



Capital Cost Factors and Fundamental Expenses

Introduction

There is a lot of money on the line when you scale a process from a lab to a commercial plant. Taking a lab-scale process to production is a major leap into the unknown, even if you have detailed information about the chemical processes involved. Process equipment introduces physical constraints, the fact that chemical interactions do not scale linearly, and other factors present a series of interrelated challenges that are hard to predict with models alone.

This is why you need a pilot plant. There are still a lot of assumptions in even the most sophisticated of computer models. It can be easy to let yourself think that a reactor is a reactor whether its 50mL or 5,000 gallons but there are some fundamental challenges that must be vetted out and overcome.

An investment made in a [pilot plant](#) can demonstrate your process technology is ready for production scale, save you money by catching design issues early on, and increase the likelihood of securing funding for new technologies. However, convincing your team and upper management to invest in one can be difficult.

A pilot plant will greatly reduce your risk and provide a feasible path to successful commercial production. But how much will a pilot plant cost you? The general answer is a small fraction of what a production level system costs, and much less than fixing an ill-performing system will.

Reasons to Invest in Pilot Modules

Upper management and your broader set of stakeholders will want to know exactly why you need a pilot plant and what it will cost. Most pilot plants cost between 10-15% of a full-production scale system, but the cost depends on many factors, which you can explore in the cost factors section below.

The value of a pilot plant is the system design knowledge you will gain. Your team should view a pilot or demonstration plant as an investment that will return:

Practical Process Data

Pilot plants can come with lots of instrumentation and sampling points to help you collect accurate data on the system as your product moves throughout it. This data helps you refine and accurately predict the following for a production level system:

- Recycle stream effects
- Product purity
- Process waste
- Refined yield estimates



Pilot Plant designed by EPIC Systems engineers - close up of process equipment

One of the biggest challenges when designing complex process systems is ensuring the ideal amount of margin for each step in the process. Variances in processing time, recirculation loops, heating and cooling times, etc. can cause complex systems to deviate outside of desired bounds. The tighter the margin in each unit operation, the harder it is for the whole system to operate correctly. Data and testing on a pilot unit can help refine, test, and perfect this on equipment in a much less risky and expensive way.

Commercial Grade Material & Equipment Testing Results

Raw materials in mass quantities cannot be affordably purchased in the highly pure state the way they can for lab experiments. These changes in quality can have major effects on your process. In addition, commercial grade equipment behaves different and has different materials of construction (in some cases) than lab equipment. Fully exploring how this affects your process is critical to success.

Usable Product

Pilot units produce usable product which you can test further, sell to current customers, or use to demonstrate viability to investors.

Market Feasibility

With viable product coming from the pilot system, you can start sharing product samples or even selling to customers, building up a user base for when the product becomes commercially available.

Hard Financial Data for Investors

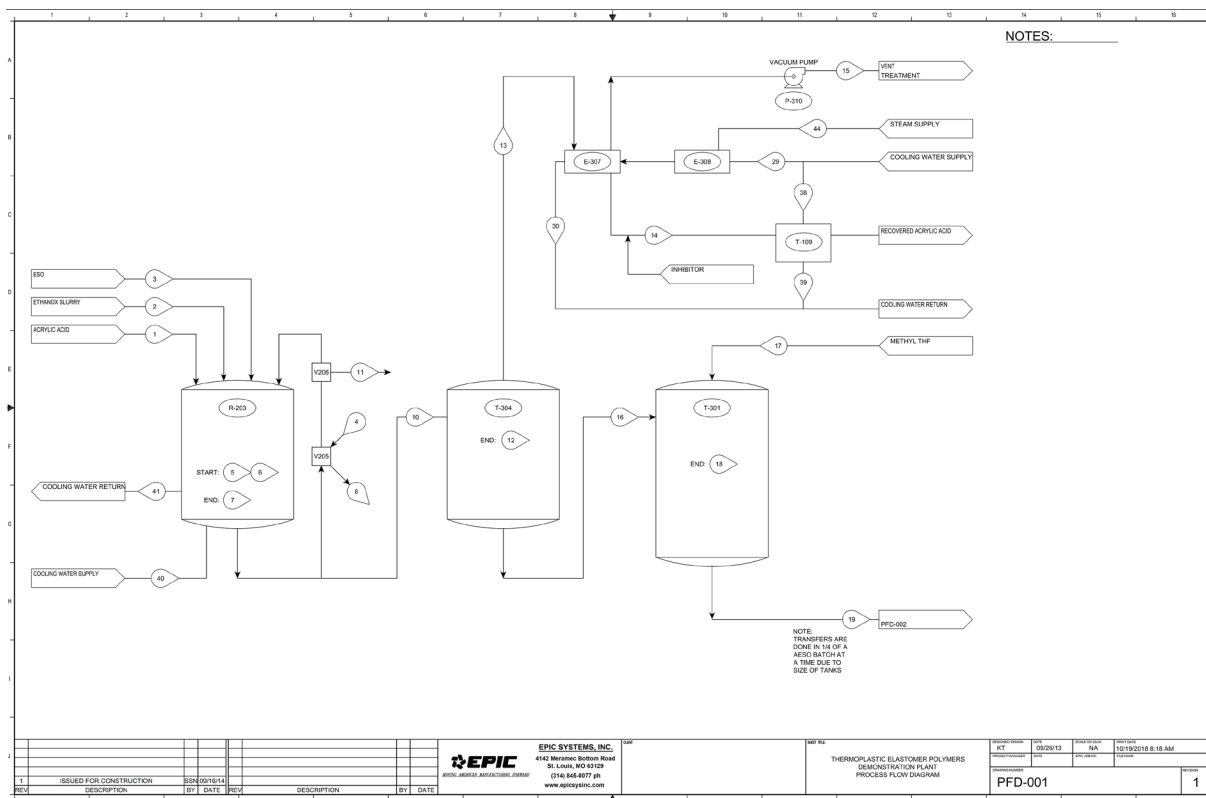
Pilot plants prove there is an affordable way to make your process technology work at a larger scale with commercial materials and equipment. In addition, you can verify production rates and better estimate investor return on investment.

A Long-Term Solution for Small-Quantity Products

While many pilot plants are retired after the commercial process comes to fruition, some are used long term to produce specialty formulations. A pilot plant can also be used to continually test tweaks on your main product, or new product lines with similar processing steps.

If a pilot plant looks like a worthwhile investment for your team, the next question becomes what will it cost? In the rest of this whitepaper, we explore what factors affect costs, how you can keep them under control, and how to get competitive quotes & design proposals from pilot plant suppliers.

Pilot Plants: Determining Costs & Fundamental Expenses



Example of a Pilot Plant PFD designed by EPIC's engineering designers

To get accurate pricing for a pilot module, you will need to reach out to firms that specialize in pilot plant design and fabrication. These firms will provide quotes for pilot skid design and fabrication, which is how you will determine costs.

When it comes to pricing pilot plants, there are two types of costs to consider. Capital Costs are the money you'll invest upfront for engineering, design and fabrication of your pilot plant. Operational Costs are the money you'll spend running the pilot plant on location including raw materials, electricity, water, and man power.

While calculating operational costs tends to be more straight-forward, capital costs are wider ranging and depend on a number of engineering decisions that need to be made during these early stages of development.

When you start working with pilot plant design and build vendors, capitol cost factors will be the main inputs driving up quotes. The top ten capitol cost factors that make pilot plants more expensive include:

Capital Cost Factors

- **Application Complexity** – a more complex process has more equipment requirements, engineering design and modeling, and more complicated programming. Each of these drives up cost and are required to make the pilot process system work properly.
- **Process Conditions** – High temperatures and high pressures also drive price up. The more difficult or unusual the process conditions, the higher cost will be. Situations that drive up temperature and pressure costs include high viscosity fluids, particulates or slurries, non-Newtonian fluids, and degree of difficulty of separation.
- **Flammables** – This is actually a process condition, but it's important to take into consideration early. Flammability changes relief sizing and electrical classification which in turn effects instrumentation cost.
- **Instrumentation** – In order to gather sufficient data to eventually build a production facility, you need to invest in sufficient instrumentation. This cost rivals other equipment costs, so understanding your critical parameters is vital. Additional instrumentation also requires more engineering time to specify and program.
- **Flow Rate** – Overall throughput of the unit also drives cost. Higher flow rates require larger piping, vessels and instrumentation sizes, resulting in higher costs. A 4-inch diameter pipe is dramatically more expensive than ½ inch.

“A RELIABLE ENGINEERING PARTNER IS ONE THAT DOESN'T SHY AWAY FROM THE TRUTH.”

- **Number of Pieces of Equipment** – More equipment means more money spent, not only on the purchasing of equipment, but also on the engineering time specifying equipment and design layouts.
- **Major Equipment Types** – Special pieces of equipment are particularly expensive and can end up driving a sizeable portion of the overall cost. Specialty items that have very few manufacturers, such as compressors, mills, other large rotating equipment all drive up cost.
- **Materials for Construction** – Will this system be built out of mild carbon steel or does the whole skid need to be glass with lined pipe? Some chemicals and processes will require more expensive materials of construction to remain safe and keep your product free of contamination. Construction materials have a large effect on piping, vessels and instrumentation cost.
- **Available Utilities** – Utilizing existing on-site utilities can allow you to use cheaper alternative equipment and/or not eliminate the need for skid-mounted utilities. If no (or few) utilities exist, these must be built into the pilot skid or added on-site.
- **Site Readiness** – Is there an existing concrete pad with electrical hookups and utilities? If not, concrete and civil work must be factored in. An advantage of a modular pilot plant design is that custom skids can be designed to fit into small existing spaces.

It is critical that you communicate with vendor engineering teams on each of these factors during pre-engineering to ensure that your pilot plant quotes cover all major cost centers and your final design will operate as intended without surprises.

Three other expenses to make sure you discuss during the quoting phase are:

- **Project Management** – It's easy to forget cost associated with project management when you are totaling your other expenses, but this is the most vital money spent on any project. The project manager's job is to

ensure that everyone involved is equipped to move the project forward on budget and on schedule.

- **Craft Labor** – The costs of setting the equipment, bolting the piping together, wiring the instrumentation and the thousand other tasks required for any construction project are commonly underestimated. This can be almost as expensive as the equipment itself.
- **Procurement** – Specifying every detail of a vessel (ex. nozzle orientation, nozzle sizing, piping hookups, pump requirements, etc..) is a detailed and difficult process. This is a critical timeline factor when discussing pilot plants. If done wrong, equipment won't be available when you need it due to long lead times. This will cause the project to quickly fall behind schedule.

To compare apples-to-apples when it comes to quotes, they all need to include the same information. The 10 cost factors we covered above are important to discuss with anyone quoting your project. For a standard pilot plant quote template you can fill out once and submit to all vendors, try our [pilot plant design specification sheet](#).

Keeping Costs Low

Higher costs make it difficult to get approval. But if you skimp on the funding, you may build a pilot unit that doesn't return enough data to make it a useful endeavor. Here are five starter tips for keeping project costs low for pilot plants.

1. **Reconsider Your Throughput Requirements:** It's important to strike a reasonable balance between cost and certainty when deciding the production rate of your pilot plant. A 1000:1 difference is too big to give much confidence in most situations and a 2:1 ratio would give an immense amount of confidence but would be a waste of money. Knowing which unit operations are most likely to change with scale (or choosing a partner who knows) will help you achieve a more favorable cost-benefit analysis.
2. **Target Sites with Utilities:** Locating your pilot plant on a site with existing utilities is another way help you save on costs. It is doubly beneficial if required draw materials already exist for your process. One word of caution here; remember to check your air and water permits, especially if your process might alter an existing permit.
3. **Cut Non-Critical Instrumentation:** Distinguish between measurements that are critical and those that are "just nice to know." If the data gathered won't change any design decisions or refine any selections, it might not be worth the extra cost. It's natural to want as much instrumentation as you can get, but prioritizing needs over wants will mitigate your costs in the end.
4. **Modular Fabrication:** You can reduce cost through off-site construction at a process system fabrication plant. Modular fabrication helps compress the project timeline, ensure quality production-like construction inside a controlled environment all while reducing OSHA exposure hours.
5. **Don't Reinvent the Wheel:** If a portion of your production facility is a mature, well understood technology then excluding it makes sense. This can be everything from having bulk tanks of CO₂ instead of scrubbing flue gas, burning syngas instead of feeding it into a second process, or not purifying your final product.



*EPIC Automation Engineers
run quality and control tests*

Because all pilot plants are different, it's important to choose an engineering and fabrication partner who is fair, flexible and who can recommend where to reduce costs. The next sections cover how to find trustworthy engineering partners and what information you will want to provide to them about your project.

Finding Trustworthy Pilot Plant Design/Build Partners

Working with an experienced engineering and fabrication firm allows you to avoid costly pitfalls during many stages of your pilot plant project. The cost factors mentioned above are not trivial matters. Having an experienced team of process and controls engineers in your corner adds invaluable security to the success of your project. If you find one that excels in all three fundamental services for pilot plants above (project management, craft labor and procurement), even better.

Your partner needs to be experienced in practical process applications and you have to be able to trust they'll deliver a job well done for all your technical, financial, and project stakeholders. Anyone can throw a website up, but how do you sift through the marketing noise to find a process engineering firm you can count on? Here are five strategies to use when vetting firms:

1. Request Case Studies, Testimonials and References

We all know to ask for proof of a firm's work with pilot plants. But how can you get more than a surface-level impression?

First, request a reference list or reach out to others who have used them before and dig deeper than the typical, "Would you use this process equipment design firm again?" Dig deeper into details by asking questions that highlight potential strengths and weaknesses, such as:

- What went right with their project?
- What went wrong? And what did they do to make it right?
- How would you rate the quality and value of the final system?
- Did the system work as planned?
- How did the project manager and craftsmen act during the project?
- What was their greatest area of expertise?
- Why did you hire them?
- What would you do differently?

A quality process engineering firm should be able to provide a strong reference list as well as relevant case study examples of previous pilot plants they've designed and fabricated. As you go through their case study materials, consider some key internal questions:

- Can you really see yourself in the clients they serve?
- Do their expertise and problem-solving capabilities translate to the sorts of challenges you experience in your plant environment?
- Can you see a consistent project management approach demonstrated in their work?
- How do they manage project schedules, the job site, safety and all the things that make a job successful?

Diving into past work may require a phone call, not just written materials. Many case studies are little more than a brand name and a logo with a few sentences of marketing fluff. Work with a partner who can genuinely tell you the stories behind how they solve challenges with pilot plants — the kinds of challenges relevant to your operation.

Do they have stories of triumph from the trenches and a joy for the job? Those things should come out in the interactions you have with your process engineering partner; a seasoned expert can pull relevant examples and solutions when asked.

(Tip: when vetting engineering and fabrication firms, be wary of “yes men.” A reliable engineering partner is one that doesn’t shy away from the truth. If your pilot plant won’t offer a favorable ROI – or just isn’t feasible – that’s something you want to know up front before spending hundreds of thousands of dollars.)

2. See the Proof

Job-site photos and videos can prove a process equipment design firm has worked in plant environments similar to your own, give you a sense of finished system quality, and even hint at their safety practices and job approach.

Ask for pictures and videos of pilot plants and go over any questions or concerns they raise with your potential partners. A good company will be happy to walk you through the key points.

3. Bring in Technical and Commercial Stakeholders

Involve both your technical engineering team and your commercial stakeholders to evaluate quotes and capabilities. A successful project for you means pleasing many masters when it comes to finance, production, and engineering. Involving these stakeholders in the vendor selection process is critical for building early buy-in and making sure you are selecting a vendor that can meet everyone’s needs.

Forwarding a presentation is not the recommended method for this.

While you may not be successful in getting everyone on-board, asking key stakeholders to at least one phone or in-person meeting is a much better approach. This allows for dynamic interaction where stakeholders can ask questions and dig deeper for clarifying information, allowing them to better gauge true capabilities.

4. Visit the Contenders

Visit your top three contenders, if possible. See their facility. Get to know their leadership and learn how they operate as a company. A company’s values, culture, and internal processes can be just as important as their technical capabilities. In our experience, a clean shop filled with empowered, passionate employees can often provide a much better service experience and better problem solving than a top-down, autocratic outfit.

Learn about turnover, how they handle turnover — if a point person leaves, who steps in? How does each process engineering firm guarantee your job runs smoothly? What kind of in-house expertise do they possess? All of these are crucial things you can learn from real world, in-person visits.

Looking for a Process Engineering Firm?

Requesting Quotes & Pricing for Pilot Plants

There are several different types of quotes you can see from vendors, with varying levels of detail. Two of the most common quotes for pilot plants are:

- Rough Order of Magnitude (ROM) will provide you with a ballpark estimate for the cost of your pilot plant. This is the minimum amount of due-diligence required for any process system project. For perspective, the cost of a pilot plant is a small fraction of what a full production system will cost and should be viewed as an engineering investment.

- Front-End Engineering Design (FFED) studies is the safest way to start your pilot plant project. A sound FEED study allows you to turn unknowns into knowns and saves you from higher costs of having to fix engineering or operational problems during design/build of the larger system. This should cost only 1-5% of the overall total cost of the pilot plant project.

Having a full system spec is not required to get started in the quoting process. Often, a design build firm can help you fill in the blanks. What is helpful is if you have the following, to provide it:

- A basic mass and energy balance
- A licensed or finalized technology with clear processing steps
- A basic process flow diagram

For a more advanced quote or a Front-End Engineering design effort, you may need to provide more. We have a [detailed pilot planner](#) you can use for this that you can access here. Project scopes (and this document) cover:

- General Project Information – this is where you'll provide your desired timeline, budget, ROI, future expansion plans and other basic information.
- Process Operating Parameters – here you'll include your process objective, major unit operations and any other process-specific requirements you might already have.
- Instrumentation – preferred control systems, desired level of automation, instrument communication type and any manufacturing preferences you might have.
- Utilities – What kinds of utilities (if any) are available onsite? How much capacity is available and at what temperature and pressure?
- Additional System Scope – are there any additional scope specifications (ex. Raw materials or final product storage tanks, additional processing steps, utilities, etc..) you'd like to share with your process engineering team?
- Depending on which type of quote you are getting, you can expect various deliverables from the quoting process. Typical deliverables for ROM's and FEED efforts are:



Client reviews pilot plant designed by EPIC engineers

ROM Deliverables:

- Estimated price. Be sure the clarify the error margin (+/- 15%, 20%, 50%, etc)
- Basic equipment lists
- Basic design docs (P&ID's, Process Flow Diagrams, General arrangements, etc.)

Front-End Engineering Deliverables:

- Fixed bid quote

- Base P&ID's
- Description of scope and boundary limits
- Equipment, instrument and valve list based on budgetary quotes
- Complete PFD's
- Project timeline
- Quotation peer review
- Technical peer review

Varying levels of design often begin during the quoting phase. Once you review your quote(s) and select a project partner, the engineering team will pick up where the quoting process left off and design of pilot plants begins.

Typical Design & Build Process for Pilot Plants

Each firm will have its own unique approach, but a typical pilot plant design and build process follows these steps:

- Pilot plant concept development and front-end engineering (may be in the quoting stage) – A thorough discussion of your system concept and requirements. You share details of your process technology, and your design firm helps you develop finished process flow diagrams (PFD)'s, piping and instrumentation diagrams (P&ID's), and other basic system requirements. Basic process flow, system layout, proposed location, safety considerations, cost and time constraints, etc. are established.
- Detailed design – during this phase, P&ID's are finalized, equipment selection is made, and a 2D design is developed. The conversations started in front-end engineering are put to paper and continue to evolve.
- 3D modeling and simulation – using a professional program like Aspen Plus or HYSYS, mathematically simulations of your pilot plant are developed into working models. During this simulation many of the challenges to process scale-up are explored and resolved. Process parameters and finalized material balances are complete.
- Fabrication and assembly – the system is built and assembled. At EPIC, we use a dedicated, production style shop with a full-time shop staff highly specialized in module production. Pilot plants are constructed off-site at our facility as self-contained skids. This minimizes interruptions to your existing operations, compresses project timelines, and allows for higher quality construction in a controlled environment.
- Shipment and testing – The completed pilot plant will be full tested before shipment ensuring a short start-up at your facility and minimal interruption to existing processes. Testing will ensure the pilot system functions correctly, including controls, safety devices and shut-down/start-up procedures.
- Installation and Commissioning – Onsite installation is completed at your facility. Once the pilot system is up and running at your plant, full system check-out will be completed with punch-list resolution. Operator and maintenance training are also performed onsite, and all project documentation is handed over.
- Support – After we turn the system over, you can still count on us to be there when you need it. Call EPIC: 314-310-1549 or email us at: support@epicsysinc.com.

Timelines vary based on system size, complexity, equipment lead times and many other factors. However, our modular approach and off-site fabrication & testing methods regularly reduce project timelines by 2-4 months over more conventional approaches.

