Techno-Economic Analysis for New Technology Development

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ABSTRACT

Techno-economic modeling is a valuable tool for connecting R&D, engineering, and business. By linking process parameters to financial metrics, businesses can better understand the factors affecting the profitability of their projects and establish a basis for making objective, informed decisions.

Though not a new concept, TEM is still widely underutilized in new technology development. Developers and investors alike would benefit from awareness and earlier adoption of economic analysis. This paper addresses the techniques used in techno-economic analysis and their specific application to evaluating and developing new chemical, bioprocess, and related technologies.

Keywords: techno-economic, economic analysis, new technology development, innovation

1 INTRODUCTION

Techno-economic modeling (TEM) is a valuable tool for connecting R&D, engineering, and business. By linking process parameters to financial metrics, businesses can better understand the factors affecting the profitability of their projects.

TEM is useful throughout the technology development lifecycle. While considering new ideas, innovators can use TEM to assess economic feasibility and potential. At the bench scale, scientists can use TEM to identify the process parameters that have the greatest effect on profitability. During process development, engineers can use TEM to compare the financial impact of different process conditions and configurations. TEM incorporates information from all these stages of development, and offers a basis for making objective decisions.

2 THE TECHNO-ECONOMIC MODEL

A techno-economic model might also be called an integrated process and economic model, since it typically includes a process model, capital cost model, operating cost model, and cash flow analysis.

The process model generates a stream table, which is the foundation of the techno-economic model. Information from the stream table is used in equipment sizing calculations to derive parameters necessary for estimating capital and operating costs. A user interface can consolidate important input and results on a single sheet, facilitating model operation and sensitivity analysis (Fig. 1). When combined, these components allow us to efficiently explore process economics.

2.1 The Process Model

The process model calculates stream properties used to estimate equipment sizes and costs, and typically consists of a process flow diagram, user input, calculations, and a stream table. The process model can be developed using either spreadsheet software or process simulation software.

2.2 The Capital Cost Model

Capital costs are one-time expenses, typically incurred at the beginning of a project. They can range from thousands of dollars for a small system, to billions of dollars for a large plant. Capital costs are the investment on which economic benefits are expected to provide a return.

In techno-economic modeling, capital costs are usually best estimated by applying historical-data-derived multiplying factors to major equipment costs. Major equipment costs can be estimated based on correlations from literature or from vendor quotes. The accuracy of these methods is typically in the range of -30% to +50%. [1,2]

2.3 Operating Costs

Operating costs can be divided into three categories: variable, fixed, and general. Variable operating costs scale with operating rate, whereas fixed operating costs do not. General operating costs are not directly related to operation, but still need to be considered for a complete economic analysis.

The four major variable operating costs are raw materials, waste treatment, utilities, and operating labor. These are estimated based on the stream table, equipment sizing, and market prices. Fixed and general operating costs are then derived by applying multiplying factors to the variables costs and the capital costs. [1,2]

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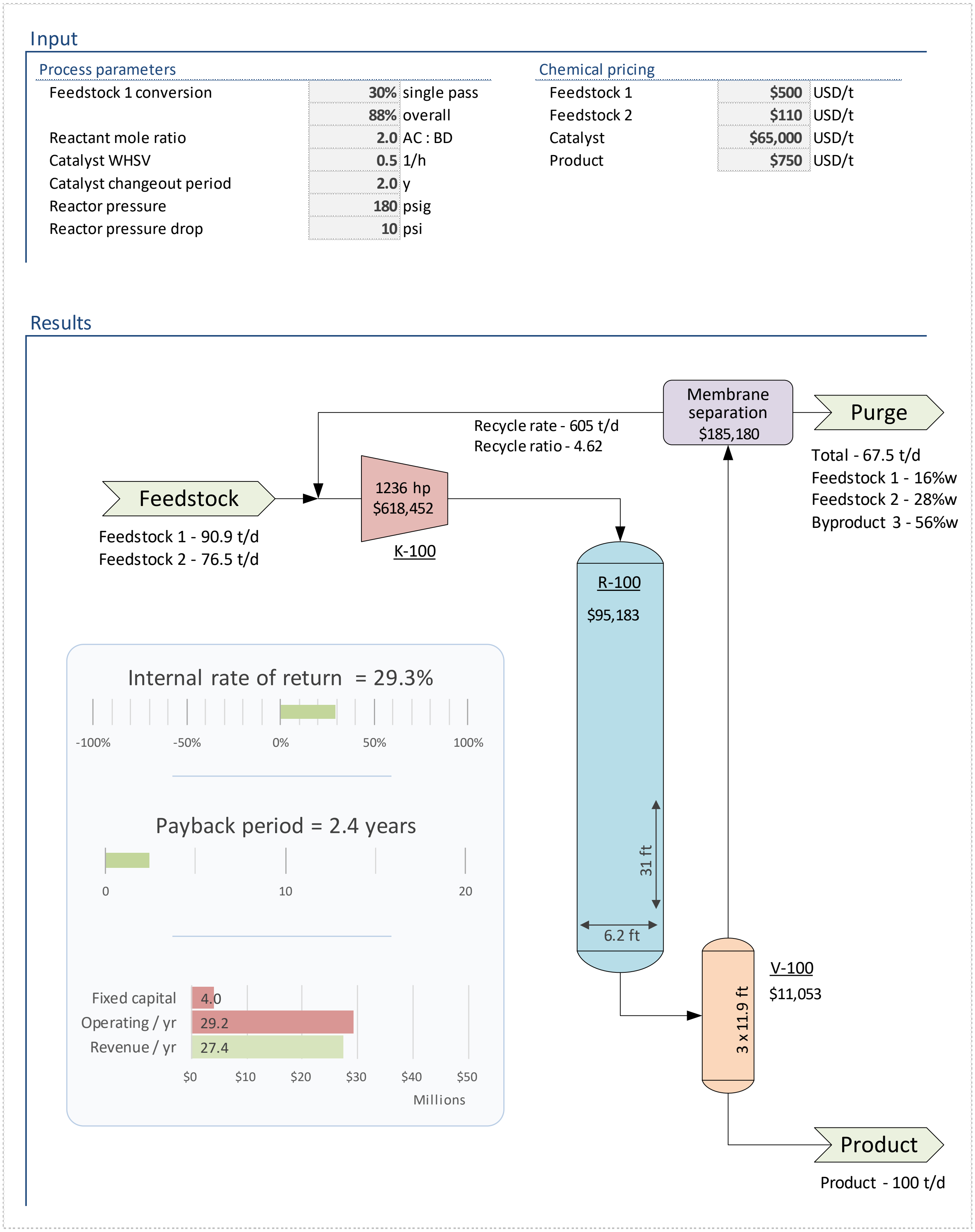

Figure 1: User interface of a techno-economic model for a fictional and generalized catalytic process that converts gaseous Feedstocks 1 & 2 into a product and byproduct.

2.4 Cash Flow Analysis

The economic benefit of a process is typically either in realized revenue or reduced costs. Economic value metrics balance these economic benefits against capital and operating costs, to represent the overall economic value of a technology. Ideally, this provides a single metric for evaluating the technology being modeled, and a basis for comparing it to alternative technologies and investment opportunities.

These metrics are calculated using traditional cash flow analysis methods. [1,2]

3 SENSITIVITY ANALYSIS

Sensitivity analysis investigates the interactions between input and output parameters. It is a valuable tool for identifying opportunities and threats, and for understanding process dependencies. Three types are presented below.

3.1 Univariate Optimization

In univariate optimization (Fig. 2), a single input parameter is varied over a range, while the values for an output parameter are recorded and plotted. This is easily accomplished for any set of variables in a well-designed techno-economic model.

This technique allows us to understand the relationships between variables in the model and to optimize them. It is also valuable for troubleshooting.

3.2 Monte Carlo Analysis

Monte Carlo analysis (Fig. 3) allows us to quantify the magnitude and nature of uncertainty in our estimates. It is an iterative numerical algorithm that uses probability distributions for the input parameters to develop probability distributions for the output parameters.

This information is important for both project management and project evaluation. With quantitative information about uncertainty, we can:

- develop more accurate budgets, justifying contingency allowances with statistical metrics;
- quantitatively evaluate risk mitigation strategies;
- consider organizational risk tolerance in decisions;
- make better decisions when choosing between project alternatives. [3]

3.3 Tornado Diagrams

A tornado diagram (Fig. 4) is a special type of bar chart used for comparing the relative impact of multiple input parameters on one result parameter, typically an economic value metric.

In building a tornado diagram, three values are specified for each input parameter: *expected case*, *worst case*, and *best case*. The center axis corresponds to the expected result – the value when all input parameters are set to their expected-case values. The bars extending to the left and right of the central axis reflect the relative effects of changing the associated input parameter to its worst-case and best-case values. Arranging the parameters in order of magnitude gives the diagram its tornado shape, and highlights the most influential parameters. [4]

Tornado diagrams help identify the key variables that are critical to profitability. With this information, we can more efficiently direct R&D resources to the highest impact areas.

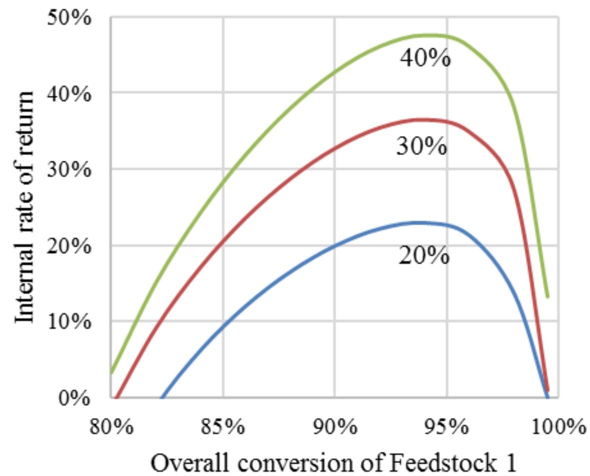

Figure 2: Univariate optimization for process shown in Figure 1. IRR is plotted against Overall Conversion for three values of Single-Pass Conversion. A maximum can be seen near an ‘Overall conversion’ of 94%. Further improvement beyond this would reduce profitability.

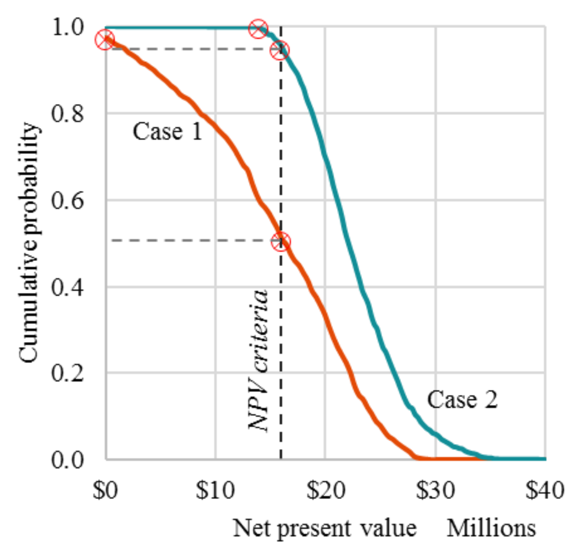

Figure 3: Monte Carlo analysis for the process shown in Figure 1. Note the indicated points on the chart. Case 1 is predicted to have a 52% chance of exceeding the NPV criteria, and a 4% chance of being less than 0. Case 2 is predicted to have a 95% chance of exceeding the NPV criteria, and a worst-case value of around $14MM.

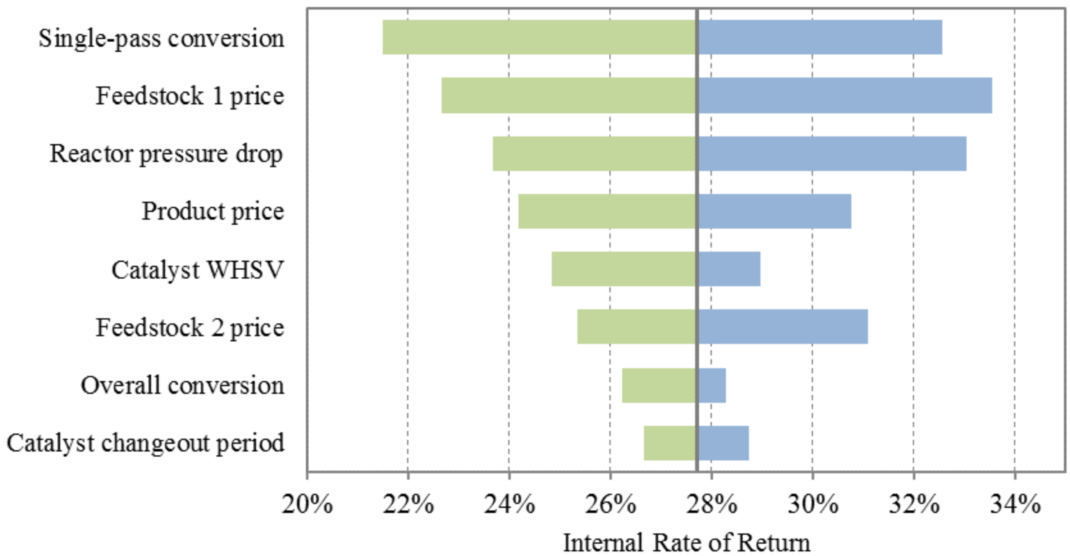

Figure 4: Tornado diagram showing the effects of eight variables on internal rate of return for the process shown in Figure 1. 'Single pass conversion' is on the top of the chart, indicating that it would be a good parameter to target with R&D. Improvements to 'Catalyst changeout period', on the other hand, will have little effect on IRR. 'Feedstock 1 price' is also shown to strongly affect IRR.

4 CLOSING THOUGHTS

In the chemical, bioprocess, and related industries, capital and operating costs are high and they depend strongly on the results of R&D and scale-up. Further, lengthy timelines increase chances that market conditions will change. The impact of these factors can be difficult and time-consuming to estimate. So, they are often visited once at the beginning of a project and then largely ignored in favor of the tasks at hand.

This doesn't have to be the case. Techno-economic analysis offers a way to rapidly assess and reassess profitability and risk in terms of process and market parameters.

When is the right time to engage in this sort of economic analysis? The earlier the better. As we progress through R&D, it becomes more difficult and expensive to change course. The investment required to develop a techno-economic model varies, but it is generally small compared to the typical associated R&D budget. Regardless of how little information is available, systematic economic analysis lays the foundation for objective unbiased decision-making. It gives us confidence in our decisions, helps us avoid surprises, increases our credibility to investors, and guides us along the most efficient path to commercialization.

REFERENCES

[1] **Turton, R., *et al.*,** "Analysis, Synthesis, and Design of Chemical Processes," 4th ed., Prentice Hall, Upper Saddle River, NY (2012).

[2] **Peters, M. S., *et al.*,** "Plant Design and Economics for Chemical Engineers," 5th ed., McGraw-Hill, New York, NY (2003).

[3] **Dienemann, P. F.,** "Estimating Cost Uncertainty Using Monte Carlo Techniques," RAND Corporation, Santa Monica, CA (1966).

[4] **Eschenbach, T. G.,** "Technical note: constructing tornado diagrams with spreadsheets," Engineering Economist, 15 (2), pp. 195−204 (June 2006).