



# THREE KEYS TO SUCCESS FOR COMMERCIALIZING BIOPROCESSING TECHNOLOGIES

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Advances in industrial bioprocessing have enabled [new technologies to emerge](#) ready for scale-up and commercial development. To meet market demands, companies are searching for efficient and cost-effective commercialization solutions with fast-tracked schedules. However, every process will encounter technical scale-up challenges. These may include:

- commercial equipment selection
- converting batch processes into semi-continuous and continuous systems
- non-linear scale-up design
- waste handling
- operational flexibility
- selecting appropriate and cost-effective materials of construction

[Merrick](#) has been engineering bioprocessing projects for over 25 years, specializing in scale-up and commercialization of first of a kind technologies. While the commercialization path for every project is unique, we've identified three keys to success that are common when taking bioprocessing technologies to the next level.



Lab Scale System <sup>[2]</sup>



Pilot Scale System



Commercial Scale System

## KNOW THE COST

This may seem obvious, but the importance of developing a bankable cost estimate early in the commercialization process cannot be overstated. The Total Installed Cost (TIC) often drives design decisions on plant capacity, location, reliability, and flexibility. Obtaining a reliable cost estimate early in Front End Engineering Design (FEED, also known as Front End Loading, or FEL) reduces the risk of making capital cost related design changes later in the design process, when it is more costly and time consuming to do so.

What does a bankable cost estimate entail? For many of our bioprocessing projects, we recommend first developing a Class 4/3 cost estimate as defined by the [Association for the Advancement of Cost Engineering](#) (AACE) guidelines <sup>[1]</sup>. As the project design progresses, the achievable cost estimate accuracy tightens. A Class 4/3 cost estimate typically has an accuracy around  $\pm 30\%$  and at a minimum requires the following deliverables <sup>[1]</sup>.

- Basis of Design
- Process Flow Diagrams
- Mass and Energy Balance
- Utility and Chemical Summary
- Sized Equipment List
- Site Plot Plan
- General Equipment Arrangement Drawings
- Overall Electrical One-line Diagrams and Load List
- Control Architecture Overview
- Budgetary Equipment Quotes for Major Equipment
- Basis of Estimate

This level of cost estimate can be developed early in FEED, typically costing up to 0.5-1.0% of the project TIC. Investing in the engineering effort to develop this cost estimate ensures that the project moves forward with a design that is in-line with capital cost expectations. It also reduces the risk of capital cost surprises after project funding has been secured.

## IDENTIFYING AND QUANTIFYING RISKS

Not only is it important to identify project and technology risks but quantifying them can help focus process development and engineering efforts. Prior to commencing engineering design, most companies have developed detailed business cases and/or pro forma financial statements for the commercial project. These, of course, are essential for evaluating the project financials, such as Net Present Value (NPV) and Internal Rate of Return (IRR).

The one limitation is that these statements assume fixed inputs, such as product and feedstock pricing, process yield, utility usage, capital cost, and plant availability. These values are derived from engineering and development efforts and represent the best data known at the time. In reality, the values of these inputs fall within a range. The exact value of each parameter is not known, but the likely range for these inputs is typically understood.

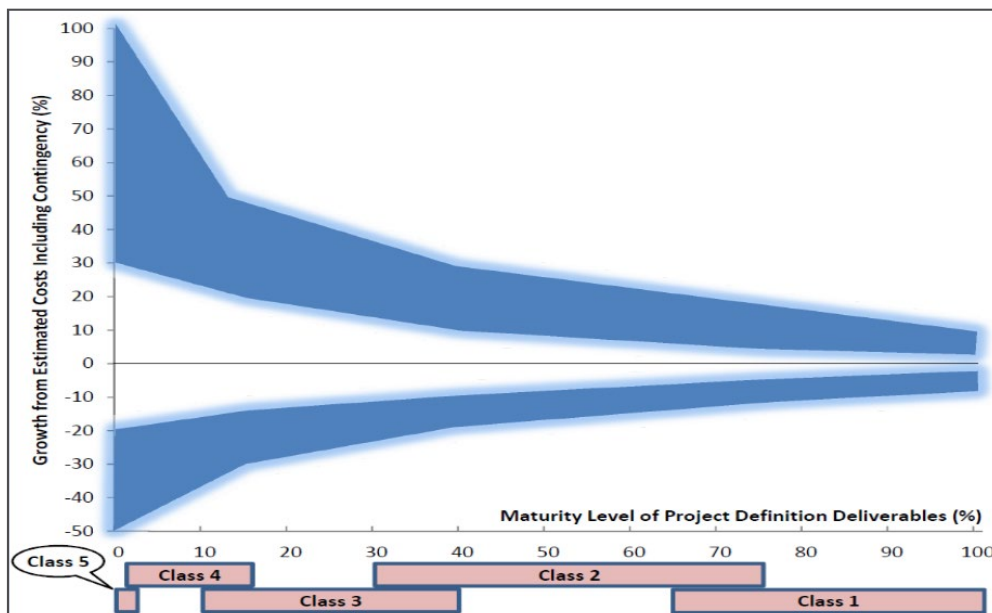
A decision and risk analysis (D&RA) uses statistical analysis to assimilate these known ranges and account for the uncertainty in specific values to come up with a more robust framework for TIC estimating. The use of this methodology also enables a project owner to conduct contingency and scenario analysis to examine the effect of internal and external forces on the project economics.

A common method for defining uncertain variables is to use the P10/50/90 framework.

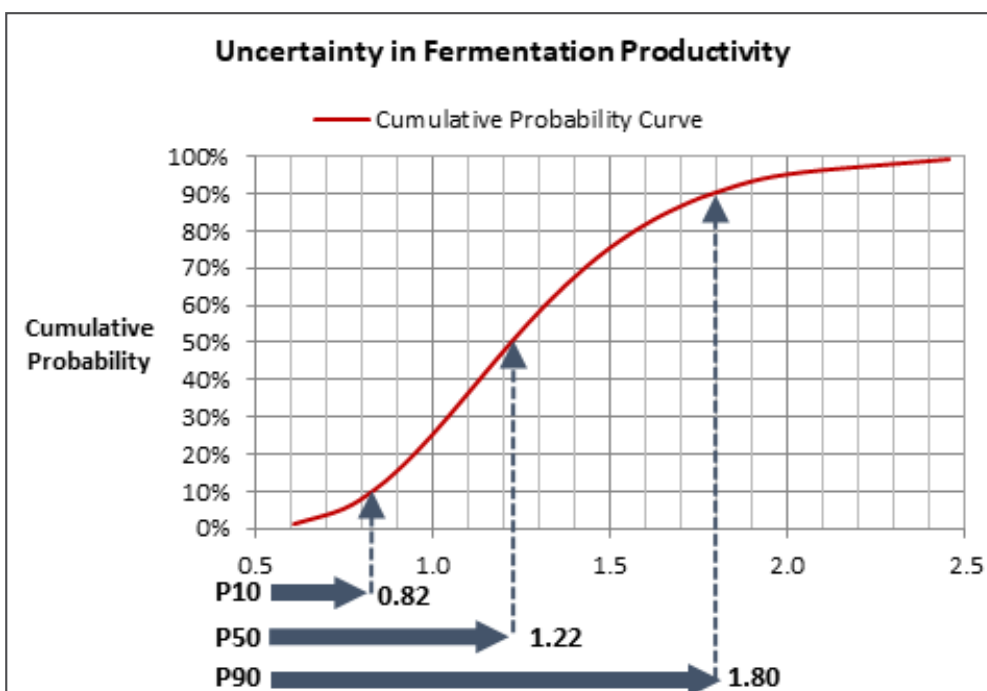
The P10, P50, and P90 represent the 10th, 50th, and 90th percentiles of the ranges, respectively. Conceptually, the P10 is lowest value that the project team thinks that the uncertain variable could be in realistic scenarios. The P50 is the most likely value. The P90 is the highest value the variable is likely to be in realistic scenarios.

By defining the P10/50/90 values for project variables and integrating the cost analysis and mass and energy balance with the financial models, not only can project risks be identified, they can also be quantified. Tornado diagrams are often used to illustrate the impact of variable uncertainty on the project financials.

The tornado diagram depicts uncertainties ranked by potential impact to the decision criteria (often NPV or IRR). Each bar of the tornado is generated by varying the input variable across its uncertainty range while keeping all other variables at their 50th percentile values (the P50s). By evaluating and ranking the risk associated with each variable



Variability in Accuracy Ranges for a Process Industry Estimate from AACE Guidelines<sup>[1]</sup>



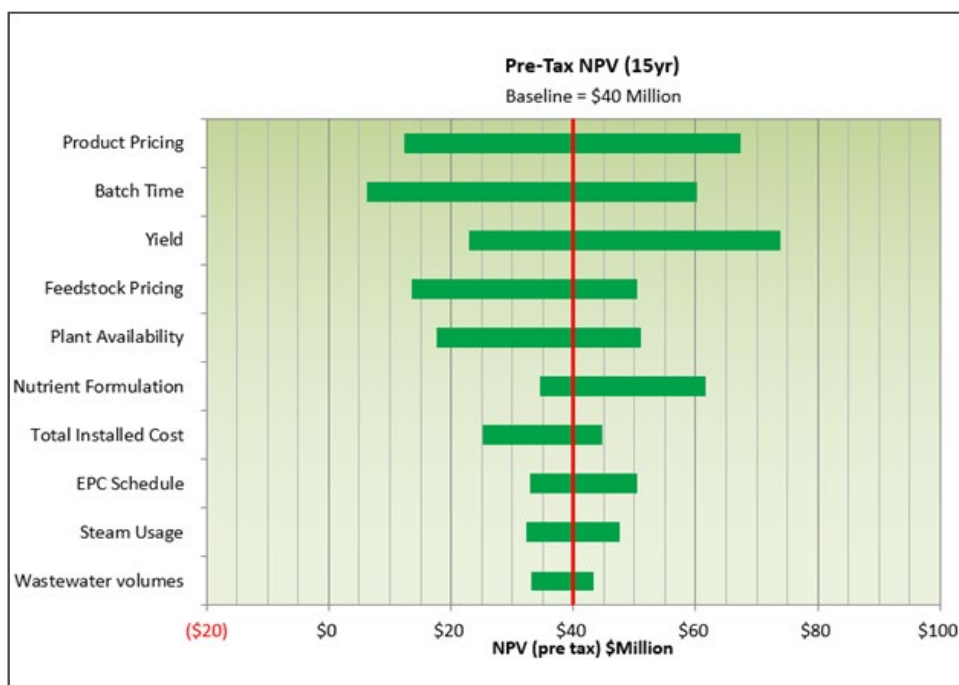
P10/50/90 Range Example for a Process Variable



range, engineering and development efforts can be focused to mitigate those with the largest impact to the success of the project.

Merrick recently developed a techno-economic analysis with tornado diagrams for a biofuels client to evaluate and quantify project risks. To no surprise, product and feedstock pricing were at the top of the tornado diagram, but in this case the operating company had no control over those markets. Plant availability was also high on the diagram. Up until the analysis was conducted, the project team was focused on reducing capital cost. Many of the cuts that were being made reduced the process reliability, meaning that the facility would be operational fewer hours per year.

The tornado diagram quantified the impact of the reduced plant availability on the IRR. It turned out to be much greater than the impact of the increased capital cost necessary to ensure a reliable process. Armed with this data, the project team was able to convince investors that the increased capital cost was a sound economic decision, and the resulting increased plant availability would ensure a shorter payback period.



Example Tornado Diagram

## UNDERSTANDING FEED AND UTILITY REQUIREMENTS

Successful companies first demonstrate their core technology at pilot and demonstration scales before commercialization. However, the design of auxiliary systems, such as feedstock handling, water and wastewater treatment, and utilities, are usually not addressed or optimized until commercial scale. The capital and operating costs of these systems can have a significant impact on the facility economics so it's extremely important to understand and define the requirements early in the commercial design.

**Feedstock Requirements** – Regardless of the type of feedstock, it's likely that the feedstock used at a commercial site will differ from what was used at pilot and demonstration scales. For example, biomass

sourced from the field will contain more foreign matter than commercially processed material (e.g. landscaping wood chips); storing and transferring 95 liquid dextrose is much different than handling powder; bulk algae from open raceway ponds will contain dust, sand, and other foreign matter. Feedstock handling might be trivial at small scales, but it can become complicated and require large footprints at commercial scales. Therefore, it's important to understand the challenges and requirements early in the commercial design process in order to mitigate project risks.



**Wastewater Treatment** – Evaluating wastewater treatment strategies during the scale-up process is key to the success of the overall facility design. Wastewater treatment systems are designed based on quantity (flowrate) and composition (BOD, TSS, etc.). Each industrial wastewater is unique, as are the local water discharge constraints and permitting requirements. Therefore, characterization of wastewater streams from the pilot or demonstration facilities is essential to the commercial design. Additionally, treatability studies and wastewater pilot testing can help optimize the commercial design and further reduce project risks.

**Utilities** – Utility usage is a major input into developing the operating costs for the commercial financial models. A detailed utility summary should be developed as part of the FEED, to not only verify the inputs into the financial model, but also to evaluate opportunities to reduce usage. Water recycle and/or heat integration strategies can be implemented to reduce utility usage and operating costs.

Commercializing any new technology will come with a set of challenges, especially as the process continues to evolve after the commercial design basis has been fixed. Identifying and mitigating project risks early in the design is key to executing a successful project that meets quality, schedule, and cost expectations.

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References:

1. 18R-97: Cost Estimate Classification System – As Applied In Engineering, Procurement, and Construction for the Process Industries. TCM Framework: 7.3 – Cost Estimating and Budgeting, Rev March 1, 2016.
2. Algae to Bio-Crude in Less Than 60 Minutes, Pacific Northwest National Laboratory, December 17, 2013, [https://www.youtube.com/watch?time\\_continue=49&v=Qs0QZJ0rea0&feature=emb\\_logo](https://www.youtube.com/watch?time_continue=49&v=Qs0QZJ0rea0&feature=emb_logo)