnesota.

Tiffany, D. 2008. Personal communication 7/11/08 (research fellow, University of Minnesota Department of Applied Economics).

Townsend, A. R., R. W. Howarth, F. A. Bazzaz, M. S. Booth, C. C. Cleveland, S. K. Collinge, A. P. Dobson, P. R. Epstein, E. A. Holland, D. R. Keeney, M. A. Mallin, C. A. Rogers, P. Wayne, and A. H. Wolfe. 2003. Human health effects of a changing global nitrogen cycle. *Frontiers in Ecology and the Environment* 1(5): 240–46.

Turner, R., and N. Rabalais. 2003. Linking landscape and water quality in the Mississippi River basin for 200 years. *Bioscience* 53:563–72.

USACE (U.S. Army Corps of Engineers). 1995. Floodplain management assessment of the Upper Mississippi River and Lower Missouri rivers and tributaries. Vol. 6.Washington, D.C.: USACE.

U.S. Department of Energy. Energy Information Administration. http://www.eia.doe.gov (July 2008).

US FW fact sheet 2001. http://www.fws.gov/partners/docs/factsheets/2007/81.pdf

Walsh, Richard G., F. Ward, and J. Olienyk, 1989. Recreational demand for trees in national forests. *Journal of Environmental Management* 28.

Westra, J. V., J. K. H. Zimmerman, and B. Vondracek. 2005. Bioeconomic analysis of selected conservation practices on soil erosion and freshwater fisheries. *Journal of the American Water Resources Association* 41(2): 309–22.

Weyer, P. J., J. R. Cerhan, B. C. Kross, G. R. Hallberg, J. Kantaneni, G. Breuer, M. P. Jones, W. Zheng, and C. F. Lynch. 2001. Municipal drinking water nitrate level and cancer risk in older women: The Iowa women's health study. *Epidemiology* 12:327–38.

Wilcove, D. S., M. McMillan, and K. C. Winston. 1993. What exactly is an endangered species? An analysis of the U.S. endangered species list: 1985¬–1991. *Conservation Biology* 7:87–93.

Wilson, M. A.. and Carpenter, S. R., 1999. Economic valuation of freshwater ecosystem services in the United States: 1971–1997. *Ecological Applications* 9(3).

Winter, T.C. 2000. The vulnerability of wetlands to climate change: A hydrological perspective. *Jour. Am. Water Res. Assoc.* 36:305–11.

Woltemade, C. J. 2000. Ability of restored wetlands to reduce nitrogen and phosphorus concentrations in agricultural drainage water. *J Soil Water Conserv* 55:303–09.

Woodward, R. T., and Y. Wui. 2001. The economic value of wetland services: a meta-analysis. *Ecological Economics* 37:257–70.

Zedler, J. B., and S. Kercher. 2005. Wetland resources: Status, trends, ecosystem services, and restorability. *Annu. Rev. Environ. Resour.* 30:39–74.