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The Economic Impacts of Alternatives to Open-Field Burning of Agricultural Residues

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD
Research Division

THE ECONOMIC IMPACTS OF ALTERNATIVES TO OPEN-FIELD BURNING OF AGRICULTURAL RESIDUES

Final Report
Contract No. A132-121

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Abstract

This report relied upon field interviews, existing analytical data, and the development of a computable general equilibrium model to investigate the economic implications of policies limiting the ability of almond, rice, walnut, and wheat growers to burn their crop residues. Through this investigation it was determined that, in the face of a straw residue burning phase-down, the majority of rice and wheat growers would soil-incorporate their straw with minimal economic disruption. However, if such a practice results in significant yield reductions, noticeable individual and regional economic impacts would be engendered. Almond and walnut growers cannot soil-incorporate their residues without significant changes to production practices. Given the limited economically feasible methods of disposing of residues off-site, a prohibition on almond and walnut residue burning could create substantial economic and technical difficulties for these growers.

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Executive Summary

As byproducts of California agriculture, approximately 450,000 tons of almond prunings, 1.2 million tons of rice straw, 170,000 tons of walnut prunings, and 1.5 million tons of wheat straw are produced annually in the state. Open-field burning of these agricultural residues is a common waste disposal practice among growers -- particularly rice farmers -- in California's Central Valley. As a result of open-field burning of these crops, upwards of 5 million pounds of particulate matter is emitted into California's skies. Residue burning is an inexpensive and effective method of clearing fields and orchards of unwanted post-harvest debris. In the case of rice and wheat, residue burning also protects fields against the incidence of yield-reducing diseases.

While residue burning is an effective and efficient method of disposing of unwanted agricultural material, burning emits polluting air emissions into the atmosphere. As what was once primarily agricultural areas in the Central Valley become increasingly urbanized, these polluting emissions can adversely affect growing populations, creating visibility problems and potentially leading to greater incidences of morbidity. Because of concerns over the adverse effects of residue burning in the Sacramento Valley, a recently enacted state law -- Assembly Bill (A.B.) 1378, first implemented in September, 1992 -- will phase down most rice straw residue burning by the turn-of-the-century.

This report presents the findings of an eighteen-month investigation into the economic and financial implications of potential policies to prohibit the burning of almond, rice, walnut and wheat residues. These findings are based on information collected through focus group meetings with farmers and agricultural experts; a comprehensive analysis of the feasibility of various non-burning residue management approaches; and a case study analysis of the financial implications of adopting non-burning residue management strategies. In addition, a computable general equilibrium (CGE) model framework was used to project the regional economic implications of the current law rice straw burning prohibition in the Sacramento Valley. Key analytical findings are as follows:

Potential Residue Disposal Alternatives

- There are **two primary alternatives to crop residue burning: off-site residue disposal or soil incorporation**.

    - **Off-site disposal** involves collecting residues from fields or orchards, preparing the residues for transportation -- including baling rice and wheat straw or chipping almond and walnut prunings into small pieces -- and disposing of the material in some manner. Total costs to collect and transport rice and wheat straw to a disposal site are estimated to average between $50 to $75 per acre, with ultimate costs depending on farm location, soil conditions, and the weather. Incremental costs to collect and transport orchard residues to a disposal site are estimated to average $20 per acre. **Potential end-uses for off-site disposal of residues fall into two categories: energy production or non-energy products.**

        - Utilizing residues for energy production could potentially consume a large quantity of crop residues. **Currently, approximately 4.5 million tons of wood residues from sawmills, orchard prunings, and, to a more limited extent,**

rice and wheat straw -- are utilized to produce electricity under the California Public Utilities Commission's (CPUC) Interim Standard Offer Number Four (ISO4) contracts. ISO4 contracts provide sufficient payments to cover the costs of transporting residues from fields and orchards to generating stations, and enable biomass "brokers" to make a small profit. However, most ISO4 contracts will expire by the turn-of-the-century. Because of low forecasted prices for non-biomass fuels -- particularly natural gas -- coupled with expiration of the ISO4 contracts, the price paid for biomass material is likely to fall dramatically by the year 2000. After the year 2000 it is estimated that growers will have to pay biomass operators a "tipping" fee of $17 to $50 a ton to accept their residues if these plants continue to operate without a subsidy. As a result, **use of agricultural waste as biomass to generate electricity does not appear to be a viable disposal alternative after the turn-of-the-century**.

- **Utilizing residues to produce ethanol offers another potentially large-scale means of disposing of crop residues**. The Sacramento Municipal Utility District (SMUD) Financing Authority, in partnership with ARKENOL, Inc. (ARK Energy, Inc.), is currently exploring the feasibility of the Sacramento Ethanol Project (SEPCO). **The ethanol plant is designed to consume 132,000 tons of agricultural residues annually. SEPCO would purchase straw at a price sufficient for brokers to make a small profit, or, at minimum engender no additional disposal costs for growers**. However, **a comparison of SEPCO's planning documents with existing studies of ethanol production costs under a variety of conditions suggests that SEPCO may not be financially viable**. The financial feasibility of the project depends heavily on the price received for production byproducts -- such as sodium silicate -- and on federal ethanol subsidies, and is based on levels of production efficiencies that appear optimistic. As a result, it is unclear whether or not SEPCO will eventually provide growers with a means of disposing of their residues. **If the plant is ultimately successful, it could lead to additional plants being built, thereby creating a large end-use market for crop residues. However, if the plant fails, or is never built, this potential residue disposal opportunity will not be available to growers**.

- **There are a large number of potential non-energy related uses for crop residues, including use in mushroom composting, erosion control, and landfill covering. However, the aggregate demand for residues for these uses is small relative to the amount of residues produced; the markets are already saturated; and potential demand is not expected to grow significantly in the near future. As a result, any substantial expanded use of, for example, rice straw for any of these purposes would simply act to displace another crop residue**.

- **Soil incorporation** involves assimilating the residues back into the field or orchard, where it decomposes and becomes a part of the soil.

- **Soil incorporation of almond and walnut prunings is not feasible under existing cultivation practices.** Since nuts are harvested by "sweeping" the orchard floor, prunings left in the orchard could impede harvesting, leading to delay and equipment break-down. In addition, almond and walnut growers do not typically till their orchards, a necessary procedure under a soil incorporation regime.

- **Soil incorporation is a feasible practice for rice and wheat residues, and is currently a common practice among wheat growers.** Total costs of rice straw incorporation are estimated to range from as little as $10 to as much as over $90 per acre, with an average long-run cost of between $20 to $35 per acre. The average long-run incorporation cost associated with wheat straw is somewhat lower than for rice straw, due to differences in straw volume and characteristics, and soil composition. The main impediment to wheat straw incorporation is that, because of the time required for the straw to decompose, adoption of this practice could impede some growers' existing crop patterns, eliminating these growers' ability to double-crop. In addition, soil incorporation of wheat residues could necessitate increased use of herbicides, thereby raising production costs even beyond those estimated above.

- **The primary barrier to soil incorporation of rice straw residues is the potential that such a procedure will lead to either increased incidence of disease -- chiefly stem rot -- or change soil conditions in such a way as to reduce crop yields.** Insufficient data exists with which to evaluate the likelihood that replacing open-field rice straw burning with soil incorporation will lead to significant yield changes. However, **the potential for substantial yield declines represents the largest financial risk to rice growers under an incorporation regime.**

- Based on this analysis, it appears most likely that **in response to the residue burning prohibition <u>the majority of</u> rice growers will soil incorporate their straw**. In fact, it appears that a significant number of rice growers adopted this practice during the 1992 and 1993 growing seasons. Likewise, **most wheat farmers will soil incorporate if their ability to burn residues is severely limited**. However, **should almond and walnut residue burning be prohibited, in the short-term these farmers are more likely to dispose of their residues off-site**. In the longer-term, almond and walnut growers may change their production practices to make soil incorporation more feasible.

Financial Impact of Adopting Non-Burn Alternatives

- Based on an examination of the financial characteristics of a number of case-study almond, rice, walnut, and wheat operations, **a policy to prohibit agricultural residue burning would result in modest financial impacts to California growers.**

- Almond production typically generates high per acre net revenues, ranging from a low of $200 to over $1,000 per acre. **Although available evidence indicates that the additional costs associated with non-burn alternatives could not be passed on to consumers in the form of higher prices, these additional costs could likely be absorbed by most almond growers with little financial hardship.** Growers who currently have marginal revenues would experience an approximate 10 percent reduction in their per acre revenues. As a result, some of these growers may become uncompetitive. However, most almond growers' per acre revenues would be reduced by less than 2 percent. While any decline in income is unwelcome, this revenue decrease could generally be absorbed without significant hardship. **In most cases, revenue losses would be absorbed through lower land values.**

- Per acre net revenues for walnuts are even higher than for almonds, ranging from $600 to over $1,700. As with almonds, the additional costs induced by adoption of non-burn alternatives could not be passed on to consumers. However, **for most walnut growers these additional costs would reduce per acre net revenues by less than three percent**. This revenue decline would not significantly disrupt walnut growers' financial health.

- Per acre net revenues for rice are much lower than for the orchard crops, ranging from $130 to $225. However, **the cost increases induced by adopting non-burn residue management alternatives alone are not high enough to induce financial hardship on most rice growers. However, should soil incorporation lead to consistent yield reductions of more than 5 percent -- and permission to burn is not granted by the county agricultural commissioners -- rice growers could face significant financial hardship**. For example, if yields were reduced by 15 percent, net revenues per acre would decline by one-third or more. Such yield reductions would result in short-run losses in farm income, while in the long-run the declines would be absorbed by reductions in land values -- wealth. Current law only allows for burning exemptions if yield losses are induced by stem rot disease, not if loses are related to other factors, such as soil poisoning (i.e., organic material decay products). **It is important to note, however, that the <u>limited</u> research available suggests that incorporation-induced soil poisoning is unlikely to induce large-scale and widespread yield losses.**

- Because of low per acre net revenues -- ranging from $20 to $135 -- **wheat growers who currently burn their residues would be hardest hit by a burn ban**. The costs associated with soil incorporation could put some wheat growers whose practice is to burn out-of-business, or force them to switch to an alternative crop. Field removal of residues is prohibitively expensive for most wheat growers unless a market is available for their straw, an unlikely circumstance for growers who do not currently have contracts with end-users. Approximately two-thirds of the state's wheat growers have already adopted non-burn residue management practices, implying those operations that continue to burn do so because it is either financially difficult for them to adopt alternative disposal methods, or burning allows them to increase their profits by planting follow-on crops.

Regional Impact of Adopting Non-Burn Alternatives

- Since in general the individual financial impacts of adopting non-burn residue management alternatives on almond, rice, walnut, and wheat growers are not likely to be large, the regional implications of such policies will likewise be small. **Absent soil incorporation-induced yield reductions, the prohibition on rice straw burning will engender virtually no noticeable regional economic changes in the Sacramento Valley. Under a worst case scenario -- soil incorporation induces a 10 percent reduction in rice yields; no public subsidy is available for residue management costs; and no new demand is created for rice straw -- gross regional product (GRP) in the Sacramento Valley would fall by less than $10 million, smaller than one-tenth of one percent of total GRP.**

- Under the yield loss scenarios most of the loss in GRP would be isolated to the agricultural sector -- **other economic sectors would not be noticeably impacted by the rice straw burning prohibition. In addition, while in some cases the short-term adjustment process to the burn prohibition could result in noticeable economic disruption in particular communities, in the long-run much of the agricultural sector's losses would be felt in reductions in land value -- wealth -- rather than a direct decreases in income**.

- Regional impacts would partially be muted by the ability of <u>some</u> rice growers to grow alternative crops, including sorghum, alfalfa, and corn. The changes in rice production levels likely to be induced by the non-burn policy generally fall within the historical rise and fall of rice production in the Sacramento Valley.

- While A.B. 1378 provides some protection from economic disruption related to the incidence of stem rot disease, should soil poisoning (i.e., OM decay products) act to reduce yields in concentrated areas of the Sacramento Valley, these localities could experience significant economic disruption. However, no evidence is available indicating such an occurrence is likely.

Finally, an important consideration in developing residue management policies related to orchard crops is the limited market for additional residue supplies. Since current cultural practices make it difficult for nut growers to soil incorporate, unless new markets are developed for residues -- or new production technologies are created enabling growers to change their current harvesting practices -- a prohibition on open-field burning of almond and walnut prunings would in the short-term act to flood surrounding communities with agricultural wastes. This material would have to be either stored on agricultural land, dumped in landfill, or centrally burned. Alternatively, if existing economic and technical barriers to large-scale use of agricultural residues in energy production can be overcome, significant economic benefits to the Central Valley would be induced. As a result of these factors, **a policy to prohibit the burning of orchard residues should be carefully considered before being adopted**.

1.0 Introduction

Open-field burning of agricultural residues -- particularly rice straw, wheat residues, and almond and walnut tree residues -- is employed routinely as a means of disposing of unharvested materials.[1] Residue burning helps to prepare fields for tillage, improves the establishment of new crops, and aids in pest and weed abatement. However, open-field burning also contributes to air pollution. For example, between one half and two million tons of rice straw are burned in the Sacramento Valley each year, releasing millions of pounds of particulate matter, hydrocarbons, and other gaseous pollutants.

Depending on the proximity of the burn to populated areas and prevailing atmospheric conditions, smoke from agricultural burning can increase the risk of morbidity and mortality. The particulate matter generated from rice straw burning -- which includes very fine particles -- may be particularly hazardous. Tiny particulates can take a long time (days or weeks) to settle out of the atmosphere. When inhaled these particles travel to the deep lung, where potential for lung damage is greatest. Because of growing urbanization of the state's agricultural regions, the health and environmental risks posed by agricultural residue burning have become a matter of increasing concern by state and local policy makers. As a result, in 1991 legislation to phase down rice straw burning was enacted.[2]

1.1 Legislation Will Restrict Open-Field Burning of Rice Straw

Until recently, attempts to mitigate the adverse health risks associated with agricultural residue burning have consisted primarily of managing the timing of the burning.[3] However, Assembly Bill (A.B.) 1378 requires that, beginning September 1, 1992, the burning of rice straw residue in the Sacramento Valley Air Basin (SVAB) be phased down over an eight year period. A.B. 1378 mandates that the number of rice acres that can be burned in the SVAB will be limited to the following percentage of the amount of acres planted in the prior year:

- In 1992, 90 percent;
- In 1993, 80 percent;
- In 1994, 70 percent;
- In 1995, 60 percent;
- In 1996, 50 percent;
- In 1997, 38 percent;
- In 1998, 25 percent;
- In 1999, 25 percent.

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[1]Residues from several other crops -- principally apricots, cherries, pistachios, peaches, and barley -- are also burned. However, open-field burning of residues from these crops is not as significant as the study crops, and does not appear to generate significant polluting emissions.

[2]This legislation was limited to rice straw burning in the Sacramento Valley only. No other crop residues will be directly affected by the burning prohibition.

[3]The different crops are burned at various times of the year. For example, rice straw residue is typically burned in the fall or spring. The adverse health and environmental impacts associated with burning are significantly affected by the timing and location of the burn.

In the year 2000 and thereafter the maximum number of rice acres in the SVAB that can be burned will be limited to the lesser of (1) The total of 25 percent of each individual applicant's acres on which rice is grown during the year; or (2) A total of 125,000 acres.[4] Within this aggregate limit rice growers will be permitted to burn rice straw residues only if the county agricultural commissioner determines that residue burning is the only economically and technically feasible method of eliminating crop diseases.[5]

1.2 Study Purpose

While passage of the A.B. 1378 rice burning phase-down prompted this study, the analyses contained herein are based on generic policies to phase out residue burning for the four study crops. That is, the policy question to be answered is, what would be the financial and economic implications of a prohibition on almond, rice, walnut, and wheat residue burning? It is important to note that, in general, the analyses assume a simple prohibition on residue burning, rather than a slowly implemented policy which encourages growers to change their residue management strategies over a period of years. Such a phased-in approach would likely result in somewhat smaller impacts than an immediate prohibition, as it would give growers more time to adjust.

This inquiry is being conducted for a number of reasons. First, rice straw residue burning *will* be phased down by law over the next decade. As a result, it is important to determine the implications of this policy to California's agricultural communities so that, if necessary, appropriate mitigating measures can be adopted. Second, by examining the potential implications of burn prohibitions on the study crops which are not currently covered by the A.B. 1378, as well as their surrounding communities, the state legislature and regulatory agencies will have useful information with which to weigh the merits of such action. Third, by evaluating the financial and economic implications of the potential alternatives to residue burning the state legislature and regulatory agencies will have information with which to develop policies that act to reduce agriculturally-related polluting air emissions while simultaneously minimizing the resulting harm to farm communities. And finally, the regional impact model developed as part of this project will be available to the CARB and other state agencies for use in other economic impact projects.[6]

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[4]Between 1958 and 1986 an average of 356,000 acres was planted to rice in the state. Based on this average it is likely that the 25 percent rule will be the binding requirement.

[5]It is important to note that non-disease-related economic losses are <u>not</u> covered under the legislative exemption. So, for example, yield declines resulting from changing soil conditions would not qualify a farming operation to apply for a burn permit. This could be an important factor in cases in which residue incorporation disrupts soil fertility and induces significant yield losses over the long-run.

[6]This model could be used to examine the economic implications of other environmental policies affecting the Sacramento Valley, including pesticide regulation and changes in water supply policies.

1.3 General Description of Report Methodology

As indicated in Figure 1-1, this report is based upon a number of inter-related efforts to collect and analyze information. Key analytical steps included the following:

(1) **Develop project database**. Analytical information was collected as follows:

- Much of the information utilized in the report was derived from formal focus group meetings which were organized for each of the four study crops. These meetings were held throughout the Central Valley. The majority of the focus group attenders were growers, but the meetings also included agricultural cooperative extension agents and staff from various commodity associations. A complete list of focus group attenders is provided in Appendix G.

- Information was also collected through telephone interviews and field visits with agricultural extension agents, "straw brokers,"[7] commodity organizations, and other relevant individuals. Extension agents specializing in rice cultivation in the Sacramento Valley were particularly helpful in evaluating the cost and yield implications of various alternatives to residue burning.

- Publications -- particularly from the U.S. Department of Agriculture (USDA), the California Department of Food and Agriculture (CDFA), and the University of California, Davis (UCD) -- formed the basis for much of the information used in the study related to the amount of crop acreage under production, commodity prices, quantities produced, and the like. Recent UCD reports provided important information related to the costs of potential soil incorporation techniques.

(2) **Conduct alternatives financial and feasibility analysis**. Based on the information collected in step one, a financial and feasibility analysis of the potential alternatives to crop residue burning was conducted. For each of the study crops the universe of potential alternatives was identified (e.g., soil incorporation; composting; use as biomass in cogeneration; use for ethanol production; etc.). The costs and potential implications associated with each of the alternatives were estimated, as well as the potential demand for the alternative's end-use product. This analysis resulted in an estimate of the per acre cost -- or dollar benefit -- to growers of adopting each alternative, as well as estimates of the total amount of residue that could potentially be disposed of in a particular fashion.

(3) **Develop case study financial analysis**. Based on the alternatives analysis, a case study-based

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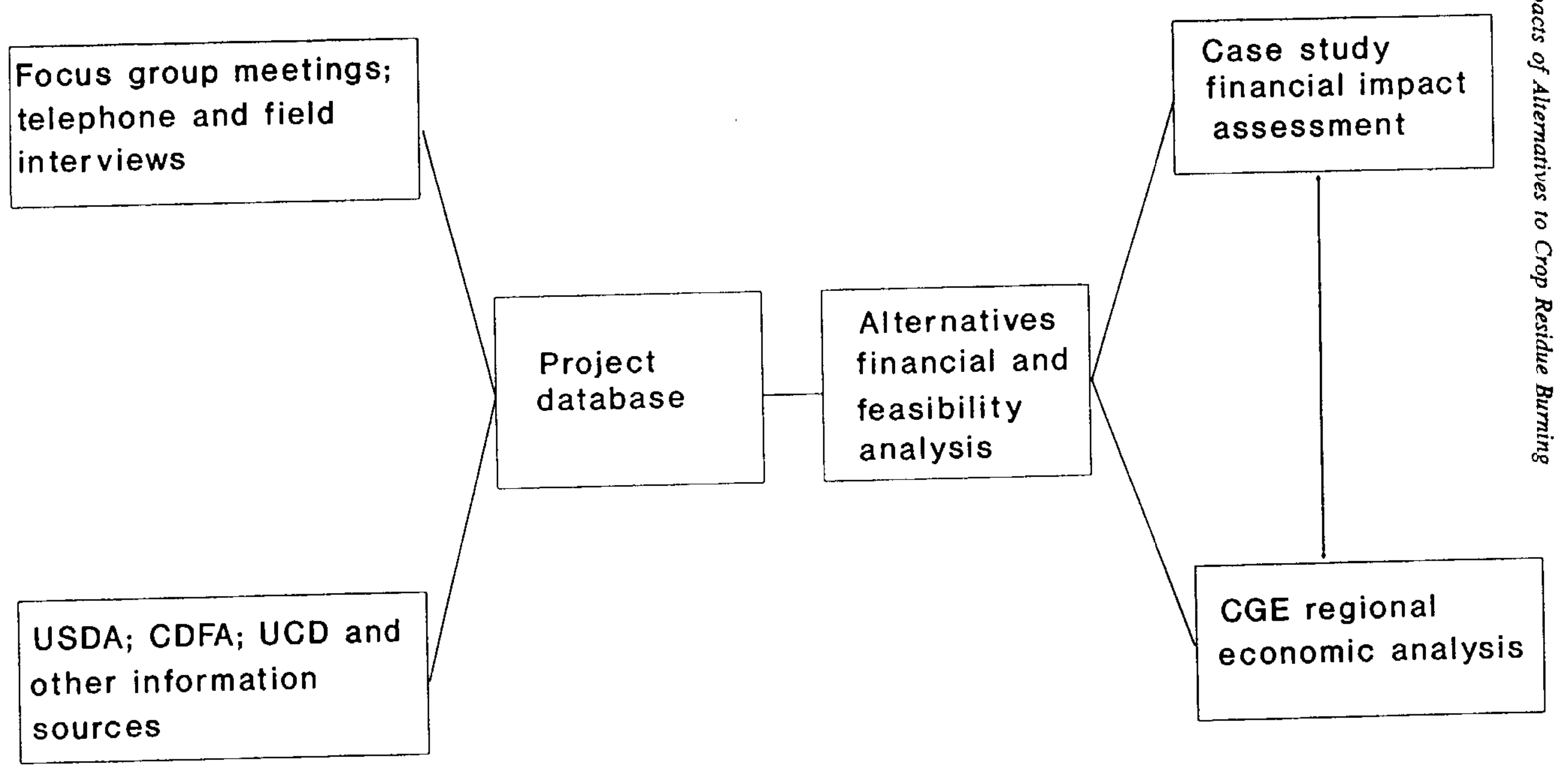
[7]Even prior to the rice straw burning phase-down a small industry of crop residue brokers has been operating in the Central Valley. These individuals treat crop residues as a commodity, typically purchasing residues at low or no cost from growers, and re-selling it as mushroom compost, race track fodder, biomass material, or any one of a number of different end uses. While there is a clear niche for these brokers in the residue market, brokering is not highly profitable, and the number of individuals acting as brokers is small.

Figure 1-1
Residue Study Analytical Steps



Source: Foster Associates, Inc.

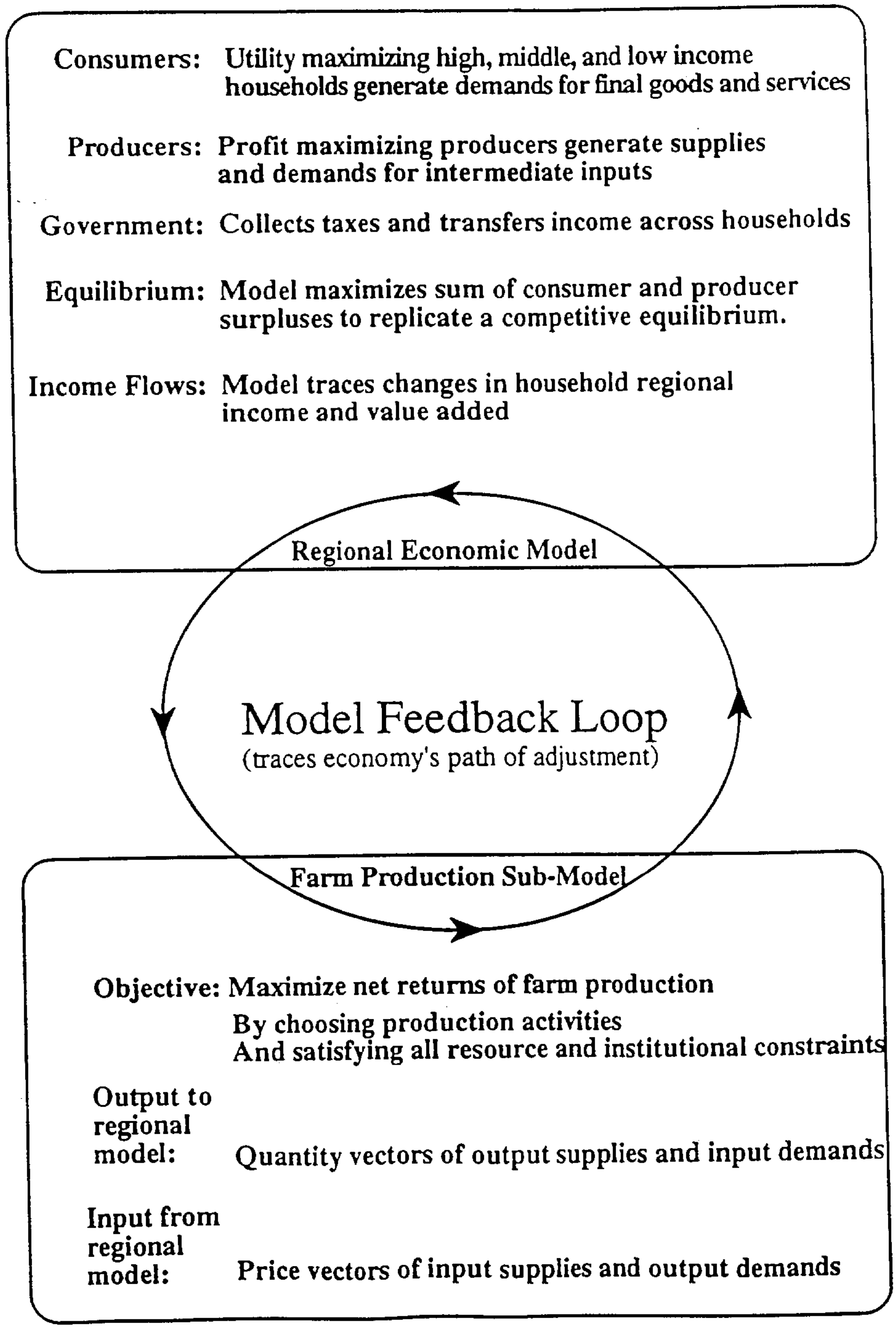
financial and feasibility analysis was conducted. This effort was led by Economic Applications International, Inc. (EAI), and consisted of developing separate financial spreadsheets analyzing the costs of operating illustrative farms using different residue disposal strategies under various capital and equipment complements. The spreadsheet analyses included the per acre costs of various disposal alternatives, as well as expected crop prices. Sensitivity tests based on different yield assumptions were conducted on rice and wheat as a means of analyzing the expected yield loss risks associated with the disposal alternatives.

(4) **Develop computable general equilibrium model for regional economic analysis.** The regional economic impacts associated with changes in rice straw management practices were assessed using a modified computable general equilibrium (CGE) model framework. A CGE model is a general equilibrium approach that is based on modeling the behavior of "utility" maximizing consumers (i.e., consumers generally act in ways to maximize utility), whose decisions determine the demand for goods and services in a region; profit maximizing producers (i.e., producers tend to act in ways to maximize profits), whose decisions determine the supply of goods and the demand for primary factors (i.e., labor, capital, land, and water) in a region; and government, which collects taxes and provides transfers, subsidies, and services within a region. CGE models account for interregional trade patterns and specify the market-clearing conditions which balance supply with demand and determine equilibrium prices in a regional economy.

A CGE model was built to examine the implications of the rice straw burning prohibition. The rice CGE model was constructed for the eight counties of the Sacramento Valley, the state's primary rice growing region (and the area affected by A.B. 1378, the legislation which phases down rice straw residue burning). Based on the exogenous analysis of the costs associated with potential non-burn residue management alternatives, the model traces the impacts of alternative rice straw disposal practices as they ripple through the regional economy. Measured impacts include changes in sectoral factor demand, sectoral output, regional value-added, interregional trade, and household income.

In evaluating the economic implications of alternative rice straw disposal practices, the CGE-based analysis explicitly accounts for regional land and water supply constraints, technological constraints, and market and institutional constraints. To incorporate the detail of these various factors into the analysis, a farm-production sub-model of Sacramento Valley's rice sector was developed. This model estimates the likely farm-level responses to restrictions on rice straw burning. The sub-model is based on the assumption that growers will select alternative straw disposal practices on the basis of farm income maximization, as limited by regional production and market constraints. Changes to regional farm sector production and demand for inputs induced by adoption of the selected alternative are fed back into the regional CGE model, which estimates the impact these changes will have on the regional economy as a whole. Changes to regional economic parameters, in turn, feedback into the farm-production sub-model, which will again adjust production to maximize farm income. This iterative process continues until a regional equilibrium is reached. Figure 1-2 presents a schematic of the modeling formulation.

Figure 1-2
Regional Economic Impact Assessment Model



It is important to note that each of the elements of this analysis is based on particular assumptions. In general the analysis does not account for the implications of significant events that may occur in the future which could alter the financial viability of the study crops. For example, although the potential for water marketing is qualitatively discussed, the current distribution of water supplies is assumed in the analysis, as opposed to widespread buying and selling of water supplies. In this respect it is important to note that, with the passage of Title XXXIV, coupled with new instream rules related to the Endangered Species Act, existing surface water distribution patterns to the agricultural sector may not hold true for long. Likewise, existing federal crop support programs for rice are assumed to continue unchanged, as are current trade patterns (e.g., it is assumed that the Japanese rice market will remain closed).

1.4 Report Structure

In addition to this introduction, this report is divided into four primary chapters, as follows:

- Chapter Two briefly reviews existing residue management practices among the four study crops.
- Chapter Three presents analyses related to the potential alternatives to crop residue burning. This chapter can be divided into two broad categories: after-market disposal alternatives and in-field incorporation.
- Chapter Four presents a financial analysis of the implications of adopting potential non-burn alternatives.
- Chapter Five presents a CGE-based analysis of the regional economic implications of the prohibition on rice straw burning in the Sacramento Valley.

In addition to these primary chapters, the report contains appendixes further describing the report methodology, a list of focus group participants, and evaluations of the potential effects of water marketing and wetlands on rice straw residue costs.

2.0 Existing Burning Practices

The percentage of the residue generated by the four study crops which is **burned** varies widely, and can be characterized as follows:

- Approximately 450,000 tons of **almond** and 170,000 tons of walnut prunings are produced statewide every year, including wood waste resulting from tree removal.[8] One ton of almond prunings can result in 1.9 pounds of particulate emissions.[9] The great majority of almond and walnut growers currently move their prunings to the side of the orchard, where larger pieces are separated and sold as firewood, and the remainder is burned.[10,11]

  Growers prefer to burn their residues as soon as possible, as long-term storage can impede access to the orchard for farm equipment, and can lead to bird and rodent infestation.[12] The timing of the pruning can significantly affect how long residues must be stored. For example, a recent study found that almond trees could be pruned earlier in the fall without inhibiting orchard productivity, thereby lowering labor costs and improving the likelihood that either the waste can be burned or removed without weather-related impediments.[13] Growers prefer burning to other disposal alternatives because it is quick and inexpensive. However, burning is not without its risks -- occasionally the fires jump pass the burn area, and consume trees not meant to be burned.

- Prior to the implementation of A.B. 1378, over ninety percent of **rice** acreage -- representing up to 1.2 million tons of straw -- in California was burned. Approximately 1.4 pounds of

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[8]Almond prunings average one ton per bearing acre after the removal of large limbs for use as firewood. Up to 30 percent of the almond prunings come from tree removal, with about 10,000 trees removed per year.

[9]According to Ellis F. Darley, "Hydrocarbon Characterization of Agricultural Waste Burning," Final Report, Cal/ARB Project A7-068-30, April, 1979.

[10]Lloyd Forrest, TSS Consulting, personal communication, September 24, 1992; Almond Growers Focus Group, op.cit.

[11]While almond wood is attractive for use as firewood, many farmers believe that the small operators who remove the trees for firewood are unreliable, and may induce liability problems, and as a result the firewood-sized residues may be burned at the orchard. Almond Growers Focus Group, October, 1992.

[12]Almond Growers Focus Group, op. cit.

[13]Wilbur Reil, et al, "Fall almond prunings has practical advantages, no adverse effects," California Agriculture, 45:3, pp.18-19, (May-June 1992).

particulates are produced by every ton of rice straw burned.[14] Rice straw residue is burned for two primary reasons. First, it is the least-cost residue disposal method. Second, it is the most effective method of controlling destructive rice straw diseases, principally stem rot and aggregate sheath spot.[15] Absent the incidence of either one of these diseases, available evidence indicates that rice yields on straw-incorporated acres is the same or better than yields on burned acres.[16]

- Approximately one-third or less of the 1.5 million of **wheat** residues produced in the state are burned. When burned, one ton of wheat straw can produce up to 1.6 pounds of particulate matter.[17] Wheat residues are much less harmful to soils than rice straw -- they do not induce disease -- and there is a significant existing market for these residues.[18] Those wheat growers who do burn their residues tend to do so as a means of preparing their fields for an immediate follow-on crop.

Burning is a fairly simple and low-cost procedure, consisting essentially of sending a worker to the field and lighting a match. Labor costs are approximately one to three dollars an acre. Burn permit costs vary by county, but are typically much less than one dollar per acre. However, it should be noted that regardless of existing laws and regulations, it is quite likely that residue burning costs for all crops will increase significantly over the next decade, as counties raise their permit fees and air quality agencies impose more stringent emission requirements. As a result, growers will experience growing economic pressure to find non-burning methods to dispose of their crop residues.

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[14]E. Darley, op. cit.

[15]With the potential of reducing yields significantly, stem rot and sheath spot are the two most economically damaging rice diseases in California. J.J. Oster, "Stem Rot and Sheath Spot: Symptoms and Control," in Rice Field Day, September 9, 1992.

[16]G.S. Pettygrove and J.F. Williams, "Impact of Straw Incorporation and Winter Green Manuring on Rice N Fertilizer Requirement," in Rice Field Day, op. cit. However, long-term incorporation of rice straw residues could affect soil conditions, and ultimately reduce yields. Work is still underway on this issue, and the disease impacts of straw incorporation may not become apparent for several years.

[17]E. Darley, op. cit.

[18]According to the Wheat Residue Focus Group meeting, 1993. See also Section Three.

3.0 Potential Alternatives to Open-Field Burning of Residues

A prohibition on open-field residue burning would force some growers through a series of decisions, beginning with whether or not they want to continue to farm through the various alternatives to residue burning. Although this decision process would be essentially the same for all four study crops, the characteristics of the crop residues, as well as the farm operations, would give rise to different crop-specific options and associated costs.

Figure 3-1 indicates the potential alternative paths that could be engendered by a phase-down of crop residue burning. Should farmers decide to discontinue existing crop production, they would have several potential alternatives, including selling their land, selling their water, or growing an alternative crop. Each of these alternatives would induce different third party impacts to the surrounding communities.

Those growers who choose to continue with the same crop would have the option of following one of two primary paths. The farmers could either:

(1) Incorporate the residues into the soil, thereby incurring the additional costs associated with soil incorporation and engendering the risks associated with resulting changes in soil composition. Soil incorporation necessitates a choice of incorporation techniques. For example, in the case of rice straw incorporation could be conducted under wet (flooded) or dry conditions.[19] For all crops various equipment complements -- and chopping methods -- could be used to incorporate the residue into the soil; and/or

(2) Remove the residues from the field entirely, and dispose them off-site. Off-site disposal would entail collecting and baling the residue, and identifying an end-use, or at least a final resting place, for it. Potential end uses include biomass-based cogeneration, ethanol production, paper pulp production, and use as compost.

The viability of the second path depends on the level of demand for agricultural residues. Figure 3-2 shows possible bounds on expected demand and supply for agricultural residues in the year 2000 based on the analysis which follows in this Chapter.[20] The supply curves are represented by two relatively parallel lines denoted "High Cost Supply Scenario" and "Low Cost Supply Scenario." The difference between the high and low cost scenarios represents the range of uncertainty related to long-term residue collection and transportation costs. The demand curves, shown as "High Demand Scenario" and "Low Demand Scenario," differ based on assumptions about potential demand from the energy production sector. For example, if:

- Existing biomass generation-PG&E (Interim Standard Offer 4) contracts are renegotiated and extended beyond their current expiration dates in the late 1990s;

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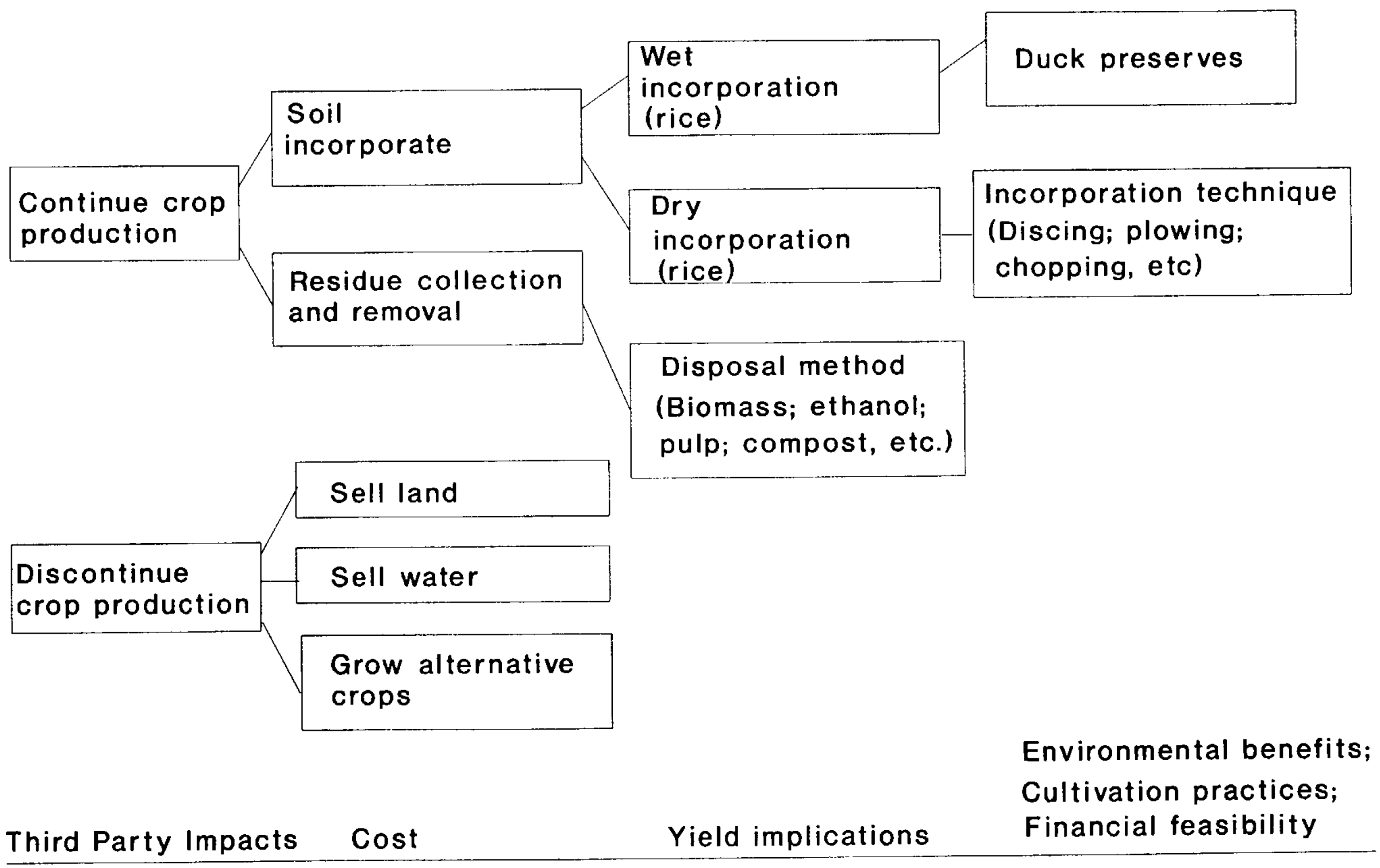
[19]Seasonal rains in some years will force a wet environment.

[20]Prices are shown for 1993 levels to reflect the inability to accurately forecast prices for the year 2000 in most of these categories. Without major technological breakthroughs or disruptions in energy supplies, these prices should remain stable over this period.

Figure 3-1
Alternatives to Crop Residue Burning

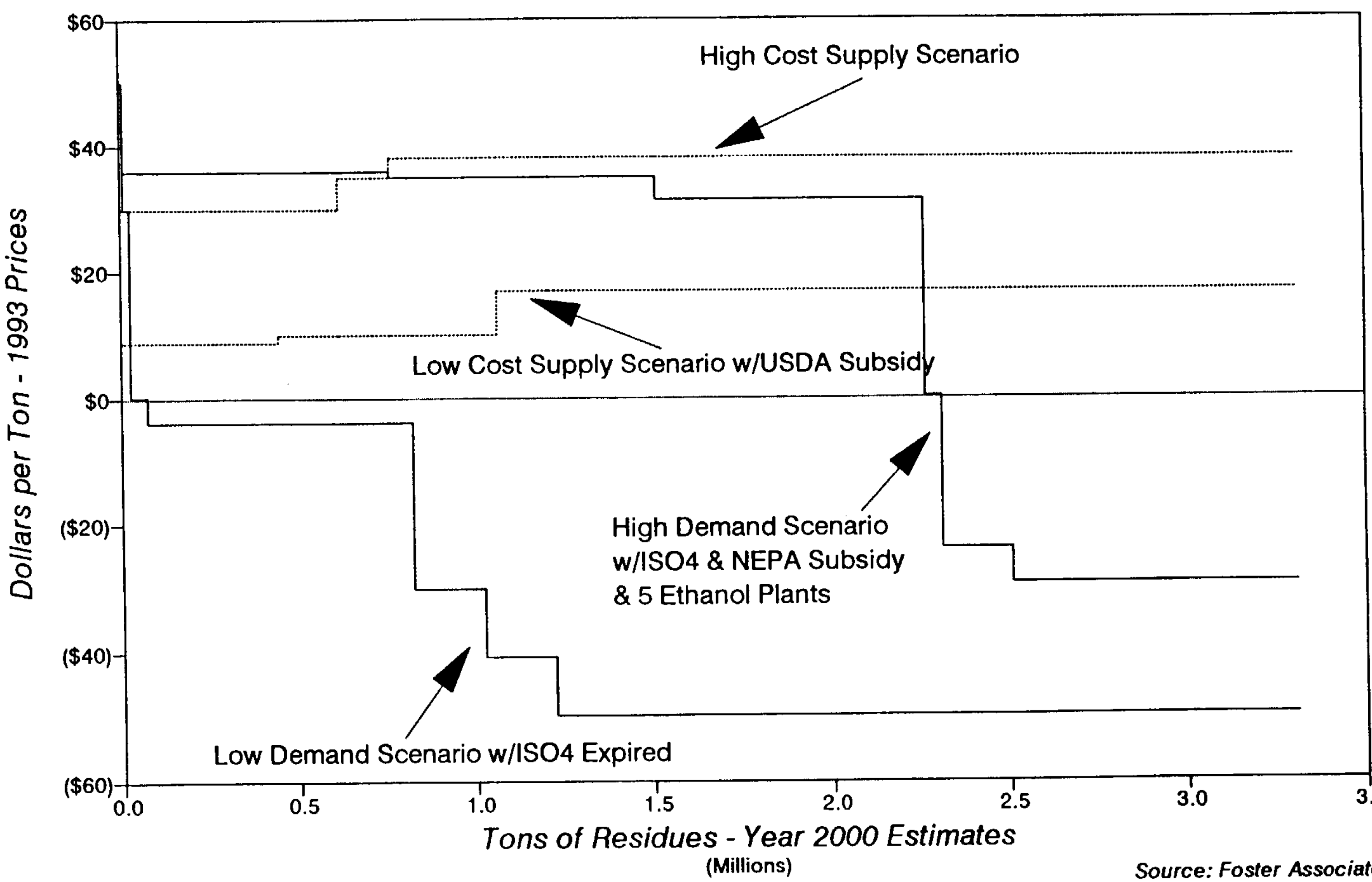


Source: Foster Associates, Inc.

Figure 3-2

Agricultural Residues Supply & Demand

Almond, Rice, Walnut, Wheat-1985 Acres



Source: Foster Associates, Inc

- SMUD chooses to expand its use of biomass in electricity generation; and

- the Sacramento Ethanol Project facility is successful and engenders similar plants,

residue demand will follow the high scenario, and up to one million tons of residue will be consumed without further government intervention. However, **existing information suggests that the lower bound demand estimate appears to be more likely, implying a very limited amount of agricultural residues will be demanded in the future.**

Under an optimistic but plausible scenario, ethanol production and forest fire rehabilitation might consume up to 30 percent of the over one million tons of rice straw produced each year. Other uses of rice straw would simply displace other agricultural residues, such as wheat straw. The remaining rice straw will have to be incorporated into the soil or burned under the AB 1378 exemption. An additional issue arises if burning of orchard prunings are phased out. No economically viable disposal alternative has been identified for large amounts of this material beyond energy conversion in electricity generation.

The analyses presented in this Chapter indicates the large uncertainty surrounding existing agricultural residue disposal cost estimates, the potential demand for residues, and the price likely to be paid for such material. The total costs of removing and transporting agricultural residues depends on how technological and managerial advancements affect costs over the long-term, the distance from the field or orchard to end-use markets, and the continuation of public residue management subsidy programs.

3.1 Costs Associated with Soil Incorporation – Rice Straw

Rice growers are experimenting with a variety of techniques to promote complete and efficient soil incorporation. For example:

- Dry soil incorporation entails the use of a number of different equipment regimes to mix the straw and soil, including the use of plows, discs, and tillers.[21] Alternatively, the straw can be pressed and poked into soil using specialized "rice rollers."[22]

- Growers are currently experimenting with flooding their fields after harvest as a means of encouraging rapid straw decomposition (see Appendix E). Under this method the flooded field attracts migratory waterfowl, whose activities help matt the straw into the soil.

- Another strategy is to use field fallowing or crop rotation to promote incorporation. Currently approximately two-thirds of rice acreage is on a continuous rice cropping system with little field

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[21]In some years seasonal rains may induce voluntary wet incorporation regardless of a growers' preferences. S.C. Blank, K. Jetter, C.M. Wick, and J.F. Williams, "Rice Straw Incorporation Costs," Financial Management Topic Papers - Number 7, University of California, Davis, September, 1992.

[22]Ibid.

fallowing.[23] Field fallowing may become a more economically viable possibility with the growing potential of water marketing (see Appendix F). Crop rotation is limited by soil type, cultivation practices, and the demand for the rotated crop. In addition, growing non-rice crops requires an investment in equipment and farm management structure suitable to the alternative crop.

Under any of these regimes fall incorporation -- immediately after grain harvesting -- is preferable as it allows more time for straw breakdown to occur before planting the next year's crop.

There are a number of potential disadvantages associated with soil incorporation. These include the higher equipment costs relative to open-field burning and the increased risks associated with disease. In addition, as a result of the time needed for the straw to fully decompose in the soil, incorporation can act to delay spring planting. Due to the time needed for complete decomposition, late-maturing rice hybrids -- which bring a price premium -- may no longer be an option for some rice growers. Likewise, soil incorporation depends on fair weather -- while early rains could be beneficial to growers under flood-based soil incorporation regimes, it would reduce growers' ability to maneuver equipment in their fields for dry soil incorporation. These are also some potential advantages to soil incorporation, including increases in soil productivity engendered by increased nutrient content in the soil.

3.1.1 Additional Yield Risks Engendered by Soil Incorporation of Rice Straw

Although only limited analysis has been conducted on the yield risks associated with soil incorporation, most farm experts believe that soil incorporating rice straw could lead to changes in crop yield. Available evidence suggests that there are two factors that could affect yields should rice straw be incorporated: incidence of stem rot and soil poisoning (i.e., OM decay products).[24] In the case of stem rot expert interviews indicate that under a worst case scenario yields may fall by up to 25 percent, with an "average" case loss of 10 percent. The risks of stem rot varies by geographic area, with some rice growing regions historically exhibiting a greater propensity for the disease. Soil poisoning could likewise reduce yields substantially. In general farm experts expect rice yields to decline somewhat, due to the increased risks of stem rot, soil poisonings, and the difficulties of adjusting to new farm practices.

Since AB 1378 permits burning when the incidence of disease makes it the only economically viable alternative, it is unlikely that significant yield losses for a single farm operation would continue for more than one to three years. For example, if a grower experienced yield losses of more than 5 percent in a given season, he is likely to ask and receive permission to burn his field the following year. However, if the yield losses are associated with changes in soil character due to residue concentrations, the grower would not be eligible to burn under current law, and could experience economic losses.

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[23]Ibid.

[24]Particularly related to phosphorous build-up, methane toxicity, organic acids, and algae. This discussion is based on interviews with three Sacramento Valley agricultural extension agents. See also J.B. Dobie, G.E. Miller, and R.H. Mosley, "Ground Level Harvest of Rice Straw," Transactions of the ASAE, American Society of Agricultural Engineers.

3.1.2 Barriers to Soil Incorporation for Orchard Prunings

A key barrier to soil incorporation of almond and walnut prunings under conventional farming practices is the need for a residue-free orchard floor during harvest. Since nuts are typically harvested by "sweeping" the orchard floor, excess debris in the orchard can be mixed in with the nuts. If this debris is not removed -- a labor-intensive and expensive project -- it can jam the shelling equipment, leading to costly repair problems, equipment down-time, or labor intensive remediation. While new harvesting technologies may ultimately be developed that will eliminate the need for residue-free orchard floors -- and simultaneously minimize emissions of particulate matter -- no such advances are currently on the horizon.

As a result of the need for a clean orchard floor, soil incorporation of almond and walnut prunings is only feasible under existing harvesting practices if the debris breaks down rapidly (i.e., prior to the following year's harvest). The need for rapid decomposition necessitates that the residue be chipped into the smallest possible pieces, potentially to sawdust. Almond, and, to a lessor extent, walnut wood is quite hard; chipping it requires significant horse power, and could induce substantial wear and tear on the machinery utilized. Soil incorporation would also require that a sufficient labor force be available to chip the residue shortly after harvest season, so that the maximum amount of time would be available for the material to decompose.[25]

Almond and walnut residue soil incorporation costs would be substantially lower for farmers who maintain a less "clean" orchard floor. For example, one almond residue focus group participant stated that he currently chips his almond tree residue as part of his pruning operation, with larger logs removed for sale as firewood. Since this farmer maintains soil conditions more akin to compost, the residue tends to decompose rapidly. However, even under these conditions soil incorporation necessitates an additional tractor run to encourage maximum decomposition. This grower believed that if other nut growers adopted his cultural practices it would take them three to five years to develop the soil conditions necessary to encourage effective residue decomposition.[26]

3.1.3 Wheat Straw Incorporation

As indicated in Section Two, many wheat farmers currently soil incorporate their residues. While yield-reducing diseases can be engendered under a soil incorporation regime in cases of wheat-on-wheat rotations -- including septoria tritici, blotch, and common root rot -- soil incorporation of wheat residues does not pose the same risk of catastrophic yield losses as rice straw. Since wheat is not grown in flooded conditions there are minimal barriers to working the field after harvest. However, a significant number of wheat growers currently use burning as their primary disposal practice. Soil incorporation would lead to a number of implications for these growers,[27] as follows:

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[25]Based on the Almond Residue Focus Group meeting, chipping almond residues may cost approximately $50 an acre.

[26]It is also important to point out that the grower received higher prices for his "organic" product, prices that are not likely to be sustained if a significant number of growers adopted his practices.

[27]Wheat Growers Focus Group meeting, op. cit.

- Wheat growers who currently burn typically do so to quickly prepare the field for a follow-on crop (e.g., beans). Without burning there may be insufficient time to remove or incorporate residues before the next planting. As a result, without the ability to burn these growers may have to field fallow, thereby reducing their aggregate farm revenues.

- Wheat growers who soil incorporate and continue to plant a follow-on crop *may* have to increase the amount of herbicides they apply to the follow-on crop as a means of eliminating unwanted wheat germination. In some cases these chemicals may be ineffective in combating weeds, leading to significant yield loss.

- Wheat growers would have to increase tilling as a means of fully incorporating the residue.

3.2 Costs Associated with Residue Removal: Collection, Storage, and Transportation

Residue collection and processing costs are a significant factor in determining the feasibility of residue removal alternatives. This is especially true for rice straw, both because of the special problems associated with its collection and the sheer bulk of the entire crop. The costs associated with removing crop residues from harvested fields vary widely. Removal costs depend on (1) the crop type; (2) local conditions (e.g., weather, timing of follow-on crop) for collecting the residue; and (3) the distance from the field to the residue-use market.

Collecting, processing -- typically baling -- and transporting rice straw to a local consumer is estimated to cost between $20 and $40 per ton, or between $60 to over $100 per acre.[28] Per acre costs for wheat growers are estimated to range from $33 to $65 per acre.[29] Orchard farmers face incremental removal costs of $14 to $30 per ton, and, with about 1 to 1.3 tons of prunings per acre, these costs equal between $14 to $39 per acre. In addition, the elimination of residual ash from rice straw burning could engender the need to add nutrients to the fields, at a cost of $5 to $10 per acre.

3.2.1 Wet Soils Increase Rice Straw Removal Risks and Costs

Current field removal and baling costs for rice straw range between $16 and $23 per ton, but future costs could go as low as $12 per ton if the practice becomes widespread.[30] The lower bound cost estimates are based on the assumption that existing equipment used for hay and alfalfa baling can be adapted to rice straw harvesting at a relatively low cost and that growers will either share the equipment

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[28]Assuming 2 to 4 tons of straw per acre. Currently, most non-burn disposal work is done by custom harvesters using hay and alfalfa equipment, customized to the boggier soil conditions in which rice is grown. Estimates for the current costs of removing rice straw are drawn from two sources: a U.C. Davis Agricultural Cooperative Extension study; and an interview with one of the largest custom harvesters.

[29]Costs for wheat straw removal are lower than for rice straw due to the more favorable conditions associated with removal (i.e., dry soil, lower silicate content) and the lower amounts of straw generated per acre.

[30]Appendix A contains a more detailed review of various studies that estimate the straw collection costs for rice straw.

with their neighbors or have large enough operations to sufficiently spread costs. The high-side costs are not true upper bounds because they do not include obstacles that might arise during the collection process.

Virtually all farmers, harvesters, end-users and application experts interviewed for this study identified two problems with rice straw harvesting. First, the straw has a high silica content, leading to substantial wear on farm equipment compared with other crops. Silica-induced wear, in turn, leads to higher equipment depreciation rates and investment costs for rice straw collection than for collecting other crop residues. Second, in some cases -- for example, during periods of late harvesting and early rains -- rice acreage is particularly "boggy" after rice harvesting. Hauling heavy equipment through the wet fields can lead to soil damage, such as wheel ruts, which can make it extremely difficult to remove or closely chop the straw. The additional uncertainty associated with rain-induced difficulties in straw removal can increase *expected* costs -- from a statistical standpoint -- well above those shown in Appendix A. An accurate accounting of the risks associated with rice straw removal would require a determination of the opportunity costs associated with and probability of weather-related circumstances that would prohibit straw removal. Such an accounting has not been included in this report because no accurate assessment is currently available related to the probability of the incidence and amounts of straw that may be unrecoverable.

In addition to potential technological improvements and economies of scale in straw recovery, various residue management programs may act to reduce growers' future field removal costs. For example, the USDA has instituted a demonstration program that provides a subsidy of $25 per acre for removing rice straw residues for off-farm disposal.[31] At present, this program is limited to annual payments of $3,500 per eligible person per year, or the equivalent of 140 acres of rice straw removal.[32] In addition, the program is not available to all rice growers.[33] With the average farm "unit" being about 400 acres for USDA accounting purposes, the program could effectively lower average removal costs by about $8.75 per acre.

3.2.2 Costs Associated With Orchard Prunings Removal

Costs for removal of orchard prunings are in addition to the in-orchard pruning costs that are already induced. Orchard-side processing costs range from $5 to $15 per ton, depending on the removal process utilized and expected equipment capacity. Average costs are estimated to be approximately $9

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[31]*ACP SP-56 Rice Residue Management Demonstration Program,* ASCS News, USDA Agricultural Stabilization and Conservation Service, 1992.

[32]Due to farm management practices induced by federal farm subsidy policies, this limit is effectively $7,000 for a farm owned by a couple. To be eligible for the program rice must have been planted on the acreage four out of the last five years, and cost-sharing is limited to 90 percent of eligible farm program acreage, which usually is not a binding constraint. The program applies to four systems of soil incorporation or residue removal. It is unknown how long this program will be available to rice growers.

[33]For example, Sutter County provided a total of $90,000 of ASCS SP-56 funds to 30 growers in fiscal year 1992.

per ton.[34] Costs per dry ton transported to the roadside would be about 25 percent higher than orchard-side processing.

3.2.3 Transportation Costs for Straw Waste

A large cost component of residue removal is transportation. The cost analysis relied on current transport rates paid by hay and alfalfa growers.[35] Since hay and alfalfa are comparable to straw in density and composition, transportation rates for these crops are likely to be similar. The rates do not increase linearly with distance, since they reflect the fixed costs of owning and operating the trucks.

Large-scale transportation of rice straw residues would be induced by significant demand for the residue, demand that is only likely to be engendered by the development of processing facilities to turn the straw into useful products (see below). Estimates of the average transportation costs for a ton of straw residue are highly sensitive to the size of the end-use processing facility and its location relative to the growing region. Transportation rates are nonlinear with respect to distance, and a larger facility requires a larger straw collection radius to guarantee sufficient straw supplies. As a result, average costs must be calculated by adding "bands" of collection zones with the relevant rates. For example, a typical 25 to 30 megawatt biomass plant might use 200,000 tons of straw per year. With an average trip of 10 to 15 miles, the average transportation cost would be between $6.00 to $7.25 per ton. Alternatively, the cost range for hauling straw from a roadside between 1 and 100 miles would be between $5.00 to $15.00 per ton, with rapidly decreasing costs on a per-mile basis due to high fixed costs. A long haul to Southern California could cost as much as $50 per ton.

3.2.4 Storage Costs

Storage costs are another factor contributing to the overall expense associated with residue removal. Increased use of agricultural waste products by an end-use market would act to tie the end-use production process to residue availability. However, residue availability could vary substantially due to seasonal harvesting practices and weather conditions, which can affect collection accessibility (e.g., rain-soaked soils bogging down removal equipment). As a result, storage would be necessary to insure that residue supplies are available at relatively constant input levels. Such storage facilities would have to be constructed so as to maintain the quality of the residue while in storage, most likely by covering the straw. For example, the Sacramento Ethanol Project plans to use at least 65 acres for storing an annual throughput of about 150,000 tons of agricultural residue.[36] With agricultural land values ranging from $1,500 to upwards of $4,000 per acre, this adds from $100,000 to over $250,000 to the cost of the project, or about 5 to 20 cents per ton annually.

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[34]The Almond Board commissioned a series of studies on brush utilization in the early 1980s, which included a limited examination of orchard removal costs. While the estimates contained herein have been updated to reflect higher labor costs and lower fuel costs, they may be optimistic. CH2M Hill, *Annual Report No. 81-33 Brush Utilization Study: Densifying and Transporting Brush*, For California Almond Board, Sacramento, California, January 1992.

[35]The various rates are shown in Appendix A.

[36]SEPCO Project, op. cit.

Many growers do not have adequate space to store residue for long time periods without inhibiting other farm practices. If ample storage is available on-farm, off-site removal becomes more feasible, as growers would have greater flexibility related to the timing of the removal. A potential solution to space limitations for orchard residues is to remove a row of trees; however relative to existing practices this would act to reduce per acre yields, revenues, and profits, though the reduction may be less than other alternatives. In places where orchards are contiguous it may also be possible to form a cooperative to support adequate storage space.

3.3 After-Market Disposal Alternatives

Potential end-uses for crop residues generally fall into one of two categories: energy production or non-energy products. The former includes use of the residue for electricity generation and for ethanol fuel production. The latter includes use of the residue for road and hillside erosion control, mushroom compost, construction or fiber materials, and a host of other non-energy-related end-uses.

Although there are currently several markets for utilizing agricultural crop residues, in general the effective price paid to farmers for their residue essentially nets to zero. That is, if the farmer receives anything for the residue this amount is completely offset by the farmer's costs associated with residue collection, storage, and transportation. As the prohibition on straw burning takes effect, however, both the cost of residue removal and the prices paid for straw are likely to change. On the one hand, as noted above, because widespread residue collection is a relatively recent activity, costs may fall over time due to innovations in harvesting and baling equipment and techniques, resulting in a net payment for residue. On the other hand, as the option to burn is eliminated more growers will seek markets for their straw, thereby increasing supply, and reducing prices.

3.3.1 Energy Production Alternatives for Crop Residues

Energy production from agricultural crop residues holds the most promise for large-scale residue disposal. The two most likely categories of energy production are as follows:

(1) **Biomass-fueled electricity generation**. Use of agricultural residues to generate electricity has been the most successful energy-related application to date because of the significant price incentives embodied in the now-suspended Interim Standard Offer (ISO) Number Four, extended by the California Public Utilities Commission (CPUC) from 1982 to 1985. However, such price offers are no longer available, and future electricity payments are likely to be substantially lower, making electricity generation much less attractive for new biomass plant developers.

(2) **Ethanol fuel production**. A large ethanol plant, which would consume upwards of 100,000 tons of agricultural residue annually, has been proposed to be built in Sacramento County. The plant would draw straw residues from seven counties surrounding the site. This project, as with virtually all ethanol production in the U.S., relies on the continuation of existing federal price subsidies for ethanol to be economically viable.

Another possible use of agricultural residues in energy production is **low-Btu methane gas from aneraerobic digestion**. However, under current price forecasts, aneraerobic digestion production costs for methane appear to be only cost competitive with natural gas in remote, isolated locations.[37] In general, oil and gas prices are forecasted to remain low, putting substantial pressure on the economic feasibility of this option.

In the sections that follow the economic feasibility and residue consumption potential are evaluated for each of the potential energy production uses.

3.3.2 Feasibility of Biomass Electricity Generation

Even before taking into account the substantial economic barriers to widespread use of agricultural residues in biomass-based electricity generation, **there are significant technical hurdles to the use of straw for this purpose, particularly rice straw.**[38] Rice straw, has two significant drawbacks as a boiler fuel relative to wood waste or orchard prunings. First, the straw ash tends to agglomerate on the inner surfaces when providing more than 10 to 15 percent of total fuel content for the generating facility. Rice straw has an ash content of 14 to 18 percent and wheat straw near 8 percent, while prunings and wood typically are below 2 percent. The CEC is currently funding research at U.C. Davis in an effort to solve this problem. Second, the ash, especially for rice straw, can be a hazardous material, making disposal more difficult. While non-straw residues do not face these same challenges, these technological problems make it unlikely that rice straw will become an important feedstock for biomass plants in the near future, regardless of the economic feasibility of biomass-based electricity generation.

The limited economic potential of the use of agricultural residues in biomass-based electricity generation likewise suggests that this is not a viable disposal alternative. An analysis of the feasibility of using agricultural residues for biomass-fired electricity generation indicates that flat demand and competitive prices for alternative energy resources create low netback prices for agricultural crop residues.[39] The following figures compare the cost of biomass generation to utility avoided-cost forecasts and alternative generating resources, such as natural gas-fired combined cycle and geothermal units. In most cases, the netback price for residue is negative throughout the next twenty years. This analysis implies that agricultural waste prices to biomass plant operators would have to be subsidized in some fashion to make biomass generation feasible (e.g., farmers might have to pay a tipping fee or a tax credit would have to be provided to encourage plant construction).

Assuming biomass can be made economically viable -- again, absent subsidies, not a good assumption -- based on the heat content in the residue materials the amount of additional biomass

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[37]A digester project in Colorado produces gas at a cost of $4.98 to $7.87 per MCF, the lower cost being for wastes that had no net collection and transportation costs. (Western Regional Biomass Energy Program, Biomass Bulletin, V1:2 (Summer 1992).)

[38]B. M. Jenkins and G. Knutson, "Energy Balances in Biomass Handling Systems: Net Energy Analysis of Electricity from Straw," for presentation at the 1984 Winter Meetings American Society of Agricultural Engineers, Paper Number 84-3593, New Orleans, LA, December, 1984.

[39]*Netback prices* refer to the maximum price a biomass plant operator would be willing to pay for a unit of delivered agricultural residue.

generation capacity needed to consume various levels of waste can be estimated.[40] Depending on the mix of fuel resources, to consume 200,000 tons per year, between 20 and 37 megawatts (MW) of biomass capacity would have to be built; to consume 1 million tons annually, between 99 and 187 MW would have to be constructed. However, **none** of the utilities serving Northern California expect to require new generating resources beyond those already selected before the turn-of-the-century. However, Pacific Gas and Electric Company (PG&E) **is** expected to require an additional 1,077 MW of generation capacity between 2001 and 2010; Sacramento Municipal Utility District (SMUD) is expected to add 350 MW in the same period; and the Northern California Power Agency (NCPA) is forecasted to need 166 MW of additional capacity.[41,42] Thus setting aside factors related to economic feasibility, there will be sufficient demand for new capacity to prompt consideration of new biomass facilities by the turn-of-the-century.

The Interim Standard Offer #4 contracts were lucrative for biomass generators but are no longer available for new projects, having been suspended in 1985 by the California Public Utilities Commission when the offer became obviously oversubscribed. Virtually all operating biomass projects have ISO #4 contracts and came on-line between 1989 and 1991.[43,44] Of about 744 MW now on line, about 293 MW can burn crop residues, with capability of consuming 1.5 to 3 million tons of agricultural wastes per year.[45] Only one however, Wadham Energy in Williams, has recently burned rice straw -- about 5 percent of 1991 fuel input was met by straw.[46] It now refuses to accept rice straw due to

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[40]Appendix A contains a detailed estimate of potential capacity additions for various levels of residue.

[41]The capacity and operating costs were assessed using the protocol applied in the CEC's Iterative Cost Effectiveness Method (ICEM), which allows comparison on a year-by-year basis rather than the present value in a single year.

[42]The Foster analysis relies on California Energy Commission (CEC) assumptions and data used in developing the 1992 Electricity Report (ER92), as well as Sacramento Municipal Utility District data. The analysis focuses on Pacific Gas and Electric's and SMUD's service territory because these two utilities, plus the Northern California Power Agency, are the most likely to receive biomass generation bids.

[43]Appendix A contains a detailed listing of biomass projects which now or potentially can burn agricultural residues.

[44]The two facilities using nutshells as fuel signed their contracts before ISO #4 became available. These plants are linked to food processing facilities, generally making their fuel costs incidental to overall operations, thereby creating more favorable economics than for stand-alone plants.

[45]An ongoing survey and study by the CEC estimates the amount and types of fuel burned by these facilities as well as their financial conditions. This report should be available for public review by Summer, 1993. (California Energy Commission, *Biomass Facilities Survey for California*, Draft September 18, 1992.)

[46]Merrill Churchill, Colusa APCD, personal communication, September 1992.

technical problems. Other plants rely mostly on urban and lumber mill wood waste to supply the bulk of their requirements.

In general, wood waste prices from forest slash, mill residues and urban waste dictate the market price for agricultural wastes, because wood waste provides substantially more fuel and has lower removal costs. Current wood waste and orchard pruning prices range from $30 to $50 per ton.[47] While in 1992 and 1993 fuel has been in short supply -- and some operators have been paying premium prices -- due to previous drought conditions and associated forest damage, these plants cannot be expected to consume a substantial portion of any new waste stream since, with the exception of the Marysville plant, they currently operate near capacity. In addition, their financial situation could change significantly after the energy payment portion of ISO #4 expires, creating a price "cliff" at the turn of the century.[48]

3.3.2.1 Additional Biomass Generation Capacity Unlikely

To determine the economic feasibility of building additional biomass facilities, the costs of constructing a hypothetical new biomass plant was compared to (1) the forecasted avoided costs for PG&E and SMUD and (2) preferable identified deferrable resources (IDR) forecasted in the CEC's ER92. An avoided-cost forecast asks "If another kilowatt of capacity or kilowatt-hour of energy was added today, how much would the purchasing utility be willing to pay?" This question can be broken down into short-term and long-term perspectives. Another way of looking at long-term costs is with the IDR. In this case, the question is "If a utility needs to purchase additional capacity and energy over a long-time horizon, what would be the cheapest available resource?" Biomass and other qualifying facility developers receive payments based on the analytic answers to these questions.

In projecting the netback price for straw, comparisons were made under a range of ownership options -- investor-owned and municipal utilities and third-party QFs -- and different payment structures -- system avoided costs and IDRs, as follows:[49]

- Figures 3-3 and 3-4 show netback prices for straw biomass under QF ownership with PG&E and SMUD forecasted avoided-cost payments. As can be seen in the Figures, absent ISO #4 contracts **netback prices remain negative for the foreseeable future**.
- Only under SMUD ownership, as indicated in Figure 3-5, do prices rise above zero. Even with SMUD ownership prices are expected to remain close to zero except under the SMUD ACS-High scenario.

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[47]Almond Growers Focus Group, op. cit.; Narsai Gonzales, CARB, personal communication, October 1992.

[48]Jan Hamrin and Tom Jackels, *A QF Industry White Paper: The Development and Implications of the Interim Standard Offer 4 Contract in California*, Draft, Independent Energy Producers Association, Sacramento, CA, September 1, 1992.

[49]The detailed analysis for these ownership scenarios, plus other types of ownership and payment combinations, are contained in Appendix A.

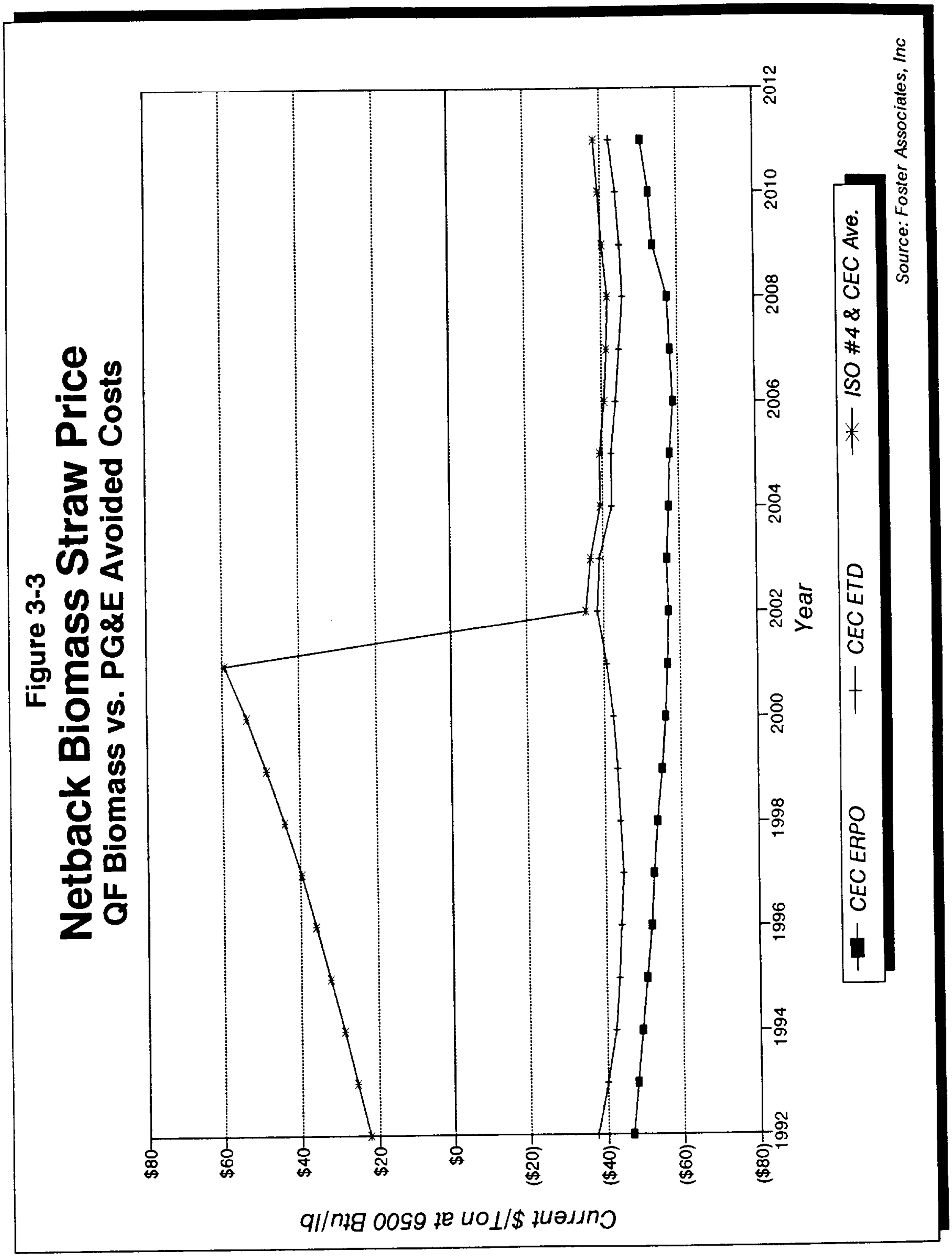
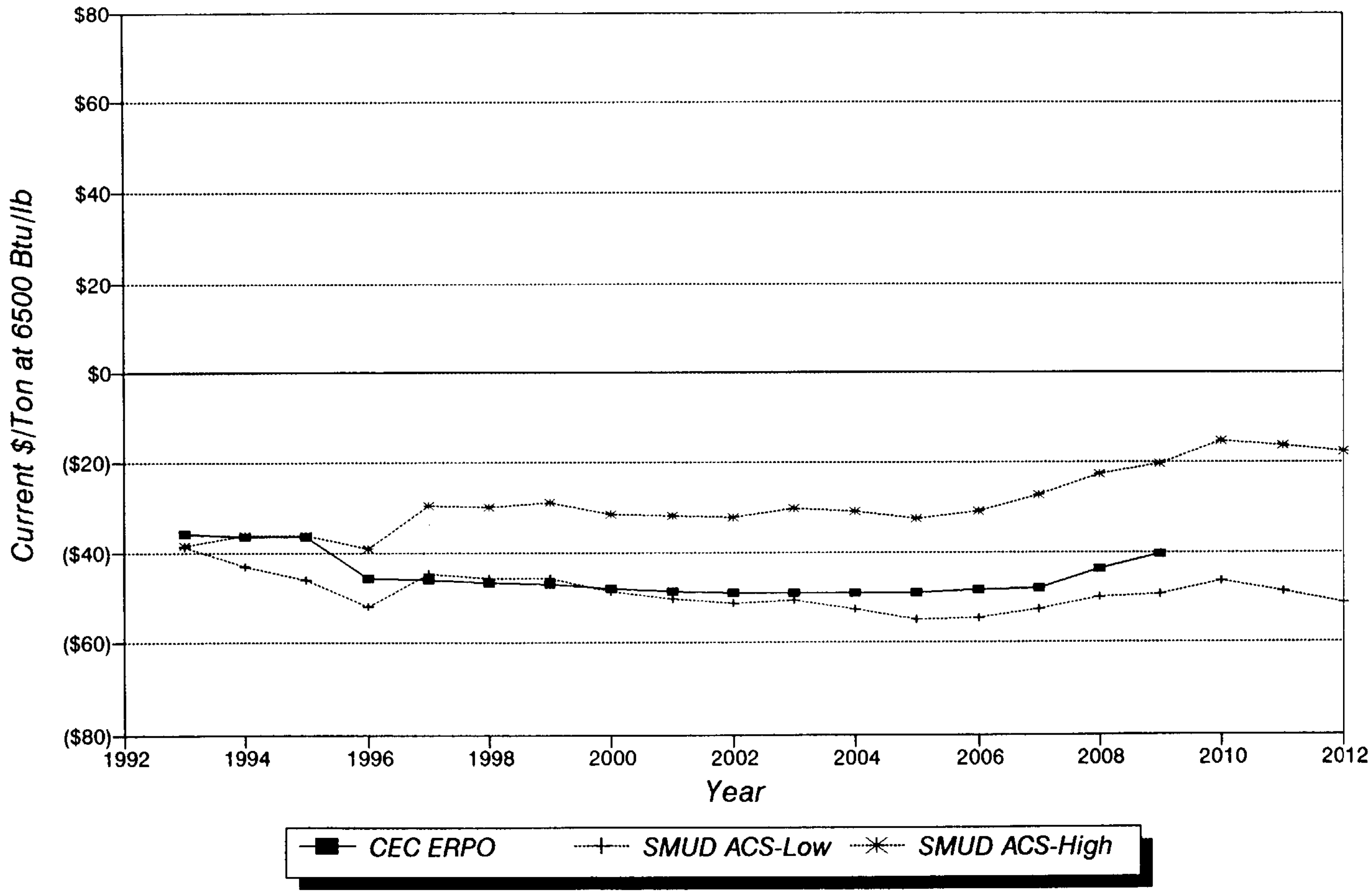


Figure 3-3
Netback Biomass Straw Price
QF Biomass vs. PG&E Avoided Costs

Figure 3-4

Netback Biomass Straw Price

QF Biomass vs. SMUD Avoided Costs

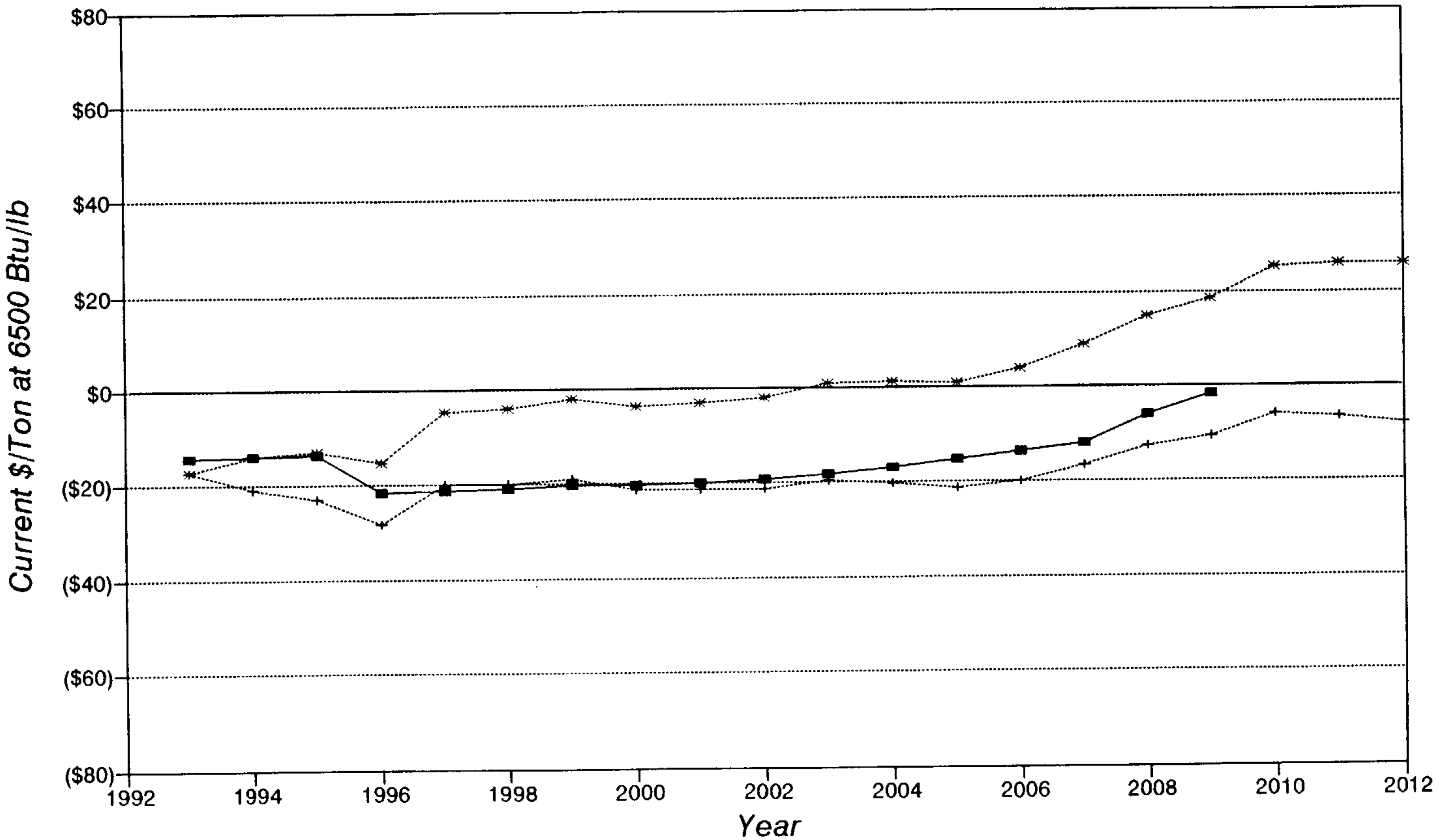


Source: Foster Associates, Inc

Figure 3-5

Netback Biomass Straw Price

SMUD Biomass vs. Avoided Costs



Source: Foster Associates, Inc

- Figure 3-6 compares different utility/IDR-based payment scenarios -- in every year less than zero -- for QF ownership.

Utility ownership generally leads to the ability to pay higher prices due to lower costs for capital.[50] However, while the costs for utility ownership might lead to better biomass economics, almost all of these facilities, as with virtually any new generation resources, are and will be owned by third parties. SMUD, with its aggressive diversification strategy to invest in alternative energy sources, might be the only utility in the state willing to purchase a stake in a biomass plant to improve its feasibility, as it has done with the Sacramento Ethanol Project, a 148 MW facility discussed later in this Chapter.

The ISO #4 netback straw price forecast, shown in Figure 3-3, indicates how lucrative the straw market is under these contracts, but warns ominously that these markets are likely to collapse after the year 2000.[51] Once ISO #4 contracts expire, these facilities are likely to either switch to a load-following or intermediate operating mode which maintains their capacity payments but dramatically decreases the amount of fuel consumed, or to slip into bankruptcy, in which they would either shutdown or be taken over by the utility.[52] PG&E forecasts that 30 percent of existing biomass facilities will fail at the end of the fixed energy price period in their contracts.[53] In general, biomass generation facilities do not offer an attractive economic alternative unless biomass fuel prices are heavily subsidized in some fashion.

The National Energy Policy Act of 1992 calls for an incentive payment of 1.5 cents per kilowatt-hour to be paid to eligible renewable resource power generators, including biomass facilities.[54] Plants built between 1993 and 2003 are eligible for the incentive payments for a ten-year period. These payments, using the CEC assumptions, translate to $12 per ton of straw and $14 per ton of orchard prunings in increased netback prices. However, the total netback rates are still negative even with these payments, and the payments do not appear to provide sufficient incentive to develop additional biomass resources in California.

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[50]The qualifying facility (QF) ownership parameters came from the "low" case assumptions in the ETSR, while the utility parameters came from the *TCR*.

[51]The netback prices shown correspond closely with actual current prices offered by different facilities, especially if corrected for the higher Btu content of wood waste (~8000 Btu/lb), which adds about 25 percent to the price.

[52]Hamrin and Jackels, op.cit.

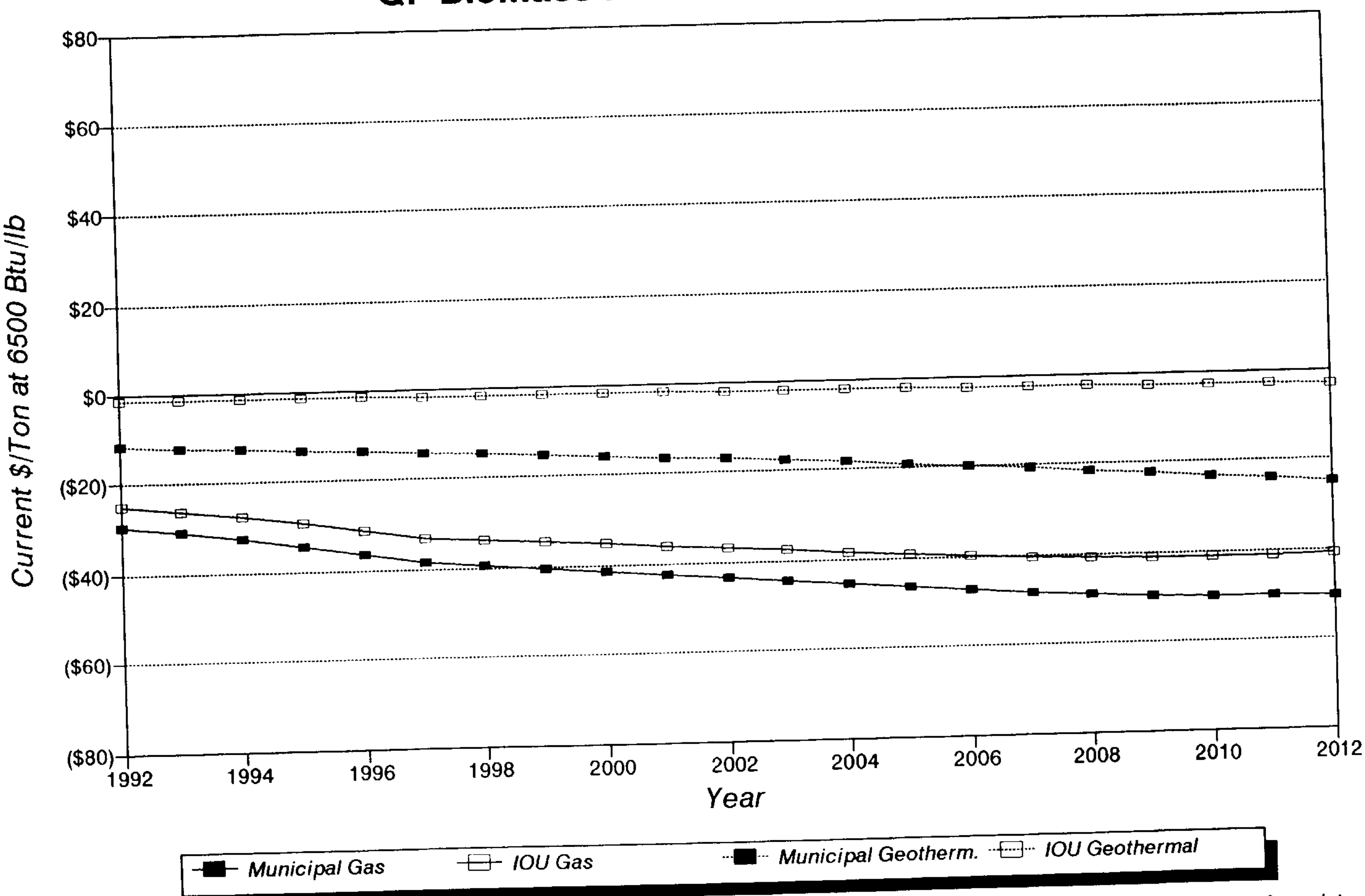
[53]Pacific Gas and Electric, *IEP Second Data Request dated August 9, 1993*, CEC Docket No. 93-ER-94, August 24, 1993, Response No. 6.

[54]*Conference Report on H.R. 776, Comprehensive National Energy Policy Act,* Congressional Record, October 5, 1992, Section 1313.

Figure 3-6

Netback Biomass Straw Price

QF Biomass Plant vs. Utilities IDRs



Source: Foster Associates, Inc

3.3.3 Potential for Agricultural Residues to Produce Ethanol Fuel

Another potential use for agricultural residues is for the ethanol production. Ethanol is chiefly used as an octane enhancement to replace lead.[55] As a component of "gasohol" (i.e., 10 percent ethanol) or as an additive (e.g., as an MTBE substitute in reformulated gasoline), ethanol producers are eligible to receive an income tax credit of 54 cents per gallon, or fuel blenders as a sliding scale excise tax exemption beginning at 5.4 cents per gallon.[56] The U.S. market for ethanol fuel peaked at 850 million gallons at the end of 1987, with about 77 percent of this amount being produced by the nation's six largest plants.[57] The California market for ethanol sales to oil refineries is projected to range from 53 to 58 million gallons per year in 1995 when reformulated gasoline standards are in place, should grow slowly to 55 to 60 million gallons by the turn of the century.[58] Of this amount. About 8 million gallons could be currently provided from local sources, with the rest coming from the Midwest.[59,60]

A recent decision by the U.S. Environmental Protection Agency (EPA) permits ethanol to be included as a component of oxygenated gasoline now required in large urban markets to meet winter-time air quality standards under the 1990 Clean Air Act Amendments (CAAA). This decision could act to increase ethanol demand, particularly in such non-attainment areas as California's South Coast. A second potential market is as an oxygenate for reformulated gasoline, substituting for MTBE with ETBE if methanol capacity falls short or prices are competitive.

The only large ethanol fuel production facility under consideration for construction in California is the Sacramento Ethanol Project (SEPCO Project). The SEPCO project, if ultimately built, would be the first large-scale lignocellulosic ethanol production plant. The project is a joint venture between ARKENOL, Inc. (ARK Energy, Inc.) and SMUD Financing Authority, with separate ownership and operation of the ethanol and cogeneration facilities.[61] The project is expected to generate 148 MW at

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[55]However, ethanol has a lower energy content per unit than gasoline -- 84,600 Btus per gallon versus 125,000 Btus per gallon.

[56]Ethanol subsidies recently were extended by the U.S. Congress until 2003. The tax subsidy issues are discussed in greater detail in Appendix A.

[57]Sally Kane and John M. Reilly, *Economics of Ethanol Production in the United States*, USDA ERS Agricultural Economic Report No. 607, March 1989.

[58]*California Oxygenate Outlook,* California Energy Commission, P300-93-002, March 1993. p.16.

[59]Ibid, p.34.

[60]Since ethanol is produced by breaking down the sugars contained in the cellulose structure of straw, most ethanol is currently produced from sugar-rich feedstock such as corn or sugar cane. Production from woody material such as timber or agricultural residues, known as lignocellulosic feedstock, has not been done on a large scale to date, but some engineering estimates of the use of these feedstocks have been developed. **These estimates are discussed in greater detail in Appendix A.**

[61]SEPCO 92-AFC-2, August 1992. **A detailed economic analysis of the SEPCO Projects is in Appendix A.**

peak load from a natural gas-fired combined cycle unit and cogenerate heat for an ethanol plant projected to produce 11.3 million gallons per year using a concentrated acid method while consuming about 132,000 tons of rice straw, wheat straw and safflower. The plant is expected to produce approximately 86 gallons of ethanol from each ton of rice straw, along with other byproducts to be sold in other markets.

The interim power purchase agreement between SEPCO and SMUD covers the basic costs for the electric generation plant, with little in the way of cross-subsidies to the ethanol facility other than providing a no-cost steam supply. Overall, ethanol production from the SEPCO plant is estimated to cost from $1.00 to $2.25 per gallon, depending on the assumed rates and sources for debt and equity.[62] However, as noted below, the sale of byproducts has a large effect on the economic attractiveness of the project.

Several factors lead to a degree of uncertainty about the economics of the SEPCO ethanol plant, especially if the estimates are used to evaluate the potential for future ethanol-production facilities:

(1) The investment financing estimate relies on municipal financing costs, which may be appropriate for only a limited number of projects. Relying on private financing increases the costs by 78 cents per gallon, pushing the plant beyond financially-feasible bounds.

(2) The SEPCO plant's production efficiency is extraordinary in comparison to the other designs. SEPCO projects 86 gallons of ethanol per ton of biomass, while the next closest, the Stone and Webster enzymatic, is 25 percent less efficient, and the others are almost half as efficient. ARK Energy has claimed to surmount one of the most difficult problems in converting hemicellulose to sugar, and thus increased the plant efficiency in excess of 40 percent.[63] Given that the ARKENOL process is untried, a 25 percent reduction in output per ton would increase costs by 10 cents per gallon.[64]

(3) SEPCO's production costs are extremely sensitive to the price paid for sodium silicate. A decrease of sodium silicate revenue of $100 per ton would raise plant's cost by 48 cents per gallon. Also, if the plant requires more feedstock per gallon of ethanol, the output of sodium silicate would fall, further increasing net costs.

(4) If the biomass fuel market collapses with the expiration of ISO #4 contracts in 2000 -- a very likely possibility -- the price for lignin will fall as well. This revenue represents nine cents per gallon of ethanol.

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[62]The lower bound estimate is based on analysis provided by ARK Energy using financing from the California Pollution Control Financing Authority (ARK Energy Comments, October 5, 1993); the upper bound is based on CEC assumptions about financing of biomass QF plants from private sources. See Appendix A for a detailed discussion about this range of cost estimates.

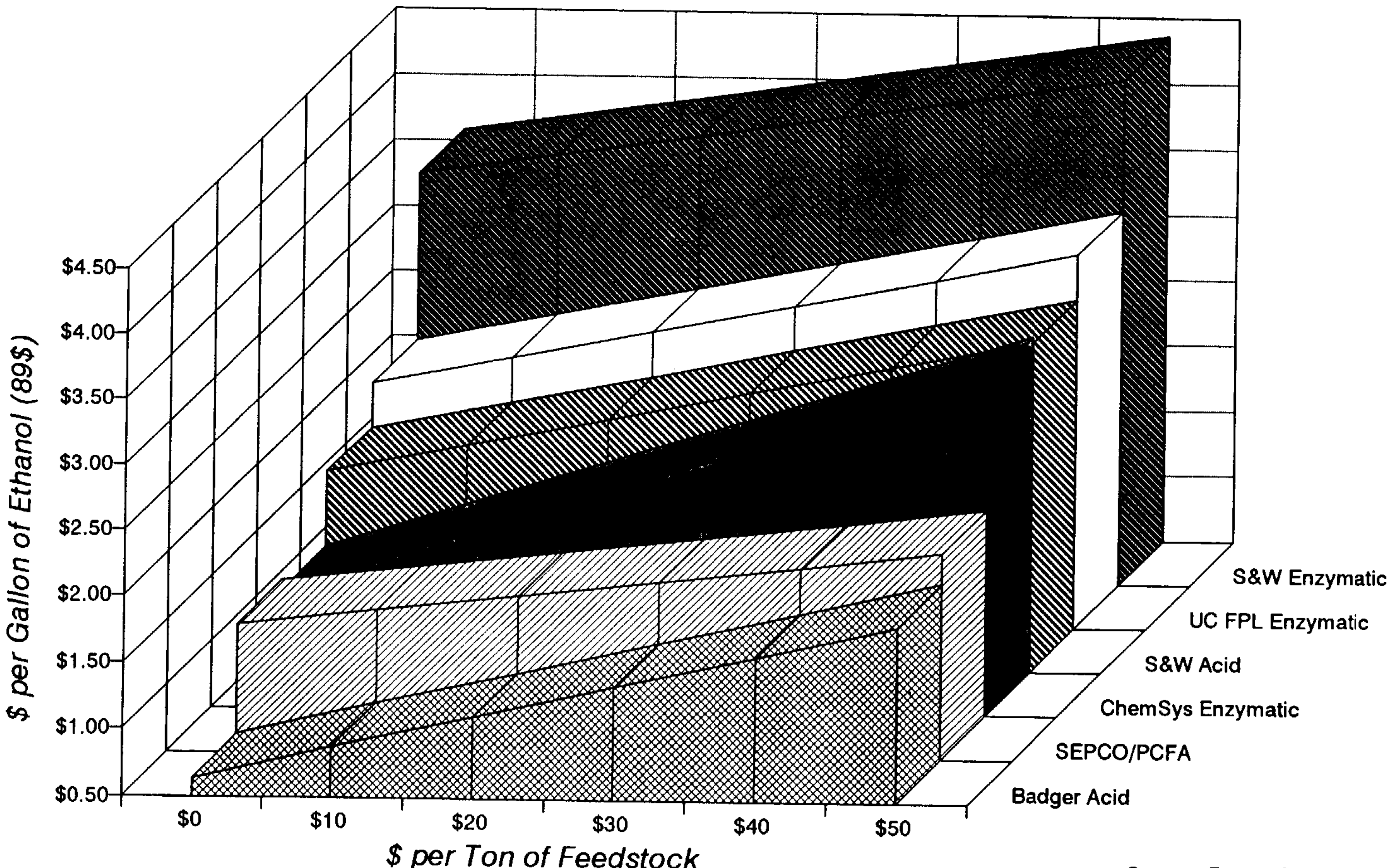
[63]Op.cit. "1st Set of Data Responses," AIR 29.

[64]The feedstock price itself should be relatively stable since SEPCO plans on collecting the residue itself.

Figure 3-7

Ethanol Production Costs

Acid & Enzymatic Processes



Source: Foster Associates, Inc

Studies conducted for other proposed ethanol plants indicate that SEPCO's cost estimates may be optimistic. Figure 3-7 compares the cost estimates from six proposed ethanol production plant designs -- three each of acid and enzymatic -- using similar economic assumptions, and how these costs change as the feedstock price varies between $0 and $50 per ton. The resulting ethanol costs per gallon show SEPCO's municipally-financed estimate of $1.88 per gallon to be at the low-end, and ranging to an estimated production cost of $4.51 for the Stone and Webster enzymatic design.[65] A more recent study by the USDA ERS projects that ethanol produced from biomass using enzymatic hydrolysis could cost as little as 82 to 87 cents per gallon excluding feedstock costs.[66] Biomass costs of $20 to $40 per ton would add about 25 to 50 cents per gallon, making biomass-derived ethanol cost competitive with corn-feedstock fuel and slightly below the range of cost estimates from SEPCO.

The cost estimates for the SEPCO plant are highly sensitive to several key financial and technological assumptions, which leads to uncertainty about the economic viability of the project until these issues are resolved.[67] As a result, it is unclear whether this plant will ultimately be built, or if it is built, whether it will be economically viable over the long-run. If the plant is successful, it could create demand for more than 10 percent of rice straw residue generated in the state. More importantly, its success could encourage other plants to be built, thereby consuming even greater amounts of straw. Given the large potential for the consumption of rice straw in ethanol production, the SEPCO plant presents a significant unknown variable in rice straw disposal costs.

3.3.4 Alternative Non-Energy Production Uses for Residue

Agricultural residues currently have a number of non-energy uses, and several potential new applications are under development. However, the most economically viable existing uses already have sufficient supply sources, and a number of potential uses face significant technical barriers, particularly related to the chemical composition of rice straw. In addition, introducing large new supplies of rice straw into the residue markets could displace significant amounts of other straws, most notably wheat straw.

3.3.5 Erosion Control and Fire Rehabilitation

The California Department of Transportation (CalTrans), Department of Parks and Recreation (CDPR) and U.S. Forest Service (USFS) all use significant amounts of straw for erosion control on

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[65]Assuming biomass feedstock prices are $40 per ton or the equivalent. These estimates are detailed in Table E-1 in Appendix E.

[66]Neil Hohmann and C. Matthew Rendleman, *Emerging Technologies in Ethanol Production*, Agriculture Information Bulletin No. 663, U.S. Dept. of Agriculture, Economic Research Service, January 1993.

[67]These differences, discussed further in Appendix A, should be resolved as part to the CEC's Application for Certification process. The purpose of this report is to evaluate the viability of future ethanol development in general, not for a specific project.

construction projects and for rehabilitation of burned areas.[68,69,70] Traditionally, straw -- typically wheat, but increasingly rice -- has been applied in two ways, either in *bales* or by *blower*. The former method is easier to handle with smaller 80 to 110 pound bales; however, it is less expensive to collect, process and transport the straw in 1,300 pound bales.[71] The latter method has two drawbacks for rice straw versus other types of straw. First, rice straw is harder on the blower mechanism due to its high silica content; and second, the blower dust from rice straw appears to be more irritating to workers.[72] Recently, a third method, *swaddling*, has been developed. In this approach, the straw is wrapped in a biodegradable netting of 8 to 12 inches in diameter and used in place of either straw bales or log erosion barriers.[73] This method shows significant promise, as the swaddled rice straw has greater resistance to rot than other organic materials and it is relatively easy to apply compared to cutting logs. Both CalTrans and USFS are currently experimenting with this application technique.

The total demand for straw for erosion control is still relatively small compared to the total amount of residues generated by rice cultivation alone. While no exact estimate is available from CalTrans, demand for straw for the erosion control may be in the order of magnitude of several thousand tons, with prices per ton ranging from $35 to $50.[74]

The USFS is currently studying the use of straw waddles for erosion control. The waddles use about 30 pounds of straw for each 25 feet, and about 2,000 feet are used on an acre.[75] While the ultimate demand for straw in this use may be large, a certain premium will be required by the waddle producers to cover expenses for the excess storage and processing capacity that may stand underutilized over a string of years when few forest fires occur.

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[68]John Haynes, CalTrans, personal communication, October 9, 1992; Shana Watkins, CDPR, communication November 4, 1992; Chuck Gowdy, USFS, personal communication, November 10, 1992.

[69]The California Department of Forestry is not responsible for burn rehabilitation on private lands, so it does not utilize straw except in some minor applications.

[70]One concern related to this use is the importation of noxious weeds in any straw material (e.g., Johnson grass with rice straw). The county agricultural commissioners must approve use of straw in these applications for this reason and acceptance vary by county.

[71]Haynes, op.cit.; Watkins, op.cit; Rudy Dyck, op.cit.

[72]Dale Wierman, California Department of Forestry, personal communication, November 4, 1992.

[73]Chuck Mitchell, El Dorado N.F., USFS, personal communication, November 10, 1992.

[74]For example, three projects in San Diego used 1,050 tons in 1992. CalTrans pays approximately $1.50 per 85 pound bale, or about $35 per ton. The CDPR uses the straw at seven parks under the management of the Division of Off-Highway Vehicles, totalling 4,000 to 5,000 bales per year or 160 to 250 tons per year. The CDPR pays a slightly higher price of $2.05 to $2.50 per bale, probably due to higher transportation costs, or about $50 per ton.

[75]Rudy Dyck, op.cit.

While no estimate of actual straw use in forest fire erosion control and soil rehabilitation is available, typically about 5 to 10 percent of the burned acreage is treated with either straw or logs, with actual amounts applied deviating dramatically according to soil conditions, accessibility and steepness.[76] Because damage and conditions vary so dramatically, a "typical" fire season cannot be identified and the demand for straw will not follow a standard pattern. Table 3-1 shows the acreage burned in California on CDF-jurisdiction and USFS National Forest land for the last ten complete years (1982-1991). Based on an application rate of 1.2 tons per acre on 5 to 10 percent of burned acreage, coupled with the experience of the last ten years, 8,000 to 16,000 tons of straw might be used in a median fire season, with a range of potential demand from only 2,000 up to 100,000 tons in any given year.

Table 3-1

California Forest Fires - Acres Burned*

Year	CDF	USFS	Total
1982	69,158	10,600	79,758
1983	70,733	8,700	79,433
1984	103,670	41,000	144,670
1985	223,288	271,000	494,288
1986	53,631	28,900	82,531
1987	86,945	710,000	796,945
1988	190,835	48,000	238,835
1989	73,601	58,000	131,601
1990	212,141	113,000	324,141
1991	23,157	10,000	33,157
Median	80,273	46,000	138,135
High	223,288	710,000	796,945
Low	23,157	8,700	33,157

*Source: California Dept. of Forestry, U.S. Forest Service

[76]Chuck Gowdy, Watershed Management, USFS, personal communication, November 10, 1992.

3.3.6 Composting for Mushroom Growing

California is second only to Pennsylvania in national mushroom production, growing 121.9 million pounds in 1991-92, or about 16.4 percent of U.S. sales.[77] However, following rapid growth in mushroom consumption between 1970 and 1989 -- when the market increased over three-fold -- production has stagnated over the last three years.

Mushroom compost is formed in one of two ways.[78] The first method relies on a mixture of 35 percent straw combined with the manure contained in animal bedding. The second method, called "synthetic" compost, is about 29 percent straw. Typically, about 20 pounds of compost is used for each square foot of mushroom cultivation. Of this, about 6 to 7 pounds is straw. Based on California production levels, about 60,000 to 75,000 tons of straw are used each year for mushroom compost.

While mushrooms require a significant amount of straw, the mushroom composting market is currently well supplied with existing agricultural waste products. For example, mushroom processors use large amounts of wheat straw, which growers prefer over other types of straw. Use of wheat straw for mushroom composting will only increase at the growth rate in the mushroom market, approximately 2 to 3 percent annually, unless straw prices fall by at least 50 percent.[79] As a result, the introduction of rice straw in large amounts would likely displace wheat straw without greatly expanding the market demand.

3.3.7 Construction and Papermaking Materials

Another alternative use involves substituting agricultural residue for wood chips in the production of fiberboard products and paper pulp. However, the limited research conducted over a decade ago found that rice straw is generally an inadequate replacement for wood chips. Agricultural residues face a number of disadvantages relative to wood chips. For example, the collection and transportation costs for agricultural residues generally are higher per unit than for wood; the harvesting period for agricultural residues is more concentrated, making storage an added requirement; and the supply of agricultural residues is relatively uncertain due to the changes in weather conditions. This is particularly true for rice, which can make the recovery of straw more difficult and expensive.[80] An additional damper on potential demand for this purpose has been the increasing use of wood waste from lumber operations, which has acted to lower the price for raw materials, placing any type of agricultural residues at a further competitive disadvantage.

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[77]"Mushroom Production Down, Value Continues to Increase," *Mushrooms*, National Agricultural Statistics Service, USDA, Washington, D.C., August 19, 1992.

[78]Paul Staments and J.S. Charlton, The Mushroom Cultivator, Agari Kon Press, Olympia, WA, 1983, Chapter V.

[79]Ted Shrivert, Monterey Mushroom, personal communication, October 1992.

[80]Mel Andrus, Rice Research Board, personal communication, September 24, 1992.

3.3.7.1 Fiberboard

Several research efforts have been made into converting rice straw into commercial grade fiberboard or straw bale houses.[81] Unfortunately, the straw was unsuitable for the most commonly used fiberboard applications due to excessive swelling and inadequate strength. Also, the straw has to be mixed with at least 50 percent wood chips to gain sufficient density for existing production equipment. Little additional research has been carried out since the early 1980s into addressing the identified shortcomings of using agricultural residues for fiberboard production.

3.3.7.2 Pulp

While the original paper made in China was produced from rice straw, wood fiber has become the primary source for pulp worldwide. Different research efforts have attempted to create a usable product from rice straw pulp, but the material has two properties limiting its use for this purpose.[82] The first shortcoming is that straw yields for usable fiber are only 25 to 35 percent, while wood yields up to 50 percent usable fiber. These low yields reduces the per unit price for straw pulp producers are willing to pay, and increases the bulk transportation costs. The second problem is that rice straw apparently cannot be bleached to an adequate brightness, making it only appropriate for lower-valued products. While Japan could be a potential market for bleached pulp or raw straw material, Japanese laws currently prohibit the importation of any rice product.[83] Given the lower cost and greater production flexibility of wood pulp, rice straw is unlikely to be used for papermaking in the near future.

A promising use for rice straw appears to be for corrugated paper for cardboard boxes, but the only such production plant in California closed in 1989.[84] Louisiana Pacific joined with the Rice Research Board in a corrugated paper production study in the early 1980s, but the study indicated that the market was inadequate to support a production facility on the West Coast.[85] The uncertainty of the

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[81]Frank Conklin, William Young, and Harold Youngberg, *Burning Grass Seed Fields in Oregon's Willamette Valley: The Search for Solutions*, Oregon State University Extension Service, Extension Miscellaneous 8397, February 1989; *Pilot Plant Project Report*, Washington Iron Works, Seattle, Washington, February 10, 1983.

[82]Conklin, Young, and Youngberg, op. cit.; S. Haig Zeronian, David Brink and Kaye McGee, "Rice Straw for Papermaking and Dissolving Pulp Grades," in J.E. Hill, ed., *Agricultural Residue Management: A Focus on Rice Straw*, A Report on the Residue Management Task Force, University of California, Davis, August 1981.

[83]Tim Crumpler, Louisiana Pacific, personal communication, October 6, 1992.

[84]David Brink, U.C. Agricultural Research Station, personal communication, August 1992.

[85]Mel Andrus, op.cit.

supply of rice straw and its relatively small size in comparison to the U.S. pulp market makes investment in the specialized equipment necessary to process straw risky.[86]

Orchard prunings could be a promising source of pulp fiber given their relatively close chemical composition to conventional wood waste. The key question for this use is whether orchard prunings can be cost competitive given their higher removal and transportation costs. Again, little research has been done on this application. However, the failure of this market to develop naturally is a strong indicator of significant barriers to its success.

3.3.8 Animal Feed

Wheat and rice straw has long been used as a food supplement for livestock, mostly as a filler due to its low nutritional value.[87] While rice straw has the potential to fill this market, its uses have significant drawbacks. Rice straw has a low level of lignin, which interferes with digestion, but a high level of silica which could offset this advantage. The application of ammonia could add sufficient nutrients to the straw, and improve digestibility. However the price of straw would then be roughly equivalent to alfalfa and hay before adding transportation costs. As a result, it is unlikely that significant amounts of rice straw will be demanded for use in animal feed beyond the present supplemental amounts.

3.3.9 Pollutant Filtration

Some research has been conducted related to using rice straw to remove heavy metals from waste waters.[88] This research indicated that straw requires little chemical treatment to achieve an adequate absorption rate. However, comprehensive studies on the range of potential commercial applications in this area are unavailable for use in this report.

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[86]Based on the ratio of recoverable fiber, 1 million tons of rice straw is about equal to 250,000 tons of wood pulp. The total U.S. wood pulp production in 1988 was 63.5 million tons. (Statistical Abstract of the United States 1991, 111th Edition, U.S. Bureau of the Census, Washington, D.C., 1991. Table No. 1195.)

[87]William Garrett and Raymond Coppock, "Rice Straw as Feedstuff for Livestock," in J.E. Hill, ed., *Agricultural Residue Management: A Focus on Rice Straw,* A Report on the Residue Management Task Force, University of California, Davis, (UCD) August 1981. See also "Costly Ban of Rice Burning," UCD Magazine, Winter 1991, page 10.

[88]R.T. Shet and S.H. Zeronian, "Polyelectrolyte Behavior of Lignocellulose, Part I: Ion Exchange Properties of Unmodified and Modified Rice Straw," Cellulose Chemistry and Technology, 18:41-48, 1984.

3.3.10 Landfill Disposal

A final resting place for agricultural waste -- should no other viable option be available -- is county landfills.[89] Except for Butte County, landfill tipping fees range from $25 to $45 per ton.[90] These costs represent a significant barrier to outright disposal when combined with removal costs. In addition, landfill costs could increase more rapidly in the future since rates presently are subsidized through increasingly scarce county property tax revenues.[91]

An additional impediment to disposing of residues in landfills is the waste stream recycling goals established by the Integrated Waste Management Board. These goals call for diverting 25 percent of existing waste streams by volume in 1995 and 50 percent by 2000 to non-landfill alternatives.[92] If the probability is sufficiently high that farmers will choose the landfill disposal option, the economic feasibility of the burn ban should include the "avoided costs" associated with diverting agricultural wastes. While current tipping fees appear sufficient to discourage dumping wastes, additional economic analysis may reveal otherwise.

At some point, farmers may find it more economical to dispose of their residues in the local landfill in the face of a burning ban. The tipping fees necessary for this type of disposal represent a "backstop" cost (i.e., the cost of landfill disposal represents the ceiling cost for disposal alternatives). Based on this test, for example, landfill disposal appears to be a more attractive alternative than biomass-based generation for rice straw, though soil incorporation would be even lower cost. Likewise, at $40 per acre, landfill disposal may be the least-cost alternative for orchard prunings. However, any strategies for implementing a burning ban for orchard residues must weigh the benefits from improved air quality, the avoided costs for diverting agricultural residues from a landfill, and the subsidies that might be required to make alternative uses of these residues economically viable.

3.3.11 Landfill Cover

While it may not be economical for farmers to dispose of their crop residues in rural landfills, the requirement by the Integrated Waste Management Board (IWMB) that landfills be covered on a daily and permanent basis could create a demand for these materials.[93] In the five Northern Sacramento Valley counties in which the rice industry is centered, about 350,000 cubic yards of ground cover is used each year. For wood chips or baled straw which weighs 270 pounds per cubic yard, this represents just over 47,000 tons of material. The minimum daily coverage is six inches of soil

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[89]Tipping fees and expected closure dates for Sacramento Valley landfills are shown in Appendix A.

[90]Butte County may want to review its landfill fees in light of the potential influx of agricultural material towards the end of the century.

[91]Mike Wochnick, IWMB, personal communication, November 13, 1992.

[92]Ibid.

[93]Trevor O'Shaghnessy, IWMB, personal communication, December 8, 1992.

equivalent. Current coverage alternatives include sewage sludge and soil with additives.[94] However, agricultural waste is currently being evaluated by the IWMB, and Yolo County is operating a pilot program to determine the feasibility of using agricultural waste for cover in its landfills.[95]

3.4 Summary of Feasibility of Potential Disposal Alternatives

Table 3-2 shows the total amount of almond, rice, walnut, and wheat residues grown in the State of California based on 1985 cropping data. The table also indicates lower and upper bound residue disposal cost estimates. For example, the delivered cost of rice straw ranges from $8 to $38 per ton. Part of the reason for this cost range is that the USDA straw removal subsidy of $25 per acre reduces costs by $8 per ton or more. However, this is a pilot program which may not be instituted permanently. Costs for delivered wheat straw residue range from $17 to $38 per ton. The cost range for orchard crops is somewhat lower -- between $10 and $30 a ton -- because under existing practices the prunings are already removed from the orchards, eliminating one additional disposal step.

Table 3-2
Potential Production of Agricultural Residues

Crop	Tons of Residue	Lower Bound Cost	Upper Bound Cost
Rice	1,212,134	$8/Ton	$38/Ton
Wheat	1,483,220	$17/Ton	$38/Ton
Almond	447,360	$10/Ton	$30/Ton
Walnut	168,199	$10/Ton	$30/Ton
Total Residues	3,310,913		

The greatest factor influencing the total demand for agricultural residues is the viability of biomass electricity generation. The total demand for all other uses is less than a quarter of the amount that might be used for electricity production. The viability of biomass generation is largely dependent on how Interim Standard Offer 4 contracts will be treated once they have expired at the turn-of-the-century; and whether or not the technological hurdles to using straw residues in biomass boilers can be overcome.

[94]Krys Jesionek, GeoSyntech Co., personal communication, December 8, 1992. The cover being used at individual landfills are shown in Appendix A.

[95]An associated survey found no use for agricultural wastes for landfill cover among 125 respondents, although 375 landfill operators have not yet responded. The study should be complete by early 1994. Jesionek, op.cit.

Table 3-3 summarizes upper and lower bound estimates of residue prices and demand for the various end-uses. Mushroom composting, roadside erosion control and biomass plants with ISO 4 contracts represent existing uses. End-uses that may emerge or grow in the future include further biomass development, erosion control in forest fire rehabilitation, the SEPCO ethanol facility and use of residues in landfill cover.

Table 3-3
Potential Consumption of Agricultural Residues

	Tons Used		Netback Price	
End Uses	**Low**	**High**	**Low**	**High**
Existing				
Mushroom Compost	8,500	11,000	$40	$50
Erosion Control	500	1,500	$35	$50
Biomass/ISO4	300,000	750,000	$33	$40
Potential				
Biomass	0	1,000,000	($50)	($17)
Ethanol	0	750,000	($4)	$36
USFS Fire Rehab.	8,000	16,000	$30	$35
Landfill Cover	0	47,000	$0	$0

With the possible, and notable, exception of ethanol production, technological and institutional barriers and long-term market conditions will severely limit the use of agricultural residues for energy and fiber production in the near future. Use of rice straw to generate electricity is currently precluded by technological constraints. Likewise, the prices offered for orchard residues will soon sharply decline as a result of the expiration of long-term energy supply contracts. Other end-use markets -- such as composting -- are too small or are already saturated. As a result, **developing alternative off-site disposal methods for agricultural residues will require much higher levels of research and development funding, and/or targeted market subsidies.**

4.0 Financial Impact Analysis

This chapter presents case study-based analyses of the financial changes engendered by growers' adoption of non-burn residue management approaches. The purpose of these case studies is to examine potential financial impacts taking into account the range of existing farm characteristics. Even within the same crop type, farm operations exhibit different production costs, financial arrangements, and crop yields. These factors can significantly affect each growers' ability to change their operations in the face of new regulatory or market conditions. By exploring a variety of farm characteristics within each crop type potential impacts that may be missed by a more aggregate approach can be identified.

It is important to carefully separate the findings of Chapter Four, which is based on case studies, from Chapter Five, which is based on "top-down" regional modeling. This Chapter provides insights into the potential financial implications to individual growers resulting from a change in residue management practices. It is designed to capture potential impacts on the directly affected growers that may be induced by non-burn policies. Chapter Five focuses on the average impact of changes in residue management approaches throughout the entire Sacramento Valley economy. As a result, while Chapter Four may identify the characteristics of particular "losers" from non-burn policies -- and provide some insight into the extent to which farmers will be able to successfully alter their residue management practices -- Chapter Five highlights whether a California region as a whole will face significant adverse impacts from such regulations.

Finally, it should be noted that both Chapters Four and Five isolate the financial and economic implications of changes in residue management approaches. Neither Chapter provides analyses of the cumulative financial and economic impacts of the range of policies and market trends that are currently buffeting California agriculture. Throughout the state growers must increasingly cope with pressures to urbanize, water scarcity, high energy prices, environmental regulations, and the year-to-year vagaries of weather, pests, and commodity prices. As a result, while changes in residue management practices alone may not induce significant hardship, when combined with these other factors non-burn policies may be "the straw that breaks the camel's back" for some growers. If so, such an effect would not be captured in this study.

4.1 Overall Methodology

For each crop type from three to nine case study farms were identified. Farms were selected to insure that the range of key operational characteristics were exhibited in the analysis. Production budgets were created for each of the farms based on information collected from the University of California Extension Service.[93] These budgets included production costs related to land, management,

[93]The U.C. farm production cost data represents a range of farm and production cost characteristics. These data also include assessments of the costs associated with establishing almond and walnut orchards. However, for the purposes of this analysis all of the case study orchard operations were assumed to be in full production (i.e., an inquiry was not made into the financial implications of non-burning residue management approaches to start-up orchard operations). In general, newly established orchards have lower yields than fully established operations. While it is likely that non-burn regulations would act as a modest barrier to entry for emerging almond and walnut farms, current conditions of

infrastructure and operating expenses, including the costs associated with existing residue management approaches. Once these farm budgets had been created, "sensitivity tests" were conducted by introducing the higher costs associated with alternative residue management practices, as well as, in some cases, modeling the financial implications of the increased residue disposal costs combined with lower crop yields.

The case study farms used in this analysis represent composites of farms actually operating in the Central Valley, as reported by UCD agricultural extension agents. The case study farms are illustrative of the different equipment configurations in use in the region. It is important to note, however, that these "paper" farms probably do not reflect any single identifiable farming operation in California. This is because in general the budget data represents the cost of creating a farm from scratch, rather than the costs of an ongoing operation, in which much of the equipment is likely to be fully depreciated.[94] As a result, the production cost contained herein tend to overestimate capital costs, leading to a conservative impact assessment.

4.2 Almonds

Six typical farm types were selected as "case study" almond farms. As indicated in Table 4-1, key differences in farm characteristics include total production acreage; price per acre/foot of water; and yields.[95] Financial spreadsheets for each of the different case study farm characteristics are provided

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excess commodity supply would be a far greater factor influencing the potential success of such start-ups. Both almond and walnut production cost estimates are based on 1988 and 1992 data.

[94]This was confirmed by data from a 1987 farm production survey carried out by DWR, CEC, and the University of California.

The farm budget data used in this analysis differs from UCD data only related to interest on operating capital and the income received by the operation. Interest on operating capital was estimated based on the following calculation:

[(Total Annual Cash Costs)*(.09/12)*7]+[(Total Annual Non-Cash Overhead)*(.04)

This equation better accounts for 9 percent per annum charges carried over a total of seven months and 4 percent opportunity costs.

[95]The following resources were used to develop almond production costs: "Cost for Establishing and Producing Almonds -- Fresno County 1988," University of California Cooperative Extension, 1988; "Cost for Establishing and Producing Almonds -- Tulare County, 1988," University of California Cooperative Extension, 1988; W. Asai, L. Hendricks, K. Klonsky, and P. Livingston, "Sample Costs to Establish and Produce Almonds, Sprinkler Irrigated and Mowed Centers in the Northern San Joaquin Valley -- 1992," University of California Cooperative Extension, 1992; W. Asai, L. Hendricks, K. Klonsky, and P. Livingston, "Sample Costs to Establish and Produce Almonds, Flood Irrigated and Mowed Centers in the Northern San Joaquin Valley -- 1992," University of California Cooperative Extension, 1992; W. Asai, L. Hendrick, P. Verdegaal, K. Klonsky, C. Ingels, P. Livingston, and L.

in Appendix B.

Table 4-1
Almond Case Study Farms

Category	Farm A	Farm B	Farm C	Farm D[96]	Farm E	Farm F
Location[97]	NSJ	NSJ	T	F	SV	SV
Total Acreage (in Production)	100 (95)	100 (95)	80 (80)	80 (80)	105 (100)	105 (100)
Value/Acre	$5,000	$5,000	$6,000	$6,000	$2,000	$1,000
Orchard Age (Years)	25	25	5	5	12	12
Irrigation System[98]	S	F	F	F	S	D
Water Price ($/acre/ft)	54	19	24	24	25	17
Yield/Acre (pounds)	2,000	2,000	1,500	1,500	2,000	1,600
Farm Gate Price	$1.30	$1.30	$1.05	$1.05	$1.05	$1.05

In the case of both almonds and walnuts it was assumed that the only viable alternative to residue burning would be to transport the prunings to a secondary user. That is, soil incorporation was

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Tourte, "Sample Costs to Produce Organic Almonds in the Northern San Joaquin Valley, Sprinkler Irrigation," University of California Cooperative Extension, 1992; W. Asai, L. Hendricks, P. Verdegaal, K. Klonsky, C. Ingels, P. Livingston, and L. Tourte, "Sample Costs to Produce Organic Almonds in the Northern San Joaquin Valley, Flood Irrigation," University of California Cooperative Extension, 1992; and J. Connell, J. Edstrom, J. Hasey, B. Krueger, J. Osgood, K. Klonsky, and J. Dubruille, "1988 Sample Costs to Establish and Produce Almonds on Class II Soil in the Sacramento Valley, University of California Cooperative Extension, 1988.

[96]While Farms C and D appear to be identical in the table, they operate in different locations in the state, and a more detailed examination of their financial structures reveals substantially different cost assumptions. These disparities likewise result in different burn-prohibition cost impacts as indicated in Table 4-2. A complete description of the financial characteristics of the two farms can be found in Appendix B.

[97](NSJ): Northern San Joaquin Valley; (T): Tulare; (F): Fresno; (SV): Sacramento Valley.

[98](S): Sprinkler; (F): Flood; (D): Drip.

not considered to be a viable option for almonds and walnut growers in the near term. This assumption was based on two considerations. First, as indicated in Section 3.1.2, the great majority of nut growers require a clean orchard floor as part of their harvesting practices. Soil incorporation induces a "messy" orchard floor, laden with twigs and excess debris. As a result, to successfully soil incorporate growers would have to substantially alter their existing cultivation practices. Second, even though there is some evidence that under changed agronomic patterns and through the use of advanced farm technologies nut growers could successfully -- and cost effectively -- soil incorporate (see also Section 3.1.2), interviews with almond and walnut growers indicate that growers are extremely unlikely to adopt this practice within the next ten years.[99]

4.2.1 Financial Analysis Findings – Almonds

Since almost all almond and walnut growers already utilize some procedure for gathering and either orchard- or road-siding residues, the additional costs induced by a non-burn policy were assumed to be limited to some combination of chipping, transportation, and "tipping" fees. As indicated in Chapter Three, chipping orchard residues may cost as much as $50 per acre, depending on the desired chip size; transportation costs could range from $5 to $30 per acre, depending on the weight carried and the distance traveled; and tipping fees could range from a cost of $50 per acre to a payment of an equal amount, depending on whether there is a demand for the residues as a commodity, or whether the residues are treated as "trash." Under a worst case scenario these costs could conceivably reach $130 per acre; however, this is extremely unlikely. Over time disposal costs are far more likely to average less than $20 an acre, as economies of scale and improved management techniques are engendered by regulatory-induced large-scale off-site disposal. Based on the analysis conducted in Chapter Three, total costs per acre were assumed to average $18 per acre over the long-term.

Even without the option to burn, residue disposal costs are small relative to total farm production costs and farm revenues. As indicated in Table 4-2, because net revenues per acre for almonds tend to be high -- ranging from as low as $200 to more than $1,000 -- the additional costs induced by adoption of non-burn residue management approaches would not result in significant financial burdens for most of the case study farms. With the exception of one farm type, per acre net revenues would decline by less than 3 percent as a result of the adoption of non-burn residue management alternatives. However, farm type C -- which generates the lowest amount of revenues among the case study farms -- would face per acre net revenue reductions of approximately 10 percent. While this income decline may not put the grower out-of-business, it would certainly be noticeable, and could necessitate production cost reductions in other areas, or require the grower to forgo needed equipment investments.

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[99]Almond and Walnut Focus Group Meetings, op. cit.

Table 4-2
Net Revenues per Almond Acre -- With and Without Burning

Farm Type	Net Revenues per Acre -- Residue Burning	Net Revenues per Acre -- Residue Removal	Net Change in Revenues per Acre -- Burn Prohibition
A	$853	$836	-$17
B	$1,032	$1,015	-$17
C	$201	$182	-$19
D	$685	$666	-$19
E	$910	$891	-$19
F	$678	$659	-$19

4.3 Walnuts

Nine typical farm types were selected for the walnut analysis. Key farm characteristics include total acreage in production; base land value, and irrigation methods, as indicated in Table 4-3

Table 4-3
Walnut Case Study Farms

Farm Type	Crop Type	Location	Total Acreage (Prod.)	Base Land Value	Irrigation System	Yield (lb/acre)
A	Lateral	SV	105 (105)	$2,500	Sprinkler	4,000
B	Hartley	SV	105 (105)	$2,250	Sprinkler	4,000
C	Early Lateral	NSJ	63 (60)	$2,500	Pumped	7,000
D	Hedgerow	NSJ	22 (20)	$4,725	Pumped	6,000
E	Late Lateral	NSJ	63 (60)	$4,400	Pumped	7,000
F	English	M	63 (60)	$4,500	Pumped	7,000
G	Early Lateral	SJS	63 (60)	$5,000	Pumped	7,000
H	Late Lateral	SJS	63 (60)	$5,000	Pumped	7,000
I	Late Terminal	SJS	63 (60)	$5,000	Pumped	7,000

Revenue estimates for in-shell walnut prices at the farm gate were based on 41 cents per pound for farm types A and B; 52 cents per pound for farm types C, D, and E; and 54 cents per pound for farm types F, G, H, and I.[100]

4.3.1 Financial Analysis Findings -- Walnuts

Table 4-4 displays estimated per acre net revenues for walnuts. As indicated in the table, per acre net revenues for walnuts range from $593 to over $1,785. As a result of adopting non-burn residue management approaches, total net revenues would decline by between $374 and $1,800 for the nine case study farms. For every farm type per acre net revenues would decline by less than one percent.

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[100]Walnut production cost data was taken from the following sources: J. Edstrom, J. Hasey, B. Krueger, B. Olson, J. Osgood, K. Klonsky, and J. Dubruille, "1988 Sample Costs to Produce Hartley Walnuts in the Sacramento Valley," University of California Cooperative Extension, 1988; J. Edstrom, J. Hasey, B. Kruger, B. Olson, J. Osgood, K. Klonsky, and J. DuBruille, "1988 Sample Costs to Produce Lateral Bearing Walnuts in the Sacramento Valley," University of California Cooperative Extension, 1988; J.A. Grant, L. Hendricks, K. Kelly, and K. Klonsky, "1990 Walnut Orchard Sample Establishment and Production Costs -- Early Leafing Lateral Bearing Varieties," University of California Cooperative Extension, 1990; J.A. Grant, L. Hendricks, K. Kelley, and K. Klonsky, "1990 Walnut Orchard Sample Establishment and Production Costs -- Late Leafing Lateral-Bearing Varieties," University of California Cooperative Extension, 1990; J.A. Grant, L. Hendricks, K. Kelley, and K. Klonsky, "1990 Hedgerow Walnut Orchard Sample Production Costs -- Northern San Joaquin Valley," University of California Cooperative Extension, 1990; L.C. Hedricks and E.A. Yeary, "Walnut Production Costs -- Merced County, 1986," University of California Cooperative Extension, 1986; G.S. Sibbett, M. Freeman, R. Beeded, H.R. Teranishi, K. Klonsky, and J. DuBruille, "Costs for Establishing and Producing Walnuts, Late-Leafing Terminal-Bearing - Southern San Joaquin Valley, 1989," University of California Cooperative Extension, 1989; G.S. Sibbett, M. Freeman, R. Beeded, H.R. Teransihi, K. Klonsky, and J. DuBruille, "Costs for Establishing and Producing Walnuts, Late-Leafing Lateral-Bearing - Southern San Joaquin Valley, 1989," University of California Cooperative Extension, 1989; G.S. Sibbett, M. Freeman, R. Beede, H.R. Teranishi, K. Klonsky, and J. Dubruille, "Costs for Establishing and Producing Walnuts, Early-Leafing Lateral-Bearing - Southern San Joaquin Valley, 1989," University of California Cooperative Extension, 1989.

Table 4-4
Net Revenues per Walnut Acre -- With and Without Burning

Farm Type	Net Revenues per Acre -- Residue Burning	Net Revenues per Acre -- Residue Removal	Net Change in Revenues per Acre -- Burn Prohibition
A	$688	$671	-$17
B	$870	$853	-$17
C	$776	$759	-$17
D	$1,785	$1,768	-$17
E	$944	$927	-$17
F	$626	$609	-$17
G	$593	$575	-$18
H	$717	$699	-$18
I	$843	$825	-$18

4.4 Rice

Three typical rice farm types were selected as "case study" farms for the purposes of this analysis. As indicated in Table 4-5, the chosen farm operations are representative of the wide range of rice farm operating characteristics in the Sacramento Valley. For example, the case study farms represent different landholding patterns, cultural practices, and yields. Two of the farms currently soil incorporate some amount of their rice straw. It should be noted that unlike the orchards crops, both rice and wheat growers receive subsidy payments from the federal government, and these payments are crucial to the financial viability of rice cultivation in the Sacramento Valley.

Table 4-5
Case Study Rice Farms

	Typical Farm Types		
	Type #A	**Type #B**	**Type #C**
Year Surveyed	**1992**	**1992**	**1988**
Characteristics			
Farm Size	1,000 Acres 750 Acres Rice	400 Acres 400 Acres Rice	600 Acres 600 Acres Rice
Land Tenure	Share Rent @ 25% of dry crop value	Owned by Grower $2,000 per acre value	Cash Lease $185/acre
Cultural	Continuous Rice 25% Continuous Fallow	Continuous Rice Temporary Levee System	Continuous Rice
Water	Irrigation District	Irrigation District; Supplemental Wells	Water/Irrigation/ Reclamation District
Current Residue Removal Method	10% Incorporation 90% Burned	30% Incorporation 70% Burned	100% Burned
Yields	80 cwt/acre 13% moisture	75 cwt/acre 13% moisture	65-75 cwt/acre 13% moisture
Returns	$7.50/cwt	$7.35/cwt	$5.50-$11.00/cwt
Government Programs	USDA Crop Programs CCC Loan Program SP-56 Rice Residue Program	USDA Crop Programs CCC Loan Program SP-56 Rice Residue Program	USDA Crop Programs CCC Loan Program SP-56 Rice Residue Program
Counties Described	Butte County	Sutter, Yuba, Placer, & Sacramento County	Colusa, Glenn, & Yolo Counties

For each case study farm the costs of adopting various residue management approaches were incorporated into the growers' operating budget.[101] Seven different soil incorporation techniques were

[101]Operating income was estimated based on a number of different data sources. Rice production revenues were estimated from State of California and national data sources. In addition, typical California rice farm revenues were augmented by federal crop and crop loan program payments, as well as with subsidies from a USDA crop residue management demonstration program. Operating costs for typical farms in different counties of California's rice growing region were taken from University of California Agriculture Cooperative Service studies. The costs used in these estimates include all reported operating costs under current crop residue practices.

modeled for each case study farm.[102] A description of the characteristics and costs of each of these practices is shown in Table 4-6.

Most of the farm revenue estimates -- especially for USDA program payments -- were based on 1988 USDA data. California Agricultural Soil Conservation Service (ASCS) offices were also contacted, and Sacramento Valley farmers and rice mill operators interviewed, to obtain additional price and cost information.

A price of $6.05/cwt was used in the analyses. Commodity Credit Corporation loan rate assumptions were based on an estimated $3.07/cwt deficiency payment rate. A USDA demonstration program -- the SP-56 Rice Residue Management Cost Share -- contributes $25 per acre to rice farmers using non-burn residue management alternatives. This program has been included in the financial analyses as an increment to farm income in the non-burn financial scenarios. However, it is important to note that this is a temporary program, which may not be available to growers in the long-term.

The farms selected as typical for the growing region are large, and farm support programs have total dollar limits. As a result, in the analyses federal crop payment programs were assumed to be limited to $50,000 per farm, and the California SP-56 program was limited to $3,000 per acre. In reality, each of the typical farms used in the analyses would exceed these limits if payments were made on the basis of crop yields and total acreage planted. The per acre revenue contributions from these programs were calculated by dividing the total payment amounts by the number of acres assumed to be in production.

Operating costs were divided into four broad categories: cultural operations, harvest operations, post-harvest operations, and other expenses. Operating costs under normal conditions for each of these farm types were obtained from the following sources: Scardaci, S.C., J. DuBruills, *Rice Production Costs, Colusa, Glenn, and Yolo Counties*, U.C. Cooperative Extension, April, 1989; *U.S. Rice Production Costs, Workshop Proceedings*, Agriculture and Rural Economy Division, USDA-ERS, July, 1988; Wick, C.M., K. Klonsky, P. Livingston, *Sample Costs to Produce Rice in Butte County - 1992*, U.C. Cooperative Extension, 1992; Williams, J., K. Klonsky, P. Livingston, *Sample Costs to Produce Rice in Sutter, Yuba, Placer, & Sacramento Counties - 1992*, U.C. Cooperative Extension, 1992.

[102]These alternatives were taken from Blank, et. al. "Incorporating Rice Straw Into Soil May Become Disposal Option For Growers," California Agriculture, Volume 47, Number 4, July - August, 1993, pages 8 - 12. Although the Blank report indicates many different variations for each of the soil-incorporation alternatives, the costs used in the financial analyses are based on the costs that would be incurred if each farm acted to minimize its expenses by using its currently available equipment and resources.

Table 4-6
Residue Disposal Alternatives

Rice Straw Disposal Methods	Range of Costs[103] ($/Acre)
Chop straw, leave it on the ground.	$3.50 - $50.12
Chop straw, disc field once.	$9.64 - $58.66
Chop straw, disc and plow field once.	$18.61 - $80.60
Chop straw, till field once.	$15.88 - $65.30
Chop straw, roll field once.	$7.12 - $9.49
Roll field once.	$3.71 - $5.99
Remove straw from field.[104]	$58.00 - $75.00
Burn straw.	$2.70 - $3.03

Assuming that the great majority of growers choose to incorporate their straw rather than remove it and dispose of it elsewhere -- a reasonable assumption based on the analysis presented in Chapter Three -- it is unknown which particular soil incorporation regime growers will select. It is most likely, however, that growers will choose a method that achieves a balance between:

(1) Cost;

(2) Use of their existing equipment complements (i.e., growers will try to avoid purchasing new equipment to be used for soil incorporation purposes only); and

(3) As complete soil incorporation as possible (i.e., within the limits of the other two factors growers will seek a method that maximizes contact between the straw and the soil, so as to encourage rapid and complete decomposition).

Once the costs of each of the potential incorporation methods had been modeled, sensitivity tests related to potential changes in crop yields were conducted. The purpose of this analysis was to determine how potential yield changes induced by disease or altered soil conditions would affect the financial viability of the farms. As indicated in Chapter Two, little data is available to predict yield

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[103]As indicated in the table, the range of costs associated with each potential disposal method is quite wide. Cost is chiefly dependent on the type of equipment complements utilized; and whether these complements are already owned by the grower, and thereby can be amortized over other uses, or whether new equipment, which may not be utilized for other production purposes, must be purchased.

[104]Not including transportation or tipping fees.

changes with any certainty. However, based on interviews with agricultural cooperative extension agents, per acre crop yield reductions of five and fifteen percent were used in this analysis as low and high crop yield losses. It should be stressed that **these yield changes are in no way predictive, and there is no evidence indicating that yield changes of greater than 5 percent are likely to occur as a result of the burn prohibition.** Instead, the yield-based sensitivity tests are meant to frame the potential financial implications to the case study farms **should** yields decline.

Finally, it is important to note that three land tenure possibilities are represented by the three study farms: crop share rent, implicit rent from owned land, and cash rent. Differences in land tenure can importantly affect the ultimate financial consequences of production cost increases and yield changes. For example:

- When land is owned, consistent yield changes affect land values in the long-term. This in turn affects wealth, rather than income, and could have implications for bank credit.

- When cash rents are paid, or when rents are treated as a share of crop returns, yield declines initially result in reduced income to the grower. In the longer-term, consistent yield declines create pressure for rent adjustments. In the short-term changes in rent paid affect landowner income, while in the long-term such changes affect wealth.

4.4.1 Financial Analysis Findings -- Rice

As shown in Table 4-7, in most cases adoption of non-burn alternatives is likely to result in only modest changes in per acre net revenues.[105] Should soil incorporation lead to yield reductions, however, net revenues per acre would begin to decline noticeably. As indicated in Table 4-8, assuming a 5 percent reduction in yields all of the case study farms under the most likely soil incorporation alternatives to be adopted would face reductions in per acre net returns of between $6 and $72. While all of the operations would remain viable, such reductions could lead to land devaluations, and force growers to forgo needed capital investments. If yields were to decline by 15 percent, as shown in Table 4-9, net returns per acre would fall even more dramatically, by between $43 and $115. Such loses would severely test the financial viability of the case study farms.

[105]A complete set of financial analysis tables have been provided in the Appendix B.

Table 4-7

Net Benefits Per Acre
For Non-Burn Alternatives
0% Assumed Yield Reductions

Yield Per Acre (cwt)	50	60	70	80	90	100	110
Farm Type A							
Alternative #1	$11.51	$11.51	$11.51	$11.51	$11.51	$11.51	$11.51
Alternative #2	$4.07	$4.07	$4.07	$4.07	$4.07	$4.07	$4.07
Alternative #3	($7.21)	($7.21)	($7.21)	($7.21)	($7.21)	($7.21)	($7.21)
Alternative #4	($4.38)	($4.38)	($4.38)	($4.38)	($4.38)	($4.38)	($4.38)
Alternative #5	$7.02	$7.02	$7.02	$7.02	$7.02	$7.02	$7.02
Alternative #6	$9.70	$9.70	$9.70	$9.70	$9.70	$9.70	$9.70
Alternative #7	($47.02)	($47.02)	($47.02)	($47.02)	($47.02)	($47.02)	($47.02)
Farm Type B							
Alternative #1	$14.79	$14.79	$14.79	$14.79	$14.79	$14.79	$14.79
Alternative #2	$7.35	$7.35	$7.35	$7.35	$7.35	$7.35	$7.35
Alternative #3	($3.93)	($3.93)	($3.93)	($3.93)	($3.93)	($3.93)	($3.93)
Alternative #4	($1.10)	($1.10)	($1.10)	($1.10)	($1.10)	($1.10)	($1.10)
Alternative #5	$10.30	$10.30	$10.30	$10.30	$10.30	$10.30	$10.30
Alternative #6	$12.98	$12.98	$12.98	$12.98	$12.98	$12.98	$12.98
Alternative #7	($43.74)	($43.74)	($43.74)	($43.74)	($43.74)	($43.74)	($43.74)
Farm Type C							
Alternative #1	$7.06	$7.06	$7.06	$7.06	$7.06	$7.06	$7.06
Alternative #2	($3.15)	($3.15)	($3.15)	($3.15)	($3.15)	($3.15)	($3.15)
Alternative #3	($14.40)	($14.40)	($14.40)	($14.40)	($14.40)	($14.40)	($14.40)
Alternative #4	($8.79)	($8.79)	($8.79)	($8.79)	($8.79)	($8.79)	($8.79)
Alternative #5	$2.57	$2.57	$2.57	$2.57	$2.57	$2.57	$2.57
Alternative #6	$5.25	$5.25	$5.25	$5.25	$5.25	$5.25	$5.25
Alternative #7	($51.32)	($51.32)	($51.32)	($51.32)	($51.32)	($51.32)	($51.32)

Table 4-8

Net Benefits Per Acre For Non-Burn Alternatives 5% Assumed Yield Reductions

Yield Per Acre (cwt)	50	60	70	80	90	100	110
Farm Type A							
Alternative #1	$0.17	($2.10)	($4.37)	($6.64)	($8.90)	($11.17)	($13.44)
Alternative #2	($7.27)	($9.54)	($11.81)	($14.08)	($16.34)	($18.61)	($20.88)
Alternative #3	($18.55)	($20.82)	($23.09)	($25.36)	($27.63)	($29.90)	($32.16)
Alternative #4	($15.72)	($17.99)	($20.26)	($22.53)	($24.80)	($27.07)	($29.34)
Alternative #5	($4.33)	($6.59)	($8.86)	($11.13)	($13.40)	($15.67)	($17.94)
Alternative #6	($1.64)	($3.91)	($6.18)	($8.45)	($10.72)	($12.99)	($15.26)
Alternative #7	($58.36)	($60.63)	($62.90)	($65.17)	($67.44)	($69.71)	($71.97)
Farm Type B							
Alternative #1	($0.33)	($3.36)	($6.38)	($9.41)	($12.43)	($15.46)	($18.48)
Alternative #2	($7.77)	($10.80)	($13.82)	($16.85)	($19.87)	($22.90)	($25.92)
Alternative #3	($19.06)	($22.08)	($25.11)	($28.13)	($31.16)	($34.18)	($37.21)
Alternative #4	($16.23)	($19.25)	($22.28)	($25.30)	($28.33)	($31.35)	($34.38)
Alternative #5	($4.83)	($7.85)	($10.88)	($13.90)	($16.93)	($19.95)	($22.98)
Alternative #6	($2.15)	($5.17)	($8.20)	($11.22)	($14.25)	($17.27)	($20.30)
Alternative #7	($58.87)	($61.89)	($64.92)	($67.94)	($70.97)	($73.99)	($77.02)
Farm Type C							
Alternative #1	($8.07)	($11.09)	($14.12)	($17.14)	($20.17)	($23.19)	($26.22)
Alternative #2	($18.28)	($21.30)	($24.33)	($27.35)	($30.38)	($33.40)	($36.43)
Alternative #3	($29.53)	($32.55)	($35.58)	($38.60)	($41.63)	($44.65)	($47.68)
Alternative #4	($23.92)	($26.94)	($29.97)	($32.99)	($36.02)	($39.04)	($42.07)
Alternative #5	($12.55)	($15.58)	($18.60)	($21.63)	($24.65)	($27.68)	($30.70)
Alternative #6	($9.88)	($12.90)	($15.93)	($18.95)	($21.98)	($25.00)	($28.03)
Alternative #7	($66.44)	($69.47)	($72.49)	($75.52)	($78.54)	($81.57)	($84.59)

Table 4-9

Net Benefits Per Acre
For Non-Burn Alternatives
15% Assumed Yield Reductions

Yield Per Acre (cwt)	50	60	70	80	90	100	110
Farm Type A							
Alternative #1	($22.52)	($29.32)	($36.13)	($42.94)	($49.74)	($56.55)	($63.35)
Alternative #2	($29.96)	($36.76)	($43.57)	($50.38)	($57.18)	($63.99)	($70.79)
Alternative #3	($41.24)	($48.05)	($54.85)	($61.66)	($68.46)	($75.27)	($82.08)
Alternative #4	($38.41)	($45.22)	($52.02)	($58.83)	($65.64)	($72.44)	($79.25)
Alternative #5	($27.01)	($33.82)	($40.63)	($47.43)	($54.24)	($61.04)	($67.85)
Alternative #6	($24.33)	($31.14)	($37.94)	($44.75)	($51.56)	($58.36)	($65.17)
Alternative #7	($81.05)	($87.86)	($94.66)	($101.47)	($108.27)	($115.08)	($121.89)
Farm Type B							
Alternative #1	($30.58)	($39.66)	($48.73)	($57.81)	($66.88)	($75.96)	($85.03)
Alternative #2	($38.02)	($47.10)	($56.17)	($65.25)	($74.32)	($83.40)	($92.47)
Alternative #3	($49.31)	($58.38)	($67.46)	($76.53)	($85.61)	($94.68)	($103.76)
Alternative #4	($46.48)	($55.55)	($64.63)	($73.70)	($82.78)	($91.85)	($100.93)
Alternative #5	($35.08)	($44.15)	($53.23)	($62.30)	($71.38)	($80.45)	($89.53)
Alternative #6	($32.40)	($41.47)	($50.55)	($59.62)	($68.70)	($77.77)	($86.85)
Alternative #7	($89.12)	($98.19)	($107.27)	($116.34)	($125.42)	($134.49)	($143.57)
Farm Type C							
Alternative #1	($38.32)	($47.39)	($56.47)	($65.54)	($74.62)	($83.69)	($92.77)
Alternative #2	($48.53)	($57.60)	($66.68)	($75.75)	($84.83)	($93.90)	($102.98)
Alternative #3	($59.78)	($68.85)	($77.93)	($87.00)	($96.08)	($105.15)	($114.23)
Alternative #4	($54.17)	($63.24)	($72.32)	($81.39)	($90.47)	($99.54)	($108.62)
Alternative #5	($42.80)	($51.88)	($60.95)	($70.03)	($79.10)	($88.18)	($97.25)
Alternative #6	($40.13)	($49.20)	($58.28)	($67.35)	($76.43)	($85.50)	($94.58)
Alternative #7	($96.69)	($105.77)	($114.84)	($123.92)	($132.99)	($142.07)	($151.14)

4.5 Wheat

Five typical irrigated wheat farms were examined in this analysis. Key characteristics for wheat operations include geographic location, production acreage, land value, and operating expenses, as indicated in Table 4-10.

Table 4-10
Irrigated Wheat Case Study Farm Characteristics

Farm Type	A	B	C	D	E
Location	**Yolo County**	**Glenn County**	**Sacramento County**	**Sacramento County**	**San Joaquin County**
Total Acreage (Production Acreage)	2,900 (900)	1,500 (375)	N/A	N/A	1,200 (300)
Rental Rate	28% of Gross	25% of Gross	15% of Gross	15% of Gross	$50/acre
Typical CWT/Acre Yields	55	50	56	56	60
Farm Gate Cash Price (per CWT)	$6.40	$5.38	$6.40	$6.40	$5.38
ASCS Payments (per CWT)[106]	$.53	$2.13	$.53	$.53	$2.13

Total revenues for each farm operation were estimated by multiplying cash crop prices plus ASCS deficiency payments by per acre yields and the number of acres available for cultivation. This method resulted in conservative revenue estimates, for two reasons. First, net revenue per acre estimates were calculated based on each farm's acreage base, rather than actual acreage in production. Second, each of the case study farms used in the analysis rents land. In most farm operations implicit, or non-cash operating costs, are used to buffer swings in cash returns (i.e., even though non-cash operating costs will eventually have to be recovered, they are not usually a cash drain on operations). For the case study farms, however, since land expenses are generally expressed as a percentage of gross returns, these costs represent explicit cash costs of operations.

[106]Like rice growers, wheat farmers receive a deficit payment equal to the difference between an established target price and the market price.

In addition to conservative revenue estimates, the irrigated wheat analysis also reflects residue management costs that may be somewhat inflated. That is because while the production cost and crop price data are expressed in nominal dollar terms for the year in which the data was collected,[107] the agricultural residue cost data are based on current prices. However, the impact of this mismatch on the analytical findings is likely to be quite small.

In the case of irrigated wheat it was assumed that growers could either soil incorporate or dispose of their residues off-site. As indicated in Chapter Three, soil incorporation of wheat straw does not appear to induce disease problems, and does not pose the same operational challenges as rice straw soil incorporation (e.g., wheat fields are not flooded, thereby reducing the possibility of limits on equipment maneuverability). Based on the Chapter Three analysis it was assumed that wheat straw could be soil incorporated at a cost of $16.50 an acre. This cost, however, does not include any additional expenses associated with the need to add more herbicides to fields in which straw has been incorporated; nor does it include potential reductions in overall revenues associated with having to eliminate one crop rotation, as discussed in Chapter Three. The financial implication of these additional burdens was investigated by examining per acre revenues in light of yield reductions.

Residue removal costs were assumed to total $45 an acre. No additional revenue was assigned to these residues (i.e., it was assumed that wheat growers would not be paid for their residues, or if they were, the total transfer netted to zero, not including the costs of straw collection and transportation). Although there is a small market for wheat straw (see Chapter Three), it was assumed that this market has been fully saturated. As a result, it is important to note that this analysis focuses on those wheat growers who currently burn their straw, and excludes entirely the large number of growers whose existing practice is to dispose of their straw off-site, or who soil incorporate.

4.5.1 Financial Analysis Findings -- Wheat

Table 4-11 shows net revenue per acre with residue burning, soil incorporation, and residue removal, assuming both typical wheat yields and a 5 percent yield reduction. None of the operations would do well under a residue removal regime. As indicated in the table, farm type A would suffer a net revenue decline of 35 percent under the residue removal alternative. Likewise, residue removal would not be a viable option for marginal operations, as illustrated by farm types B and C. Because per acre net revenues are so low for irrigated wheat, even the modest additional expenses associated with soil incorporation could create financial discomfort for wheat growers. For example, replacing burning with soil incorporation would reduce farm type A, D and E's per acre net revenues by more than 12 percent. Under a soil incorporation regime farm type C would be put out-of-business, and farm type B would be placed in an extremely precarious financial position. However, it is important to note that farm type C is almost a non-viable operation even without changes in residue management practices, as demonstrated by the fact that even without a change in residue management practices, a 5 percent decline in yields would likewise put this farm out-of-business.

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[107]Either 1989 or 1990.

Table 4-11
Net per Acre Irrigated Wheat Revenues
Under Residue Burning, Incorporation, and Removal

Farm Type	Residue Burning, Typical Yields	Residue Burning, -5 CWT/Acre Yields	Residue Incorporation, Typical Yields	Residue Incorporation, -5 CWT/Acre Yields	Residue Removal, Typical Yields	Residue Removal, -5 CWT /Acre Yields
A	$128	$103	$112	$87	$83	$58
B	$37	$9	$21	-$8	-$8	-$36
C	$17	-$13	0	-$29	-$29	-$58
D	$135	$106	$119	$89	$90	$61
E	$130	$92	$113	$76	$85	$47

It is important to note that approximately two-thirds of the state's wheat farmers have already adopted non-burn residue management practices, either soil incorporating or selling their residues for mushroom composting, erosion control, or other uses (see Chapter Three). This implies that those growers who continue to burn their stubble do so because their particular characteristics make it either financially costly or particularly profitable to do otherwise. That is, those growers who continue to burn likely do so for one of two reasons. Either through burning they are able to quickly clear their fields for a follow-on crop, thereby maximizing their annual income; or their operations cannot financially support even the small additional expenses associated with soil incorporation. Table 4-11 indicates that while a small proportion of growers fall into the later category, most growers fall into the former grouping. That is, wheat farming provides positive benefits for other crops in rotation (e.g., drying-out sub-irrigated soils) -- or is part of an integrated cattle-feeding operation -- making wheat cultivation sufficiently attractive despite its low-returns.

5.0 Regional Economic Impact Assessment

This chapter presents analyses of the regional economic implications of policies to limit rice straw burning in the Sacramento Valley.[108] The purpose of these analyses is to examine whether the grower-specific impacts of adoption of residue management alternatives -- as described in Chapter Four --would collectively act to disrupt the Sacramento Valley economy.

5.1 Impact Methodology

The regional economic impacts associated with changes in crop residue management practices were assessed using a modified computable general equilibrium (CGE) model framework combined with a farm production sub-model. A schematic of the model formulation was presented in Figure 1-3 in Chapter One, and a technical description of the model's components is located in appendices C and D.[109]

In general, use of the CGE model in this analysis proceeds in a stepwise fashion. First, a policy scenario is postulated (e.g., rice straw burning is prohibited). Second, the direct costs associated with this policy are determined, as was done in the Chapter Three analysis, and these costs are introduced into farm-level production costs through the farm production sub-model. Third, the production sub-model is designed to mimic how farmers will change their production patterns in reaction to new costs. And finally, the cumulative effects of the higher costs, changes in yields and production changes are gathered together and distributed among the impacted sectors by the CGE model.

It is important to be aware of the limitations of the CGE-based analysis. First, the model does not completely capture the adjustment costs associated with the production changes that may be induced by the policy being modeled. Essentially, the model acts as if growers are presented with potential costs and yield implications prior to making their production decisions, and allows them to respond as though they know the outcome with certainty. In reality, rice growers will choose a residue management strategy, without complete information related to the risks of that approach, plant their crops, and be subjected to whatever are the resulting yield changes. In other words, in the early stages of the phase-down growers will not be able to know with certainty their yield losses. As a result, growers will only significantly alter their behavior if they believe there is a substantial probability that significant yield declines will be induced by a particular strategy, or after the declines have actually occurred. This issue of uncertainty

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[108]This report was originally going to include regional impact assessments of the other study crops as well. However, because the case study analyses indicated that farm level impacts were unlikely to be large for these crops, and after examining results of the Sacramento Valley CGE model, it was determined that the regional impacts resulting from changes in wheat and orchard production practices are unlikely to be significant, and do not merit a full CGE analysis.

[109]For a more technical description of the CGE methodology, interested readers are encouraged to review the academic literature. See in particular Peter Berck, Sherman Robinson, and George Goldman, "The Use of Computable General Equilibrium Models to Assess Water Policies," University of California, Berkeley; and Sherman Robinson, Shankaer Subramanian, and Jacqueline Geoghegan, "A Regional Environmental Computable General Equilibrium Model of the Los Angeles Basin," Department of Agricultural and Resource Economics, University of California, Berkeley, March 1993.

of general response and associated yield loss is treated by modeling multiple scenarios reflecting a variety of yield and cost outcomes. This sensitivity analysis reflects the range of likely impacts on the regional economy.

Second, while the CGE model measures regional economic adjustments to changes in aggregate agricultural production levels, it does not assess changes which may occur when production levels remain constant but demands for inputs change. For example, the model does not fully incorporate the economic changes that may be caused if rice yields remain the same, but growers purchase additional amounts of farm equipment to deal with straw residues. In such a situation -- when factor demand increases with no increase in output (i.e., yield) -- income would be transferred from the residual claimant (i.e., land) to purchasable inputs (i.e., labor and such intermediate inputs as equipment and energy). The net effect could be to increase or decrease economic activity in a region. An increase could occur if income to land was spent outside the region, but income to purchased input was spent within the region. However, results from the farm production sub-model indicate that changes in factor demands resulting from the rice straw burning phase-down are not likely to be significant; in a regional context these changes would not be measurable.

Finally, because Sacramento County's economy is large relative to the seven other rice producing counties included in the analysis, it may mask potentially important local implications. However, the farm production sub-model is used to identify counties for which the burn prohibition will have the biggest impact on production and farm income.

5.1.1 Model Calibration and Parameter Specification

Calibrating the regional impact model requires specifying a number of key production parameters. The calibration process is outlined in appendices C and D. The key parameter specifications and data sources are as follows:

(1) **Initial Year**: The model is calibrated to 1985 and regional economic changes resulting from phase-out scenarios are calculated as deviations from initial year conditions.

(2) **Regional Economic Activity**: initial year regional industrial output and income flows are adapted from the U.S. Forest Service's IMpact analysis for PLANing input-output modeling system (IMPLAN).

(3) **Productive Acreage**: crop acreage data are classified by soil type and yield potential and derived from U.S. Soil Service County Soil Surveys.

(4) **ASCS Rice Base Acreage**: county rice acreage enrolled in the federal rice program was obtained from county Agricultural Stabilization and Conservation Service offices.

(5) **Yield**: yields for crops and soil types included in the model were estimated with county soil surveys and county agricultural commissioner reports, and updated to reflect relative yield increases that have occurred over time.[110]

(6) **Variable production costs**: production cost estimates were based on the U.C. Davis Farm Production Cost Survey and crop budgets.[111]

(7) **Soil incorporation costs**: were assumed to be $30 per acre. As indicated in Chapter Four, potential soil incorporation costs vary widely, with the average costs associated with different equipment complements ranging from just under $8 per acre to over $85 an acre. The incorporation cost estimate used in this chapter is somewhat higher than that used in Chapter Four so as to insure potential regional impacts are adequately captured.

(8) **Field removal costs**: were assumed to total $75 per acre. This is based on the assumption that field clearing costs will average $60 per acre, while transportation costs will average $15 per acre, as discussed in Chapters Three and Four. No costs -- or revenues -- are associated with final residue disposal. As indicated in Chapter Three, while this appears to be a plausible assumption, the actual benefits or costs related to disposing of straw as a commodity will depend on whether or not its use is viable for energy production, as discussed in Chapter Three.

(9) **USDA residue disposal cost share**: was based on USDA's rice residue management program payments of $25 an acre, not to exceed $3,500 per eligible grower per year.[112] Based on the size distribution of rice operating units, a per acre subsidy of $8.75 was estimated for the entire rice base.

(10) **Ethanol demand for rice straw**: was based on the Chapter Three analysis, under some of the policy scenarios it was assumed that the SEPCO ethanol plant will demand 100,000 tons of rice straw. This straw is assumed to be collected from Placer, Sacramento, Sutter and Yolo counties, the counties closest to the proposed plant site. Based on a 75 percent

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[110]Yield data was obtained from the following USDA reports: "Soil Survey: Colusa County, California," Soil Conservation and Forest Service, 1948; "Soil Survey: Glenn County, California," Soil Conservation Service and Forest Service, 1968; "Soil Survey: Sutter County, California" Soil Conservation Service and Forest Service, 1988; "Soil Survey: Yolo County, California," Soil Conservation Service and Forest Service; "Soil Survey: Placer County, California," Soil Conservation Service and Forest Service, 1980; "Soil Survey, Yuba County, California," Soil Conservation Service and Forest Service, preliminary, 1993; "Soil Survey: Sacramento County, California," Soil Conservation Service and Forest Service, preliminary, 1993; and "Agricultural Commissioners' Data," California Department of Food and Agriculture, 1985 - 1990.

[111]See Chapter Four for a complete list of references.

[112]"ASCS News."

utilization rate, the ethanol scenarios likewise were based on the assumption that straw will be collected from 44,400 acres of rice land.

(11) **Prices:**[113]

- Grain and other field crops: the grain prices received by farmers are assumed to be determined by federal price support programs. This assumption is especially important for rice because participation among rice growers is nearly universal. The estimated changes in acreage for all non-rice grain crops are assumed to be too small to impact prices.

- Alfalfa: price fluctuations for alfalfa are primarily demand driven (i.e., changes in demand by the dairy sector is the primary determinant of alfalfa price adjustments). Changes in regional alfalfa production were determined to be too small to impact the state's alfalfa market. Therefore, alfalfa prices are held constant.

- Tomatoes and sugar beets: it was assumed that no rice acreage would be converted to these crops. This assumption was based on conversations with rice growers who indicated that production of tomatoes and sugar beets is limited by existing supply contracts which are generally not available to entry-level growers.

5.2 Initial Year Regional Economic Activity

In the regional analysis, changes in economic activity resulting from alternative phase-down policies were calculated as deviations from initial year conditions. Tables 5-1 through 5-4 characterize regional economic activity, sector interdependencies, and sector contributions to regional value-added for initial year 1985. Whereas the regional economic model used in the analysis estimates production changes for 14 sectors (6 agricultural, 2 agricultural processing, manufacturing, mining, and 4 service), these tables characterize the production side of the economy using only 8 sectors. The agricultural production and processing sectors are aggregated into two sectors in the tables to highlight agriculture's role in total regional economic activity. Dollar amounts in these tables are in millions of 1985 constant dollars.

[113]These assumptions are based on the rice focus group meeting; and personal communication with Keith Knapp, Associate Professor of Resource Economics, University of California Riverside. Also see, K. Konyar and K. Knapp, "Demand for Alfalfa Hay in California," Giannini Foundation Research Report Number 333.

Regional purchases of intermediate goods and services, as shown by Table 5-1,[114] totaled slightly over $8 billion in 1985, representing 22 percent of regional gross product. Agricultural production and processing directly accounted for 13 percent of total intermediate purchases. This compares to shares of 11.4 percent for manufacturing, 3.5 percent for freight, 13.8 percent for trade, and 15.3 for banking.[115] Thus agriculture can be considered an important component of regional intermediate demand, on par with manufacturing, trade, and banking. Note, however, that a full 43 percent of intermediate purchases are accounted for by the sectoral aggregate "Other", indicating that a significant amount of the region's economic activity occurs in non-industrial sectors, such as government.

Table 5-2 shows how one sector's purchases contribute to another sector's total intermediate sales. For example, slightly more than 38 percent of sales of intermediate goods and services by the agricultural production sector are to itself, while nearly 40 percent are made to agricultural processing. This table illustrates the linkages between agricultural production and processing and the region's remaining sectors; agriculture accounts for 15 percent of purchases of intermediate goods and services for freight, 22 percent for trade, 11.5 percent for manufacturing, and 7.5 percent for banking.

Table 5-3 shows total regional output by sector. In initial year 1985, output exceeded $36.5 billion, with 11 percent of this total coming from agricultural production and processing. Table 5-4 shows the regional value added and employment generated by this output. The upper section of the table shows employment and value-added by sector. Agricultural production and processing directly accounted for 47 thousand jobs (8.4 percent of total regional employment) and $1.5 billion in value-added (6.9 percent of regional value-added). The lower section of the table gives low, medium, and high estimates of the regional employment and value-added that is related to agricultural production and processing.[116] Based on the middle estimate, approximately 10 percent of initial year regional economic activity is related to agriculture.

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[114]The data in this table indicate how each regional sector contributes to another sector's sales of goods and services. Reading down the table's columns shows sectoral purchases while reading across the rows shows sectoral sales. For instance, the agricultural production sector purchased from agricultural processing $2.17 million in goods and services and sold them $131.1 million.

[115]Banking includes insurance and real estate.

[116]The low estimate is simply the sum of employment or value added in the agricultural production and processing sectors. However, agriculture is responsible for some fraction of the economic activity in other sectors. The high estimate accounts for this by adding to the low estimate a fraction of each sector's employment or value-added based on agriculture's share of the sectors intermediate input demand. The medium estimate weights agriculture's share of each sector's intermediate input demand by the intermediate demand share in total sectoral output.

TABLE 5-1

INTERMEDIATE DEMAND BY MAJOR SECTOR: SACRAMENTO VALLEY - 1985

millions 1985$	Agriculture Production	Agricultural Processing	Other Manufacturing	Mining	Freight	Trade	Banking	Other	Total
Agriculture Production	126.59	131.10	0.75	0.01	0.16	7.34	12.21	51.23	329.39
Agricultural Processing	2.17	74.86	2.22	0.01	0.06	0.16	0.02	90.56	170.07
Other Manufacturing	17.94	82.54	346.63	0.76	7.07	91.38	24.61	302.63	873.56
Mining	0.49	0.10	1.10	2.43	1.53	0.40	0.08	13.09	19.22
Freight	22.90	53.59	72.23	0.69	109.87	70.00	15.03	170.07	514.37
Trade	67.58	147.55	155.22	1.80	27.51	59.86	12.94	504.31	976.77
Banking	97.42	24.25	62.27	10.50	29.49	233.71	712.05	471.50	1,641.17
Other	64.46	133.95	270.95	9.78	107.98	643.77	443.34	1,802.54	3,476.76
Total	399.55	647.95	911.37	25.97	283.67	1,106.61	1,220.27	3,405.92	8,001.31

Notes: Columns represent expenditures, rows represent receipts.

Source: U.S. Forest Service, IMPLAN computer program, version 91-09.

TABLE 5-2

SECTORAL SHARE OF INTERMEDIATE DEMAND: SACRAMENTO VALLEY - 1985

Column Sectors Share of Row Sectors Intermediate Demand	Agriculture Production	Agricultural Processing	Other Manufacturing	Mining	Freight	Trade	Banking	Other
Agriculture Production	38%	40%	0%	0%	0%	2%	4%	16%
Agricultural Processing	1%	44%	1%	0%	0%	0%	0%	53%
Other Manufacturing	2%	9%	40%	0%	1%	10%	3%	35%
Mining	3%	1%	6%	13%	8%	2%	0%	68%
Freight	4%	10%	14%	0%	21%	14%	3%	33%
Trade	7%	15%	16%	0%	3%	6%	1%	52%
Banking	6%	1%	4%	1%	2%	14%	43%	29%
Other	2%	4%	8%	0%	3%	19%	13%	52%

Source: U.S. Forest Service, IMPLAN computer program, version 91-09.

TABLE 5-3
SECTORAL INTERMEDIATE AND FINAL CONSUMPTION DEMAND: SACRAMENTO VALLEY - 1985

	millions 1985$			Shares			Split	
	Intermed Demand	Final Demand	Industry Output	Intermed Demand	Final Demand	Industry Output	Intermed Demand	Final Demand
Agriculture Production	329	1,511	1,841	4%	5%	5%	18%	82%
Agricultural Processing	170	2,013	2,183	2%	7%	6%	8%	92%
Other Manufacturing	874	2,729	3,603	11%	10%	10%	24%	76%
Mining	19	175	194	0%	1%	1%	10%	90%
Freight	514	687	1,201	6%	2%	3%	43%	57%
Trade	977	4,010	4,987	12%	14%	14%	20%	80%
Banking	1,641	3,158	4,799	21%	11%	13%	34%	66%
Other	3,477	14,286	17,763	43%	50%	49%	20%	80%
	8,001	28,570	36,571	100%	100%	100%		

Source: U.S. Forest Service, IMPLAN computer program, version 91-09.

TABLE 5-4
SECTORAL VALUE ADDED: SACRAMENTO VALLEY - 1985

Sector	Value Added	Regional Share	Employment	Regional Share
Agriculture Production	957	4.36%	35,080	6.24%
Agricultural Processing	560	2.55%	12,179	2.17%
Other Manufacturing	1,522	6.93%	37,964	6.75%
Mining	142	0.65%	1,307	0.23%
Freight	761	3.46%	18,985	3.38%
Trade	3,513	16.00%	94,683	16.83%
Banking	3,363	15.32%	56,628	10.07%
Other	11,135	50.72%	305,657	54.34%
Total	21,952	100.00%	562,483	100.00%

	Estimate		
	Low	Medium	High
Ag Related Employment	8.4%	10.4%	17.2%
Ag Related Value Added	6.9%	9.0%	15.8%

Source: U.S. Forest Service, IMPLAN computer program, version 91-09.

The fraction of regional output related to rice production is much smaller. While precise estimates of the rice sector's share of total output are not possible because of IMPLAN sector aggregation,[117] various indicators of its share of regional agricultural production can be used to determine its relative importance. Rice production accounts for about 16 percent of farm output, 13 percent of farm value-added, and 7 percent of farm employment. Given that about 10 percent of the region's value-added and employment are generated by the agricultural sector, this suggests that about 1 percent of the region's employment and value-added come from the rice sector. Thus, small changes in output for this sector will result in very small changes to the region's economy.

5.3 Policy Scenarios

Table 5-5 displays the six scenarios for which economic impacts were modeled. As indicated in the Table, the four key variables within each of these scenarios are an inability to residue burn; the availability of the USDA residue management subsidy payments; the existence of demand for residues from the SEPCO plant[118]; and the yield loss associated with soil incorporation.

Table 5-5
Rice Straw Policy Scenarios

	Field Burn	USDA Cost Share	Ethanol Plant Demand	Yield Change
Base Case	Yes	No	No	No
Scenario One	25% of planted acres	No	No	No
Scenario Two	25% of planted acres	Yes	Yes	No
Scenario Three	25% of planted acres	Yes	Yes	-5%
Scenario Four	25% of planted acres	Yes	Yes	-10%
Scenario Five	25% of planted acres	Yes	Yes	-20%
Scenario Six	25% of planted acres	No	No	-10%

5.4 Estimated Farm Production Response to Policy Scenarios

Production adjustments on the rice base acreage resulting from the policy scenarios were estimated with the farm production model described in Appendix D. Farm units could respond to a policy by (1) incorporating rice straw into the soil; (2) removing rice straw from the field; (3) adjusting the crop mix to grow less rice; (3) fallowing land; (4) participating in the USDA cost share program; or (5) selling straw to the SEPCO plant. Farm units were modeled to choose the mix of alternatives that maximized

[117]IMPLAN does not separate agricultural processing and manufacturing by crop type. Thus, the degree to which rice processing contributes to this sectoral aggregate is unknown.

[118]Ethanol plant demand: 44,000 acres in Yolo, Sacramento, and Sutter Counties.

farm income. In scenarios with yield losses, losses only occurred on acreage where straw was incorporated into the soil. If the straw was removed from the field, yield losses were assumed not to occur.[119] In scenarios that included SEPCO demand for rice straw, SEPCO covered the cost of straw collection and transportation. In switching out of rice and into other crops, farm units were constrained by soil type and market conditions (see Appendix D for fuller detail). In all the scenarios, each county is allowed to burn straw on up to 25 percent of its rice acreage.[120]

Changes in planted acreage and production for each scenario are shown in figures 5-1 and 5-2. These figures indicate that expectations of yield loss will be the primary determinant of production response by Sacramento Valley rice growers. Scenarios 1 and 2, which assume rice yield is not affected by soil incorporation, result in no appreciable change in planted acreage and output on the Sacramento Valley rice base. Scenarios 3 through 6, which assume varying degrees of yield losses, result in measurable production adjustments. For scenarios 3, 4, and 5 acreage planted to rice declines by 16,000 acres, a decrease of 4 percent from the initial year. For scenario 6, acreage planted to rice declines by 49,000 acres, a decrease of 13 percent from the initial year. The model also predicts an increase in the production of non-rice crops as farm units reduce acreage planted to rice. Note that while the crop switching helps offset the farm income loss resulting from the burn phase-down, the increased production level of in non-rice crops is not sufficiently large to affect their regional prices.

Figure 5-2 also reveals an interesting farm level response to declining rice yield. Scenarios 4 and 5, which assume 10 and 20 percent rice yield losses respectively, result in lesser reductions in rice production than scenario 3, which assumes only a 5 percent yield loss. In the former case, rice production, in tons, declines by 3.5 percent, while in the latter case, it declines by 6 percent. Why do lower yields result in lower reductions in output? If soil incorporation results in significant yield loss, as in scenarios 4 and 5, its cost relative to removing the straw from the field increases. If yields decline much beyond 5 percent, farmers switch from leaving the straw in the field to removing it to prevent yield losses.[121] As a result, output increases. However, even though rice output decreases less in scenarios 4 and 5 relative to scenario 3, net farm income decreases because the cost of production increases.

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[119]Straw removal is considered an effective preventative to stem rot and other yield reducing diseases while soil incorporation is expected to increase the incidence of stem rot. In the farm production model, farm units balance the higher cost of removing the straw from the field with the lost revenue associated with incorporating the straw into the soil. If potential yield loss is high, then removing the straw from the field will be the preferred alternative. If yield loss is low, farm units will prefer the lower cost option of incorporating the straw into the soil.

[120]The legislation phasing out field burning of rice straw allows up to 25 percent of a county's rice acreage to be burned if the county agricultural commissioner declares it necessary to control disease. The model assumes that this provision will result in a 25 percent burn each year. It is also possible that this provision in the legislation could lead to a system of trading rights to burn rice acreage within a county.

[121]In scenario 3, farm units soil incorporated the straw on 211,000 acres of rice and removed the straw from 22,000 acres. In scenarios 4 and 5 farm units did not soil incorporate straw on any acreage.

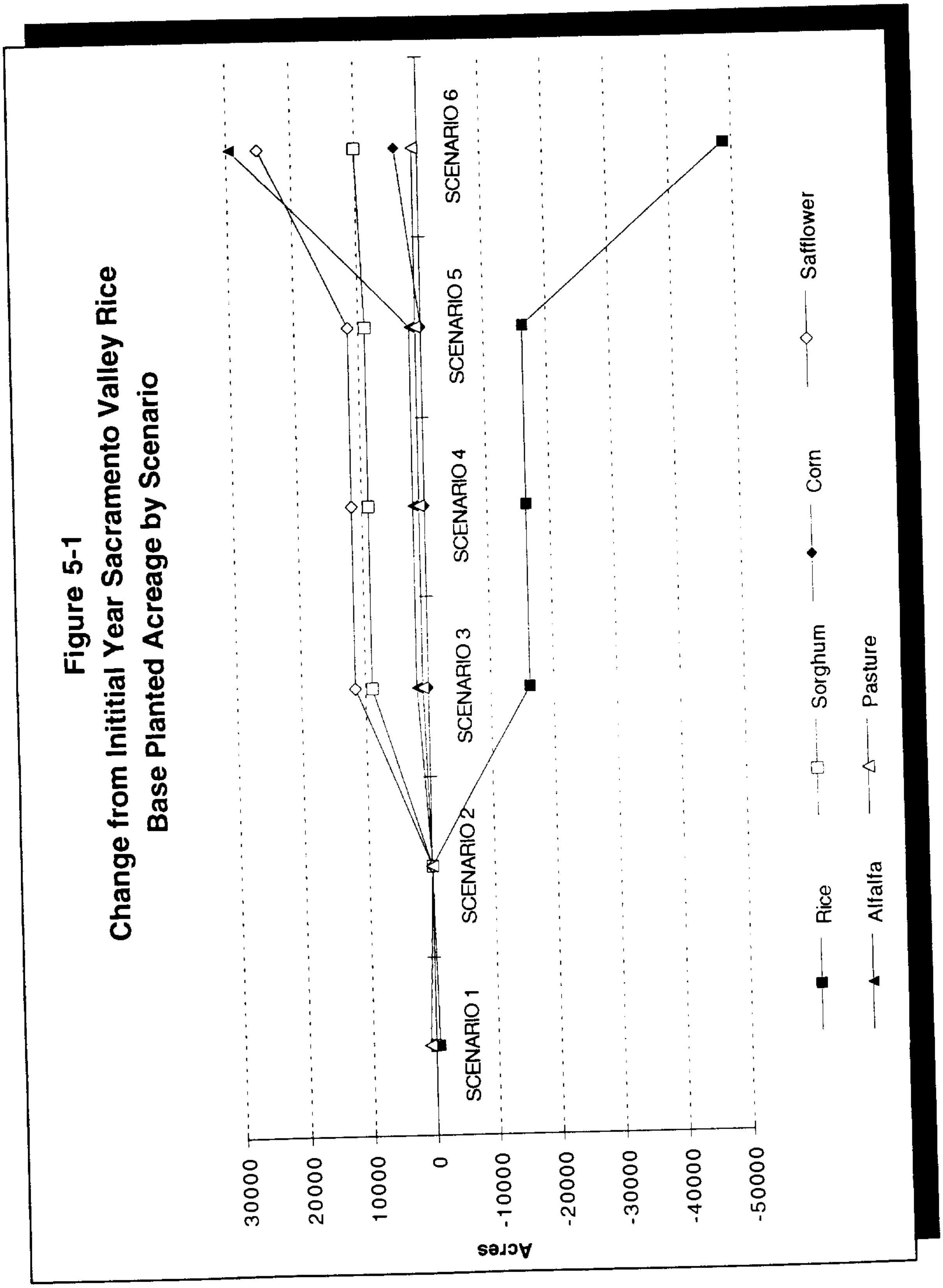

Figure 5-1
Change from Initial Year Sacramento Valley Rice Base Planted Acreage by Scenario

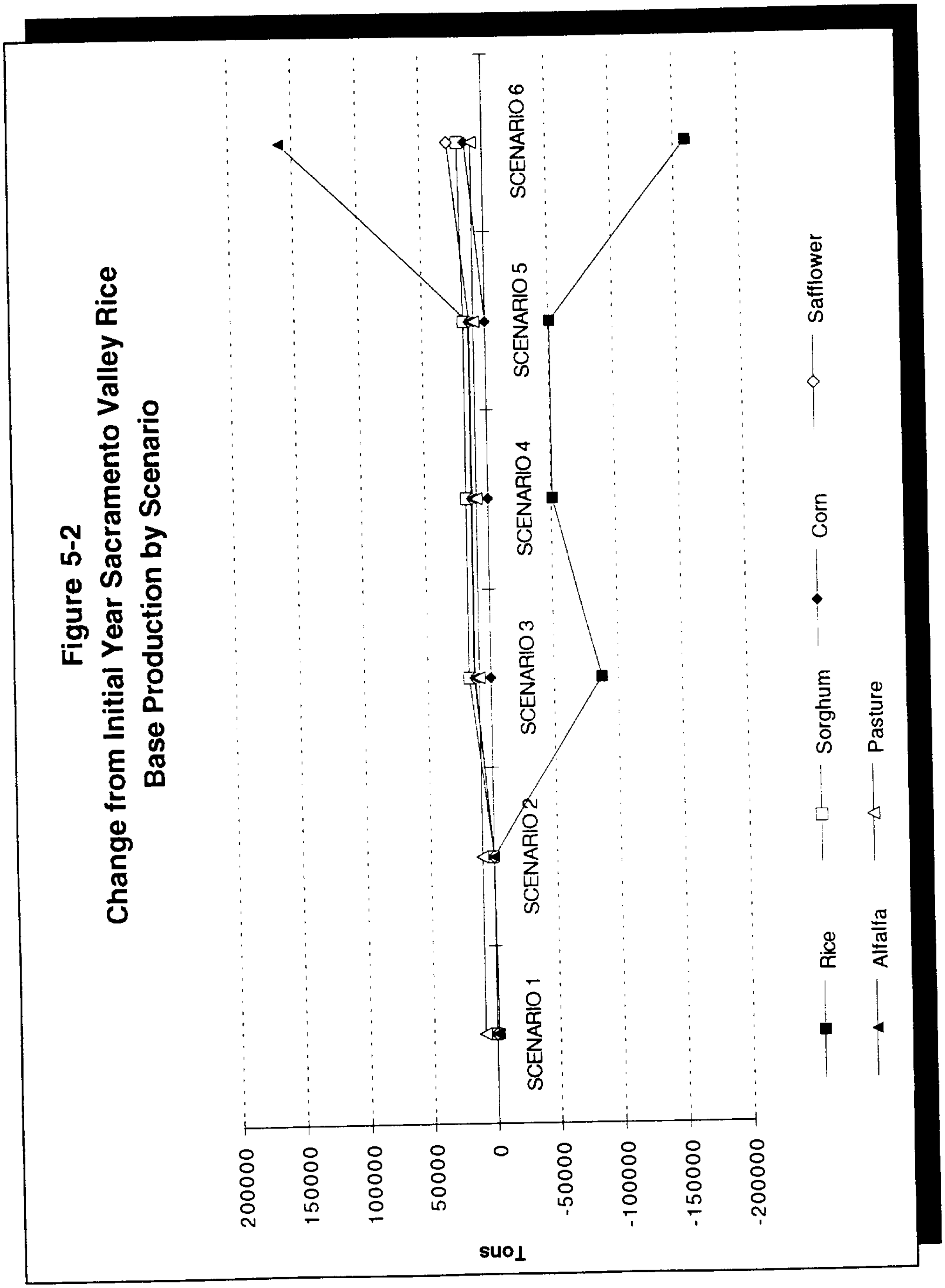

Figure 5-2
Change from Initial Year Sacramento Valley Rice Base Production by Scenario

A comparison between scenario 4 and scenario 6 also reveals the potential importance of the SEPCO plant (or some other outlet for rice straw) and the USDA cost sharing program. Both scenarios assume a 10 percent yield decline but the decline in production in scenario 6 is three times greater than in scenario 4. Note however, that if yield is not affected by the phase-down, as in scenario 1, the change in output from initial year levels is negligible even without cost share program or the SEPCO plant.

Figure 5-3 shows the change from initial year net farm income for the six scenarios. Losses range from a low of $4 million (1985 constant dollars) for scenario 2 to a high of $20.5 million for scenario 6.[122] The loss represents foregone income to land and other fixed assets and management. A portion of this income loss would be redistributed to increased purchases of inputs, such as labor or fuel, for managing the straw. Thereby resulting in a distributional change in economic activity within the region.

Figures 5-4 and 5-5 show the farm income losses for the four primary rice producing counties -- Butte, Colusa, Glenn, and Sutter -- and the four secondary rice producing counties -- Placer, Sacramento, Yuba, and Yolo. For the primary producing counties, the largest loss occurs in Colusa county, followed by Butte, Sutter, and Glenn. For the primary rice producing counties, loss is a function of the size of each county's rice base, their ability to switch into other crops, the USDA cost share subsidy, and, for Sutter county, the opportunity to supply the SEPCO plant. Colusa and Butte have relatively large losses both because they are the largest rice producing counties and because their soils planted to rice allow for very limited substitution into other crops. Losses for Glenn and Sutter counties are mitigated somewhat by a greater ability to adjust crop production and, for Sutter, the potential ability to supply SEPCO. Within the secondary producing counties, losses are much lower both because these counties produce less rice and because they are the primary SEPCO plant suppliers. It also should be stressed that crop substitution possibilities are much greater in these counties than in the primary producing counties. In scenarios that include SEPCO demand for straw and the USDA cost share, Sacramento and Placer counties actually increase income by a marginal amount while losses for Yolo county are minimal. However, Yuba county provides the exception; it has dense clay soils with poor drainage, and also lies outside the SEPCO supply area. Of the four secondary rice producing counties, its losses are the highest.

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[122]Farm income loss estimates appear similar to those estimated in an earlier study on a rice straw burning prohibition by Gardner, Howitt, and Goodman (*Impacts on California's Agriculture of a Ban on Rice Straw Burning*, Giannini Foundation Information Series No. 90-1). The authors of this study used a quadratic programming model of California agriculture to estimate producer surplus losses associated with a number of straw burning phase-out scenarios. While most of the scenario runs of the two studies are non-comparable, one scenario is identical in both studies. With a 10 percent reduction in rice yields, no USDA cost share, and no SEPCO demand, Gardner, et al., estimate farm income losses totaling $19.1 million. This is scenario 6 in the present study, which estimated losses totaling $20.5 million. The Gardner, et al. study did not conduct regional economic analysis, so comparisons for this aspect of the present study are not available.

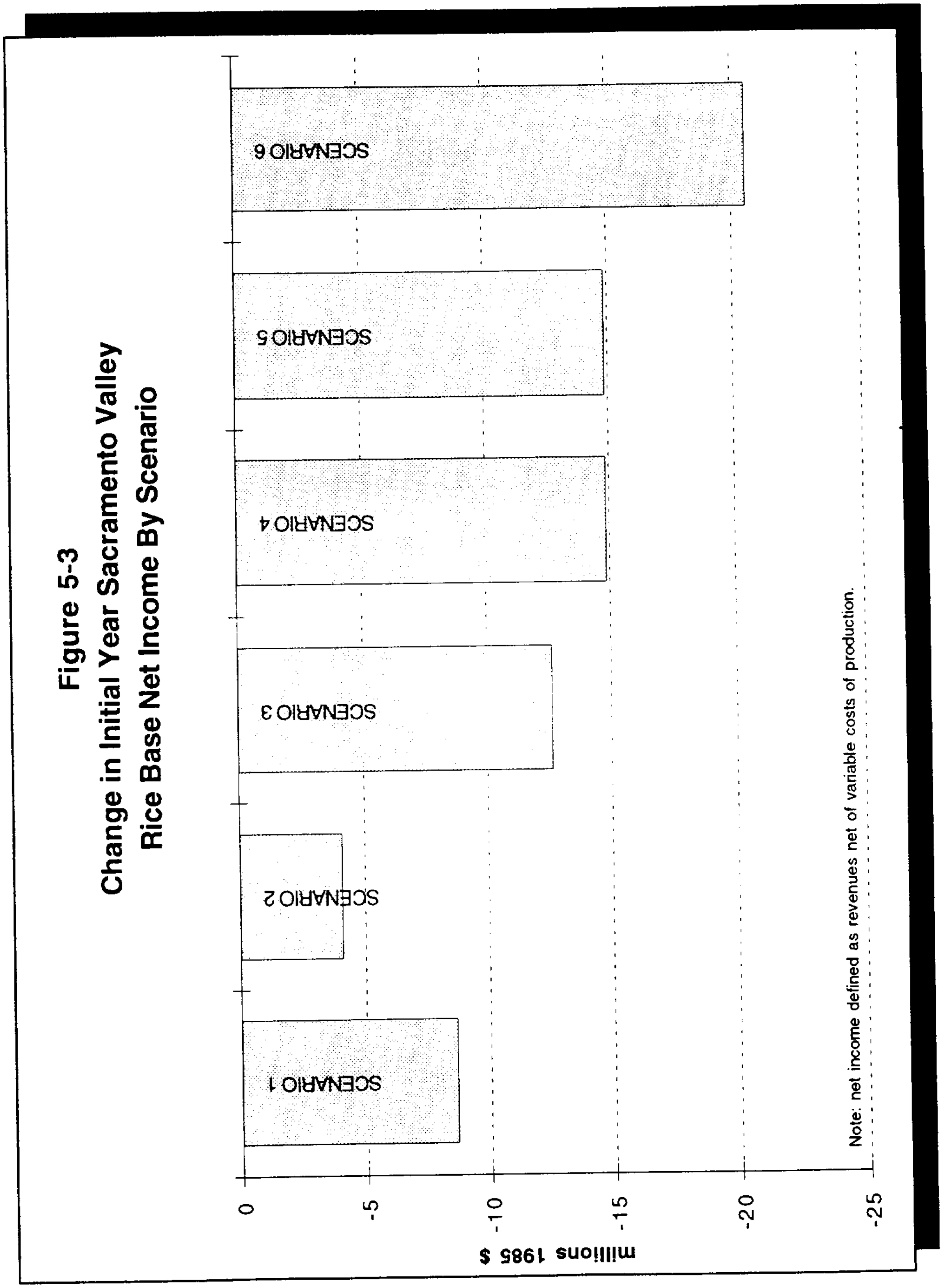

Figure 5-3
Change in Initial Year Sacramento Valley Rice Base Net Income By Scenario

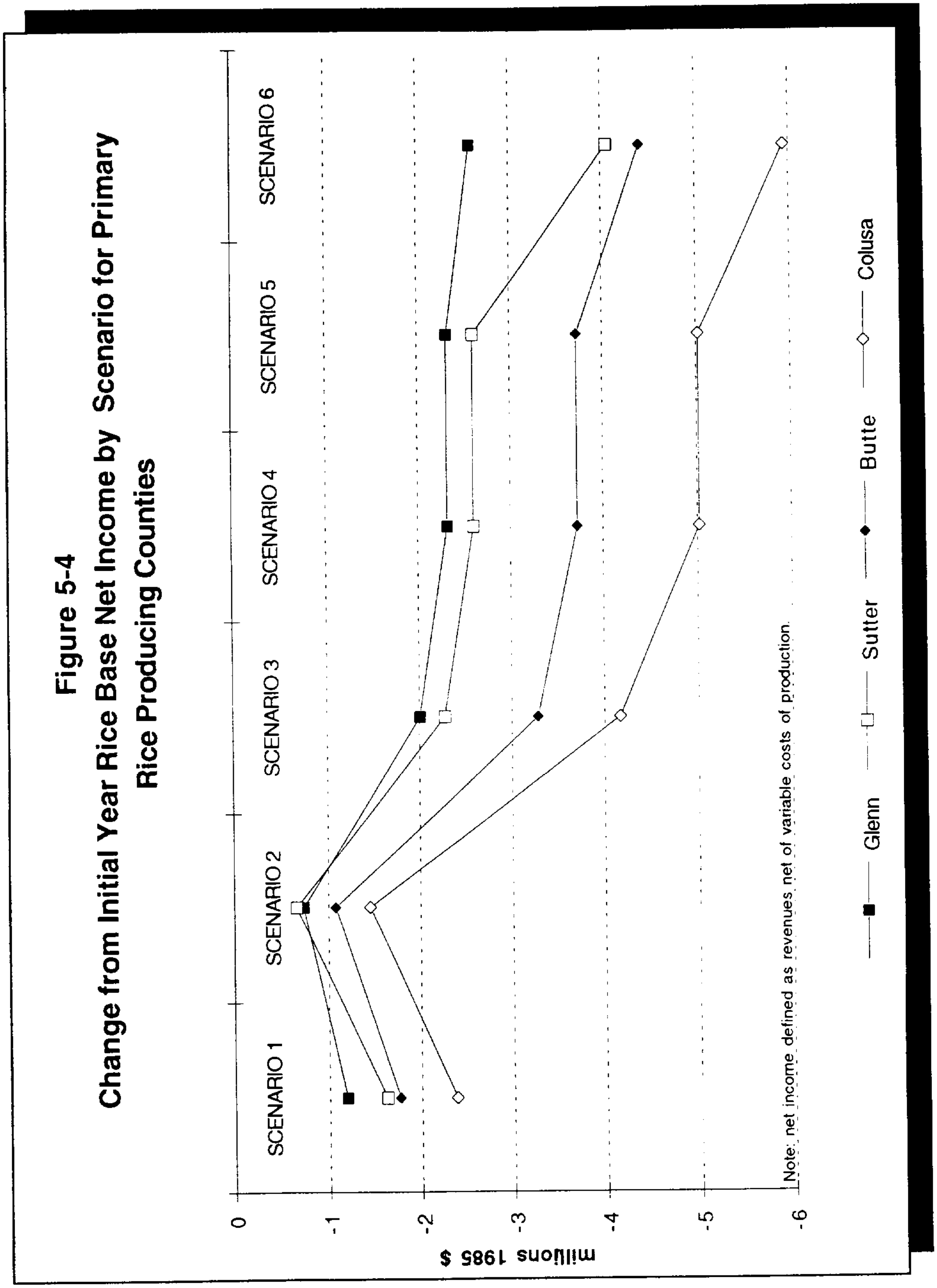

Figure 5-4
Change from Initial Year Rice Base Net Income by Scenario for Primary Rice Producing Counties

Figure 5-5
Change from Initial Year Rice Base Net Income by Scenario for Secondary Rice Producing Counties

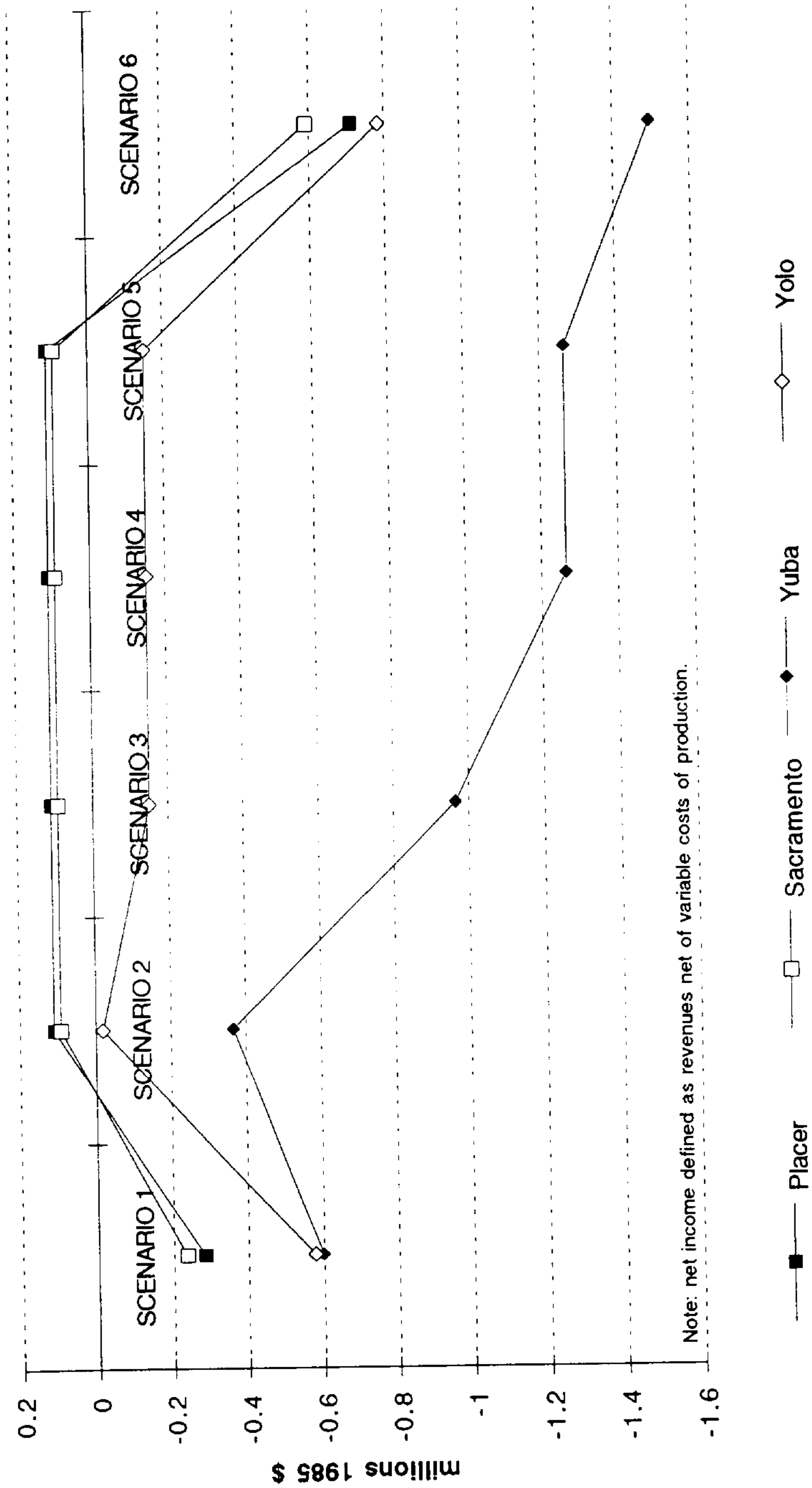

Figure 5-6 shows estimated income loss per planted acre of rice by scenario, averaged over the entire Sacramento Valley. Per acre loss ranges from a low of $10 per acre for scenario 2 to a high of almost $40 per acre for scenario 6. This loss would be shared among land and other fixed assets and management and could eventually result in a decline in rice land value as the effect of the lower return worked its way through land markets.

Production adjustments as a percent of total regional production are small and well within the band of historically observed fluctuation. Rice production declines in the worst case -- scenario 6 -- by 12 percent. This is partially offset by increases in field and grain production. In total, the value of all crop production for the region declines by less than 1 percent from initial year levels. As shown in Figure 5-7, the amount of rice acreage under production in the Sacramento Valley has varied significantly over the past two decades. The estimated 12 percent decline in rice production induced by Scenario Six falls into the general rise and fall of productive acreage exhibited by the rice industry. For example, rice production peaked at somewhat below 600,000 acres in 1981, declining to approximately 350,000 acres over the last few years. Annual adjustments in rice acreage of 50,000 acres or more in the Sacramento Valley have not been uncommon. Figures 5-8 and 5-9 show that fluctuations of similar magnitude for field crops and grains (other than rice) also have been typical. Given the magnitude and frequency of changes in acreage for crops likely to be affected by the burn phase-down, it is unlikely that the production response to the phase-down will cause significant shocks to the regional economy.

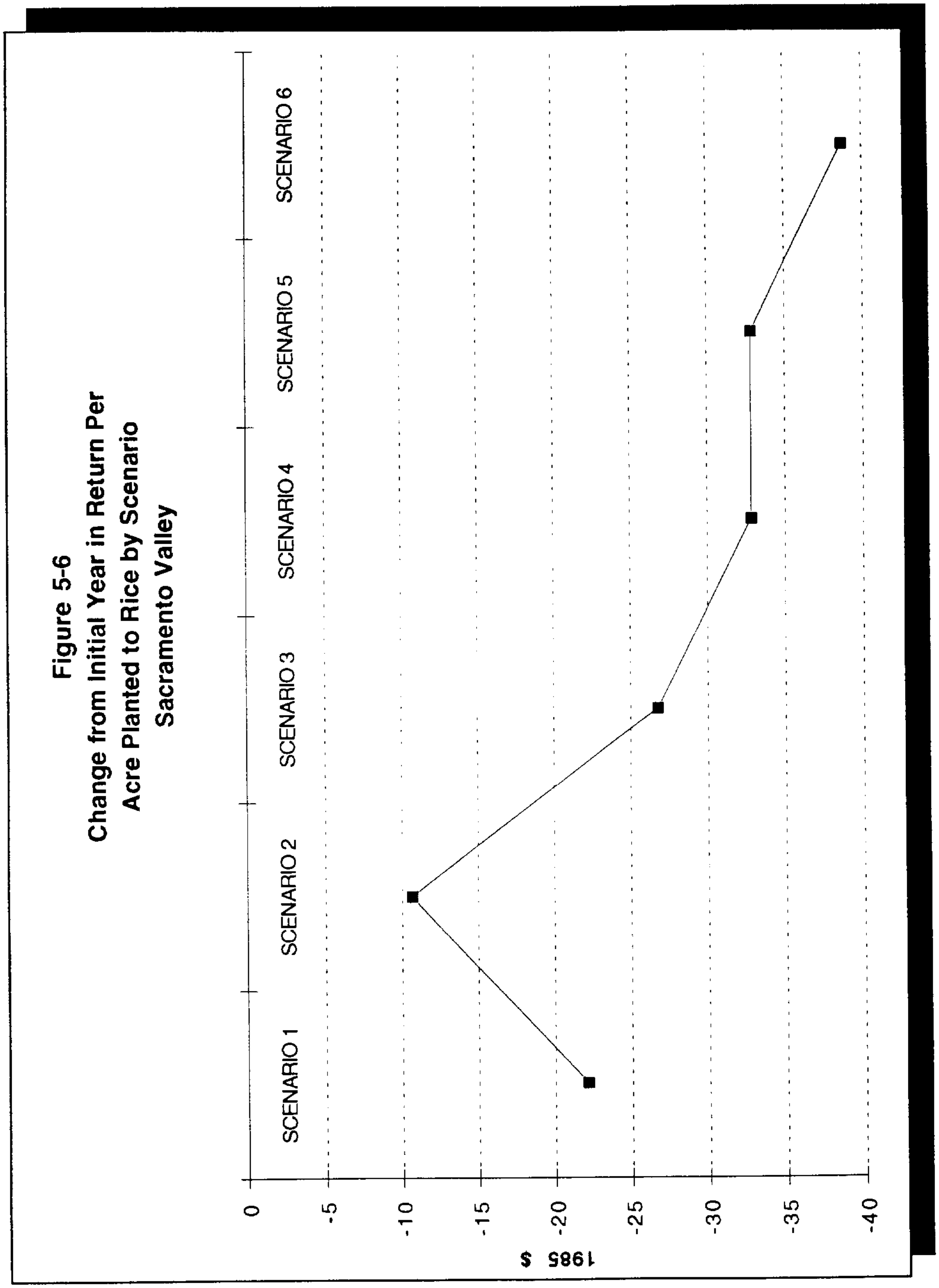

Figure 5-6
Change from Initial Year in Return Per Acre Planted to Rice by Scenario
Sacramento Valley

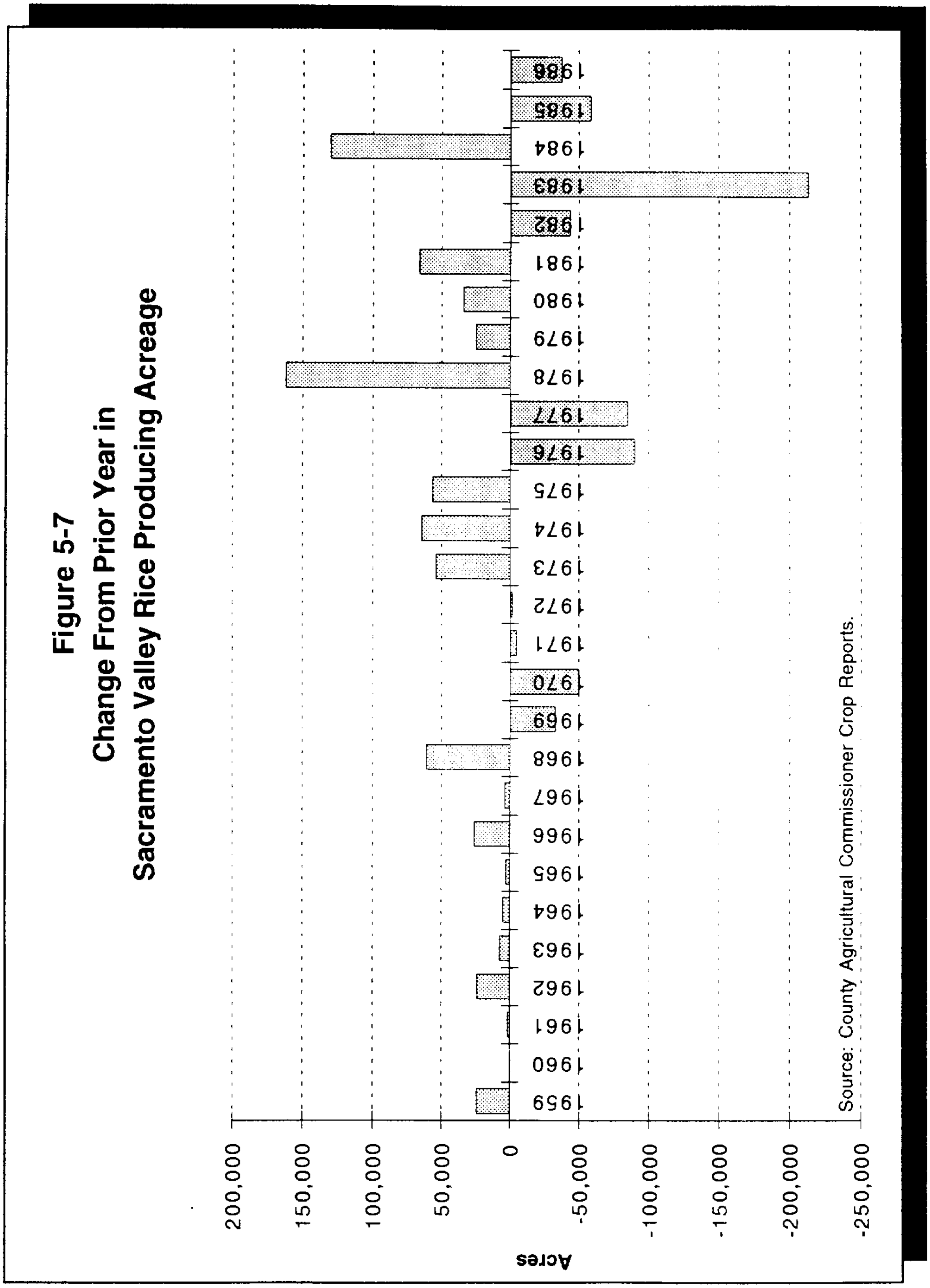

Figure 5-7
Change From Prior Year in Sacramento Valley Rice Producing Acreage

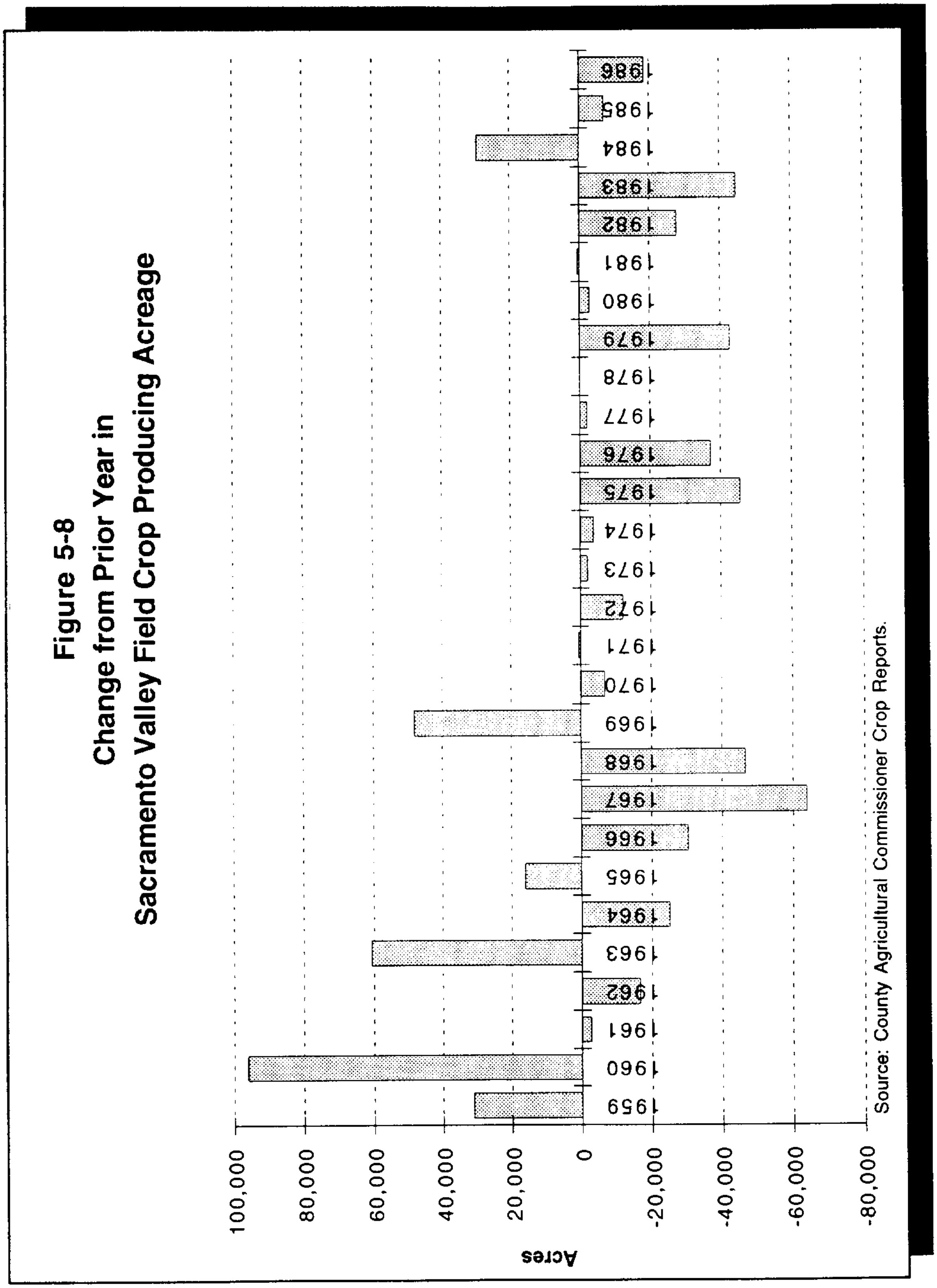

Figure 5-8
Change from Prior Year in
Sacramento Valley Field Crop Producing Acreage

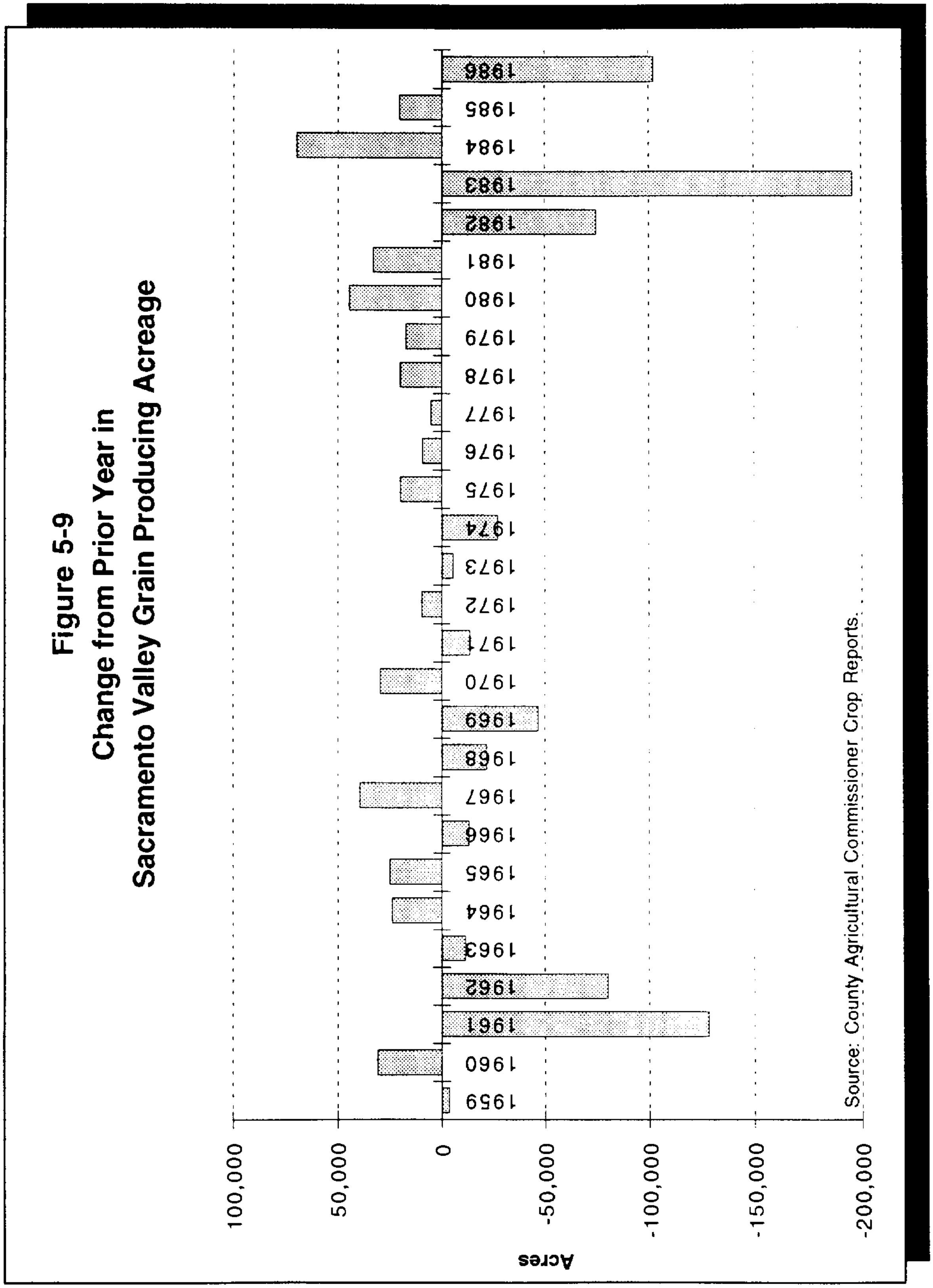

Figure 5-9
Change from Prior Year in Sacramento Valley Grain Producing Acreage

5.5 Estimated Regional Impacts

Table 5-6 displays the estimated regional economic impacts induced by each of the six policy scenarios. In general, none of the scenarios have a dramatic adverse impact on the region. Under the worst case -- Scenario Six, in which residue burning is phased down by 75 percent; the USDA residue management cost share is not available; no new demand is created for rice straw; and yields decline by 10 percent -- agricultural value-added falls by less than $10 million, a reduction amounting to less than 1 percent of initial year agricultural value-added. For the same scenario, gross regional product (GRP) falls by less .001 of a percent of total GRP.[123] The associated decline in public sector tax revenues -- approximately $1 million -- remains essentially the same in all the scenarios in which GRP falls.

A close examination of the findings displayed in Table 5-6 indicates that most of the GRP reductions are limited to the agricultural sector. That is, the non-burn policy induces little adverse impacts on the region's non-agricultural sectors. Furthermore, the policy scenarios have little or no impact on regional employment. Scenarios 1 and 2 result in no measurable employment change; scenario 3 reduces employment in the agricultural sectors by less than 20 full-time equivalents; and scenarios 4, 5, and 6 result in a net increase in agricultural employment, as production shifts out of rice and into field and grain crops.

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[123]Baseline statistics on the region's economic characteristics are presented in Section 5.2 of this Chapter.

Table 5-6
Estimated Impacts on the Sacramento Valley Economy of Rice Straw Residue Burning (millions)

Economic Indicator	One	Two	Three	Four	Five	Six
			Scenarios			
GRP	N/C	N/C	($8)	($7)	($7)	($9)
Agricultural Value-Added	N/C	N/C	($3)	($5)	($3)	($9)
Return to Land	N/C	N/C	($4)	($5)	($4)	($10)
Government Revenue	N/C	N/C	($1)	($1)	($1)	($1)
Food Grain Output	N/C	N/C	($24)	($19)	($18)	($34)
Feed Grain Output	N/C	N/C	$1	$3	$3	$17
Other Agricultural Output	N/C	N/C	$7	$7	$7	$7
Agricultural Employment	N/C	N/C	(20)	30	30	80

N/C = No change

Finally, it is important to note that while the region-wide implications of the rice straw burning phase-down do not appear to be large, should losses be concentrated within individual counties the local impacts could be significant. Since non-burn exemptions can be granted in the case of stem rot disease -- which has a tendency to cluster in particular geographic areas -- concentrated impacts could result from a specific area suffering high levels of incorporation-induced soil poisoning. Although this is a possibility, insufficient evidence is available to gauge the likelihood of such an occurrence in this report.

5.6 Regional Impacts Induced by Adoption of Alternative Residue Management Practices by Almond, Walnut, and Wheat Growers

Although comprehensive CGE-based regional impact analyses were not conducted for the other three study crops, there are several reasons to believe that the regional impacts related to adoption of non-burn residue management methods by these crops would be even smaller than those for rice. Key factors are as follows:

- While rice cultivation is tightly limited within the Sacramento Valley, almonds, walnuts, and wheat cultivation has a much wider range. For example, almonds are grown from north to south, in Kern, Stanislaus, Merced, Butte, Fresno, San Joaquin, Madera, Colusa, and Tulare counties. Because the growing region for these crops is so dispersed, it acts to greatly mitigate any potential concentration of impacts.

- As indicated in Chapter Four, almonds and walnuts are high-value crops. The additional expenses associated with alternative residue management methods are quite small compared to aggregate production value.

- Even though wheat is a low-value crop, and may suffer noticeable financial impacts from a burn ban, this crop's overall contribution to any individual county or the state's farm economy as-a-whole is small. Given that less than one-third of all wheat growers would be affected by a residue burning policy, coupled with the diminutive size of this commodity within California agriculture, the regional impacts induced by this crop are likely to be quite modest.

It is important to note that although the costs associated with non-burn residue management techniques alone are unlikely to significantly impact the Central Valley economy, the ultimate disposal method induced by a burn phase-down on all four study crops could potentially engender noticeable impacts. For example, if no substantial end-use market develops for orchard residues, the Valley would face a significant environmental issue related to where the residues would be disposed. On the other hand, should energy production become a viable means of disposing of most or all of the residues that are currently burned, such production could substantially contribute to the Valley economy. That is, if straw, or prunings, can be turned into energy producing "gold," what was once waste will become wealth. However, as indicated in Chapter Three, insufficient evidence is currently available to accurately weigh the potential for such a development.

6.0 Conclusion

The available evidence suggests that, in the face of a non-burn policy, those rice and wheat growers who currently burn their straw would instead soil incorporate. Almond and walnut growers, however, would be more likely to dispose of their residues off-site. Likewise, existing data suggests that while a potentially large end-use market exists for crop residues -- particularly related to energy production -- current economic conditions do not support widespread consumption of residues. The expiration of lucrative ISO4 contracts by the year 2000 in all likelihood will make biomass-based energy production uncompetitive with other fuels. While plans are moving forward to build an ethanol production facility in the Sacramento Valley -- which would consume up to 132,000 tons of crop residues -- an examination of the cost structure of this plant calls into question its long-term viability. There are no other residue uses on the horizon that would consume large amounts of crop residues.

Both the case study-based analysis and the regional economic impact analysis indicate that a non-burn policy is likely to have modest impacts on most almond, rice, walnut and wheat growers, and minimal impacts on the Sacramento Valley economy as-a-whole. However, some individual growers -- those whose operations currently support low net revenues per acre -- could face significant financial consequences, with the additional costs of non-burn residue management practices driving some growers out-of-business. Wheat growers with low net revenues per acre could be particularly hardhit, since this crop generates generally low receipts.

While the aggregate impacts of a burn prohibition may not be large, it is important not to trivialize the economic pain such a policy would place on some individual growers, as well as, potentially, specific localities. Adoption of non-burn residue management approaches will create financial difficulties for some growers, particularly in cases in which adoption of the new technique results in crop yield declines. Should for whatever reason these cases of hardship be clustered in particular counties, collectively the economic disruption could be significant to that locality.

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