Ethanol Long-Range Systems Analysis Spreadsheet

Concept, Initial Implementation & Illustrative Cost Curves

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Technology & Management Services, Inc.

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Ethanol Long-Range Systems Analysis Spreadsheet
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Introduction

This report documents the conception and initial implementation of the Ethanol Long-Range Systems Analysis Spreadsheet (ELSAS - Version 1.0 d) as of December 2002. In addition, the report describes the early operation of the system to produce an illustrative set of cost curves for the production of cellulosic ethanol from biomass over the time period from the year 2010 through 2050.

The results of the cost curves case study are included as Appendix A to this report. The implications of these results, with respect to ongoing research and development, and the future possible evolution of an industry based on biomass feedstock and Biorefinery technology, are discussed.

ELSAS is the most recent embodiment of market-based sensitivity analysis tools developed by Technology & Management Services (TMS) for the Biomass Program of the U.S. Department of Energy's Office of Energy Efficiency & Renewable Energy (EERE). Previous major presentations and reports by TMS on these tools, related input data, and the results of their use have been presented as follows.

- 1996 – Presentation – Ethanol Evolution Study – Risk Experimentation Model Preliminary Results
- 1996 – Report – Examining the Impacts of Risk & Uncertainty on Capital Investment Decisions
- 1996 – White Paper – Sensitivity Analysis on Feedstock Supply Curves
- 1996 – White Paper – Ethanol Risk Experimentation Model Summary Observations
- 1997 – Presentation & White Paper – A Proposed Structure for Future Phases of the Ethanol Evolution Model
- 1997 – White Paper – Calculational Sequence for ETH_CAL.XLS
- 1997 – White Paper – Preliminary Examination of Incentive Schedules
- 1997 – Presentation & Conference Paper – Cellulosic Ethanol Economics & Climate Change Benefits (Co-Authors)
- 1997 – Presentation – Blend Market Analysis
- 1997 – Report – Ethanol Evolution Study – CY 1997 Sensitivity Analysis Cases
- 1998 – White Paper – Future SAS Modifications
- 1998 – Presentation – Ethanol Industry Evolution Systems Analysis Spreadsheet (SAS)

- 1998 – Presentation & Conference Paper – Cellulosic Ethanol: R&D Status and Carbon Emission Benefits (Co-Authors)
- 1998 – Presentation – Ethanol Industry Evolution Systems Analysis
- 1998 – Presentation – Ethanol Market Issues, Analytic Approach & Results
- 1998 – Ethanol Industry Evolution Systems Analysis Spreadsheet (ESAS) - Documentation & User's Manual
- 1999 – Presentation – Growth of Cellulosic Ethanol Supply
- 1999 – Presentation – The Cost of Ethanol – What We Know & How We Use the Information
- 1999 – Presentation – Cellulosic Ethanol Cost Estimates & Projected Market Potential
- 1999 – Presentation – Ethanol Systems Analysis Spreadsheet (ESAS) Status Report
- 1999 – Presentation – Bioethanol Program Analysis Team Activities – Illustrative Results
- 2000 – Presentation – The Ethanol Industry Evolution Systems Analysis Spreadsheet (ESAS)
- 2000 – Conference Paper – Status of BioEthanol in the United States & Greenhouse Gas Benefits of Worldwide Development (Co-Authors)
- 2000 – Presentation – Year 2000 National Case Runs & Related Insights
- 2000 – Presentation – Regional ESAS (RESAS) – Status Report
- 2000 – White Paper – Regional Supply Cases for Ethanol Production
- 2000 – White Paper – Preliminary Input for Use by DAI (Regional Logistics Study)
- 2000 – White Paper – Benefits & Costs of an Emerging Ethanol Industry for Transportation Fuels
- 2000 – Presentation – The Ethanol Industry in the United States – A National Benefit/Cost Analysis
- 2000 – White Paper - Analytic Approach to Estimating Cost of Corn-Based Ethanol
- 2000 – White Paper - The Ethanol Industry Systems Analysis Spreadsheet & Its Extension to a Regional Capability
- 2000 – Report - Ethanol Industry Evolution System Analysis Spreadsheet (ESAS) – Documentation & User's Manual
- 2001 - White Paper – Possible Scope of Information on Biomass Feedstock
- 2001 – Presentation – The Economics of Biomass Supply & Ethanol Production
- 2001 – White Paper – Qualitative Analysis of Renewable Fuel Mandate Provisions
- 2001 – White Paper – A New Look at Biofuels Contribution to Energy Security

- 2001 – White Paper – Discussion of Future Prices for Corn Ethanol
- 2001 – White Paper – TMS Inputs for 2050 Study
- 2002 – White Paper – Information Regarding Ethanol Delivery Infrastructure
- 2002 – White Paper – RFS Ethanol Value Updated
- 2002 – White Paper – Ethanol Costs & Production Estimates – FY 04 Budget Metrics
- 2002 – Report – A Preliminary Study of the Market Potential of Biodiesel
- 2002 – White Paper – Thinking About Biorefineries
- 2002 – White Paper – Representing the Biorefinery for Program Analysis – A Statement of Common Approach (w/Antares)
- 2002 – Presentation – Office of the Biomass Program Long-Term View – Cellulosic Ethanol
- 2002 – Presentation – Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet – Illustrative Cost Curves

ESAS was developed through Version 5.0 e. to study cellulosic ethanol supply, demand, economics, costs and benefits. ESAS was prepared as an Excel® spreadsheet which calculated an automated and market-based supply-demand crossover solution for ethanol production at a given market price on a national basis. Regional cases were calculated using the ESAS methodology, but the tools used for this (designated as RESAS) were not developed to the status of providing an automated solution set, relying instead on iterative calculations. ESAS and RESAS calculated solutions at 5-year intervals through 2025. ELSAS, the long-range version of ESAS, was designed not only to extend the solution range through 2050, but also to update and further extend the approach to reflect cost reduction through more extensive prior R&D, more success in meeting R&D targets and in accelerated learning through actual production experience.

As of December 2002, ELSAS exists in Version 1.0 d, and it is this version that was used to create the illustrative cost curves described in this report.

Overview of ELSAS

ELSAS is an Excel® spreadsheet, with substantial user input. Version 1.0 d prints as a 45-page document. The spreadsheet is self-descriptive and self-documenting. That is to say that the spreadsheet contains a narrative presentation of all the equations, operating steps, data entry cell locations, default values, and other information necessary to use it. The spreadsheet printout is attached to this report as Appendix B.

The **Introduction Page** of ELSAS contains an **Introduction Screen**, a summary statement of the **Contents of the Spreadsheet**, **Operating Instructions**, an explanation

of **Terminology**, a discussion of the **Cellulosic Focus** (as compared to Starch-based Focus) of the analysis, information on the **Economic Incentives** approach available for use in the analysis, details of the cost estimates for **Starch-based Ethanol**, a **General Disclaimer** emphasizing the significant uncertainties in both input and output data, and a **Version History** through Version 1.0 d.

The **Feedstock Page** is used to derive feedstock supply curves (cost vs. quantity over a 50-year period). The **Product Cost** page is used to derive parameters for ethanol production, such as conversion efficiency, and associated costs (including amortization of capital costs and a return on investment) such that a plant gate price for ethanol can be determined which includes the cost of feedstock as an input material. The **Demand** page reports demand value curves (cost vs. quantity) derived through refinery modeling conducted exogenously to ELSAS, but used here to determine market-based supply-demand intersection points where supply of ethanol at a cost just satisfies demand for ethanol at the same cost. The **Calculate** Page contains the cells where case runs are executed through user entries for each time period wherein supply and demand are to be balanced. The **Summary** page is used to archive the key input assumptions for the scenario as well as the scenario results.

The remaining two pages, the **Reference Case** page and the **Aggressive Case** page are not, strictly speaking, a part of the model. They are included in order to show in substantial detail exactly how the user's inputs are processed in the model, and how a market equilibrium point is determined for each time period analyzed. In addition, the resulting cases, summarized on these pages, illustrate a range of plausible case results and the quantitative importance of several key input variables. The cases archived on these pages are the basis of the illustrative cost curves presented in a later section of this report.

The Introduction Page

The ELSAS spreadsheet provides resource availability and cost information for starch-based and cellulosic-based ethanol.

There are separate treatments of feedstock, chemical conversion, and product finishing from now through the year 2050. All economic data are expressed in year 2000 dollars.

Cells to be used for data entry are color coded, and may be overwritten. Other cells which contain equations or which present key data outputs are assigned a different color code, and are should not be changed. Default values are provided for all user inputs, and may be restored by the user after user-defined inputs have been entered to create new cases. A small number of default values are stored as data tables in the body of the spreadsheet, but most default values are stored in individual cells in Column I of the spreadsheet, directly to the right of their corresponding user entry cells in Column H.

Care is taken to identify transportation requirements and costs. Feedstock costs include transportation and are plant gate, not farm gate. Ethanol costs are presented as either D1 (Distilled, in the production facility), D2 (Distilled and Denatured, also in the production facility, described as plant gate), or D3 (Distilled, Denatured and Distributed, at the regional point of competition for the intended use). Additional transportation (and handling) costs are required to transport ethanol to outlying sections of the region from its central distribution point, or from one region center to another region center.

The study has a cellulosic focus, but recognizes the early dominance of corn-based ethanol. Once cellulosic ethanol becomes economically competitive, then-existing corn-based ethanol capacity continues to operate, but does not expand to higher levels. This competitive cross-over is assumed to occur prior to any limitation on availability or cost of starch-based feedstock. The cross-over cost is taken as $1.20 per gallon D3 at the market point of competition. The derivation of this value is recorded in the 2001 White Paper referenced above – Discussion of Future Prices for Corn Ethanol.

ELSAS and the initial case scenarios created with it assume the existence of a Renewable Fuels Standard (RFS) for ethanol, reaching 5.0 Billion Gallons per Year (BGY) in 2012, although the draft legislation to create such an RFS was not acted upon in 2002. The user can modify the RFS assumption for future cases.

Another legislative issue relates to the current economic incentive for ethanol (53 cents per gallon D3) which declines to 51 cents in 2005 and expires in 2007. ELSAS assumes the incentive is continued, although at continually declining value, and is ultimately reduced to zero. The user is allowed to set future incentive values so as to maintain smooth production and growth curves as cellulosic ethanol enters the market place. The incentive has no effect on the starch vs. cellulosic competition, because all ethanol, regardless of the source feedstock, receives the identical incentive payment.

Version 1.0 a of ELSAS dates from March 2002. Continual refinements of both data and the calculational system were added to the spreadsheet over the next 6 months. In October 2002, a major adjustment was made to conform the early year default data to the cellulosic cost and production estimates used for programmatic metrics which had been promulgated in August 2002. Independently of those early year estimates, all of the future year projected data remain quite uncertain for a variety of reasons. In some cases, information is simply lacking. In other cases, there are differing points of view among analysts. Finally, a 50-year time frame will contain numerous unforeseen advances in technology likely to impact these projections. As a result, the cases produced with ELSAS are intended to be illustrative and suggestive, rather than authoritative and final.

The Feedstock Page

On this page, the user may select input information for cellulosic feedstock supply and cost. The source of the default data is the October 2001 Final Report of Arthur D. Little, "Aggressive Growth in the Use of Bioderived Energy and Products in the United States by 2010", pages 18-22 of the view-graph version. The user may select other values for feedstock availability at the indicated prices. Pre-selected feedstock categories are Forest Residues, Agricultural Crop Residues, Potential Energy Crops and Other Wastes. Pre-selected categories for farm gate costs are $20, $30, $40, and $50 per dry ton. To the values in this feedstock matrix are added transportation charges to translate farm gate costs to plant gate costs.

The resulting feedstock availability/cost matrix must serve all feedstock users, not just cellulosic ethanol producers. To provide for this joint availability for multiple uses, the user may allocate a fraction of each of the four feedstock categories to such other uses. The allocation factor may be different for each feedstock type, reflecting awareness of the possibly superior value of particular feedstock types to particular uses. The default factors result in about 2/3 of the total being available for ethanol production, and 1/3 for use in biopower production.

Next, ELSAS recognizes that current feedstock quantities will not remain the same over time. In particular, agricultural residues are assumed to increase in quantity over time as population, food requirements and grain production increase. The user may select annual increase rates (such as 1 or 2 per cent) for Reference Case conditions and for Aggressive Case conditions, and apply them independently to both Agricultural Residues and Energy Crops.

The default assumption of 1% per year for both feedstock types for the Aggressive Case yields a total availability in 2050 approaching 600 million dry tons as the sum of all four feedstock types. At a conversion efficiency of about 100 gallons ethanol per ton feedstock, this is enough feedstock supply to produce some 60 BGY ethanol, equivalent in energy content to about 40 BGY gasoline. Note that cost may limit feedstock supply and use independently of physical availability.

The Product Cost Page

The product cost calculations make use of several different elements. First, an estimate of the **conversion efficiency**, feedstock into ethanol, is derived which depends solely on date. This allows the feedstock component, at the supply/cost relationship developed on the preceding page, to be converted into one of the components of cellulosic ethanol cost. Next, a **near term estimate** of the non-feedstock ethanol production cost component is selected, based on engineering studies conducted by the National Renewable Energy Laboratory (NREL), and used as a near-term program metric. Then, a **long-term**

estimate of the same component cost is selected, based on a futuristic analysis of ultimate technological potential conducted by Lee Lynd. Finally, these two bounding cost estimates are connected by a **learning curve**. Progress in cost reduction down the learning curve depends not on date but on cumulative prior year production. The more production, the faster the learning, and the more rapid the resulting decline in cost for subsequent years' production. The final ethanol cost is the sum of the feedstock component and the learning-curve-derived non-feedstock component.

The user may modify the proposed default values for conversion efficiency (which range from 72 gallons per dry ton in 2008 to 106 gallons per dry ton in 2020 and thereafter). The near-term ethanol non-feedstock cost component of $0.734 per gallon D1 in 2010 is derived from NREL Case I02031 in its May 30, 2002 Process Design Report, (page 71 and Appendix D). The long-term ethanol non-feedstock component of $0.16 per gallon D1 is derived from Lee Lynd's 1996 report "Likely Features and Costs of Mature Biomass Ethanol Technology". Both default values may be modified by the user.

A further user choice is associated with plant size selection and a related offsetting cost reduction for feedstock collection associated with a plant smaller than the default value of 2,000 dry tons feedstock per day. The user may set parameters for both size and cost, as well as a scaling factor used to recalculate the capital cost component as a function of plant size. In addition, performance and market risks exist for early year plants. These risks are proportionately lower for smaller size plants. The user may select appropriate values for such a factor for three different size plants. Using the various default values, early year non-feedstock costs range from $0.888 per gallon D1 for a 2,000 ton per day plant to $1.051 per gallon D1 for a 1,000 ton per day plant.

The learning curve equation was developed through the use of a curve fitting process applied to various estimates made by NREL of the cost of ethanol from plants of increasing technological sophistication. The dependency on prior year production was designed to produce similar cost reductions to those envisioned by NREL over the time periods of interest in those case studies. The learning curve section (including self-documentation) in ELSAS is still incomplete in this Version 1.0 d. Upon completion, the user will be able to modify default values and to obtain a graphical representation of the learning curve operation. The default equation used in ELSAS specifies the learning reduction in cents per gallon from the early year starting point. That reduction is 2.2378 times the cumulative prior years production (in BGY) raised to an exponent, with the result of that process reduced by 2.1. The exponent is 0.56 in the Reference Case and 0.63 in the Aggressive Case. If the learning reduction produces a cost below the long-term limiting value, that long-term lower bound is used instead.

In order to use the learning curve methodology, estimates of early year cellulosic production beginning as early as 2004 (if desired) must be entered in a set-up matrix that

extends through 2010 (when ELSAS actually begins to calculate new production quantities). This supports the calculation of prior years cumulative production required by the learning curve. The current default values for early year production are identical to those used in the August program metrics documents. ELSAS assumes that this capacity and its associated production are achieved through joint government industry programs or other special niche economics which allow these plants to come into existence prior to full market place competitiveness. The user may modify these capacity and resultant production quantities as desired.

Once production costs are determined, user-modifiable transportation costs for plant gate product are provided both for product transportation within a region and for transportation from region to region.

The user may also specify the inclusion of a Biorefinery simulation. If this simulation is on, then a credit for Biorefinery co-product value is assigned to the ethanol co-product (thus reducing its cost). A different fraction of the cost (without co-product benefit) may be assigned for each 5-year interval by the user. In a typical Reference Case, the default fraction starts at 10% in 2020 and rises to 20% in 2030 and beyond. In a typical Aggressive Case, the default fraction starts at 15% in 2020 and rises to 30% in 2035 and beyond.

The Demand Page

The self documenting aspects of the Demand Page have not yet been prepared in ELSAS Version 1.0 d. However, all the needed data are present in the spreadsheet for viewer inspection. The source material is derived from case runs of the Refinery Yield Model conducted by Oak Ridge National Laboratory (ORNL) and modified by TMS and David Andress & Associates (DAA) to generate Demand Value curves (quantity and price) for ethanol use in refineries and for blending in gasoline. Data are for the World Oil Market conditions described in the Energy Information Administration (EIA) Annual Energy Outlook 2002 Reference Case.

Demand curves have been calculated, and are displayed on the lower sections of this spreadsheet page, for each of 5 U.S. regions (and the total U.S.) for 2010 and each subsequent 5-year time period through 2025. In these ELSAS cases, demand value (blending) curves are not required from 2030 forward because cellulosic ethanol cost reductions achieved by that date are compatible with the use of neat ethanol (E 85) as an alternative transportation fuel.

Planned improvements and additions to this page (in addition to self-documentation) are intended to include additional World Oil Market cases, to simplify the use of the data, and to provide for user modification of input values.

The Calculation Page

User entries on the previous pages of the ELSAS spreadsheet have primarily been for the purpose of establishing input parameters for the case to be calculated. Typically, these inputs remain unchanged as supply/demand balances are created in the main body of the case for each time period being investigated. The Calculation Page is the location from which the periodic supply/demand balances are created. These balances, in turn, establish the rate, level, and cost of expansion of the cellulosic industry from 2010, when the annual calculations begin, through 2050, where the input data sets are terminated.

Only five entries are required as variable inputs for each supply/demand crossover calculation:

- The Year of the calculation
- An Estimated Cellulosic Ethanol Production for that year
- The Cumulative Cellulosic Ethanol Production in Prior Years
- Identification of Case Inputs as being either Reference or Aggressive
- Identification of Biorefinery Simulation as being either On or Off

The basic solution technique for ELSAS is to set those four of the above five items which are not estimates, and then to input various estimated production levels for the year of interest until desired characteristics of the solution (which balances supply with demand according to the intersection of ethanol supply and demand value curves) have been achieved.

Immediately to the left of the user input area of the page, the user can observe the results of each trial input on key intermediate and final results of the calculations. Typically, only a few trials, combined with careful observation as to how the outputs change as a result of each trial, are required to yield a satisfactory value for the time period. Once each period has been individually “solved”, the user proceeds to the next period and repeats the process.

Subsequent versions of the Calculation Page will contain more information on the operating procedure for the program.

In the current operation of ELSAS, there are 143 entries to be made per case, of which 69 are default values that remain constant throughout the case. Eventually, it is anticipated that ELSAS will be made completely automatic in operation (as is ESAS). However, the present version of the program is fully operational, as is evidenced by its use to create the Cost Curves included as Appendix A to this report.

The Summary Page

The Summary Page has not yet been implemented. Its intended purpose, similar to the Summary Page in ESAS, is to assemble in one compact location all of the key inputs and outputs of the case run, including graphical representations of the results. All of the information is already in the spreadsheet. It simply needs to be automatically copied from its other locations into a compact display on this page. In addition to providing a compact summary presentation of results, this process also facilitates archiving of the case information.

To archive the case, the user first resaves the spreadsheet under a new name which establishes the case number, name, and date. Next the user recopies the Summary Page onto itself using the "Special Paste – Values" command in the Excel® menu. This replaces all equations in cells on this page with fixed values so that the information can be stored independently of the original input data. Third, the user deletes the other pages of the spreadsheet and saves it again in that reduced form. The result is to preserve all the key input and output information on one page for future examination and for record purposes.

The Reference Case Page

This page, and the following Aggressive Case Page are not required for the operation of ELSAS. They are included in the current Version 1.0 d to show the details of the case calculational process. Unless stated otherwise, default values are used throughout.

The first requirement is to determine the year that cellulosic ethanol costs become competitive with starch-based ethanol. As indicated in the presentation above of the Introduction Page, the cost at which this occurs is taken as $1.20 per gallon ethanol D1. Cellulosic ethanol capacity and production through 2010 are assumed to result from niche market conditions and demonstration plant subsidies rather than market economics. The default data show that ethanol is not yet market competitive in 2011 so that no new capacity is built. The economic competitive point is reached in 2012. (Economics are improving slowly because the continued production from the early year plants is causing cost reduction to occur through the learning curve process as well as through research and development). Through 2015, the process uses iterative trials in which production levels and economic subsidies are adjusted to define reasonable increments of capacity growth, under conditions of supply/demand balance and market place economics.

Once the initial entry period has been detailed on a year to year basis (2010 through 2015), the process shifts to the analysis of 5-year increments (with interpolation of intermediate yearly values). An estimated 5-year compound growth rate for the entire ethanol industry (both cellulosic- and starch-based production) is selected. This provides a value for estimated cellulosic production which is then used as an input on the

Calculate Page. Again, economic subsidies are adjusted to define reasonable increments of capacity growth. In addition, however, the solution point selected should provide for only moderate rates of change in both market prices and incentive levels. The user will find that the broad outlines of the solution are relatively constrained by these requirements, and choices outside these constraints quickly lead to infeasibilities in either current or later years.

Around 2025 or 2030, the cost of ethanol reaches $0.65 per gallon D1 with only a modest level of incentives. At this point ELSAS assumes that future ethanol use can be as E 85. (There is an implicit assumption here that the future World Oil Market continues an upward cost tendency for petroleum fuels in years subsequent to those covered by the EIA documentation of AEO 2002). The same considerations of balance among market elements and reasonable rates of change in market price and incentive levels continue to apply.

Quantities of ethanol for use in blending are limited by the size of the motor fuel market. The boundaries on E 85 use are an order of magnitude larger. (ELSAS assumes that infrastructure needs are met by the market as long as moderate growth rate limitations are imposed on an annual basis). Accordingly, once the E 85 regime is reached, the incentive level should be zeroed out as rapidly as possible.

At some point, with increasing cellulosic production, learning curve cost reduction benefits are exhausted and feedstock costs continue to rise as less favorable supplies are brought into use. As a result, ethanol costs can begin to rise again and even threaten to exceed the arbitrary threshold level of $0.65 per gallon D1 for E 85 use. (In all likelihood, continually rising costs for petroleum fuels would have raised such a threshold by the time 2050 is reached. However, no attempt is made to project oil prices so far into the future). The ELSAS methodology defines this limiting condition as the sustainable level of feedstock utilization and ethanol production.

The first case created on the Reference Page does not include a Biorefinery. However, the case can be repeated with the Biorefinery switch (on the Calculate Page) set to On. This is termed the Advanced Reference Case.

Case results are identical through 2015 to the case without a Biorefinery. (This is because Biorefinery technology and economic impacts are only assumed to begin in 2015). The user can now choose either to increase production rates (at previous incentive levels), because of the more rapid cost reduction associated with economic credit for Biorefinery co-products, or to decrease incentives more rapidly at prior levels of production, or to take some lesser improvement in both production levels (up) and incentive levels (down) simultaneously. In brief, faster rates of technological and economic improvement lead to increased flexibility (broadened constraints) in industry growth patterns.

As a final information element on the Reference Case Page, the Reference Case, with and without Biorefinery, is compared in terms of differences in:

- Production Cost, Incentive Level and Market Price, and
- The Increase in Production and Use associated with Biorefinery Economics.

The Aggressive Case Page

A similar construction is used for the Aggressive Case Page.

The theory of the Aggressive Case is that improvements occur in three areas. First, more aggressive research and development efforts result in faster progress down the learning curve. (This is modeled by changing the exponent of the learning curve equation). Second, greater quantities of feedstock become available at a given price by virtue of an increase in the reference growth factor for Energy Crops (and Agricultural Residues if the user decides to include these as well). Third, in the Advanced Version of the Aggressive Case, the assumed additional effort on technical progress also results in further improvements in Biorefinery economics. These changes have relatively little effect in the near-term, but yield valuable benefits in the mid-term, and also raise the long-term sustainable level of cellulosic ethanol use.

As before, improvements from the Reference Case can be shown as reductions in the level of incentives required to support previously calculated production levels. ELSAS describes this revision as being an Aggressive Case of Type 1. Alternatively, production levels and incentive levels can be rebalanced to reflect the improved economics. ELSAS describes this revision as being an Aggressive Case of Type 2.

The Cases calculated in a stepwise fashion and summarized on the Aggressive Case Page are:

- The Aggressive Case Type 1, and
- The Advanced Aggressive Case (with Biorefinery) Type 2.

As a final information element on the Aggressive Case Page, the Aggressive Case, with and without Biorefinery, is compared in terms of differences in:

- Production Cost, Incentive Level and Market Price, and
- The Increase in Production and Use associated with Biorefinery Economics.

Finally, the Advanced Aggressive Case Type 2 is compared with the original Reference Case (no Biorefinery) from The Reference Page.

Through 2050, the cumulative usage comparison for the two cases shows an increased production of about 25 per cent. This benefit is primarily related to the enhanced technology advances and the inclusion of the Biorefinery economics. From 2050 forward,

there is an increase in the sustainable level of cellulosic ethanol use of about 50 per cent. This benefit is primarily related to the enhanced biomass feedstock supply curves.

Illustrative Cost Curves

The illustrative cost curves (in Appendix A) result from exercising ELSAS to create a range of possible future cellulosic ethanol industry growth curves with their attendant economics, with and without the benefits of Biorefinery enhancements.

In producing such projections of the future, there are numerous data and methodological issues. These are well understood, and the current work effort seeks to respond to these issues with reasonable approximations and simplifications. The capability to make analyses of this kind does not currently exist. ELSAS is viewed as a step in this direction.

The cost curves use the default economic, market, and technical assumptions in ELSAS. There are 4 cost curve cases:

- Reference,
- Advanced Reference (includes Biorefinery),
- Aggressive (Type 1 – Same annual production levels as Reference, but with lower economic incentives), and
- Advanced Aggressive (includes Biorefinery – Type 2 – Production levels and economic incentives are both modified from Advanced Reference).

Input data is derived from numerous sources (as described in the ELSAS documentation). Input capacity and production assumptions through 2010, and 2010 economic cellulosic ethanol production cost estimates are identical to program metrics as of August 2002. World oil market assumptions are those projected by EIA in its Annual Energy Outlook 2002 for its Reference Case. Assumptions with respect to future legislation include passage of the ethanol Renewable Fuels Standard as proposed in draft 2002 legislation (ethanol production to reach 5.0 BGY by 2012) and continuance past 2007 of the currently legislated economic incentive for ethanol, although at declining values, eventually phasing out completely. Output economic results are in year 2000 dollars. All results are fully compatible with classic market economics, wherein supply and demand are balanced at a common market price on their respective price/quantity relationships.

From 2012 forward, starch-based ethanol capacity remains constant at 5.0 Billion Gallons per Year (BGY). This is in addition to ethanol production from cellulosic feedstock, which varies in magnitude throughout the time period.

Figure 1 shows cellulosic ethanol production in the Reference Case from 2010 through 2050.

Figure 2 shows cellulosic ethanol production cost, incentive offset and resulting market price in the Reference Case for the same time period.

Figures 3 and 4 repeat these data presentations for the Advanced Reference Case (includes Biorefinery).

Figures 5, 6 and 7 compare results for the Advanced Reference relative to the Reference Case. The parameters examined (one in each figure) are Ethanol Production, Required Incentive Offset, and Market Price. The benefits of the Biorefinery economic credit for co-products, applied to reduce the cost of ethanol, are apparent from the figures.

The Aggressive Case (Type 1) differs from the Reference Case only with respect to a reduced level of incentive. Figure 8 compares these incentive levels for the two cases, and also plots the resulting differential cost benefit. The area under the difference curve (which plots annual points) is the cumulative economic savings for the entire time period.

Figures 9 and 10 repeat the twin data presentations of Figures 1 and 2, and Figures 3 and 4, this time for the Advanced Aggressive Case (includes Biorefinery – Type 2 – completely rebalanced market conditions).

Figures 11, 12 and 13 compare results for the Advanced Aggressive relative to the original Reference Case. The parameters examined (one in each figure) are Ethanol Production, Required Incentive Offset, and Market Price. The benefits of the combined accelerated technological advancement (e.g. resulting from higher research and development budgets), greater feedstock availability at a given cost, and the Biorefinery economic credits, applied to reduce the cost of ethanol, are apparent from the figures.

Comparing these boundary cases, there is an increase in cumulative ethanol production and use over the 50-year period of some 25 percent. In addition the continuing sustainable level of ethanol utilization in 2050 and beyond is about 50% higher.

These results should be seen as illustrative and suggestive, rather than final and authoritative. Much work remains to be done to improve the data inputs to ELSAS, to enhance the operability of the program, and to increase the confidence that can be placed in its outputs. Version 1.0 d and the current cost curve outputs are seen as a first step.

Figure 1. Cellulosic Ethanol Production – Reference

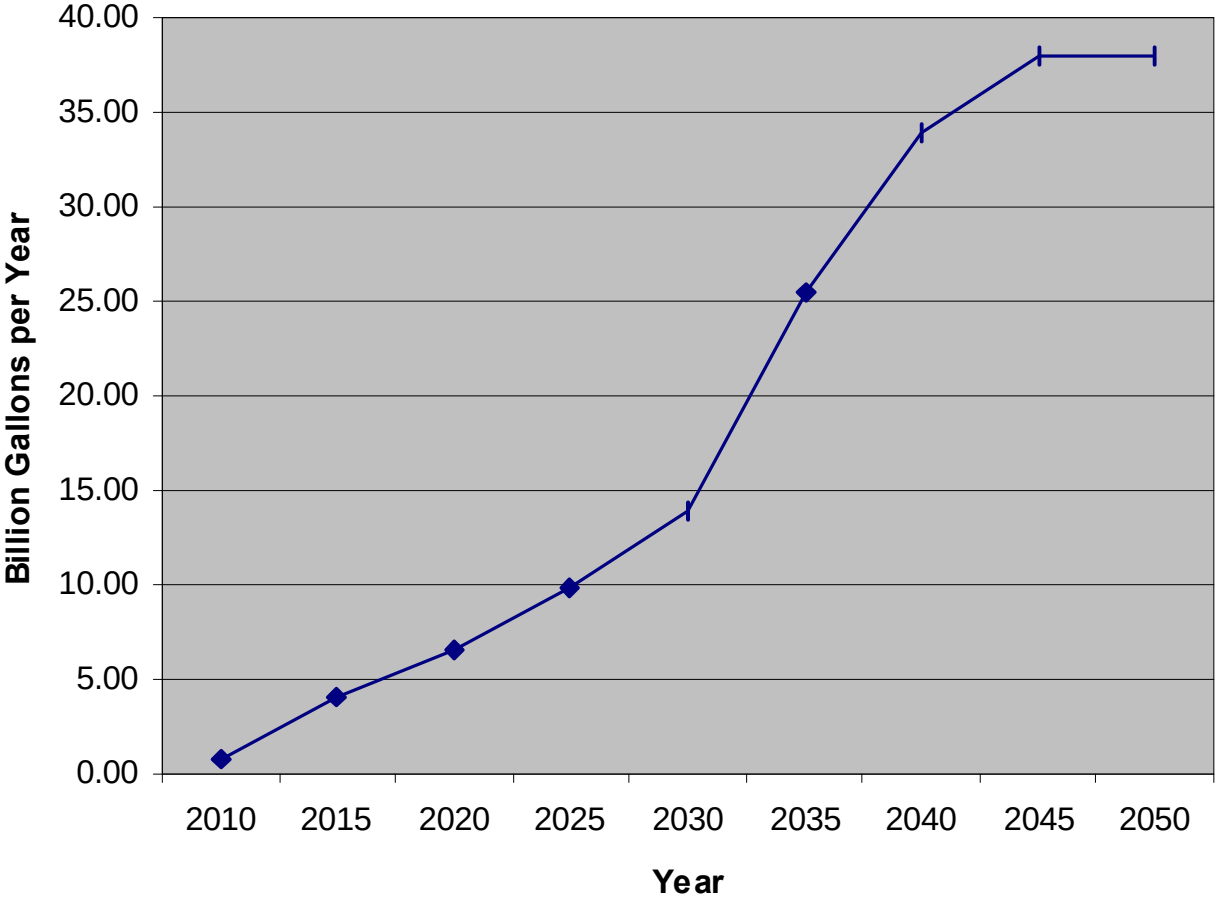


Figure 2. Cellulosic Cost & Market Price – Reference

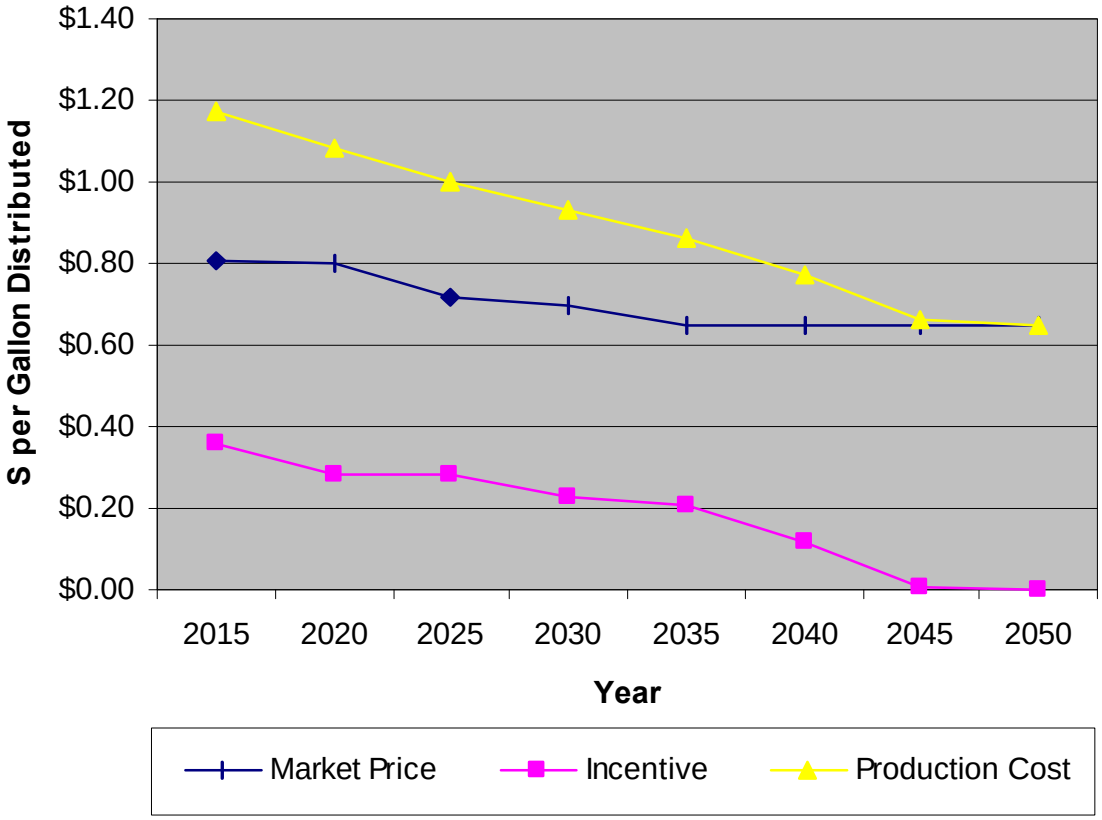


Figure 3. Cellulosic Ethanol Production – Reference Advanced

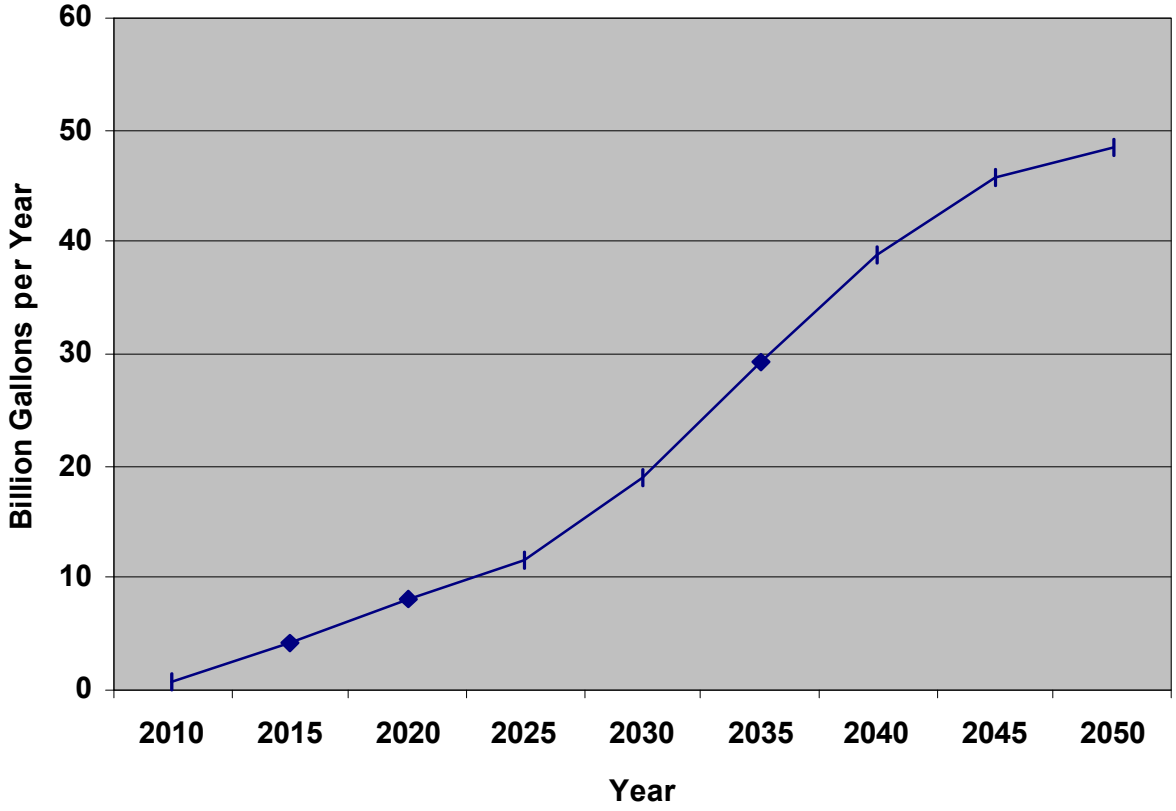


Figure 4. Cellulosic Cost & Market Price – Reference Advanced

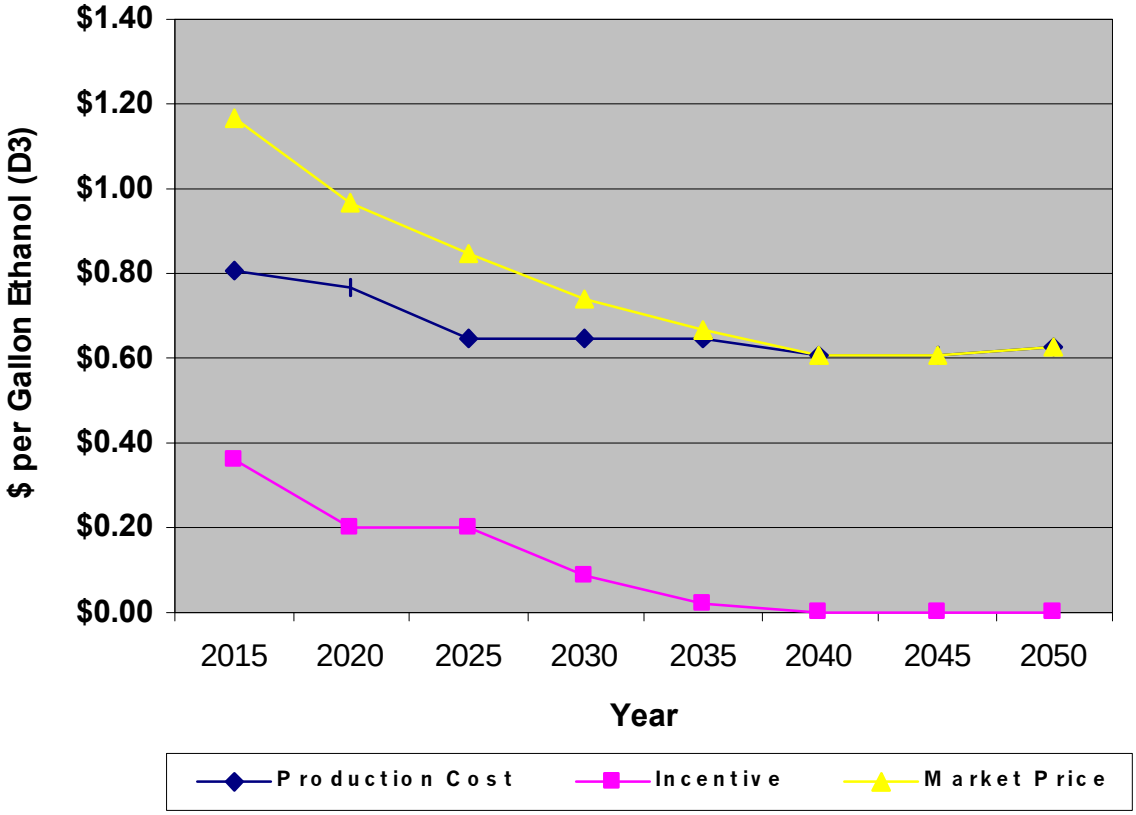


Figure 5. Production Effect of BioRefinery

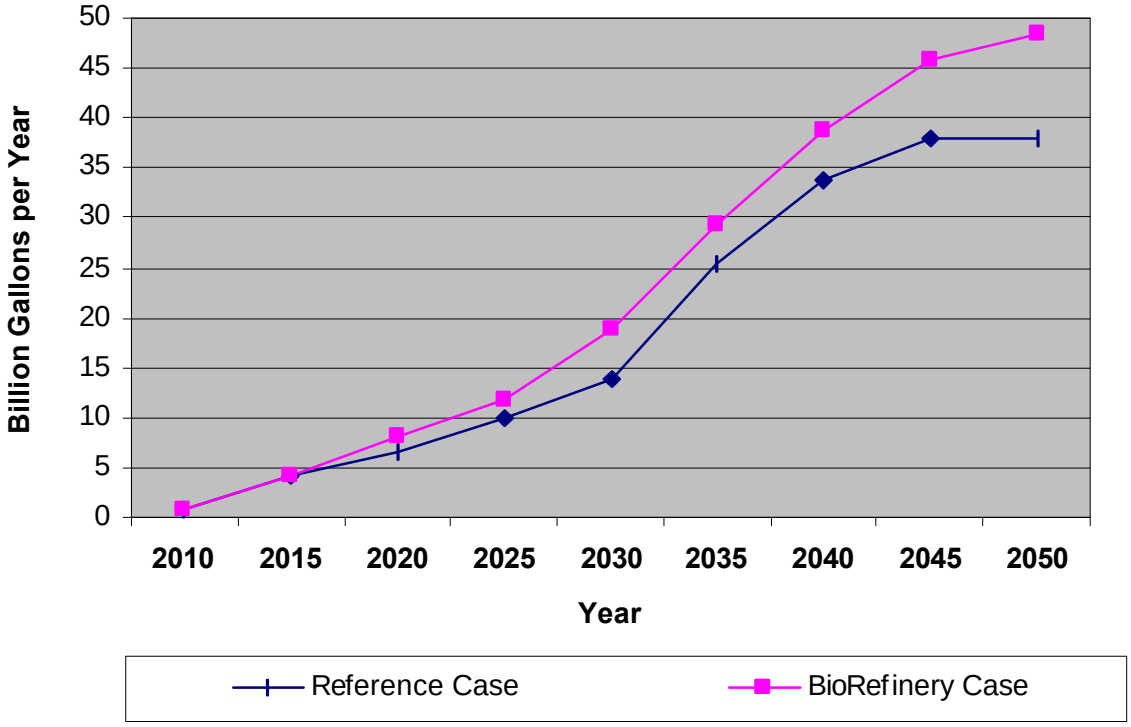


Figure 6. Biorefinery Impact on Incentive

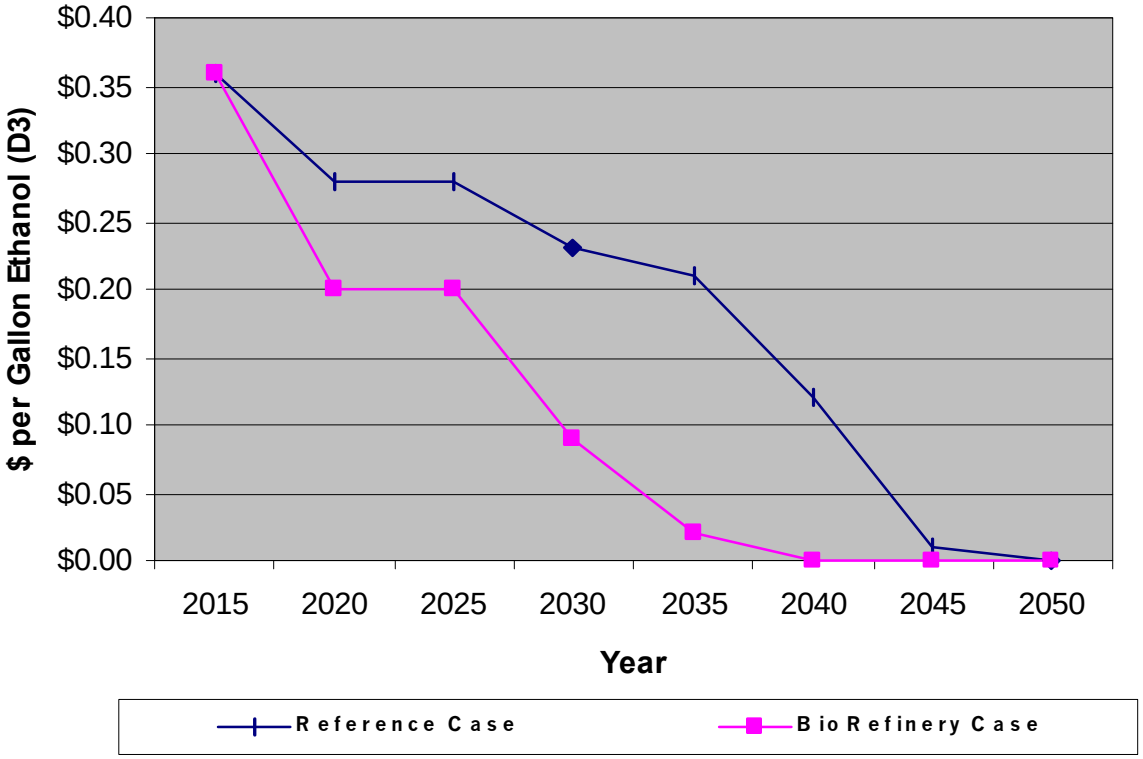


Figure 7. BioRefinery Impact on Market Price

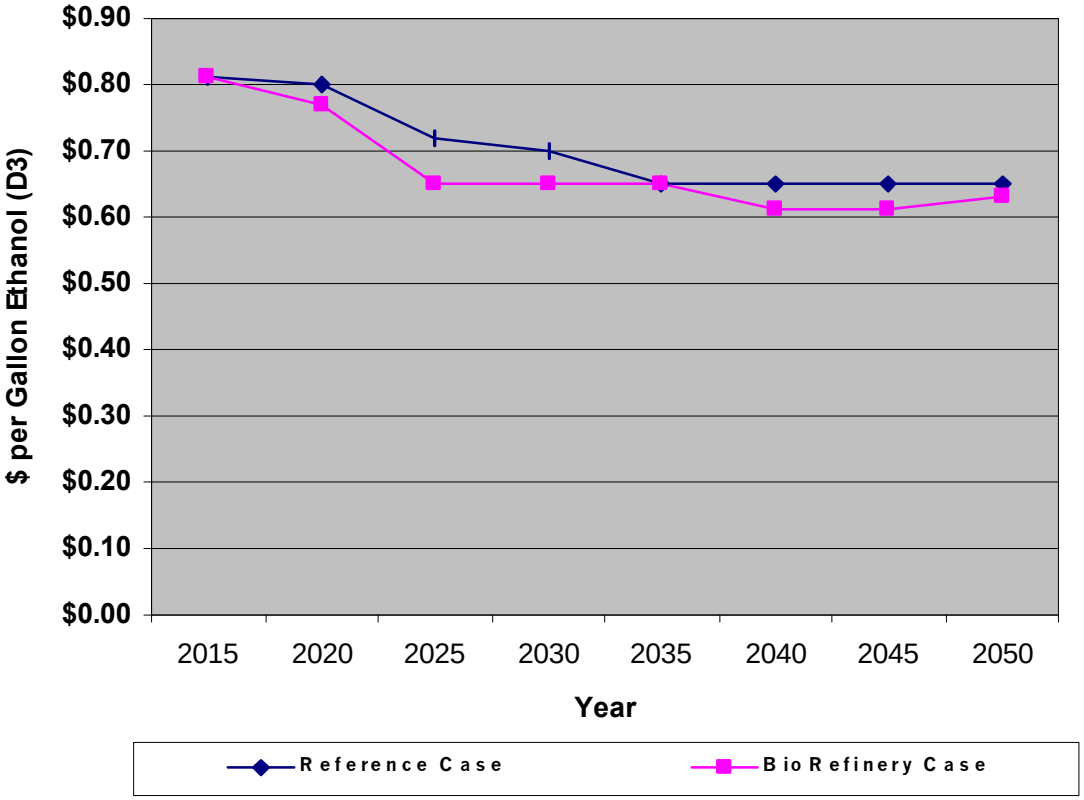


Figure 8. Incentive Levels – Excludes BioRefinery

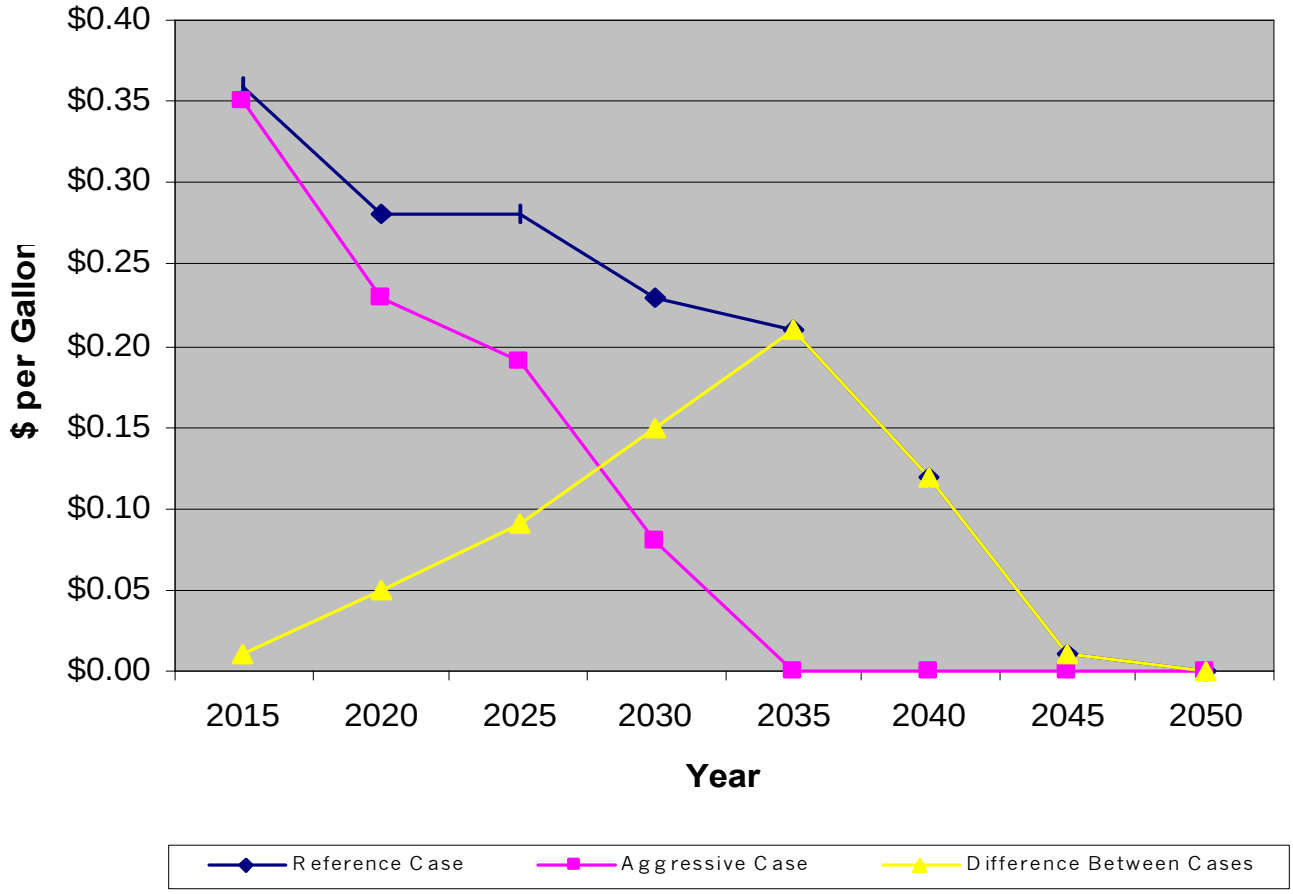


Figure 9. Cellulosice Ethanol Production – Aggressive Case Advanced Version

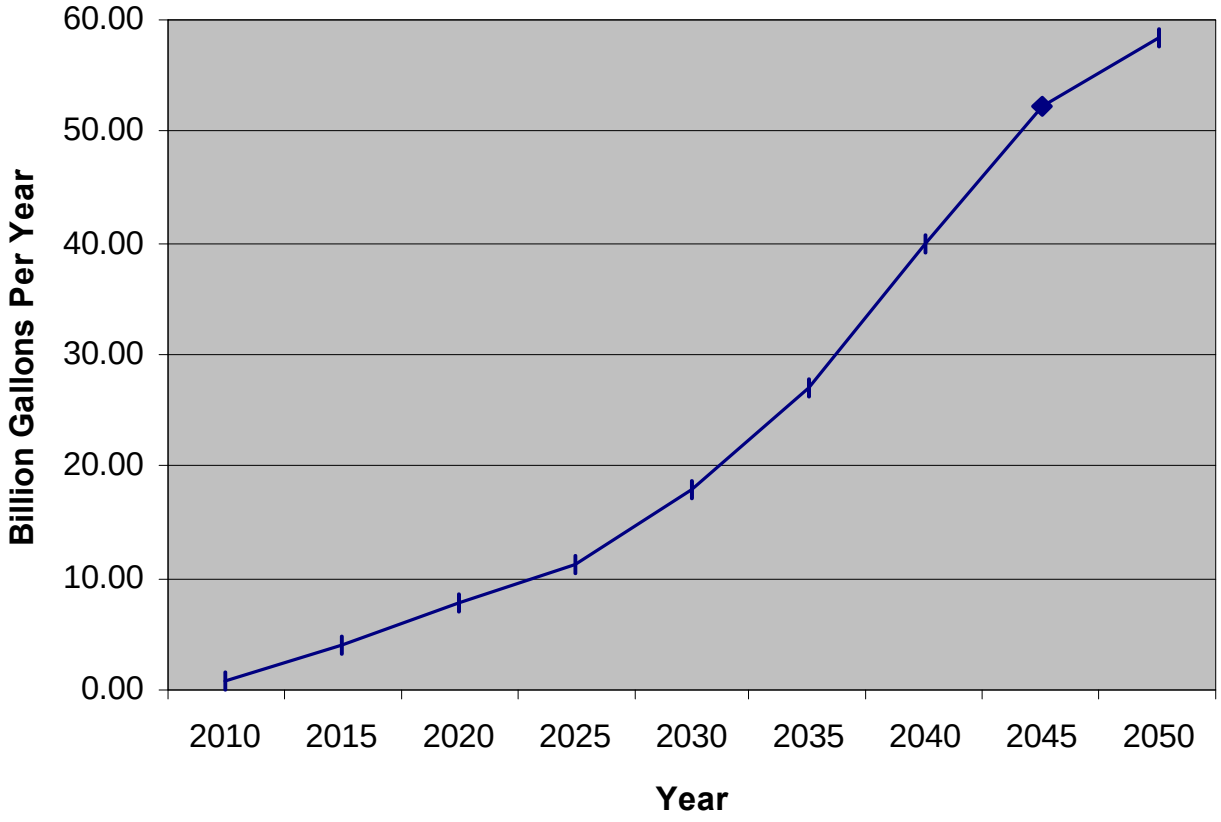


Figure 10. Market Price Economics – Aggressive Case

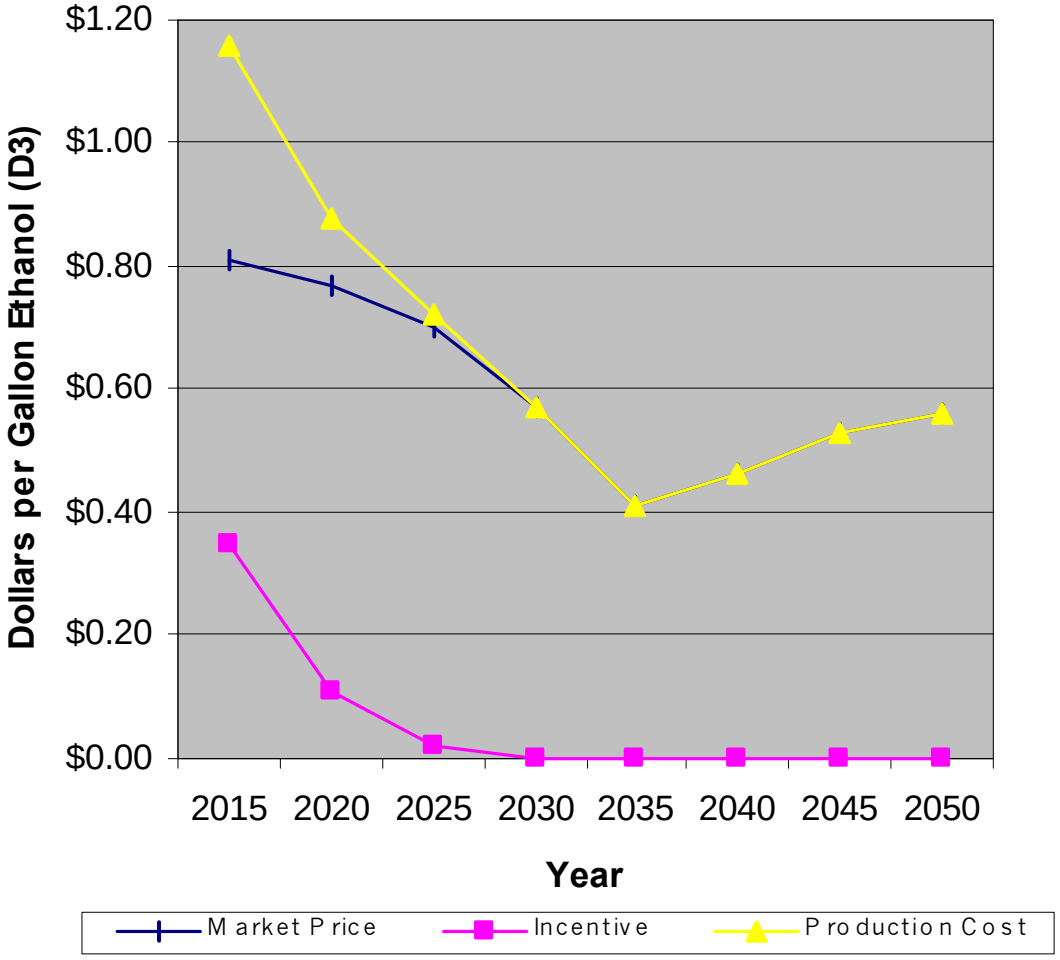


Figure 11. Cellulosic Ethanol Production

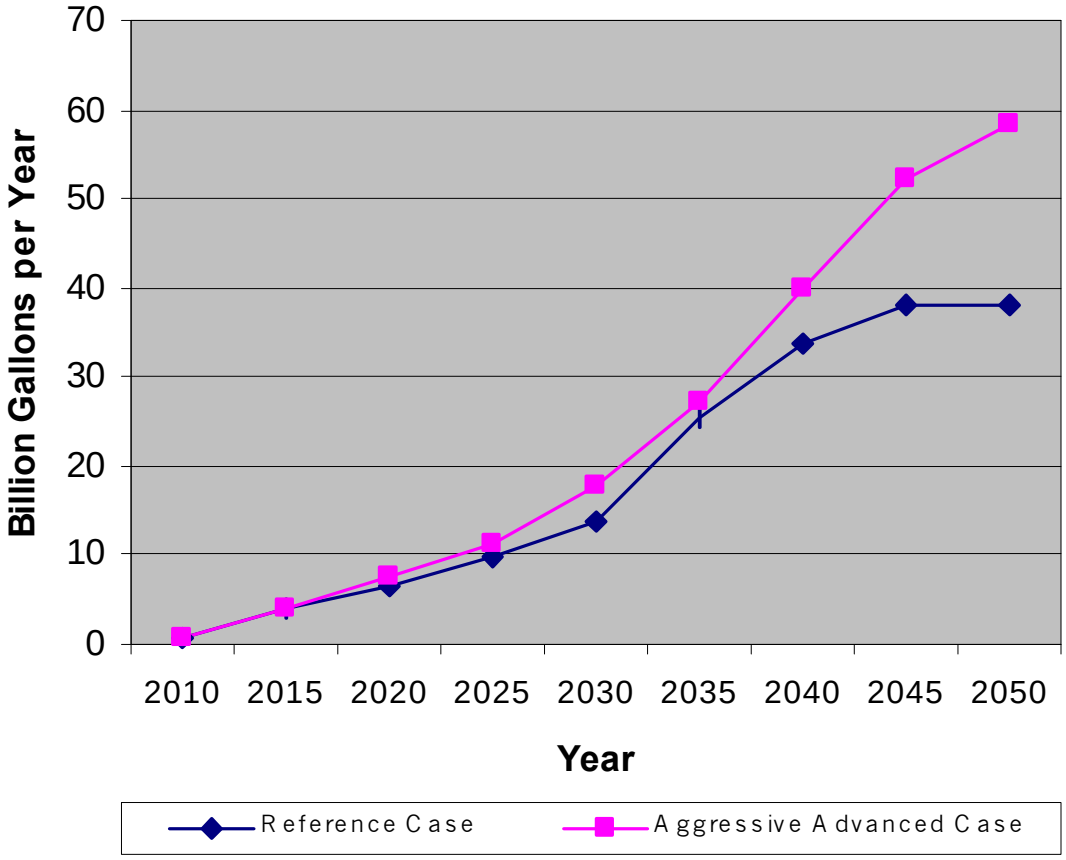


Figure 12. Market Price

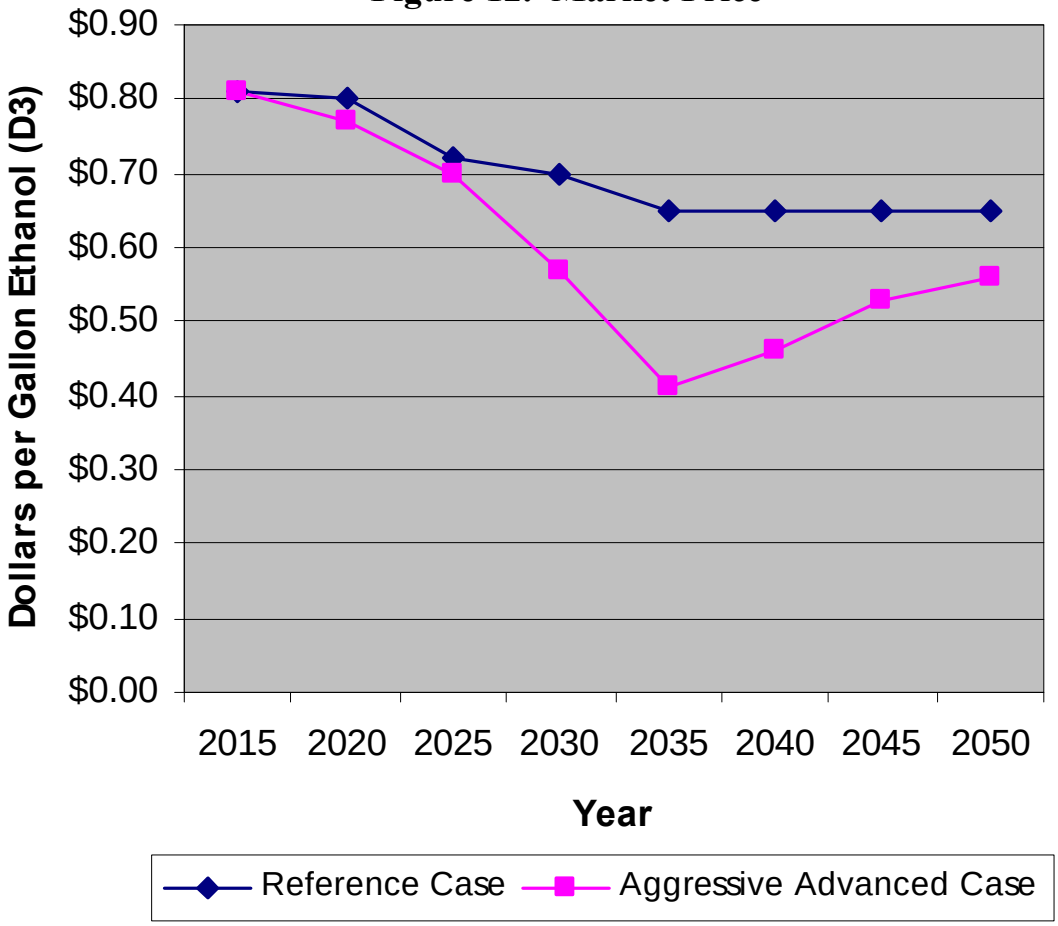
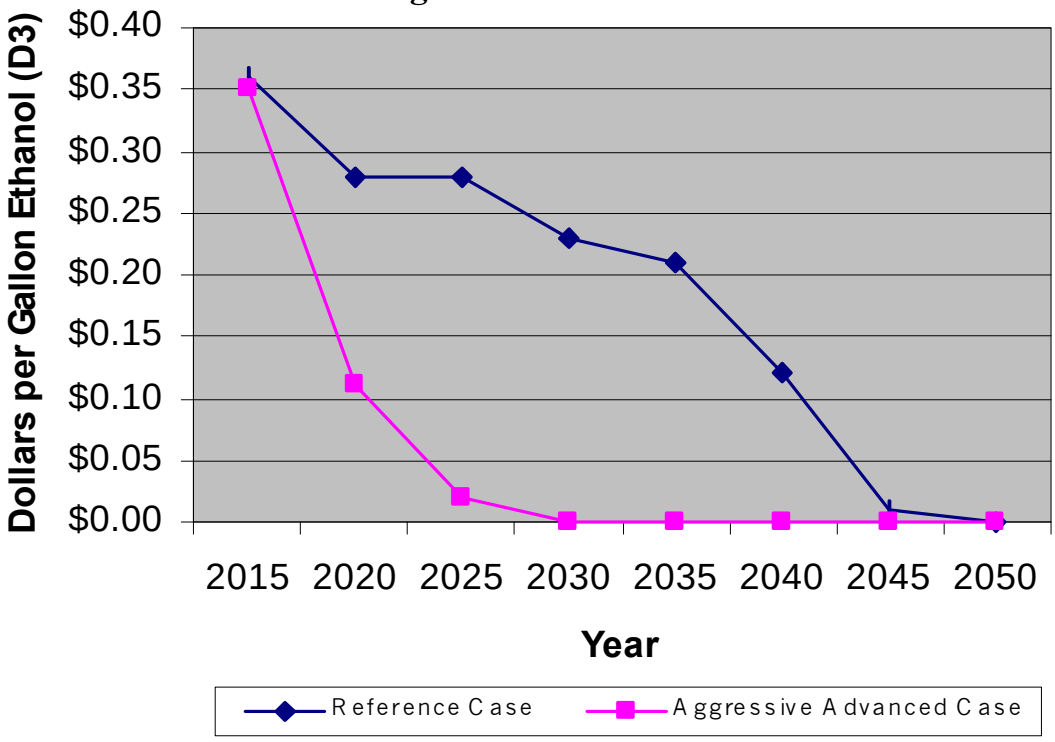


Figure 13. Incentive Levels



Appendix A

Illustrative Ethanol Industry Cost Curves
2010 Through 2050

Title Page **Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet** **Printed on 10/1/02**

Version 1.0 d
Oct-02

The attached TMS Cost Curves illustrate a range of production and cost projections for cellulosic ethanol

All costs are in $2000s. Data sources include ADL feedstock supply curves, NREL conversion cost cases, and ORNL demand value curves.

Advanced Cases include a BioRefinery simulation

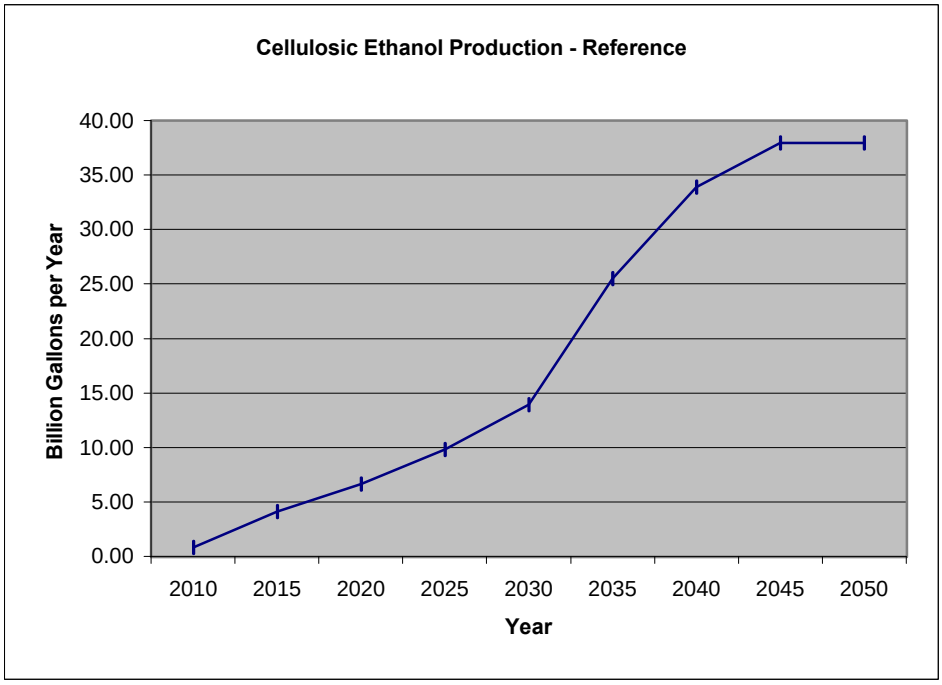
Reference Case Page **Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet** **Printed on 10/1/02**

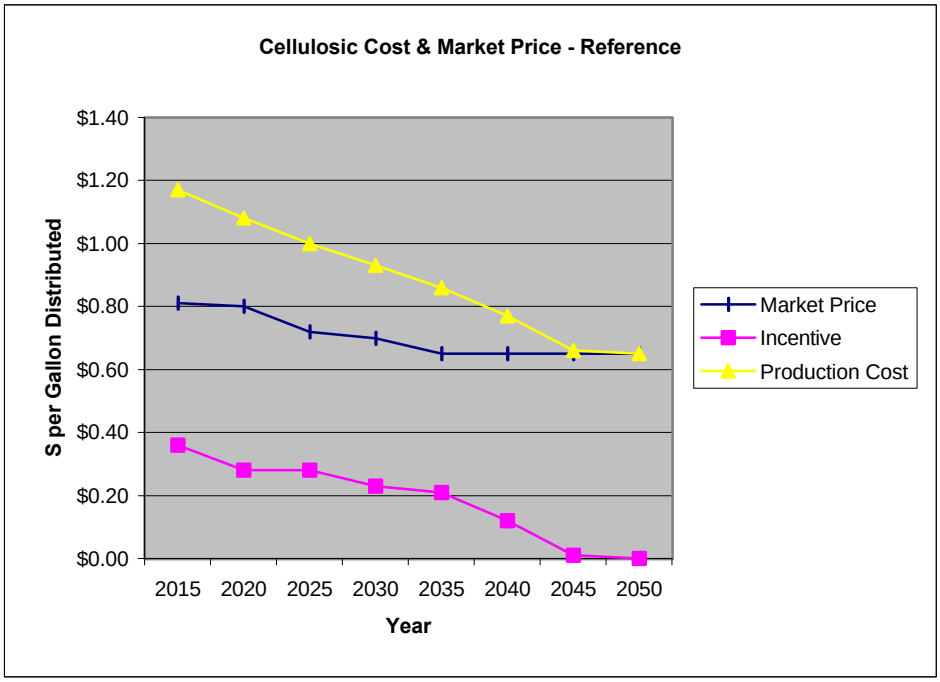
Version 1.0 d
Oct-02

Reference Case Summary

	Year	Cell Pdn BGY	Idy Growth Rate Factor	Eth Mkt Price ($/g)	Incentive $/gal	Cell Pdn Cost ($/g)	Cum Prior Cell BGY
Blend	2010	0.85	1.12			$1.23	2.4
Blend	2015	4.10	1.12	$0.81	$0.36	$1.17	10.2
Blend	2020	6.61	1.05	$0.80	$0.28	$1.08	35.7
Blend	2025	9.82	1.05	$0.72	$0.28	$1.00	75.2
Blend	2030	13.92	1.05	$0.70	$0.23	$0.93	132.5
E 85	2035	25.47	1.10	$0.65	$0.21	$0.86	225.2
E 85	2040	33.89	1.05	$0.65	$0.12	$0.77	365.5
E 85	2045	37.93	1.02	$0.65	$0.01	$0.66	543.0
E 85	2050	37.93	1.00	$0.65	$0.00	$0.65	732.7

Note 1: Total Ethanol Production includes 5.0 BGY of starch-based in addition to Cellulosic
Note 2: Industry growth rate factors include starch-based, and are for the prior time increment ending in the year cited - they are annual compound rates
Note 3: Ethanol Market Price is at distributed location, and the point of economic competition between starch-based & cellulosic ethanol
Note 4: Cumulative prior years production is for cellulosic only
Note 5: Cellulosic production rate declines as it saturates blend market, increases again as it enters & grows in E 85 market, then slows as economic limits are reached





Reference Case Advanced Version Summary

	Year	Cell Pdn BGY	Idy Growth Rate Factor	Eth Mkt Price ($/g)	Incentive $/gal	Cell Pdn Cost ($/g)	Cum Prior Cell BGY
Blend	2010	0.85	1.12			$1.23	2.4
Blend	2015	4.10	1.12	$0.81	$0.36	$1.17	10.2
Blend	2020	8.06	1.075	$0.77	$0.20	$0.97	38.6
E85	2025	11.67	1.05	$0.65	$0.20	$0.85	86.1
E85	2030	18.94	1.075	$0.65	$0.09	$0.74	159.0
E 85	2035	29.36	1.075	$0.65	$0.02	$0.67	274.6
E 85	2040	38.86	1.05	$0.61	$0.00	$0.61	440.4
E 85	2045	45.84	1.03	$0.61	$0.00	$0.61	648.7
E 85	2050	48.44	1.01	$0.63	$0.00	$0.63	888.3

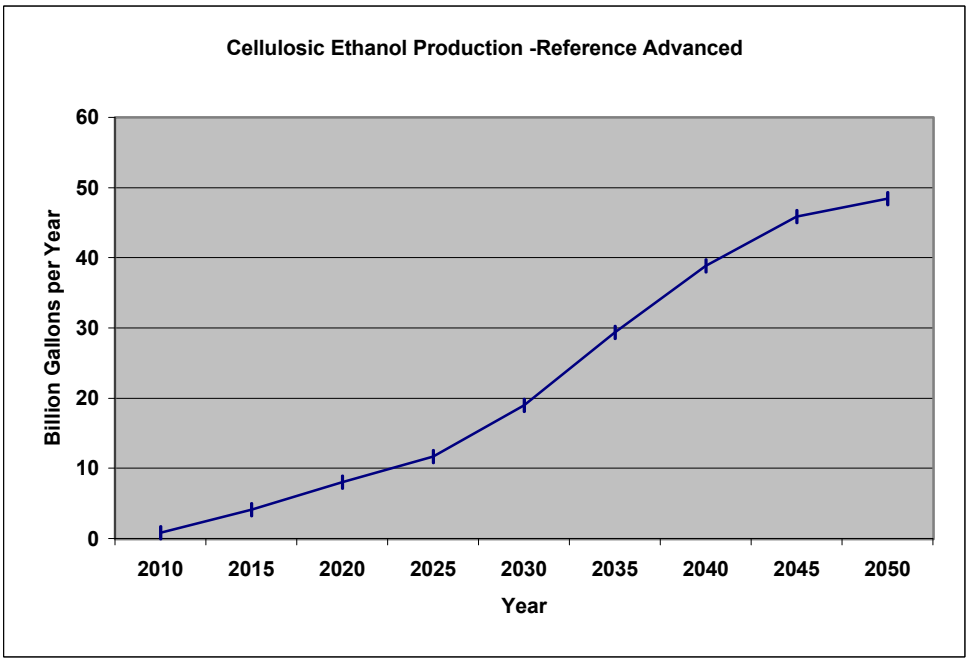
Note 1: Total Ethanol Production includes 5.0 BGY of starch-based in addition to Cellulosic

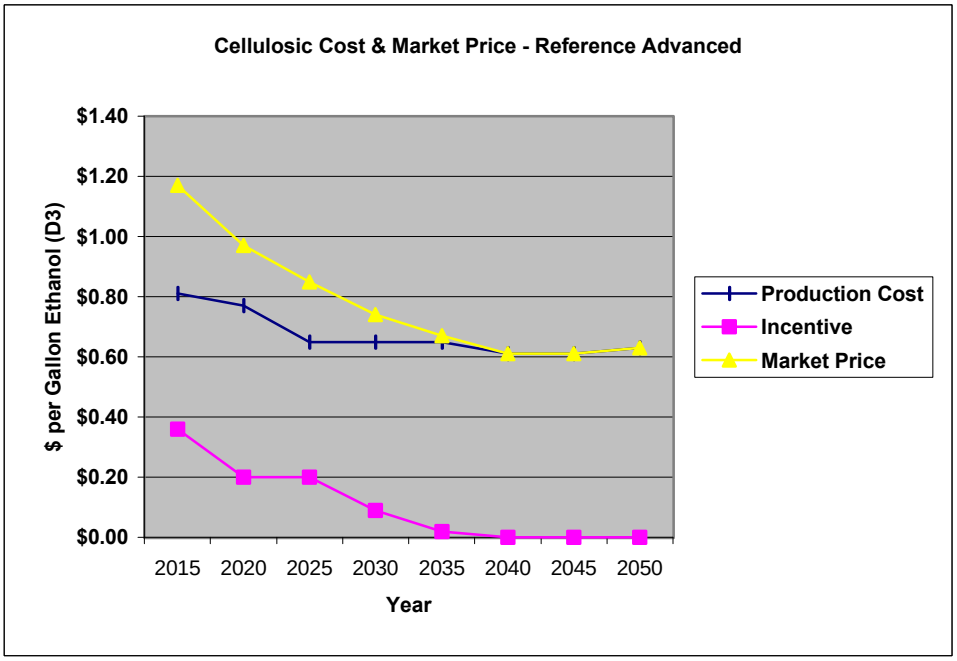
Note 2: Industry growth rate factors include starch-based, and are for the prior time increment ending in the year cited - they are annual compound rates

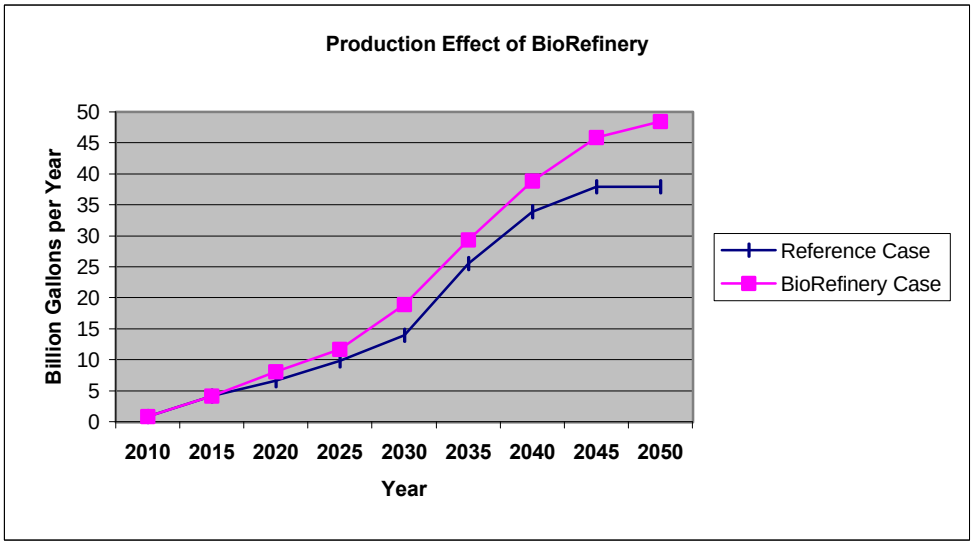
Note 3: Ethanol Market Price is at distributed location, and the point of economic competition between starch-based & cellulosic ethanol

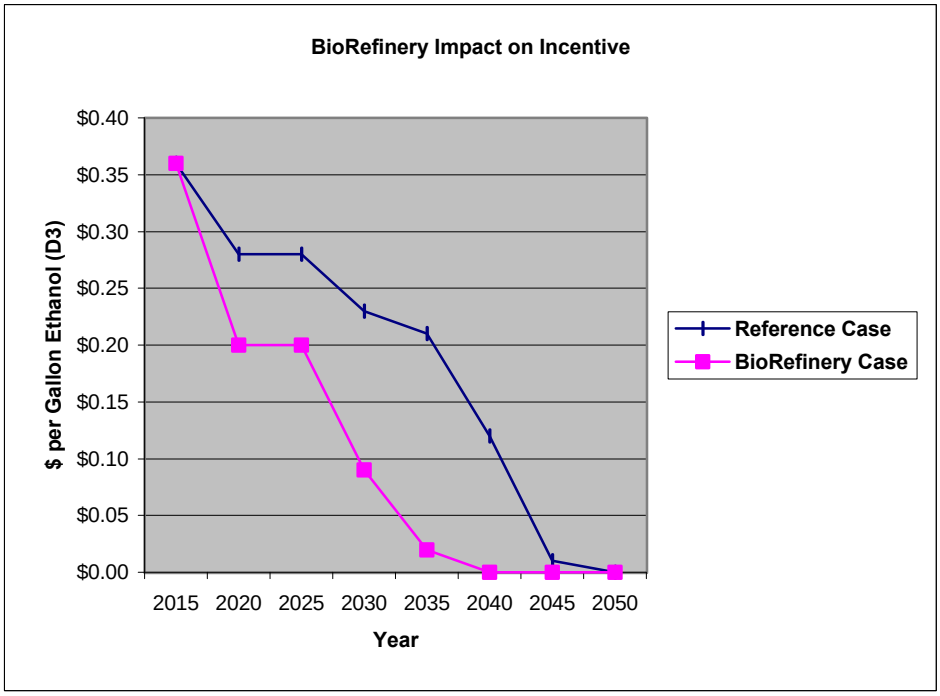
Note 4: Cumulative prior years production is for cellulosic only

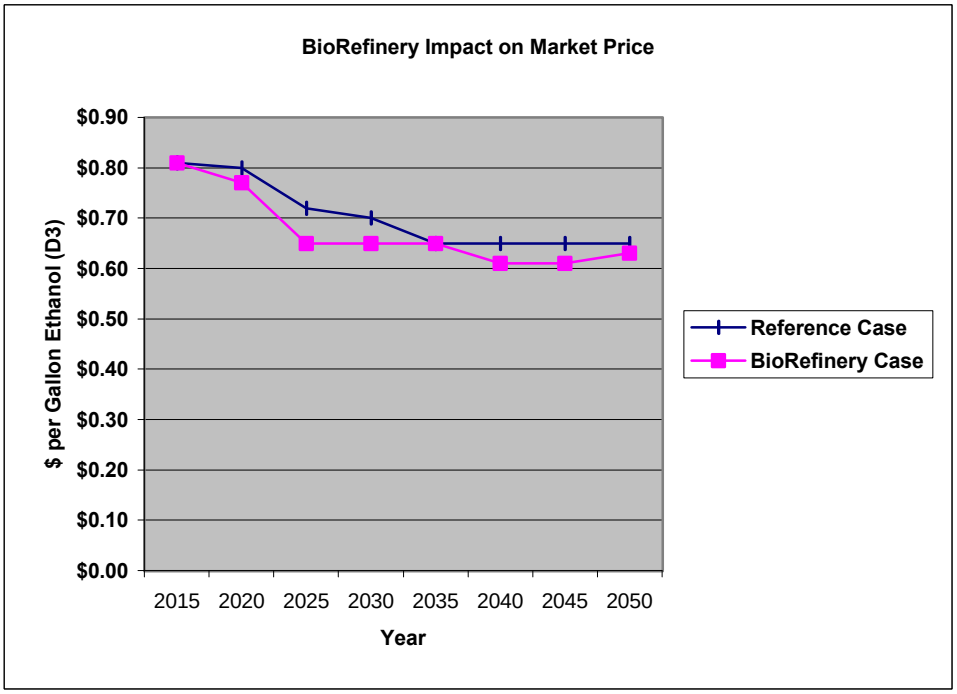
Note 5: Cellulosic production rate declines as it saturates blend market, increases again as it enters & grows in E 85 market, then slows as economic limits are reached


Cellulosic Ethanol Production -Reference Advanced
Billion Gallons per Year
60
50
40
30
20
10
0
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year


Cellulosic Cost & Market Price - Reference Advanced
$ per Gallon Ethanol (D3)
$1.40
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$0.00
2015
2020
2025
2030
2035
2040
2045
2050
Year
Production Cost
Incentive
Market Price


Production Effect of BioRefinery
Billion Gallons per Year
50
45
40
35
30
25
20
15
10
5
0
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year
Reference Case
BioRefinery Case


BioRefinery Impact on Incentive
$ per Gallon Ethanol (D3)
$0.40
$0.35
$0.30
$0.25
$0.20
$0.15
$0.10
$0.05
$0.00
2015
2020
2025
2030
2035
2040
2045
2050
Year
Reference Case
BioRefinery Case



Case Conclusions

BioRefinery Simulation Leads to
Increased Production & Use
at Similar Market Prices

E85 10 Years Earlier
Hence Increased Benefits
But Reduced Incentive Costs

Aggressive Case Page **Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet** **Printed on 10/1/02**

Version 1.0 d
Oct-02

Overview

The Theory of the Aggressive Case is that 1) More aggressive R&D expenditures result in faster progress down the learning curve (This is modeled by changing the exponent of the learning curve equation) and a biorefinery with more value in co-products, and 2) Greater quantities of feedstock become availble by virtue of an increase in the growth factor for Energy Crops (and AgResidues if the user decides to include these as well).

There are at least two types of Aggressive Cases

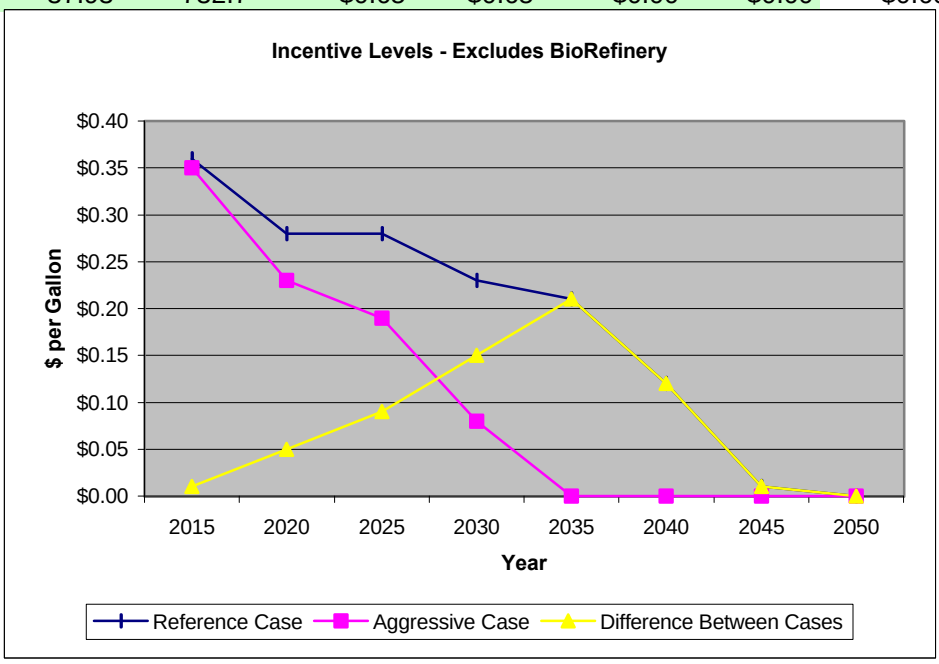
The first simply repeats the capacity/production schedule of the Reference Case, but adjusts the incentive level so as to maintain supply/demand balance. The value of the case is measured by a resulting reduction in incentive levels.

The second type of Aggressive Case is created from the ground up in the same way as a Reference Case. Its value is measured by a greater level of ethanol use.

Aggressive Case - Type 1

Reference and Aggressive Case Comparisons

Year	Cell Pdn BGY	Cum Prior Cell BGY	Both Cases Eth Mkt Price ($/g)	Ref Case Cell Pdn Cost ($/g)	Ref Case Incentive $/gal	Agg Case Incentive $/gal	Agg Case Cell Pdn Cost ($/g)	Reduction in Incentive $/gallon
2010	0.85	2.4		$1.23			$1.22	
2015	4.10	10.2	$0.81	$1.17	$0.36	$0.35	$1.16	$0.01
2020	6.61	35.7	$0.80	$1.08	$0.28	$0.23	$1.03	$0.05
2025	9.82	75.2	$0.72	$1.00	$0.28	$0.19	$0.91	$0.09
2030	13.92	132.5	$0.70	$0.93	$0.23	$0.08	$0.78	$0.15
2035	25.47	225.2	$0.65	$0.86	$0.21	$0.00	$0.63	$0.21
2040	33.89	365.5	$0.65	$0.77	$0.12	$0.00	$0.60	$0.12
2045	37.93	543.0	$0.65	$0.66	$0.01	$0.00	$0.62	$0.01
2050	37.93	732.7	$0.65	$0.65	$0.00	$0.00	$0.60	$0.00

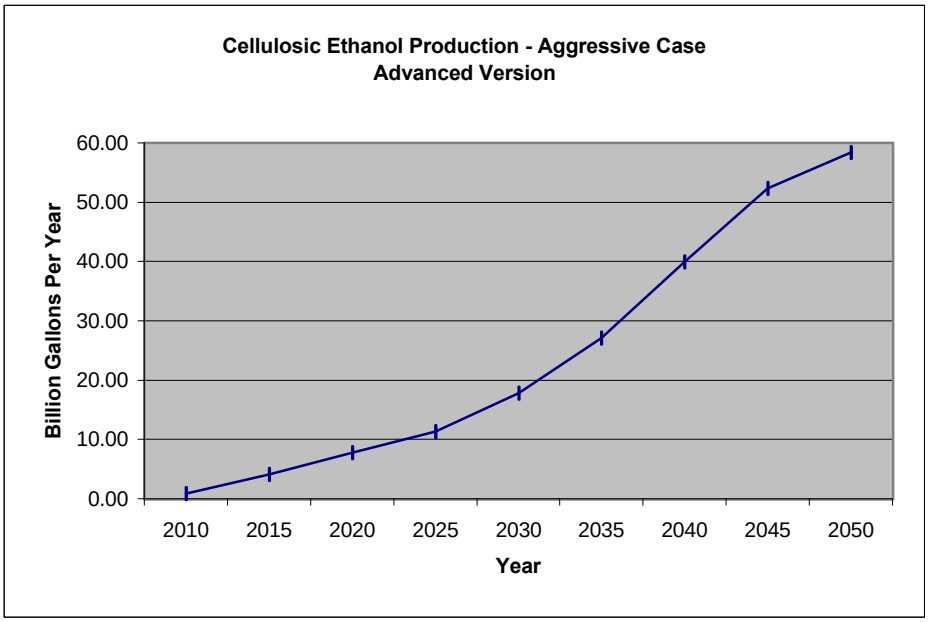


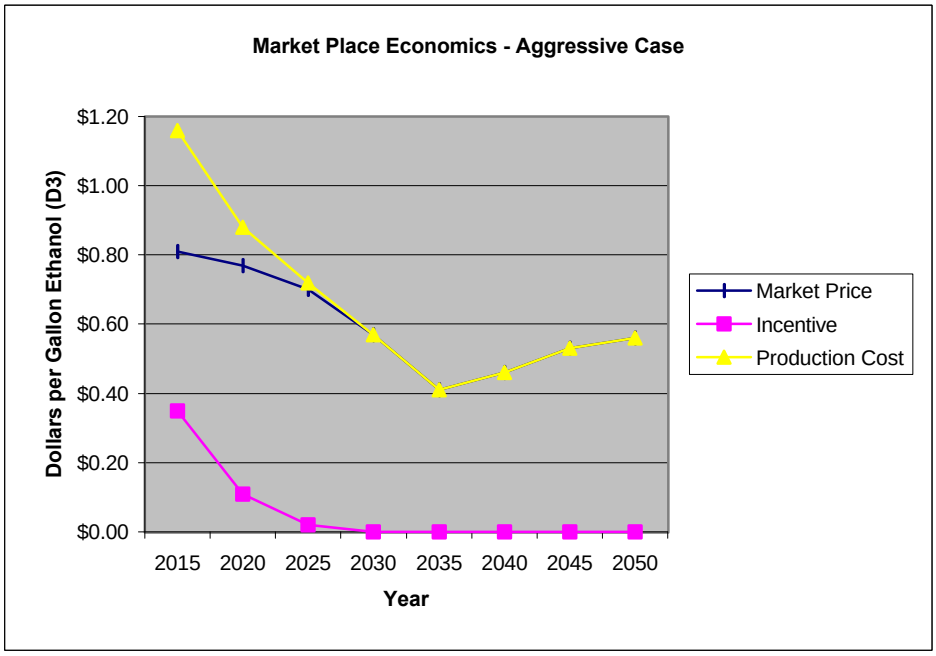
Aggressive Case - Type 2 - Advanced Version Including BioRefinery

Now we calculate the Aggressive Case analog of the Reference Case. Our analysis assumes Advanced Version conditions (Includes BioRefinery). This is a Type 2 comparison because it includes a market crossover optimization for each time period identically to the Reference Case Advanced Version.

Aggressive Case Type 2 Advanced Version Summary (Includes BioRefinery)

	Year	Cell Pdn BGY	Idy Growth Rate Factor	Eth Mkt Price ($/g)	Incentive $/gal	Cell Pdn Cost ($/g)	Cum Prior Cell BGY
Blend	2010	0.85	1.12			$1.23	2.4
Blend	2015	4.10	1.12	$0.81	$0.35	$1.16	10.2
Blend	2020	7.76	1.07	$0.77	$0.11	$0.88	38.0
Blend	2025	11.29	1.05	$0.70	$0.02	$0.72	83.9
E 85	2030	17.85	1.07	$0.57	$0.00	$0.57	153.4
E 85	2035	27.04	1.07	$0.41	$0.00	$0.41	261.1
E 85	2040	39.94	1.07	$0.46	$0.00	$0.46	422.1
E 85	2045	52.36	1.05	$0.53	$0.00	$0.53	646.6
E 85	2050	58.33	1.02	$0.56	$0.00	$0.56	920.4

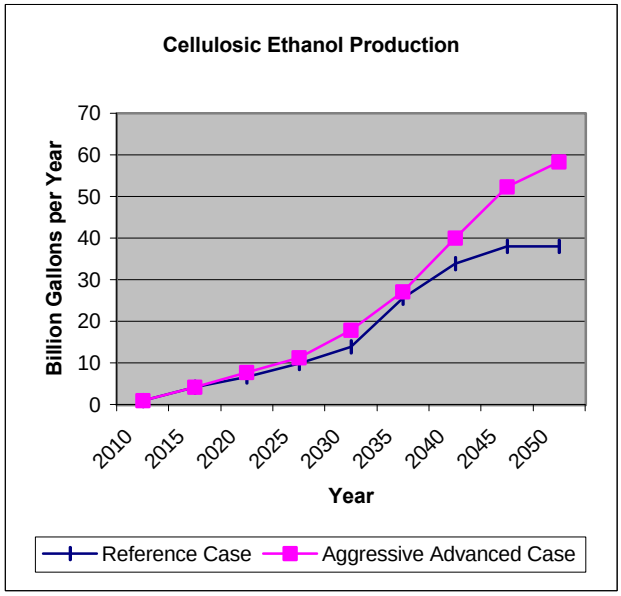




Comparisons of Reference and Aggressive Advanced (Type 2) Cases

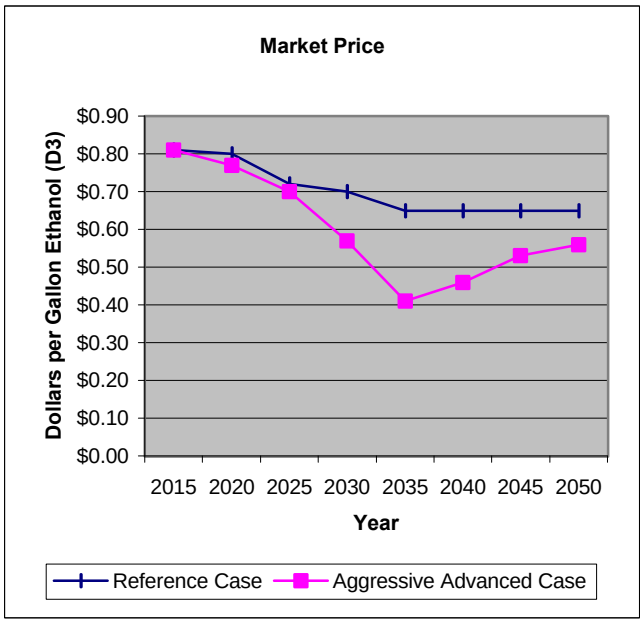
Year	Ref Cell Pdn BGY	Agg-Adv Cell Pdn BGY
2010	0.85	0.85
2015	4.10	4.10
2020	6.61	7.76
2025	9.82	11.29
2030	13.92	17.85
2035	25.47	27.04
2040	33.89	39.94
2045	37.93	52.36
2050	37.93	58.33

Production is higher both because of economic ability to use higher cost feedstock and also because of more feedstock availability



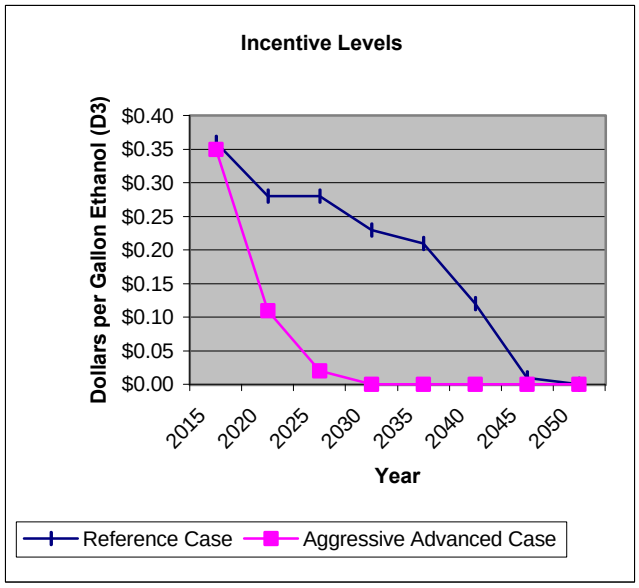
Year	Ref Market Price $/gal	Agg Adv Market Price $/gal
2015	$0.81	$0.81
2020	$0.80	$0.77
2025	$0.72	$0.70
2030	$0.70	$0.57
2035	$0.65	$0.41
2040	$0.65	$0.46
2045	$0.65	$0.53
2050	$0.65	$0.56

Market Price is Lower



Year	Ref Incentive Level $/gal	Agg Adv Incentive Level $/gal
2015	$0.36	$0.35
2020	$0.28	$0.11
2025	$0.28	$0.02
2030	$0.23	$0.00
2035	$0.21	$0.00
2040	$0.12	$0.00
2045	$0.01	$0.00
2050	$0.00	$0.00

Incentive Level is Lower



Through 2050 the cumulative usage comparison for the two cases, which is another measure of benefits received (e.g. oil imports avoided, greenhouse gas emissions avoided), and the sustainable future levels are as follows

Cum Thru 2050 BGY	Ref	Agg Adv	Factor of Increase	
	732.69	**920.4**	**1.26**	BioRefinery Related
			Benefits Thru 2050	
Sus Future 2050 on BGY	Ref	Agg Adv		
	37.93	**58.33**	**1.54**	Feedstock Related
			Benefits Long Term	

END

Appendix B

Ethanol Long-Range Systems Analyses Spread Sheet (ELSAS)

Printed on 10/1/02

Oct-02 TMS

Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet

Basis : AEO 2002 Demand Context
ADL Feedstock Supply Curves
USDA Corn Ethanol Production Cost Survey
Various Sources for Cellulosic Ethanol Costs

Year $2000s **V 1.0 d**

Page Down for Operating Instructions

Introduction Page

Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet

Version 1.0 d
Oct-02

Contents of the Spreadsheet

This spreadsheet provides resource availability and cost information for starch-based and cellulosic-based ethanol, with separate treatments of feedstock, chemical conversion, and product finishing, from now through the year 2050. All economic data are expressed in constant Year 2000 dollars.

A system is provided for the user to make these calculations, such that a price-quantity function can be calculated for each year of interest.

Questions regarding data sources or appropriate use of the spreadsheet may be directed to:

Technology & Management Services, Inc.
Roger Le Gassie, Senior Scientist
RLeGassie@TMS-HQ.com
1-301-670-6390

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Operating Instructions

Color Coding, User Input and Default Values

Color Coding is used throughout the spreadsheet to indicate cells

that contain equations and should not be overwritten
that contain user-determined input (or default values)
that contain output results and should not be overwritten

Default Values may consist of sets of data which are used as a single unit (e.g. a World Oil Market set of assumptions) and are installed and removed as a unit

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Terminology

Prioce/cost and volume statements about ethanol are subject to possible confusion because ethanol exists in several different forms and conditions. We use the following terminology.

Ethanol as initially produced is distilled. We call this D1 ethanol. Prior to shipment, it is denatured. We call this D2 ethanol. Finally, the plantgate D2 ethanol is delivered to market. We call this D3 ethanol. It has been distilled, denatured, and delivered. Many historic estimates of ethanol economics are in the form of D1. Between D1 and D2 the volume changes, as denaturant is added. We multiply D1 volume by 1.05 to get D2 volume. The per gallon cost/price of D2 is not identical to that for D1; however, the numbers are sufficiently close (and variable because denaturant costs reflect changing world oil prices) that we treat them here as identical for simplicity. Finally, between D2 and D3 the cost/price changes. We add costs (to be established by the user) to cover transportation from plantgate to market. One set of costs relates to transportation from one region to another (e.g. Midwest corn-based ethanol moved to New England); another to distribution within a region.

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Cellulosic Focus of Study

We assume a cellulosic focus. We assume that at some point in time cellulosic ethanol becomes price competitive with starch-based ethanol. Existing starch-based plants continue to produce. However, all subsequent plants are cellulosic-based. We assume this change occurs prior to the time that new starch-based plants might be constrained by any excessive impact on food supply such as might be associated with limited crop land or unacceptably high corn prices. Therefore we do not independently estimate any limit here on starch-based capacity arising from such factors. Rather, we assume that cellulosic ethanol overtakes starch-based ethanol before such factors are significant in the analysis.

Data are presented here for two cellulosic cases. We refer to them as Reference and Aggressive respectively. It is possible to construct cases less favorable for cellulosic ethanol than the Reference case, and more favorable than the Aggressive case. However, we suggest that these two cases are enough, at the present time, to usefully show some key differences in possible future conditions. The structure of these cases is such that they may be used to create still additional cases in the future, for extended sensitivity analysis.

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Economic Incentive

Ethanol currently receives a tax credit of 53 cents per gallon. This is scheduled by law to decline to 52 cents in 2003, 51 cents in 2005, and to expire in 2007. The Energy Information Administration (EIA) assumes the incentive will be continued past this scheduled expiration point. It is an objective of the cellulosic ethanol R&D program to reduce cellulosic ethanol costs sufficiently so that economic incentives are no longer required when ethanol usage becomes very large scale. Rapid closure with market-based economics would also be possible if the value of externalities improved by cellulosic ethanol use were incorporated into market prices. In any event, we use an incentive schedule which continues past 2007, but which eventually declines to zero. The pace of decline is a unique input for each case as determined by the user.

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Starch-based Ethanol

Starch-based ethanol is assumed to be able to be represented by a market price/cost of $1.13 per gallon (D3) before subsidy in the year 2000, and $1.05 to $1.10 in later years. This recognizes both increasing starch-based capacity, as well as increasing corn prices during the period. The rising feedstock cost is offset by continuing improvement in conversion technology. Based on draft legislation for a Renewable Fuels Standard, starch-based ethanol will reach a production level of 5.0 Billion Gallons per Year (BGY) in 2012.

In any event, the crossover from starch to cellulose is assumed to occur in the 2010-2015 time period. The eventual economic target for cellulosic ethanol is assumed to be the price/cost for starch-based ethanol plus a weighted average cost for transportation from the MidWest (where most starch-based ethanol is produced) to other regions of the country (where we assume an interest in indigenous cellulosic supply will spur commercialization). This transport cost differential is given a default weighted average value of 10 cents per gallon (D3).

For simplicity, given both the longer-term focus and the cellulosic focus, we assume cellulosic ethanol becomes competitive with starch-based ethanol at $1.20 per gallon D3 at the market point of competition.

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General Disclaimer

All of the projected data are quite uncertain for a variety of reasons. In some cases we simply lack information. In other cases there are differing points of view among analysts. Finally, a 50-year time frame will contain numerous unforeseen advances in technology likely to impact these projections.

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Version History

Date	Version	Characterization
Mar-02	**1.0 a**	Original version, using February 2002 input to 2050 Study Contains calculation of Reference Case and Aggressive Case - Type 1
Mar-02	**1.0 b**	Adds calculation of Aggressive Case - Type 2 (See Aggressive Case page for explanation of terminology)
Apr-02	**1.0 c**	Continues process of increasing user flexibility in inputs through conversion cost treatment of alternative early year plant size
Oct-02	**1.0 d**	Changes early year cellulosic production schedule to be consistent with Office of Biomass Program (OBP) Metrics of August 8, 2002 Changes basis of early year cellulosic conversion costs to be consistent with NREL design studies for a 2010 operating plant at a reference cost of $1.068 per gallon ethanol (D1/D2) prior to adjustments for higher costs associated with market-entry pioneer plants. The design study is "Lignocellulosic Biomass to Ethanol Process Design and Economics", May 30,2002. Adds BioRefinery and makes Reference, Aggressive & Advanced Cases.

END

Page Down

FeedStock Page | **Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet** | **Input** **Default**

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Oct-02

Cellulosic Feedstock Availability and Cost

In the following section, the user may select input information for cellulosic feedstock supply and cost. Input data are entered in designated cells in Column H, and default data for each such cell are located in Column I. The default data may be copied over the input data entries to restore all input values to defaults by copying Column I and pasting it on Column H. Alternatively, the user may select specific cells to change, leaving others untouched.

This same process of default data storage, and user input cells matched to such storage is used throughout the spreadsheet.

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Unprocessed Data Input

Input **Default**

Source : "Aggressive Growth in the Use of Bioderived Energy and Products in the United States by 2010", Arthur D. Little (ADL), October 2001, pages 18-22 of Final Report (view-graph version)

The graphical supply curves on page 20 of the reference are estimated here visually at various prices. Based on information in a March 10, 2001 draft of the report (e.g. page 68), prices appear to be in $1999s. However, given the uncertain quality of the data, difficulty of visually reading the ADL curves, and the small value of the correction (if made), we choose simply to designate these values as presented in year $2000s.

Processing the Feedstock Data

The above Source Data must be transformed and standardized for use in the subsequent calculations. This subsection covers those preparatory steps.

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Input **Default**

User Flexibility on Feedstock Availability & Cost Input Assumptions

The user may select other values for feedstock availability, and enter them in the active table on the next page down. Default data from the ADL Study are stored in the table directly below, and may be restored to use by copying them down to the active table.

Source Data - Default
Cumulative Quantity in Millions of dry tons (mmdt) available at price stated

Feed Category	Price in $ per dry ton ($/dt) Farm gate			
	up to $20	up to $30	up to $40	up to $50
Forest Residues	**0**	**25**	**80**	**100**
Agricultural Crops Residues	**0**	**125**	**150**	**150**
Potential Energy Crops	**0**	**80**	**150**	**200**
Other Wastes	**0**	**150**	**150**	**150**

If Default values have been changed (below) and you wish to restore them, copy above values down to active area below.

Page Down

Input **Default**

Active Data - Modify Table Below As Desired
Cumulative Quantity in Millions of dry tons (mmdt) available at price stated

Feed Category	Price in $ per dry ton ($/dt) Farm gate			
	up to $20	up to $30	up to $40	up to $50
Make new entries below as desired - Default values are preserved above				
Forest Residues	**0**	**25**	**80**	**100**
Agricultural Crops Residues	**0**	**125**	**150**	**150**
Potential Energy Crops	**0**	**80**	**150**	**200**
Other Wastes	**0**	**150**	**150**	**150**

First, we add transportation from farm to conversion facility so that all Feedstock Prices are Factory gate

For		category, add		
	up to $20		$7.50	$7.50
	up to $30		$10.00	$10.00
	up to $40		$12.50	$12.50
	up to $50		$15.00	$15.00

The rationale is that, as quantities get cumulatively larger, they become more costly to collect.

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Input **Default**

Next, we need to recognize that the Category of "Other Wastes" is likely not usable at the low price indicated, because of the need to perform substantial pre-processing at additional cost before it can be used.

Recast "Other Waste"	from		to		
	up to $20	0	up to $20	0	0
	up to $30	150	up to $30	20	20
	up to $40	150	up to $40	60	60
	up to $50	150	up to $50	120	120

This action removes 30 mmdt from consideration, and distributes the remainder to higher cost categories

Next, allocate some portion of each category to biopower use, such that competition for multiple uses does not require subsequent additional consideration.

		Input	Page Down Default
Fraction of **Agricultural Crops Residues**	reserved forBioFuels	1.00	1.00
Potential Energy Crops		0.75	0.75
Other Wastes		0.50	0.50
Forest Residues		0.25	0.25

The result of these assumptions is as follows

Cumulative Quantity in Millions of dry tons (mmdt) available at price stated For BioFuels

Feed Category	**Price in $ per dry ton ($/dt) Factory gate**			
	up to ($/dt)	up to ($/dt)	up to ($/dt)	up to ($/dt)
	$27.50	$40.00	$52.50	$65.00
Agricultural Crops Residues	0.00	125.00	150.00	150.00
Potential Energy Crops	0.00	60.00	112.50	150.00
Forest & Other Wastes	0.00	16.25	50.00	85.00
Total	0.00	201.25	312.50	385.00

	Input	Page Down Default

For information the resulting availability for BioPower is as follows

Cumulative Quantity in Millions of dry tons (mmdt) available at price stated For BioPower

Feed Category	**Price in $ per dry ton ($/dt) Factory gate**			
	up to ($/dt)	up to ($/dt)	up to ($/dt)	up to ($/dt)
	$27.50	$40.00	$52.50	$65.00
Agricultural Crops Residues	0.00	0.00	0.00	0.00
Potential Energy Crops	0.00	20.00	37.50	50.00
Forest & Other Wastes	0.00	28.75	90.00	135.00
Total	0.00	48.75	127.50	185.00

The result of the allocation is shown graphically below

	Input	Page Down Default

Cumulative Quantity in Millions of dry tons (mmdt) available at price stated

Price Up To ($/dt)	BioFuels Use	BioPower Use
$27.50	0.00	0.00
$40.00	201.25	48.75
$52.50	312.50	127.50
$65.00	385.00	185.00

The default process allocates about 1/3 of the total to BioPower and about 2/3 of the total to BioFuels. This is consistent with the smaller amount of available wood residues as compared to the combined availability of agricultural crop residues and energy crops.

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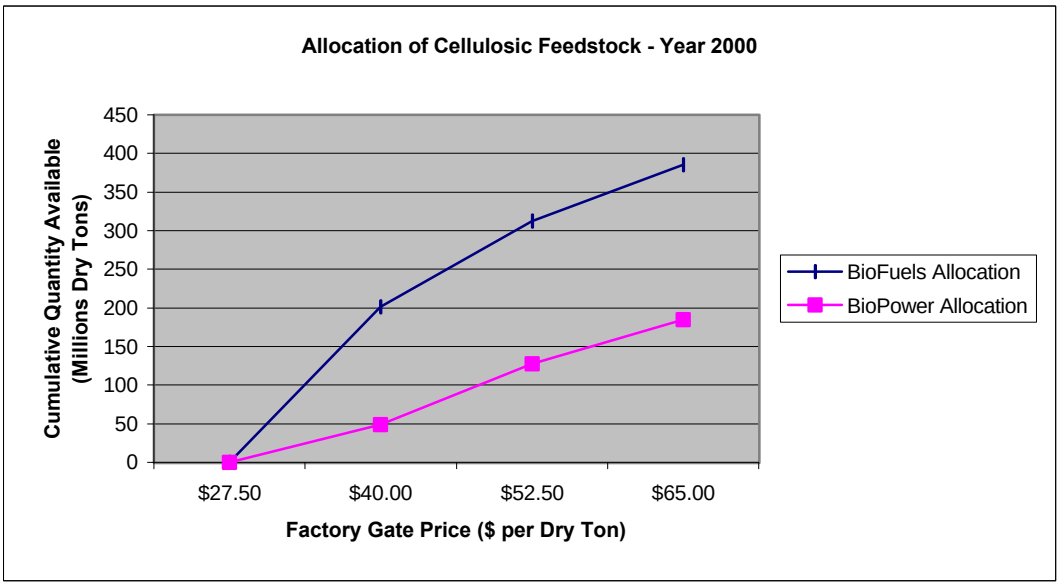
Input **Default**



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Input **Default**

Numerous references suggest that crop productivity has been increasing at 1-2 % per year, and is expected to continue to do so. Such an increase will support a continually increasing population. Accordingly, we assume that the availability of Agricultural Residues will increase by 1% annually. The user may select a different value if desired. We provide for two study cases : Reference and Aggressive. Accordingly a rate of change must be selected for each. Also, a similar choice needs to be made concerning energy crops. However, we assume a lesser rate of increase for energy crops (relative to agricultural residues) in the reference case

because large scale cultivation of energy crops (such as Switchgrass) has not yet begun, and may still be a decade or so into the future.

Reference Case	Growth Rate - %/Year	**Ag Residues**	1.00	1.00
Reference Case		**Energy Crops**	0.00	0.00
Aggressive Case		**Ag Residues**	1.00	1.00
Aggressive Case		**Energy Crops**	1.00	1.00

A 1%/y growth rate will increase availability by a factor of 1.65 over 50 years **Page Down**

Input **Default**

The Spreadsheet Calculational System uses three data inputs subsequent to this point to calculate feedstock costs :

1 Year 2000 Base Availability Table (Page Up 5 Times)
2 Case Definition (a zero entry for Reference Conditions and 1 for the Aggressive Case) - The entry is on the Calculate Page
3 Year of Calculation (with an acceptable range from 2010 through 2050) - The entry is on the Calculate Page.

The model uses items 2 & 3 above to calculate an increase factor for Ag Residues and Energy Crops relative to the Year 2000 Base Availability Table.

The model then determines how much feedstock is required in the given year by a method described on the Product Page of this Spreadsheet. The Availability Table is examined to establish the price range in which this quantity lies, and the resulting price calculated by linear interpolation within that range **Page Down**

Expanded Feedstock Availability as a Function of Date and Case Definition

	Code	Case
Case Definition from Calculate Page	1	Aggressive
Year from Calculate Page		2050

Ag Res factor over	50	years at	1.000	per year	1.645
EgyCrops factor over	50	years at	1.000	per year	1.645

Biofuels Feedstock Available in Year of Interest

Feed Category	**Price in $ per dry ton ($/dt) Factory gate**			
	up to ($/dt)	up to ($/dt)	up to ($/dt)	up to ($/dt)
	$27.50	$40.00	$52.50	$65.00
Agricultural Crops Residues	0.00	205.58	246.69	246.69
Potential Energy Crops	0.00	98.68	185.02	246.69
Forest & Other Wastes	0.00	16.25	50.00	85.00
Total	0.00	320.51	481.72	578.39

Page

Down

Feedstock

Cumulative Quantity in Millions of dry tons (mmdt) available at price stated

Price Up To ($/dt)	BioFuels Use
$27.50	0.00
$40.00	320.51
$52.50	481.72
$65.00	578.39

Above data include the expanded availability based on time and case definition

END OF SECTION

Product Cost Page | **Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet** | **Input** | **Default**

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Conversion Efficiency

The following table is based on the designated NREL cases to derive conversion efficiency (gallons ethanol D1 per dry ton feedstock). The value for 2050 considers a paper by Lee Lynd et al. "Likely Features and Costs of Mature Biomass Ethanol Technology", 1996. Lynd uses 107.7 gallons per dry ton, which is modified to 106 here to conform to the NREL estimate.

Year	Conversion Efficiency	Source	NREL Case
2008	72	NREL	I0104A
2010	89.7	NREL	I0203I
2015	98	NREL	interpolated
2020	106	NREL	J0105B
2050	106	Lynd/NREL	

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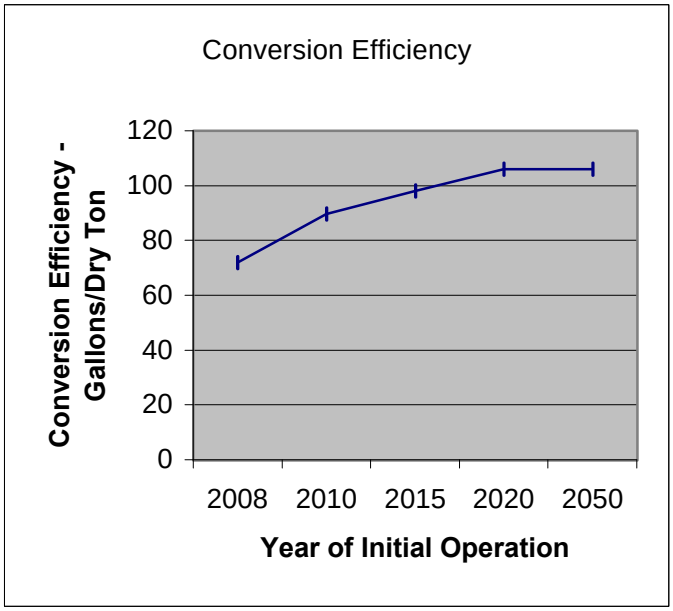
Input | **Default**

The assumption is that the efficiency changes uniformly across the intervals.



Default values are from the table directly above

2008	72	72
2010	89.7	89.7
2015	98	98
2020	106	106
2050	106	106

The graph at left reflects the user selected values

Intermediate calculations based on user input are recorded below

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Input | **Default**

User-Selected Year (Selection is made on Calculate Page) 2050

						Code	Yes or No
Year is	2010	or greater	and	less than	2015	0	No
	2015	or greater	and	less than	2020	0	No
	2020	or greater	and	less than	2050	0	No
	2050	or greater	and	less than	2051	1	Yes

Conversion Efficiency Calculation

Subtotal	0.0		Note that NREL May 30 Design		
Subtotal	0.0		Report puts theoretical yield at		
Subtotal	0.0		112.7	and that	106.0
Subtotal	106.0		is	0.94	thereof.
Total	106	gal/dt			

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Quantity of Feedstock Required — **Input** — **Default**

Based on the estimated yearly production of 58.3 BGY ethanol
as entered by the user on the Calculate Page
and the conversion efficiency of 106 gal/dt
as determined directly above
The quantity of feedstock required is 550.3 Millions of dry tons
in the year 2050

Price/Cost of Feedstock

						Code	Yes or No
Quantity is	0.00	or greater	and	less than	320.51	0	No
	320.51	or greater	and	less than	481.72	0	No
	481.72	or greater	and	less than	578.39	1	Yes
	578.39	or greater	and	less than	579.39	0	No
	Millions dry tons				Millions dry tons		

Feedstock Price/Cost	Subtotal	$0.00	
	Subtotal	$0.00	
	Subtotal	$61.37	
	Subtotal	$0.00	
	Total	$61.37	per dry ton

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Component cost of Feedstock — $0.58 — **Input** — **Default**

per gallon ethanol (D1 or D2)

Non-Feedstock Costs - Discussion

Non-feedstock costs are estimated (from referenced case data) for two time periods: "now" and "the future". Since there are many pathways to the future, the latter cost estimate is not intended to reflect a specific technology, but rather a credible economic potential for where technology development might go.

The above extreme point conditions are connected by an exponential type "learning curve" wherein the speed of change in cost from "now" to "the future" is a direct function of operating experience, I.e. the cumulative prior year production up to the point in time at which the "current" cost is being estimated.

This system requires three elements, discussed in turn below, to become operative.

Non-feedstock costs "Now"
Non-feedstock costs "In the Future"
"Learning Curve" Equation

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Non-Feedstock Costs "Now"

We use the NREL Case I0203I (May 30, 2002 Process Design Report, page 71 and Appendix D) as summarized below.

				Input	Default
Ethanol Production	69.3	Million Gallons per Year (D1)			
Ethanol Yield	89.7	Gallon per Dry US Ton			
Current Yield per Maximum	84.6	Per cent	of	106.0	
Internal Rate of Return	10	Per cent After Tax			
Equity Portion of Investment	100	Per cent			
Capital Charge Factor	0.176	Calculated			
Plant Electricity Use	1.42	Kilowatt Hours per Gallon			
Excess Electricity	2.28	Kilowatt Hours per Gallon			
Feedstock Use	0.772	Millions Dry Tons per Year (Calculated)			
Total Project Investment	$197.40	Million in $1999s			
Feedstock Cost at $30/dt	$0.334	per gallon ethanol D1/D2			
Total Cost Ethanol	$1.068	per gallon ethanol D1/D2			
Non-Feedstock Cost (Operation Year 2010, in $2000s, $/g D1/D2)				$0.734	$0.734

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Other NREL cases with different technology assumptions show both higher and lower costs for the near term. Since this analysis is directed more at the long-term, we do not view the selection of a near-term default value to be critical to the analysis. Some near term conservatism is appropriate since there are risk premiums involved in financing early-year plants which are not explicitly accounted for in these NREL technology cost estimations.

Input **Default**

Non-Feedstock Costs "In the Future"

We use the Lee Lynd 1996 paper referred to in the Conversion Efficiency section above. "Advanced Technology Case". (Note: A lower cost "Best Parameter Case" is not used)

Ethanol Production	295	Million Gallons per Year (D1)
Ethanol Yield	107.7	Gallon per Dry US Ton
Capital Recovery Factor	0.20	
Internal Rate of Return	10	Per cent After Tax
Plant Electricity Use	0.71	Kilowatt Hours per Gallon
Excess Electricity	3.06	Kilowatt Hours per Gallon
Feedstock Use	7501	Dry tons per day (Calculated)
Total Project Investment	$268.4	Million in $1994s

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	Input	Default
Non-Feedstock Cost (Future Operation Year in $2000s $/g D1/D2)	$0.160	$0.160

Plant Size

"Now" Early Year Plants are likely to be of small size (to reduce both market and investment risk). NREL studies suggest an exponent for scaling of about 0.72.

The user may modify this value (in the area to the right). 0.72 0.72
Since the default size (start of learning) is about 2000 tons feedstock per day, a smaller plant size will increase initial cost. Choose an initial plant size in dry tons feed stock per day (in the area to the right) 2000 2000
The scaling factor is applied only to the capital cost component, which is about 70 per cent of total non-feedstock costs for early year plants. Because of the smaller plant size, there is an assumed offset to operating cost associated with reduced feedstock transportation costs or other favorable entry condition.

Suggested alternative levels relative to the default value of 2000 are initial sizes of 1000 or 1500. This raises the initial 2010 estimate of non-feedstock costs (based on user input below) as follows: **Page Down**

		Input	**Default**
2010 Total Cost ($/g) for default size	0.734		
2010 Capital Component at 70% of above ($/g)	0.514		
2010 Operating Component at 30% of above ($/g)	0.220		
Reduced Feedstock Cost Offset for small plant ($/gallon per 500 ton per day reduction in size)		$0.05	$0.05
Scaling factor (selected previously)	0.720		

Market and performance risks also tend to increase financing and other costs for early-year plants. These risks can be modeled by multiplying capital cost estimates by an appropriate factor. However, risks should be perceived as being less for a smaller plant (which has already incurred a size premium).

2010 Premium Risk Factor for	1000	t/d plant	1.10	1.10
	1500		1.20	1.20
	2000		1.30	1.30

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Input	**Default**

The resulting final value for the selected size early year (2010) plant is as follows

Plant Size Dry Tons per Day	Non-Feed Stock Costs Dollars per Gallon (D1)	Selected Size and Cost
1000	1.051	0.000
1500	0.929	0.000
2000	0.888	0.888
Selected		0.888

Future

Plant sizes in the future are not specific to technology. Hence, there is no modification of the final minimum non-feedstock component in the future.

Recapitulation of Learning Curve Extremes

Learning Curve "Now" ($/g D1)	0.888	"Future" ($/g D1)	0.160

	Input	Page Down Default
Transportation Costs		
Between Regions (e.g. corn ethanol to East and West Coast markets)	$0.10	$0.10
Within Region (e.g. Plant Gate to Distribution Center)	$0.04	$0.04

BioRefinery Simulation

If turned on, Biorefinery Simulation assumes a preselected fraction of the otherwise total ethanol cost (including feedstock) is credited to biorefinery co-products

Reference

Credit fraction in year is shown to the right

Applicable Value

Year	Value
2050	0.20

		Page Down
2015	0.00	0.00
2020	0.10	0.10
2025	0.15	0.15
2030	0.20	0.20
2035	0.20	0.20
2040	0.20	0.20
2045	0.20	0.20
2050	0.20	0.20

Aggressive

Credit fraction in year is shown to the right

Applicable Value

Year	Value
2050	0.30

2015	0.00	0.00
2020	0.15	0.15
2025	0.20	0.20
2030	0.25	0.25
2035	0.30	0.30
2040	0.30	0.30
2045	0.30	0.30
2050	0.30	0.30

	Input	Default
Learning Curve Equation		

To be added

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Cumulative Prior Production of Cellulosic Ethanol **Input** **Default**

Office of Biomass Program (OBP) Metrics uses the following default estimates of near-term capacity and production - The User can select different values in Column H

Fiscal Year	Product in BGY	Cum Prod Thru Year
2004	0.000	0.000
2005	0.010	0.010
2006	0.150	0.160
2007	0.300	0.460
2008	0.450	0.910
2009	0.650	1.560
2010	0.850	2.410

Fiscal Year	Product in BGY	Product in BGY
2004	0.000	0.000
2005	0.010	0.010
2006	0.150	0.150
2007	0.300	0.300
2008	0.450	0.450
2009	0.650	0.650
2010	0.850	0.850

Results

Preliminary Estimate of Non-feedstock component of ethanol (D1)

-$0.740

Final Estimate of Non-feedstock component of ethanol (D1)

(Higher of $0.16 or Preliminary Estimate)

$0.160

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Input **Default**

END OF SECTION

Demand Page

Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet

Input **Default**

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Source data are from ESAS MultiYear Value Curves July 01
are added from AEO 2002 as of 1/23/02

Basis is AEO 99 in 1997 $s

	AEO 99	Pages A1	Pages A11		AEO 2002	AEO 2002	AEO 2002	AEO 2002
					$2000s	$2000s	$2000s	$2000s
	Reference	Price	MoGas		Price	MoGas	Price	MoGas
	Year	$/bbl	Mil B/d		$/bbl	Mil B/d	$/bbl	Mil B/d
	2000	13.97	8.59	AEO Data	Reference	Reference	High	High
Exp Interp	2001	14.90	8.74					
Exp Interp	2002	15.88	8.89					
Exp Interp	2003	16.93	9.05					
Exp Interp	2004	18.05	9.21					
	2005	19.25	9.37	AEO Data				
	2006	19.64	9.49					
	2007	20.05	9.62					
	2008	20.46	9.75					
	2009	20.87	9.88					
	2010	21.30	10.01	AEO Data	23.36	10.32	30.01	10.18
	2011	21.42	10.08					
	2012	21.54	10.14					
	2013	21.66	10.21					
	2014	21.79	10.27					
	2015	21.91	10.34	AEO Data	24.00	11.13	30.44	10.92
	2016	22.07	10.41					
	2017	22.23	10.48					
	2018	22.40	10.55					
	2019	22.56	10.62					
	2020	22.73	10.69	AEO Data	24.68	11.81	30.58	11.54
	2021	22.90	10.76					
	2022	23.07	10.83					
	2023	23.24	10.91					
	2024	23.41	10.98					
	2025	23.58	11.05		25.38	12.53	30.72	12.20

Next data set is from ESAS Regional Value Curves May 00.xls

Year 2006 All Production of Ethanol is Indigenous
1997 $s

Table 2 is Table 1 rounded to nearest cent
Consumer Demand Curves -- Totals (billion gallons)

c / g	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5	Total
36	4.65	4.20	2.25	0.48	1.76	13.33

Table 2

37	4.63	4.20	2.24	0.48	1.76	13.31
38	4.62	4.20	2.23	0.48	1.76	13.29
39	4.59	4.20	2.22	0.48	1.76	13.25
40	4.57	4.19	2.21	0.48	1.76	13.21
41	4.54	4.18	2.21	0.48	1.76	13.17
42	4.53	4.18	2.20	0.48	1.76	13.14
43	4.53	4.15	2.20	0.48	1.76	13.12
44	4.51	4.13	2.19	0.48	1.76	13.08
45	4.47	4.10	2.17	0.47	1.76	12.98
46	4.45	4.10	2.17	0.47	1.75	12.93
47	4.43	4.08	2.16	0.47	1.73	12.87
48	4.42	4.07	2.15	0.47	1.71	12.81
49	4.40	4.06	2.14	0.47	1.69	12.75
50	4.35	4.02	2.11	0.46	1.67	12.62
51	4.32	4.01	2.10	0.46	1.65	12.54
52	4.30	3.99	2.09	0.46	1.63	12.47
53	4.29	3.97	2.08	0.46	1.61	12.41
54	4.25	3.95	2.06	0.45	1.59	12.31
55	4.20	3.93	2.03	0.44	1.57	12.16
56	4.19	3.92	2.03	0.44	1.55	12.14
57	4.11	3.89	1.98	0.43	1.52	11.93
58	3.89	3.83	1.86	0.41	1.48	11.48
59	3.64	3.77	1.74	0.39	1.44	11.00
60	3.50	3.74	1.67	0.38	1.42	10.71
61	3.45	3.66	1.65	0.38	1.39	10.53
62	3.37	3.45	1.62	0.36	1.35	10.15
63	3.33	3.35	1.60	0.35	1.32	9.96
64	2.98	3.30	1.47	0.34	1.30	9.40
65	2.82	3.16	1.40	0.33	1.28	8.99
66	2.55	2.98	1.27	0.30	1.23	8.33
67	2.16	2.79	1.08	0.27	1.17	7.47
68	1.98	2.62	1.01	0.26	1.14	7.01
69	1.96	2.54	1.00	0.25	1.12	6.86
70	1.95	2.17	0.99	0.23	1.07	6.42
71	1.89	1.90	0.96	0.21	1.04	6.00
72	1.83	1.68	0.91	0.19	0.99	5.60
73	1.76	1.48	0.85	0.16	0.94	5.19
74	1.65	1.29	0.77	0.13	0.89	4.74
75	1.33	1.22	0.63	0.11	0.85	4.14
76	1.27	1.11	0.60	0.10	0.82	3.90
77	1.25	1.01	0.58	0.09	0.80	3.72
78	1.15	0.94	0.53	0.08	0.77	3.46
79	1.04	0.89	0.48	0.07	0.74	3.22
80	0.99	0.84	0.45	0.07	0.72	3.06
81	0.92	0.79	0.42	0.06	0.70	2.89
82	0.89	0.79	0.41	0.06	0.68	2.83
83	0.86	0.76	0.40	0.06	0.67	2.76
84	0.80	0.75	0.38	0.06	0.65	2.65
85	0.73	0.75	0.35	0.06	0.63	2.52
86	0.66	0.75	0.33	0.06	0.62	2.42
87	0.63	0.75	0.31	0.06	0.60	2.35

	88	0.61	0.71	0.30	0.06	0.58	2.27
	89	0.58	0.67	0.28	0.05	0.56	2.14
	90	0.57	0.66	0.27	0.05	0.54	2.08
	91	0.55	0.64	0.26	0.04	0.52	2.00
	92	0.52	0.61	0.24	0.04	0.49	1.89
	93	0.51	0.59	0.23	0.03	0.47	1.84
	94	0.48	0.57	0.21	0.03	0.45	1.74
	95	0.47	0.56	0.20	0.03	0.43	1.70
	96	0.44	0.55	0.19	0.03	0.42	1.62
	97	0.39	0.54	0.18	0.03	0.40	1.54
	98	0.36	0.53	0.17	0.03	0.39	1.48
	99	0.34	0.52	0.16	0.03	0.37	1.44
	100	0.33	0.52	0.16	0.03	0.36	1.40
	101	0.32	0.49	0.15	0.03	0.34	1.34
	102	0.28	0.43	0.12	0.02	0.31	1.17
	103	0.22	0.35	0.09	0.01	0.29	0.96
	104	0.15	0.28	0.05	0.01	0.27	0.76
	105	0.06	0.24	0.02	0.01	0.25	0.59
	106	0.02	0.22	0.01	0.01	0.24	0.49
	107	0.00	0.22	0.00	0.01	0.22	0.45
based on	108	0.00	0.15	0.00	0.00	0.15	0.29
PADD 1	109	0.00	0.06	0.00	0.00	0.06	0.12
	110	0.00	0.02	0.00	0.00	0.02	0.04
TMS	111	0.00	0.00	0.00	0.00	0.00	0.00
Extrapolati	112	0.00	0.00	0.00	0.00	0.00	0.00

Move Price by Price Ratio (Base Year to New Year)
and Corresponding Quantity by MoGas Ratio
This automatically moves year $s to $2000s
Also Adust for Price and Volume data from AEO 2002

Reference Case

$1997s	1.019
$2000s	1.061

2010 **REF**	c/g	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5	Total	c/g
	42.81	5.05	4.57	2.44	0.52	1.92	14.49	
	44.00	5.03	4.56	2.43	0.52	1.92	14.47	
	45.19	5.02	4.56	2.43	0.52	1.92	14.45	
	46.38	4.99	4.56	2.42	0.52	1.92	14.40	
	47.57	4.96	4.56	2.41	0.52	1.92	14.36	
	48.76	4.94	4.55	2.40	0.52	1.92	14.32	
	49.95	4.92	4.54	2.39	0.52	1.92	14.29	
	51.14	4.92	4.51	2.39	0.52	1.92	14.26	
	52.32	4.90	4.49	2.38	0.52	1.92	14.22	
	53.51	4.86	4.46	2.36	0.51	1.91	14.11	
	54.70	4.83	4.45	2.35	0.51	1.90	14.05	
	55.89	4.81	4.44	2.35	0.51	1.88	13.99	
	57.08	4.80	4.42	2.34	0.51	1.86	13.93	
	58.27	4.78	4.41	2.33	0.51	1.84	13.86	
	59.46	4.72	4.37	2.30	0.50	1.82	13.71	

60.65	4.69	4.36	2.28	0.50	1.79	13.63
61.84	4.67	4.34	2.27	0.50	1.78	13.55
63.03	4.66	4.32	2.26	0.50	1.76	13.49
64.22	4.62	4.29	2.24	0.49	1.73	13.38
65.41	4.56	4.27	2.20	0.48	1.71	13.22
66.59	4.56	4.26	2.20	0.48	1.69	13.20
67.78	4.46	4.23	2.15	0.47	1.66	12.97
68.97	4.23	4.16	2.03	0.45	1.61	12.48
70.16	3.96	4.10	1.89	0.43	1.57	11.95
71.35	3.80	4.07	1.82	0.42	1.54	11.64
72.54	3.74	3.98	1.79	0.41	1.51	11.44
73.73	3.67	3.75	1.76	0.39	1.47	11.03
74.92	3.62	3.65	1.74	0.38	1.44	10.83
76.11	3.24	3.59	1.60	0.37	1.42	10.21
77.30	3.06	3.44	1.52	0.36	1.39	9.77
78.49	2.77	3.24	1.38	0.33	1.33	9.05
79.68	2.35	3.03	1.17	0.29	1.27	8.12
80.87	2.16	2.85	1.09	0.28	1.24	7.62
82.05	2.13	2.76	1.08	0.27	1.21	7.46
83.24	2.12	2.35	1.08	0.25	1.17	6.97
84.43	2.06	2.06	1.04	0.23	1.13	6.52
85.62	1.98	1.83	0.99	0.20	1.08	6.08
86.81	1.91	1.60	0.93	0.17	1.02	5.64
88.00	1.79	1.41	0.84	0.14	0.97	5.15
89.19	1.44	1.33	0.68	0.12	0.93	4.50
90.38	1.38	1.21	0.65	0.11	0.89	4.24
91.57	1.35	1.10	0.63	0.10	0.86	4.04
92.76	1.25	1.02	0.57	0.09	0.83	3.77
93.95	1.13	0.97	0.52	0.08	0.81	3.50
95.14	1.07	0.91	0.49	0.07	0.78	3.33
96.32	1.00	0.86	0.46	0.07	0.76	3.14
97.51	0.97	0.86	0.45	0.07	0.74	3.08
98.70	0.94	0.83	0.44	0.07	0.72	3.00
99.89	0.87	0.82	0.41	0.07	0.71	2.88
101.08	0.79	0.82	0.38	0.07	0.69	2.74
102.27	0.72	0.82	0.35	0.07	0.67	2.63
103.46	0.69	0.81	0.34	0.07	0.65	2.55
104.65	0.67	0.77	0.33	0.06	0.63	2.46
105.84	0.63	0.73	0.30	0.05	0.60	2.33
107.03	0.62	0.71	0.29	0.05	0.58	2.27
108.22	0.60	0.69	0.28	0.05	0.56	2.18
109.41	0.57	0.66	0.26	0.04	0.54	2.06
110.59	0.56	0.64	0.25	0.04	0.52	2.00
111.78	0.52	0.61	0.23	0.03	0.49	1.89
112.97	0.51	0.61	0.22	0.03	0.47	1.84
114.16	0.48	0.60	0.21	0.03	0.45	1.77
115.35	0.43	0.59	0.19	0.03	0.44	1.68
116.54	0.39	0.58	0.18	0.03	0.42	1.61
117.73	0.37	0.57	0.18	0.03	0.41	1.56
118.92	0.36	0.57	0.17	0.04	0.39	1.53
120.11	0.35	0.53	0.17	0.03	0.37	1.46

121.30	0.30	0.47	0.13	0.02	0.34	1.27
122.49	0.24	0.38	0.09	0.01	0.31	1.04
123.68	0.16	0.30	0.06	0.01	0.29	0.82
124.87	0.07	0.27	0.02	0.01	0.27	0.64
126.05	0.02	0.24	0.01	0.01	0.26	0.54
127.24	0.00	0.24	0.00	0.01	0.24	0.49
128.43	0.00	0.16	0.00	0.00	0.16	0.32
129.62	0.00	0.07	0.00	0.00	0.07	0.13
130.81	0.00	0.02	0.00	0.00	0.02	0.04
132.00	0.00	0.00	0.00	0.00	0.00	0.00
133.19	0.00	0.00	0.00	0.00	0.00	0.00

2015

REF	c/g	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5	Total
	43.98	5.45	4.92	2.63	0.56	2.07	15.63
	45.21	5.43	4.92	2.62	0.56	2.07	15.60
	46.43	5.41	4.92	2.62	0.56	2.07	15.58
	47.65	5.38	4.92	2.61	0.56	2.07	15.54
	48.87	5.35	4.91	2.60	0.56	2.07	15.49
	50.09	5.33	4.91	2.59	0.56	2.07	15.44
	51.31	5.31	4.90	2.58	0.56	2.07	15.41
	52.54	5.31	4.87	2.58	0.56	2.07	15.38
	53.76	5.29	4.85	2.57	0.56	2.07	15.33
	54.98	5.24	4.81	2.55	0.55	2.06	15.21
	56.20	5.21	4.80	2.54	0.55	2.05	15.15
	57.42	5.19	4.79	2.53	0.55	2.03	15.09
	58.65	5.18	4.77	2.52	0.55	2.01	15.02
	59.87	5.15	4.76	2.51	0.55	1.98	14.95
	61.09	5.09	4.72	2.48	0.54	1.96	14.79
	62.31	5.06	4.71	2.46	0.54	1.93	14.70
	63.53	5.04	4.68	2.45	0.54	1.91	14.62
	64.75	5.03	4.66	2.44	0.54	1.89	14.55
	65.98	4.99	4.63	2.42	0.53	1.87	14.43
	67.20	4.92	4.60	2.38	0.52	1.84	14.26
	68.42	4.92	4.60	2.38	0.52	1.82	14.23
	69.64	4.81	4.56	2.32	0.51	1.79	13.99
	70.86	4.56	4.49	2.19	0.48	1.74	13.46
	72.08	4.27	4.42	2.04	0.46	1.69	12.89
	73.31	4.10	4.39	1.96	0.45	1.66	12.56
	74.53	4.04	4.29	1.93	0.44	1.63	12.34
	75.75	3.95	4.04	1.90	0.42	1.59	11.90
	76.97	3.91	3.93	1.88	0.41	1.55	11.67
	78.19	3.49	3.87	1.72	0.40	1.53	11.02
	79.42	3.30	3.71	1.64	0.39	1.50	10.54
	80.64	2.99	3.49	1.49	0.36	1.44	9.76
	81.86	2.53	3.27	1.27	0.32	1.37	8.76
	83.08	2.33	3.08	1.18	0.30	1.34	8.22
	84.30	2.30	2.98	1.17	0.30	1.31	8.04
	85.52	2.29	2.54	1.16	0.27	1.26	7.52
	86.75	2.22	2.22	1.13	0.25	1.21	7.03
	87.97	2.14	1.97	1.07	0.22	1.16	6.56

89.19	2.06	1.73	1.00	0.19	1.10	6.08
90.41	1.93	1.52	0.91	0.15	1.05	5.55
91.63	1.56	1.43	0.73	0.13	1.00	4.85
92.85	1.49	1.30	0.70	0.12	0.96	4.57
94.08	1.46	1.18	0.68	0.10	0.93	4.36
95.30	1.35	1.10	0.62	0.09	0.90	4.06
96.52	1.22	1.04	0.56	0.08	0.87	3.77
97.74	1.16	0.98	0.53	0.08	0.85	3.59
98.96	1.08	0.93	0.49	0.07	0.82	3.39
100.19	1.05	0.92	0.48	0.07	0.80	3.32
101.41	1.01	0.89	0.47	0.07	0.78	3.23
102.63	0.94	0.88	0.44	0.07	0.76	3.10
103.85	0.85	0.88	0.41	0.07	0.74	2.96
105.07	0.77	0.88	0.38	0.07	0.72	2.83
106.29	0.74	0.87	0.37	0.07	0.70	2.75
107.52	0.72	0.83	0.35	0.07	0.68	2.66
108.74	0.68	0.79	0.33	0.06	0.65	2.51
109.96	0.67	0.77	0.32	0.05	0.63	2.44
111.18	0.65	0.74	0.30	0.05	0.60	2.35
112.40	0.61	0.71	0.28	0.04	0.58	2.22
113.62	0.60	0.69	0.27	0.04	0.56	2.15
114.85	0.56	0.66	0.25	0.04	0.53	2.04
116.07	0.55	0.66	0.24	0.03	0.51	1.99
117.29	0.51	0.64	0.22	0.03	0.49	1.90
118.51	0.46	0.63	0.21	0.03	0.47	1.81
119.73	0.42	0.62	0.20	0.04	0.46	1.73
120.96	0.40	0.61	0.19	0.04	0.44	1.69
122.18	0.39	0.61	0.19	0.04	0.42	1.65
123.40	0.38	0.58	0.18	0.04	0.40	1.57
124.62	0.32	0.51	0.14	0.02	0.37	1.37
125.84	0.26	0.41	0.10	0.02	0.34	1.12
127.06	0.17	0.32	0.06	0.01	0.31	0.89
128.29	0.07	0.29	0.03	0.01	0.30	0.69
129.51	0.02	0.26	0.01	0.01	0.28	0.58
130.73	0.00	0.26	0.00	0.01	0.26	0.53
131.95	0.00	0.17	0.00	0.00	0.17	0.34
133.17	0.00	0.07	0.00	0.00	0.07	0.14
134.40	0.00	0.02	0.00	0.00	0.02	0.04
135.62	0.00	0.00	0.00	0.00	0.00	0.00
136.84	0.00	0.00	0.00	0.00	0.00	0.00

2020

REF	c/g	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5	Total
	45.23	5.78	5.22	2.79	0.59	2.19	16.58
	46.49	5.76	5.22	2.78	0.59	2.19	16.55
	47.74	5.74	5.22	2.78	0.59	2.19	16.53
	49.00	5.71	5.22	2.77	0.59	2.19	16.48
	50.26	5.68	5.21	2.75	0.59	2.19	16.43
	51.51	5.65	5.21	2.74	0.59	2.19	16.39
	52.77	5.63	5.19	2.74	0.59	2.19	16.35
	54.02	5.63	5.16	2.74	0.59	2.19	16.32

55.28	5.61	5.14	2.73	0.59	2.19	16.27
56.54	5.56	5.10	2.70	0.59	2.19	16.14
57.79	5.53	5.10	2.69	0.59	2.17	16.08
59.05	5.51	5.08	2.68	0.59	2.15	16.01
60.31	5.49	5.06	2.67	0.58	2.13	15.94
61.56	5.47	5.05	2.66	0.58	2.10	15.86
62.82	5.41	5.01	2.63	0.58	2.08	15.70
64.08	5.37	4.99	2.61	0.57	2.05	15.60
65.33	5.35	4.96	2.60	0.57	2.03	15.51
66.59	5.33	4.94	2.59	0.57	2.01	15.44
67.85	5.29	4.91	2.56	0.56	1.98	15.31
69.10	5.22	4.88	2.52	0.55	1.95	15.13
70.36	5.22	4.88	2.52	0.55	1.93	15.10
71.61	5.11	4.84	2.46	0.54	1.89	14.84
72.87	4.84	4.76	2.32	0.51	1.84	14.28
74.13	4.53	4.69	2.17	0.49	1.80	13.68
75.38	4.35	4.65	2.08	0.48	1.76	13.32
76.64	4.29	4.55	2.05	0.47	1.73	13.09
77.90	4.20	4.29	2.01	0.44	1.68	12.62
79.15	4.15	4.17	1.99	0.43	1.65	12.39
80.41	3.71	4.10	1.83	0.43	1.62	11.69
81.67	3.50	3.94	1.74	0.41	1.59	11.18
82.92	3.17	3.71	1.58	0.38	1.53	10.36
84.18	2.69	3.47	1.34	0.34	1.46	9.29
85.43	2.47	3.26	1.25	0.32	1.42	8.72
86.69	2.44	3.16	1.24	0.31	1.39	8.53
87.95	2.43	2.69	1.23	0.29	1.34	7.98
89.20	2.36	2.36	1.19	0.26	1.29	7.46
90.46	2.27	2.09	1.13	0.23	1.23	6.96
91.72	2.19	1.84	1.06	0.20	1.17	6.46
92.97	2.05	1.61	0.96	0.16	1.11	5.89
94.23	1.65	1.52	0.78	0.14	1.06	5.15
95.49	1.58	1.38	0.74	0.12	1.02	4.85
96.74	1.55	1.26	0.72	0.11	0.99	4.63
98.00	1.43	1.17	0.66	0.10	0.95	4.31
99.25	1.29	1.11	0.59	0.09	0.92	4.00
100.51	1.23	1.04	0.56	0.08	0.90	3.81
101.77	1.14	0.98	0.52	0.08	0.87	3.59
103.02	1.11	0.98	0.51	0.08	0.85	3.53
104.28	1.08	0.95	0.50	0.08	0.83	3.43
105.54	1.00	0.94	0.47	0.08	0.81	3.29
106.79	0.90	0.94	0.44	0.08	0.79	3.14
108.05	0.82	0.94	0.40	0.08	0.77	3.01
109.31	0.78	0.93	0.39	0.08	0.75	2.92
110.56	0.76	0.89	0.38	0.07	0.72	2.82
111.82	0.73	0.84	0.35	0.06	0.69	2.66
113.08	0.71	0.82	0.34	0.06	0.67	2.59
114.33	0.69	0.79	0.32	0.05	0.64	2.49
115.59	0.65	0.75	0.29	0.05	0.61	2.35
116.84	0.64	0.73	0.29	0.04	0.59	2.29
118.10	0.60	0.70	0.26	0.04	0.56	2.17

119.36	0.58	0.70	0.25	0.04	0.54	2.11
120.61	0.54	0.68	0.24	0.03	0.52	2.02
121.87	0.49	0.67	0.22	0.04	0.50	1.92
123.13	0.45	0.66	0.21	0.04	0.48	1.84
124.38	0.43	0.65	0.20	0.04	0.47	1.79
125.64	0.41	0.65	0.20	0.04	0.45	1.75
126.90	0.40	0.61	0.19	0.04	0.42	1.67
128.15	0.34	0.54	0.15	0.03	0.39	1.45
129.41	0.27	0.43	0.11	0.02	0.36	1.19
130.66	0.18	0.34	0.07	0.01	0.33	0.94
131.92	0.08	0.30	0.03	0.01	0.31	0.73
133.18	0.02	0.28	0.01	0.01	0.29	0.61
134.43	0.00	0.27	0.00	0.01	0.27	0.56
135.69	0.00	0.18	0.00	0.00	0.18	0.36
136.95	0.00	0.08	0.00	0.00	0.08	0.15
138.20	0.00	0.02	0.00	0.00	0.02	0.05
139.46	0.00	0.00	0.00	0.00	0.00	0.00
140.72	0.00	0.00	0.00	0.00	0.00	0.00

2025

REF	c/g	PADD 1	PADD 2	PADD 3	PADD 4	PADD 5	Total
	46.51	6.13	5.54	2.96	0.63	2.33	17.60
	47.80	6.11	5.54	2.95	0.63	2.33	17.57
	49.10	6.09	5.54	2.95	0.63	2.33	17.54
	50.39	6.06	5.54	2.93	0.63	2.33	17.49
	51.68	6.03	5.53	2.92	0.63	2.33	17.44
	52.97	6.00	5.52	2.91	0.63	2.33	17.39
	54.26	5.98	5.51	2.90	0.63	2.33	17.35
	55.56	5.97	5.48	2.90	0.63	2.33	17.31
	56.85	5.95	5.46	2.90	0.63	2.33	17.26
	58.14	5.90	5.41	2.87	0.62	2.32	17.13
	59.43	5.87	5.41	2.86	0.62	2.30	17.06
	60.72	5.85	5.39	2.85	0.62	2.28	16.99
	62.02	5.83	5.37	2.84	0.62	2.26	16.91
	63.31	5.80	5.35	2.82	0.62	2.23	16.83
	64.60	5.74	5.31	2.79	0.61	2.21	16.65
	65.89	5.70	5.30	2.77	0.61	2.18	16.55
	67.18	5.67	5.27	2.76	0.61	2.16	16.46
	68.48	5.66	5.24	2.75	0.60	2.13	16.38
	69.77	5.62	5.21	2.72	0.60	2.10	16.25
	71.06	5.54	5.18	2.68	0.59	2.07	16.05
	72.35	5.54	5.18	2.68	0.59	2.05	16.02
	73.64	5.42	5.14	2.61	0.57	2.01	15.75
	74.94	5.14	5.05	2.46	0.54	1.96	15.15
	76.23	4.81	4.98	2.30	0.52	1.91	14.52
	77.52	4.61	4.94	2.21	0.51	1.87	14.14
	78.81	4.55	4.83	2.18	0.50	1.84	13.89
	80.10	4.45	4.55	2.13	0.47	1.79	13.39
	81.40	4.40	4.43	2.11	0.46	1.75	13.15
	82.69	3.93	4.36	1.94	0.45	1.72	12.40
	83.98	3.72	4.18	1.85	0.44	1.68	11.87

85.27	3.36	3.93	1.67	0.40	1.62	10.99
86.56	2.85	3.68	1.42	0.36	1.54	9.86
87.86	2.62	3.46	1.33	0.34	1.50	9.25
89.15	2.59	3.35	1.31	0.33	1.47	9.06
90.44	2.58	2.86	1.31	0.30	1.42	8.47
91.73	2.50	2.50	1.27	0.28	1.37	7.92
93.02	2.41	2.22	1.20	0.25	1.31	7.39
94.32	2.32	1.95	1.12	0.21	1.24	6.85
95.61	2.17	1.71	1.02	0.17	1.18	6.25
96.90	1.75	1.61	0.83	0.15	1.13	5.46
98.19	1.68	1.47	0.79	0.13	1.09	5.15
99.48	1.65	1.33	0.76	0.12	1.05	4.91
100.78	1.52	1.24	0.70	0.10	1.01	4.57
102.07	1.37	1.18	0.63	0.09	0.98	4.25
103.36	1.30	1.10	0.60	0.09	0.95	4.04
104.65	1.21	1.04	0.56	0.08	0.92	3.81
105.94	1.18	1.04	0.54	0.08	0.90	3.74
107.24	1.14	1.01	0.53	0.08	0.88	3.64
108.53	1.06	0.99	0.50	0.08	0.86	3.49
109.82	0.96	0.99	0.46	0.08	0.84	3.33
111.11	0.87	0.99	0.43	0.08	0.82	3.19
112.40	0.83	0.98	0.41	0.08	0.79	3.10
113.69	0.81	0.94	0.40	0.08	0.77	2.99
114.99	0.77	0.89	0.37	0.07	0.73	2.83
116.28	0.76	0.87	0.36	0.06	0.71	2.75
117.57	0.73	0.84	0.34	0.06	0.68	2.64
118.86	0.69	0.80	0.31	0.05	0.65	2.50
120.15	0.68	0.78	0.30	0.05	0.63	2.43
121.45	0.64	0.75	0.28	0.04	0.60	2.30
122.74	0.62	0.74	0.27	0.04	0.57	2.24
124.03	0.58	0.73	0.25	0.04	0.55	2.14
125.32	0.52	0.71	0.23	0.04	0.53	2.04
126.61	0.47	0.70	0.22	0.04	0.51	1.95
127.91	0.45	0.69	0.22	0.04	0.49	1.90
129.20	0.44	0.69	0.21	0.04	0.47	1.85
130.49	0.43	0.65	0.20	0.04	0.45	1.77
131.78	0.37	0.57	0.16	0.03	0.41	1.54
133.07	0.29	0.46	0.12	0.02	0.38	1.26
134.37	0.19	0.36	0.07	0.01	0.35	1.00
135.66	0.08	0.32	0.03	0.01	0.33	0.78
136.95	0.02	0.29	0.01	0.01	0.31	0.65
138.24	0.00	0.29	0.00	0.01	0.29	0.59
139.53	0.00	0.19	0.00	0.00	0.19	0.39
140.83	0.00	0.08	0.00	0.00	0.08	0.16
142.12	0.00	0.02	0.00	0.00	0.02	0.05
143.41	0.00	0.00	0.00	0.00	0.00	0.00
144.70	0.00	0.00	0.00	0.00	0.00	0.00

Calculation Page | **Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet** | **Printed on 10/1/02**

Version 1.0 d
Oct-02

Overview

User Inputs are entered in the color-coded cells to the left below

Key final results are reported in the color-coded cells to the right below

Intermediate results can be viewed beside and below the data entry area

All entries refer to cellulosic ethanol only. All ethanol quantities are billion gallons per year. All Feedstock quantities are millions of dry tons. All unit prices are dollars per gallon for liquids, and dollars per dry ton for solids.

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User Inputs - Make Entries Here

Year	2050
Ethanol Production in that Year (D3)	58.33
Cumulative Ethanol Production in Prior Years (D3)	920.4
Case - Enter 0 for Reference and 1 for Aggressive	1

The Aggressive case increases availability of energy crops and speeds cost reduction achieved through R&D and learning

Case - Enter 1 for BioRefinery Sim, or 0 for None	1

Key Final Results Directly Below

Feedstock Price	$61.37	$/dt
Ethanol Cost (D3)	$0.56	$/gal

Intermediate Results Below this Section

Conversion Efficiency	106	gal/dt
Feedstock as a component of ethanol cost	$0.58	$/gal
Non-Feedstock component of ethanol cost	$0.16	$/gal
BioRefinery Credit	$0.22	
Total Ethanol (D1/D2)	$0.52	$/gal
Total Ethanol (D3)	$0.56	

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Intermediate Results

To Be Added

Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet

Version 1.0 d
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To Be Completed

Reference Case Page **Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet** **Printed on 10/1/02**

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Use ESAS MultiYear Value Curves Jan 02 for Demand Values

Start with 0.850 BGY Cellulosic Ethanol in 2010
Based on Niche Feedstocks and Demo Plant Subsidies rather than Market Economics
Assume Ref World Oil & Reference Ethanol Cases

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result
0	2010	2.410	0.85	$1.23	No new cellulosic capacity
0	2011	3.260	0.85	$1.21	No new cellulosic capacity
0	2012	4.110	1.25	$1.20	Add cap - eq pt w/corn is $1.20
0	2013	5.360	1.85	$1.19	Continue

The 2010 starting conditions above (prior & current production) are fixed by OBP Metrics. Subsequent entries are results of trials from Calculate Page

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Above calculation establishes 2012 as year to initiate competitive cellulosic capacity
Starch-based capacity at that point is 5.0 BGY (See paragraph on starch-based ethanol on Intro Page)

Use Demand Value Curve for 2012 data point to estimate total ethanol market
Find a cross-over point where cost of production less incentive level matches demand value

Assume total of $1.19 with subsidy at approx 36 cents - Calc Pdn at 83 cents

Year	Quantity	
2010	7.00	from curve
2014	7.96	interpolated
2015	8.20	from curve

This is presently a trial and error, repetitive calculation in which we assume various subsidy levels in order to get a reasonable product increment

In 2014	Sources	Quantity	
	Starch	5.00	
	Prev Cell	1.85	
	New Cell	1.11	by difference
		7.96	

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We now reprise the prior results and locate the crossover point for 2015

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result
0	2010	2.41	0.85	$1.23	No new cellulosic capacity
0	2011	3.26	0.85	$1.21	No new cellulosic capacity
0	2012	4.11	1.25	$1.20	50% growth from cellulosic base
0	2013	5.36	1.85	$1.19	50% growth from prior cellulosic

0	2014	7.21	2.96	$1.19	Subsidy @ $0.36
0	2015	10.17	4.10	$1.17	Subsidy @ $0.36

This is presently a trial and
error, repetitive calculation
in which we assume various
subsidy levels in order to get
a reasonable product increment

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We now explore means to estimate 2020

Industry (starch-based and cellulosic ethanol) production has been projected as

growing from		1.60	BGY in	2000
to		6.25	bgy in	2012
	a factor of	1.12	per year cumulatively	

Based on draft RFS schedule of 4.3 BGY in 2010

Industry production growth (including starch-based) is projected above at

going from		5.15	BGY in	2010
to		9.10	BGY in	2015
	a factor of	1.12	per year cumulatively	

There is no need to stay with annual calculational intervals - Move to 5 year spaces

Assume a yearly growth factor of	1.05	because of approach to blend saturation		
Yields a 5-year factor of	1.276	or	11.6	BGY
This requires (from 2020 curve)		a cost of	$0.80	per gal

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Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2015	10.17	4.10	$1.17	Incentiv @	$0.36	previous
0	2016	14.27	4.60				
0	2017	18.87	5.11				
0	2018	23.98	5.61				
0	2019	29.59	6.11				
0	2020	35.70	6.61	$1.08	Incentiv @	$0.28	target

Assume a growth factor of	1.05			
Yields a 5-year factor of	1.276	or	14.8	BGY
This requires (from 2025 curve)		a cost of	$0.72	per gal

0	2020	35.7	6.61	$1.08	Incentiv @	$0.28	previous
0	2021	42.3	7.26				
0	2022	49.6	7.90				
0	2023	57.5	8.54				

0	2024	66.0	9.18					
0	2025	75.2	9.82	$1.00	Incentiv @	$0.28	target	**Page Down**

Assume a growth factor of	1.05		
Yields a 5-year factor of	1.276	or	18.9 BGY
		a cost of	$0.70 per gal

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2025	75.2	9.82	$1.00	Incentiv @	$0.28	previous
0	2026	85.0	10.64				
0	2027	95.7	11.46				
0	2028	107.1	12.28				
0	2029	119.4	13.10				
0	2030	132.5	13.92	$0.93	Incentiv @	$0.23	target

At price/costs of around 65 cents, in the post 2025 time frame E 85 use should be feasible

Assume a growth factor of	1.10		
Yields a 5-year factor of	1.611	or	30.5 BGY
		a cost of	$0.65 per gal

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Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2030	132.5	13.92	$0.93	Incentiv @	$0.23	previous
0	2031	146.4	16.23				
0	2032	162.6	18.54				
0	2033	181.2	20.85				
0	2034	202.0	23.16				
0	2035	225.2	25.47	$0.86	Incentiv @	$0.21	target

Assume a growth factor of	1.05		
Yields a 5-year factor of	1.276	or	38.9 BGY
		a cost of	$0.65 per gal

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2035	225.2	25.47	$0.86	Incentiv @	$0.21	previous
0	2036	250.7	27.15				
0	2037	277.8	28.19				
0	2038	306.0	29.23				
0	2039	335.2	30.27				
0	2040	365.5	33.89	$0.77	Incentiv @	$0.12	target

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Growth rates were slowed again as we began to reach limits of economic feedstock
E 85 usage should now remain economic, even with slowly rising feedstock costs,
because of slowly rising world oil prices

Assume a growth factor of	1.02

	Yields a 5-year factor of			1.104	or	42.9	BGY
					a cost of	$0.65	per gal

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2040	365.5	33.89	$0.77	Incentiv @	$0.12	previous
0	2041	399.4	34.70				
0	2042	434.1	35.50				
0	2043	469.6	36.31				
0	2044	505.9	37.12				
0	2045	543.0	37.93	$0.66	Incentiv @	$0.01	target

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	Assume a growth factor of			1.00			
	Yields a 5-year factor of			1.000	or	42.9	BGY
					a cost of	$0.65	per gal

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2045	543.0	37.93	$0.66	Incentiv @	$0.01	previous
0	2046	581.0	37.93				
0	2047	618.9	37.93				
0	2048	656.8	37.93				
0	2049	694.8	37.93				
0	2050	732.7	37.93	$0.65	Incentiv @	$0.00	target

Next we summarize these results graphically

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Reference Case Summary

	Year	Cell Pdn BGY	Idy Growth Rate Factor	Eth Mkt Price ($/g)	Incentive $/gal	Cell Pdn Cost ($/g)	Cum Prior Cell BGY
Blend	2010	0.85	1.12			$1.23	2.4
Blend	2015	4.10	1.12	$0.81	$0.36	$1.17	10.2
Blend	2020	6.61	1.05	$0.80	$0.28	$1.08	35.7
Blend	2025	9.82	1.05	$0.72	$0.28	$1.00	75.2
Blend	2030	13.92	1.05	$0.70	$0.23	$0.93	132.5
E 85	2035	25.47	1.10	$0.65	$0.21	$0.86	225.2
E 85	2040	33.89	1.05	$0.65	$0.12	$0.77	365.5
E 85	2045	37.93	1.02	$0.65	$0.01	$0.66	543.0
E 85	2050	37.93	1.00	$0.65	$0.00	$0.65	732.7

Note 1: Total Ethanol Production includes 5.0 BGY of starch-based in addition to Cellulosic

Note 2: Industry growth rate factors include starch-based, and are for the prior time increment ending

in the year cited - they are annual compound rates

Note 3: Ethanol Market Price is at distributed location, and the point of economic competition between starch-based & cellulosic ethanol

Note 4: Cumulative prior years production is for cellulosic only

Note 5: Cellulosic production rate declines as it saturates blend market, increases again as it enters & grows in E 85 market, then slows as economic limits are reached

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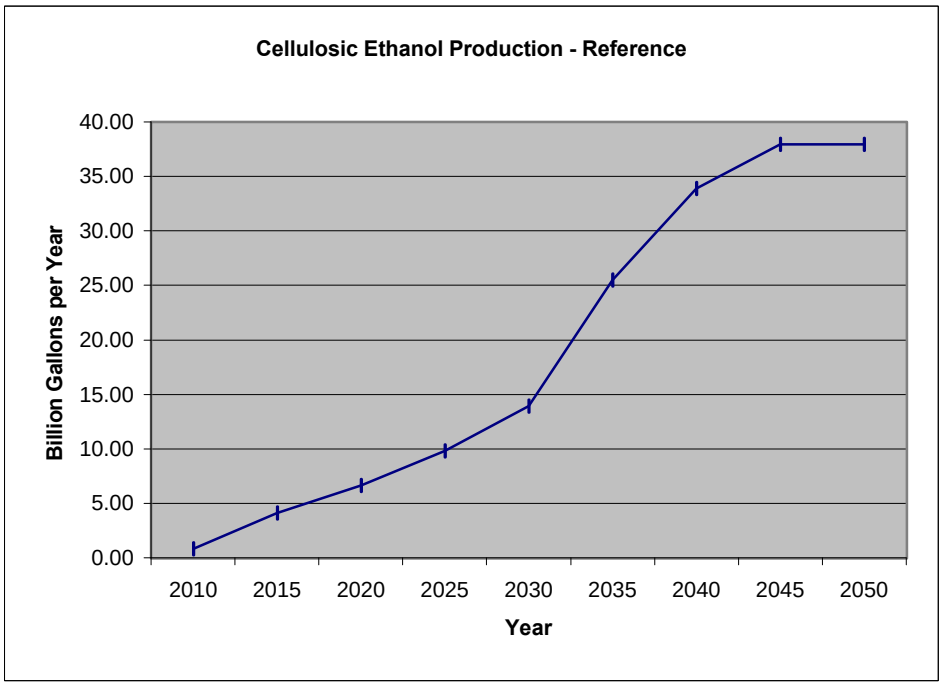

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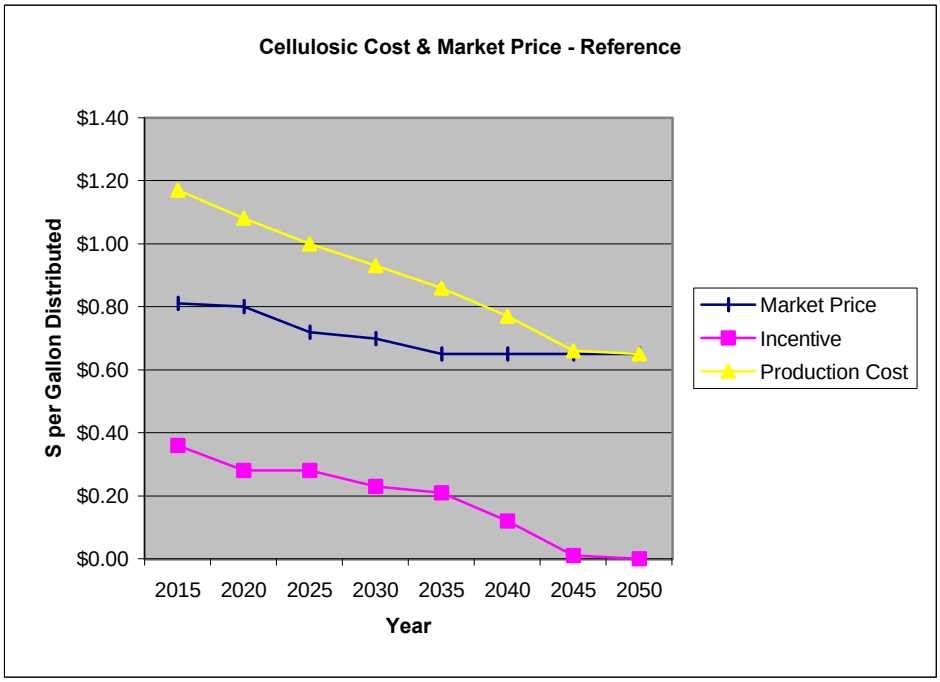

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Reference Case - Advanced Version - Includes BioRefinery Simulation

In 2015 Case results are identical to Standard Reference Case because Biorefinery economic impacts are not present in 2015

In 2020	Assume a yearly growth factor of	1.075				
	Yields a 5-year factor of	1.436	or	13.1	BGY	
	This requires (from 2020 curve)		a cost of	$0.77	per gal	

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2015	10.17	4.10	$1.17	Incentiv @	$0.36	previous
0	2016	14.27	4.89				
0	2017	19.16	5.69				
0	2018	24.85	6.48				
0	2019	31.33	7.27				
0	2020	38.60	8.06	$0.97	Incentiv @	$0.20	target

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In 2025	Assume a yearly growth factor of	1.050					
	Yields a 5-year factor of	1.276	or	16.7	BGY		
	This requires (from 2020 curve)		a cost of	$0.65	per gal	(E85 Use)	

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2020	38.60	8.06	$0.97	Incentiv @	$0.20	previous
0	2021	46.66	8.79				
0	2022	55.45	9.51				
0	2023	64.96	10.23				
0	2024	75.19	10.95				
0	2025	86.14	11.67	$0.85	Incentiv @	$0.20	target

In 2030	Assume a yearly growth factor of	1.075			
	Yields a 5-year factor of	1.436	or	23.9	BGY
	This requires (from 2020 curve)		a cost of	$0.65	per gal

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Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2025	86.1	11.67	$0.85	Incentiv @	$0.20	previous
0	2026	97.8	13.13				
0	2027	110.9	14.58				
0	2028	125.5	16.03				
0	2029	141.5	17.48				
0	2030	159.0	18.94	$0.74	Incentiv @	$0.09	target

In 2035	Assume a yearly growth factor of	1.075			
	Yields a 5-year factor of	1.436	or	34.4	BGY
	This requires (from 2020 curve)		a cost of	$0.65	per gal

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result			
0	2030	159.0	18.94	$0.74	Incentiv @	$0.09	previous	
0	2031	178.0	21.02					
0	2032	199.0	23.11					
0	2033	222.1	25.19					
0	2034	247.3	27.28					**Page**
0	2035	274.6	29.36	$0.67	Incentiv @	$0.02	target	**Down**

In 2040	Assume a yearly growth factor of	1.05			
	Yields a 5-year factor of	1.276	or	43.9	BGY
	This requires (from 2020 curve)		a cost of	$0.65	per gal

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2035	274.6	29.36	$0.67	Incentiv @	$0.02	previous
0	2036	303.9	31.26				
0	2037	335.2	33.16				
0	2038	368.4	35.06				
0	2039	403.4	36.96				
0	2040	440.4	38.86	$0.61	Incentiv @	$0.00	target

In 2045	Assume a yearly growth factor of	1.03			
	Yields a 5-year factor of	1.159	or	50.8	BGY
	This requires (from 2020 curve)		a cost of	$0.65	per gal

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Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
0	2040	440.4	38.86	$0.61	Incentiv @	$0.00	previous
0	2041	479.2	40.26				
0	2042	519.5	41.65				
0	2043	561.2	43.05				
0	2044	604.2	44.45				
0	2045	648.7	45.84	$0.61	Incentiv @	$0.00	target

In 2050	Assume a yearly growth factor of	1.01			
	Yields a 5-year factor of	1.051	or	53.4	BGY
	This requires (from 2020 curve)		a cost of	$0.65	per gal

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result			
0	2045	648.7	45.84	$0.61	Incentiv @	$0.00	previous	
0	2046	694.5	46.36					
0	2047	740.9	47.76					
0	2048	788.6	49.16					
0	2049	837.8	50.56					**Page**
0	2050	888.3	48.44	$0.63	Incentiv @	$0.00	target	**Down**

Reference Case Advanced Version Summary

	Year	Cell Pdn BGY	Idy Growth Rate Factor	Eth Mkt Price ($/g)	Incentive $/gal	Cell Pdn Cost ($/g)	Cum Prior Cell BGY
Blend	2010	0.85	1.12			$1.23	2.4
Blend	2015	4.10	1.12	$0.81	$0.36	$1.17	10.2
Blend	2020	8.06	1.075	$0.77	$0.20	$0.97	38.6
E85	2025	11.67	1.05	$0.65	$0.20	$0.85	86.1
E85	2030	18.94	1.075	$0.65	$0.09	$0.74	159.0
E 85	2035	29.36	1.075	$0.65	$0.02	$0.67	274.6
E 85	2040	38.86	1.05	$0.61	$0.00	$0.61	440.4
E 85	2045	45.84	1.03	$0.61	$0.00	$0.61	648.7
E 85	2050	48.44	1.01	$0.63	$0.00	$0.63	888.3

Note 1: Total Ethanol Production includes 5.0 BGY of starch-based in addition to Cellulosic

Note 2: Industry growth rate factors include starch-based, and are for the prior time increment ending in the year cited - they are annual compound rates

Note 3: Ethanol Market Price is at distributed location, and the point of economic competition between starch-based & cellulosic ethanol

Note 4: Cumulative prior years production is for cellulosic only

Note 5: Cellulosic production rate declines as it saturates blend market, increases again as it enters & grows in E 85 market, then slows as economic limits are reached

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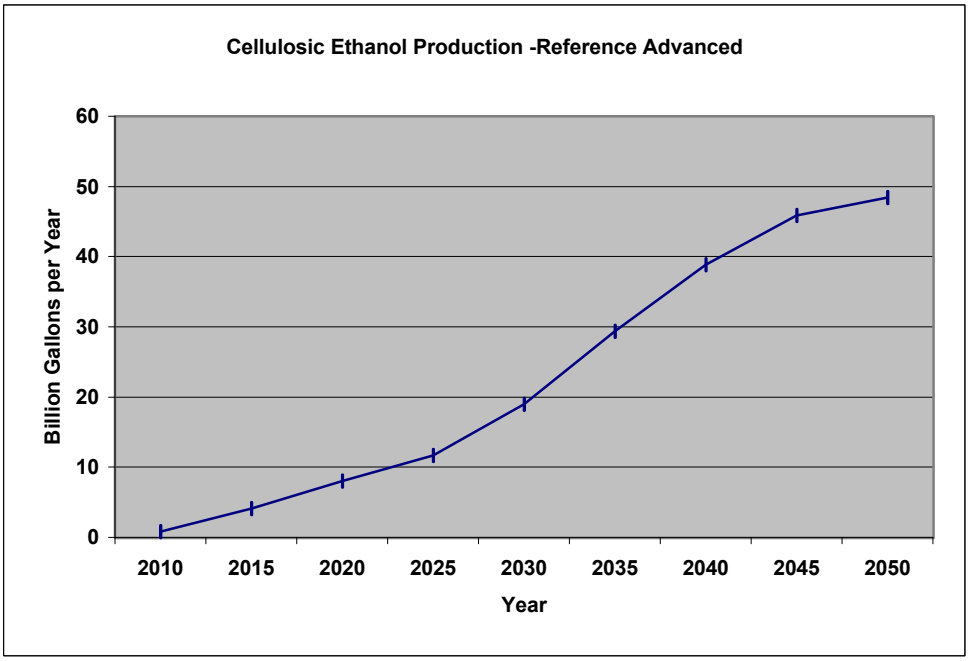

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Data for Production Comparison		
2010	0.85	0.85
2015	4.10	4.10
2020	6.61	8.06
2025	9.82	11.67
2030	13.92	18.94
2035	25.47	29.36
2040	33.89	38.86
2045	37.93	45.84
2050	37.93	48.44

Data for Incentive Comparison
and Market Price Comparison

	Incentive		Market Price	
2015	$0.36	$0.36	$0.81	$0.81
2020	$0.28	$0.20	$0.80	$0.77
2025	$0.28	$0.20	$0.72	$0.65
2030	$0.23	$0.09	$0.70	$0.65
2035	$0.21	$0.02	$0.65	$0.65
2040	$0.12	$0.00	$0.65	$0.61
2045	$0.01	$0.00	$0.65	$0.61
2050	$0.00	$0.00	$0.65	$0.63

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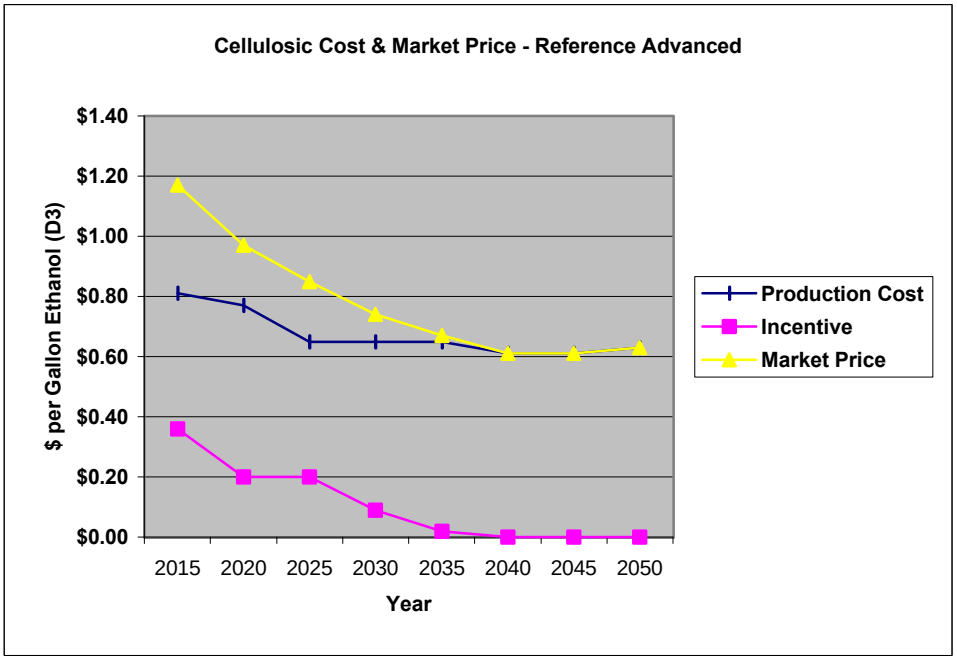

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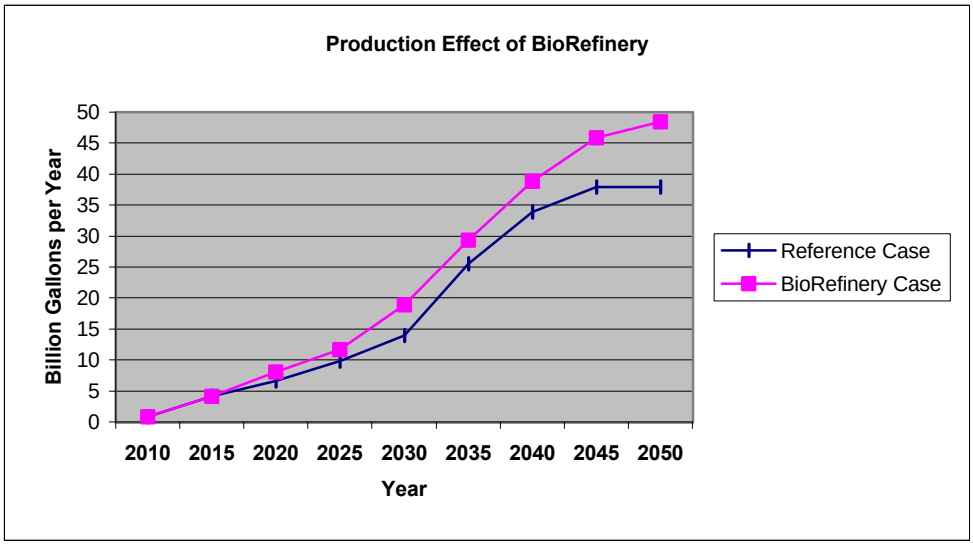

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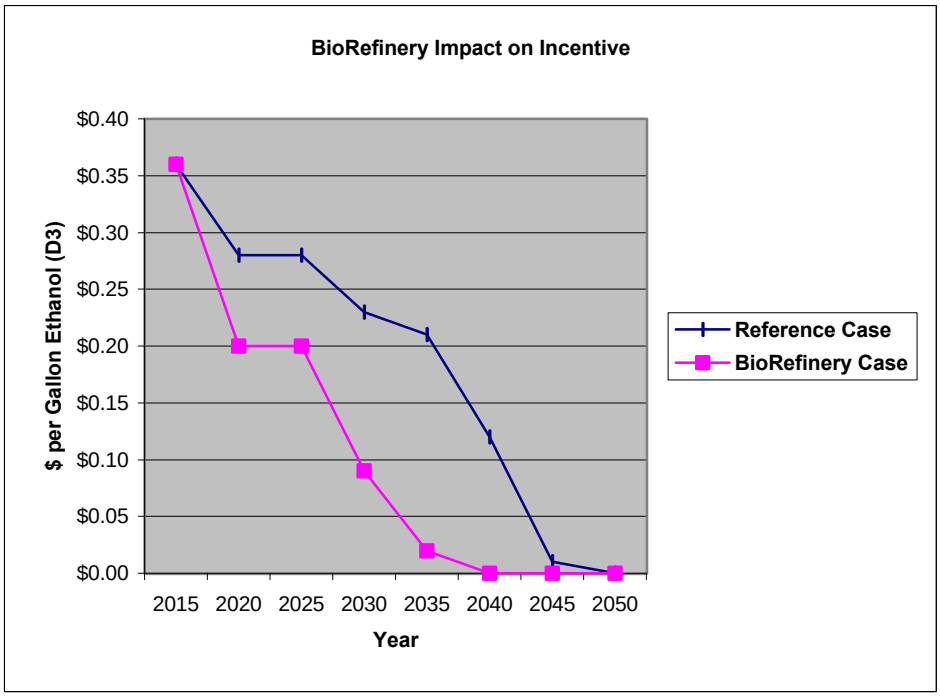

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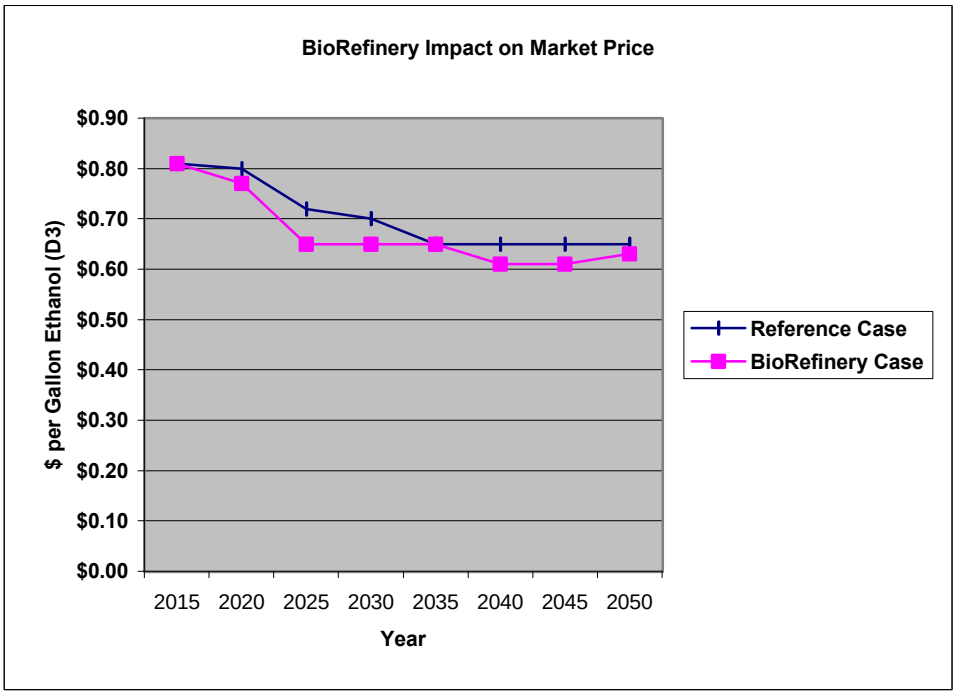

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Case Conclusions

BioRefinery Simulation Leads to
Increased Production & Use
at Similar Market Prices

E85 10 Years Earlier
Hence Increased Benefits
But Reduced Incentive Costs

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Aggressive Case Page **Ethanol Industry Evolution Long-Range Systems Analysis Spreadsheet** **Printed on 10/1/02**

Version 1.0 d
Oct-02

Overview

The Theory of the Aggressive Case is that 1) More aggressive R&D expenditures result in faster progress down the learning curve (This is modeled by changing the exponent of the learning curve equation) and a biorefinery with more value in co-products, and 2) Greater quantities of feedstock become availble by virtue of an increase in the growth factor for Energy Crops (and AgResidues if the user decides to include these as well). Both of these factors improve mid-term economics - The second also provides a modest improvement in long-term economics. The BioRefinery is only in the Advanced Version.

There are at least two types of Aggressive Cases

The first simply repeats the capacity/production schedule of the Reference Case, but adjusts the incentive level so as to maintain supply/demand balance. The value of the case is measured by a resulting reduction in incentive levels.

The second type of Aggressive Case is created from the ground up in the same way as a Reference Case. Its value is measured by a greater level of ethanol use.

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Aggressive Case - Type 1

We copy over here the results from the previous Reference Case

Reference Case Summary

	Year	Cell Pdn BGY	Idy Growth Rate Factor	Eth Mkt Price ($/g)	Incentive $/gal	Cell Pdn Cost ($/g)	Cum Prior Cell BGY
Blend	2010	0.85	1.12			$1.23	2.41
Blend	2015	4.10	1.12	$0.81	$0.36	$1.17	10.17
Blend	2020	6.61	1.05	$0.80	$0.28	$1.08	35.70
Blend	2025	9.82	1.05	$0.72	$0.28	$1.00	75.19
Blend	2030	13.92	1.05	$0.70	$0.23	$0.93	132.49
E 85	2035	25.47	1.10	$0.65	$0.21	$0.86	225.18
E 85	2040	33.89	1.05	$0.65	$0.12	$0.77	365.50
E 85	2045	37.93	1.02	$0.65	$0.01	$0.66	543.02
E 85	2050	37.93	1.00	$0.65	$0.00	$0.65	732.69

Next we reenter the inputs under Aggressive Case conditions, and calculate a revised result for cellulosic production cost. We then determined the revised incentive level to maintain the same supply/demand crossover. This base case and its comparison excludes any biorefinery.

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Reference and Aggressive Case Comparisons

Year	Cell Pdn BGY	Cum Prior Cell BGY	Both Cases Eth Mkt Price ($/g)	Ref Case Cell Pdn Cost ($/g)	Ref Case Incentive $/gal	Agg Case Incentive $/gal	Agg Case Cell Pdn Cost ($/g)	Reduction in Incentive $/gallon
2010	0.85	2.4		$1.23			$1.22	
2015	4.10	10.2	$0.81	$1.17	$0.36	$0.35	$1.16	$0.01
2020	6.61	35.7	$0.80	$1.08	$0.28	$0.23	$1.03	$0.05
2025	9.82	75.2	$0.72	$1.00	$0.28	$0.19	$0.91	$0.09
2030	13.92	132.5	$0.70	$0.93	$0.23	$0.08	$0.78	$0.15
2035	25.47	225.2	$0.65	$0.86	$0.21	$0.00	$0.63	$0.21
2040	33.89	365.5	$0.65	$0.77	$0.12	$0.00	$0.60	$0.12
2045	37.93	543.0	$0.65	$0.66	$0.01	$0.00	$0.62	$0.01
2050	37.93	732.7	$0.65	$0.65	$0.00	$0.00	$0.60	$0.00

This type of case is simple and quick to calculate, but conservative in the sense that lower long-term costs should actually produce higher long-term growth in the period in which incentives no longer apply

Below, we display graphically dome key elements of this case

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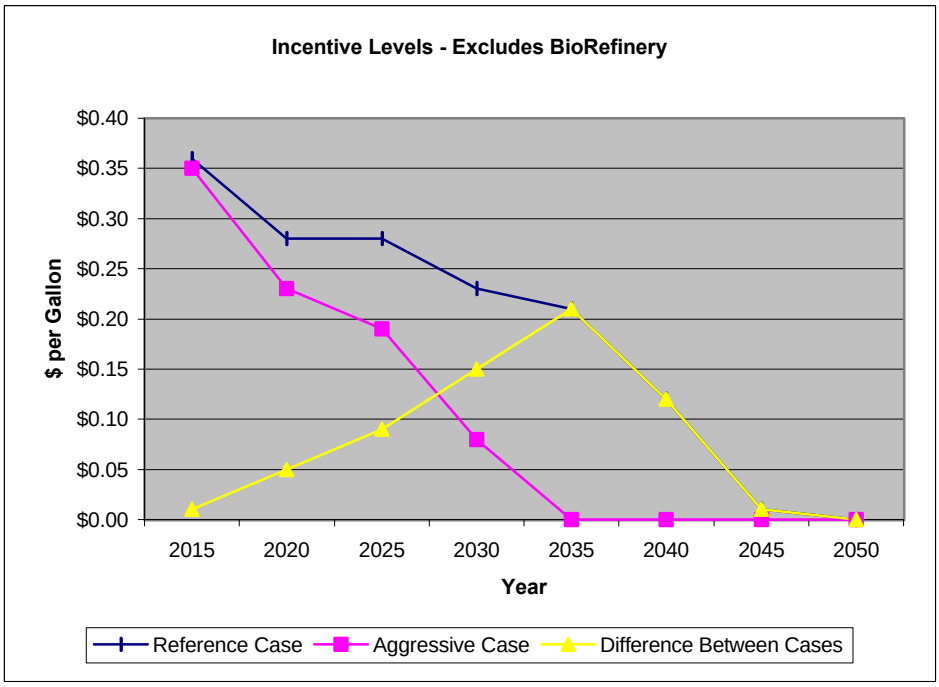

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Aggressive Case - Type 2 - Advanced Version Including BioRefinery

Now we calculate the Aggressive Case analog of the Reference Case. Our analysis assumes Advanced Version conditions (Includes BioRefinery). This is a Type 2 comparison because it includes a market crossover optimization for each time period identically to the Reference Case Advanced Version.

For simplicity, we start from the 2015 Aggressive Case Type 1 result directly above.

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
1	2015	10.2	4.1	$1.16	Incentiv @	$0.35	
	Previous growth factor was			1.12	Production	9.10	
	Assume a growth factor of			1.07			
	Yields a 5-year factor of			1.403	or	12.8	BGY
	This requires (from 2020 curve)				a cost of	$0.77	per gal

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Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
1	2015	10.2	4.10	$1.16	Incentiv @	$0.35	previous
1	2016	14.3	4.83				
1	2017	19.1	5.57				
1	2018	24.7	6.30				
1	2019	31.0	7.03				
1	2020	38.0	7.76	$0.88	Incentiv @	$0.11	target
	Assume a growth factor of			1.05			
	Yields a 5-year factor of			1.276	or	16.3	BGY
	This requires (from 2025 curve)				a cost of	$0.70	per gal

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
1	2020	38.0	7.76	$0.88	Incentiv @	$0.11	previous
1	2021	45.8	8.47				
1	2022	54.2	9.17				
1	2023	63.4	9.88				
1	2024	73.3	10.58				
1	2025	83.9	11.29	$0.72	Incentiv @	$0.02	target

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	Assume a growth factor of			1.07			
	Yields a 5-year factor of			1.403	or	22.8	BGY
					a cost of	$0.65	per gal (E 85)

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
1	2025	83.9	11.29	$0.72	Incentiv @	$0.02	previous
1	2026	95.2	12.60				
1	2027	107.8	13.91				
1	2028	121.7	15.22				
1	2029	136.9	16.54				
1	2030	153.4	17.85	$0.57	Incentiv @	$0.00	target

Assume a growth factor of				1.07			
Yields a 5-year factor of				1.403	or	32.0	BGY

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Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
1	2030	153.4	17.85	$0.57	Incentiv @	$0.00	previous
1	2031	171.3	19.69				
1	2032	191.0	21.53				
1	2033	212.5	23.37				
1	2034	235.9	25.20				
1	2035	261.1	27.04	$0.41	Incentiv @	$0.00	target

Assume a growth factor of				1.07			
Yields a 5-year factor of				1.403	or	44.9	BGY

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
1	2035	261.1	27.04	$0.41	Incentiv @	$0.00	previous
1	2036	288.1	29.62				
1	2037	317.7	32.20				
1	2038	349.9	34.78				
1	2039	384.7	37.36				
1	2040	422.1	39.94	$0.46	Incentiv @	$0.00	target

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Assume a growth factor of				1.05			
Yields a 5-year factor of				1.276	or	57.4	BGY

Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
1	2040	422.1	39.94	$0.46	Incentiv @	$0.00	previous
1	2041	462.0	42.43				
1	2042	504.4	44.91				
1	2043	549.4	47.39				
1	2044	596.7	49.88				
1	2045	646.6	52.36	$0.53	Incentiv @	$0.00	target

Rate of growth is being slowed because of nearing of economic & resource limits

Assume a growth factor of				1.02			
Yields a 5-year factor of				1.104	or	63.3	BGY

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Case	Year	Prior Yr Cum Pdn	Cur Pdn	Eth Cost $/g	Result		
1	2045	646.6	52.36	$0.53	Incentiv @	$0.00	previous
1	2046	699.0	53.55				
1	2047	752.5	54.75				
1	2048	807.3	55.94				
1	2049	863.2	57.14				
1	2050	920.4	58.33	$0.56	Incentiv @	$0.00	target

Next we summarize these results graphically

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Aggressive Case Type 2 Advanced Version Summary (Includes BioRefinery)

	Year	Cell Pdn BGY	Idy Growth Rate Factor	Eth Mkt Price ($/g)	Incentive $/gal	Cell Pdn Cost ($/g)	Cum Prior Cell BGY
Blend	2010	0.85	1.12			$1.23	2.4
Blend	2015	4.10	1.12	$0.81	$0.35	$1.16	10.2
Blend	2020	7.76	1.07	$0.77	$0.11	$0.88	38.0
Blend	2025	11.29	1.05	$0.70	$0.02	$0.72	83.9
E 85	2030	17.85	1.07	$0.57	$0.00	$0.57	153.4
E 85	2035	27.04	1.07	$0.41	$0.00	$0.41	261.1
E 85	2040	39.94	1.07	$0.46	$0.00	$0.46	422.1
E 85	2045	52.36	1.05	$0.53	$0.00	$0.53	646.6
E 85	2050	58.33	1.02	$0.56	$0.00	$0.56	920.4

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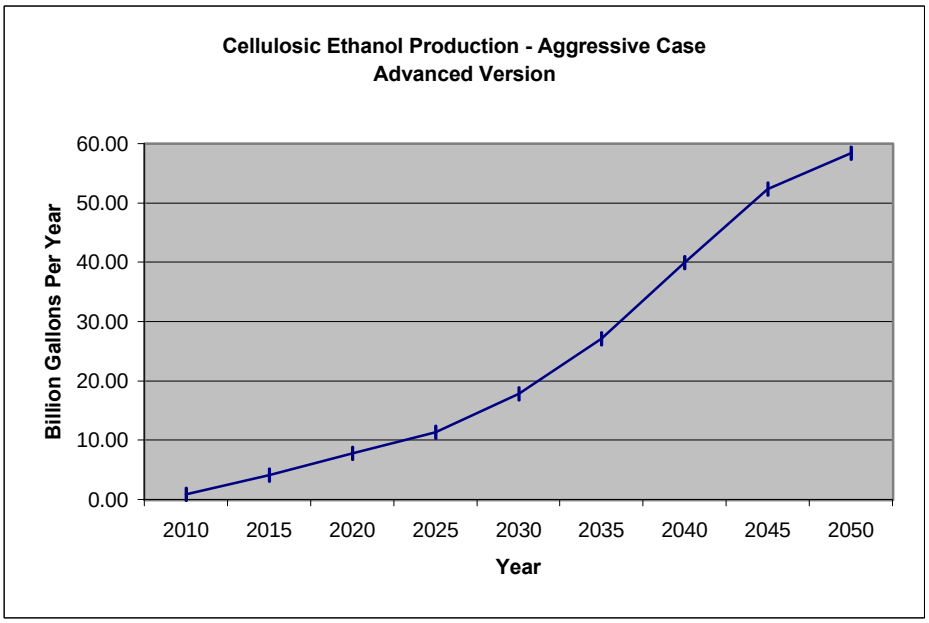

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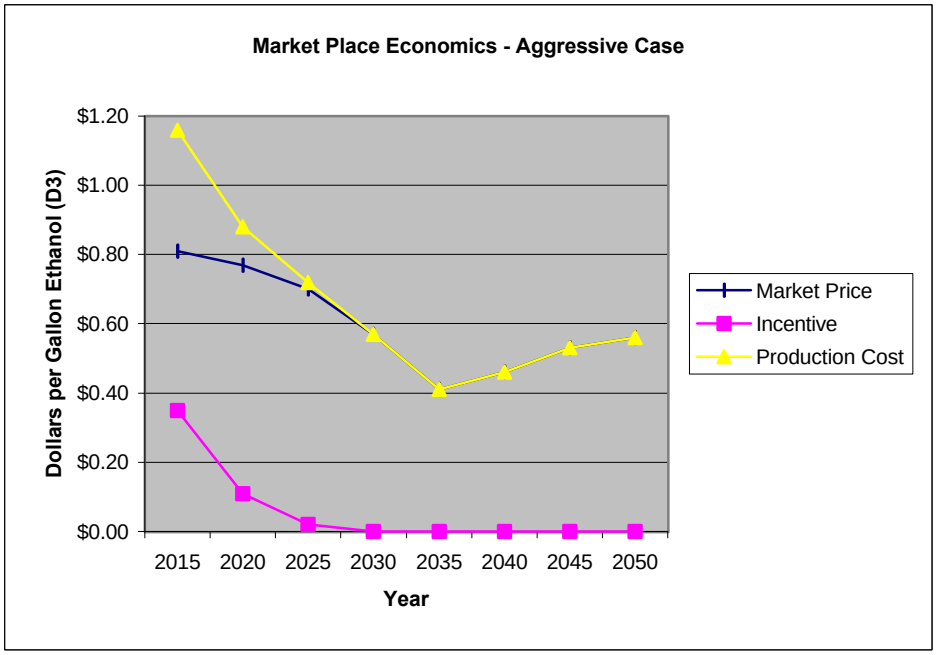

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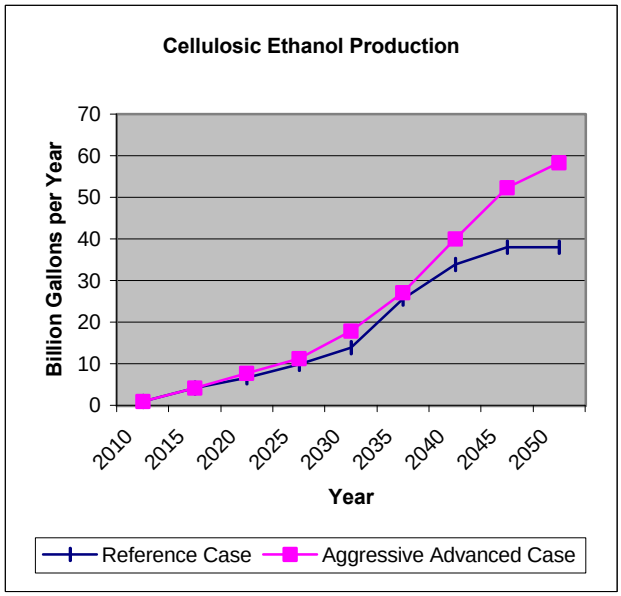
Comparisons of Reference and Aggressive Advanced (Type 2) Cases

Year	Ref Cell Pdn BGY	Agg-Adv Cell Pdn BGY
2010	0.85	0.85
2015	4.10	4.10
2020	6.61	7.76
2025	9.82	11.29
2030	13.92	17.85
2035	25.47	27.04
2040	33.89	39.94
2045	37.93	52.36
2050	37.93	58.33

Production is higher both because of economic ability to use higher cost feedstock and also because of more feedstock availability



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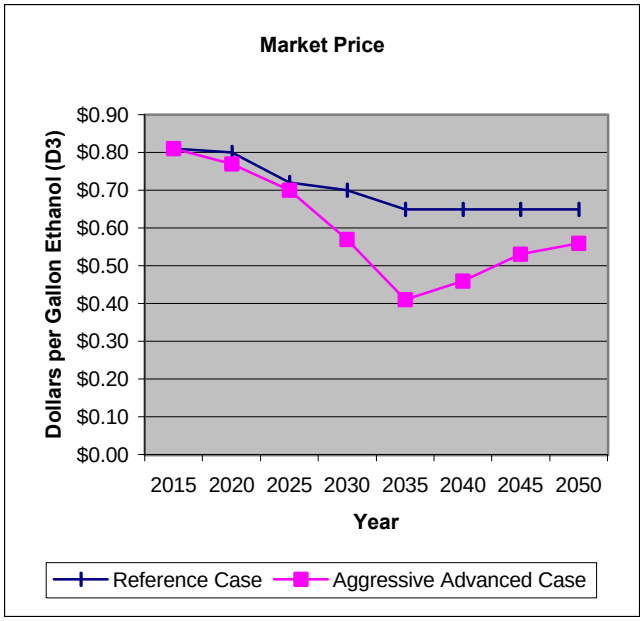
Year	Ref Market Price $/gal	Agg Adv Market Price $/gal
2015	$0.81	$0.81
2020	$0.80	$0.77
2025	$0.72	$0.70
2030	$0.70	$0.57
2035	$0.65	$0.41
2040	$0.65	$0.46
2045	$0.65	$0.53
2050	$0.65	$0.56

Market Price is Lower



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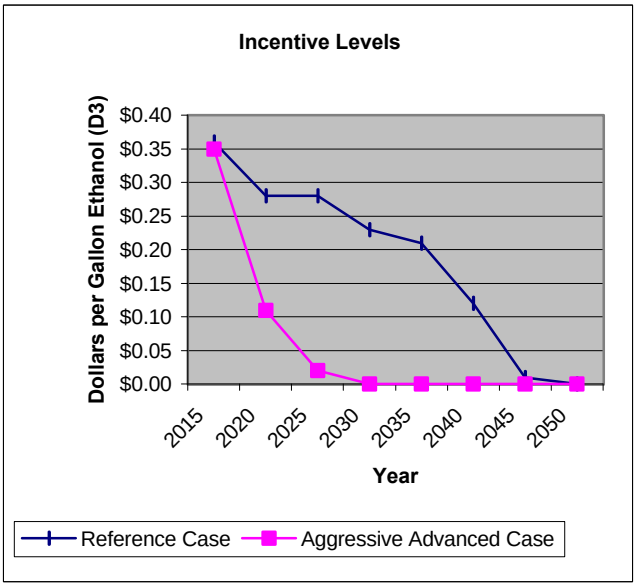
Year	Ref Incentive Level $/gal	Agg Adv Incentive Level $/gal
2015	$0.36	$0.35
2020	$0.28	$0.11
2025	$0.28	$0.02
2030	$0.23	$0.00
2035	$0.21	$0.00
2040	$0.12	$0.00
2045	$0.01	$0.00
2050	$0.00	$0.00

Incentive Level is Lower



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Through 2050 the cumulative usage comparison for the two cases, which is another measure of benefits received (e.g. oil imports avoided, greenhouse gas emissions avoided), and the sustainable future levels are as follows

Cum Thru 2050 BGY	Ref	Agg Adv	Factor of Increase	
	732.69	**920.4**	**1.26**	BioRefinery Related
			Benefits Thru 2050	
Sus Future 2050 on BGY	Ref	Agg Adv		
	37.93	**58.33**	**1.54**	Feedstock Related
			Benefits Long Term	

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NREL

National Renewable Energy Laboratory

For: Howard Brown (1 Page)
From: Steve Zukor May 20, 2003

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Date

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