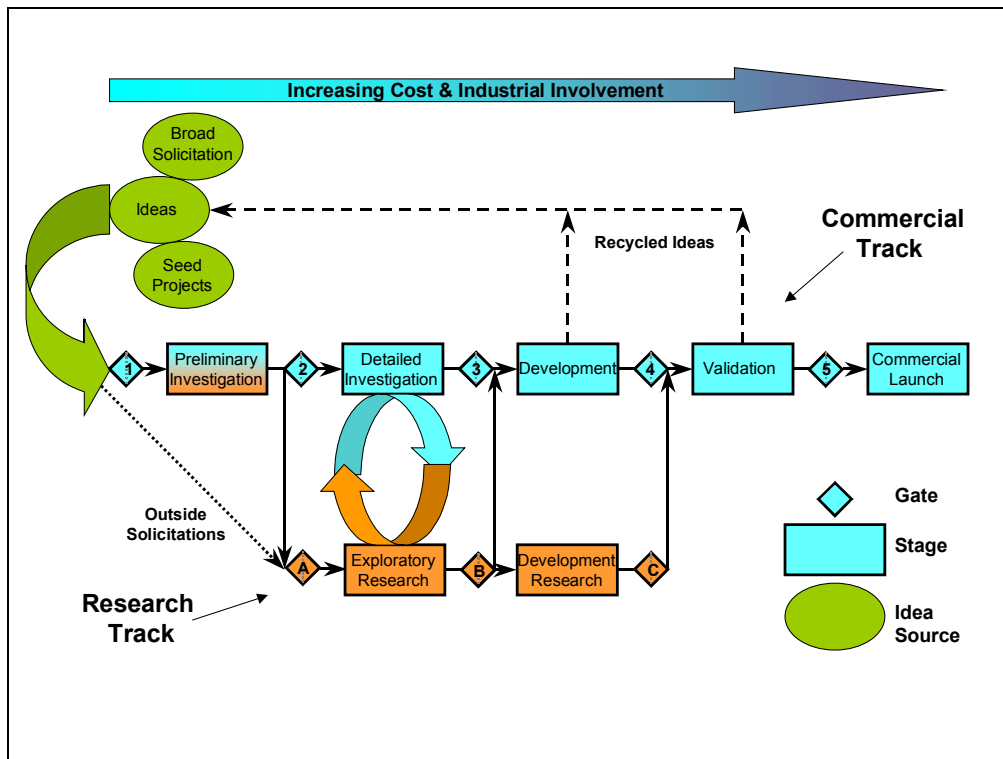

Stage Gate Management in the Biofuels Program



**Prepared by
The National Renewable
Energy Laboratory**



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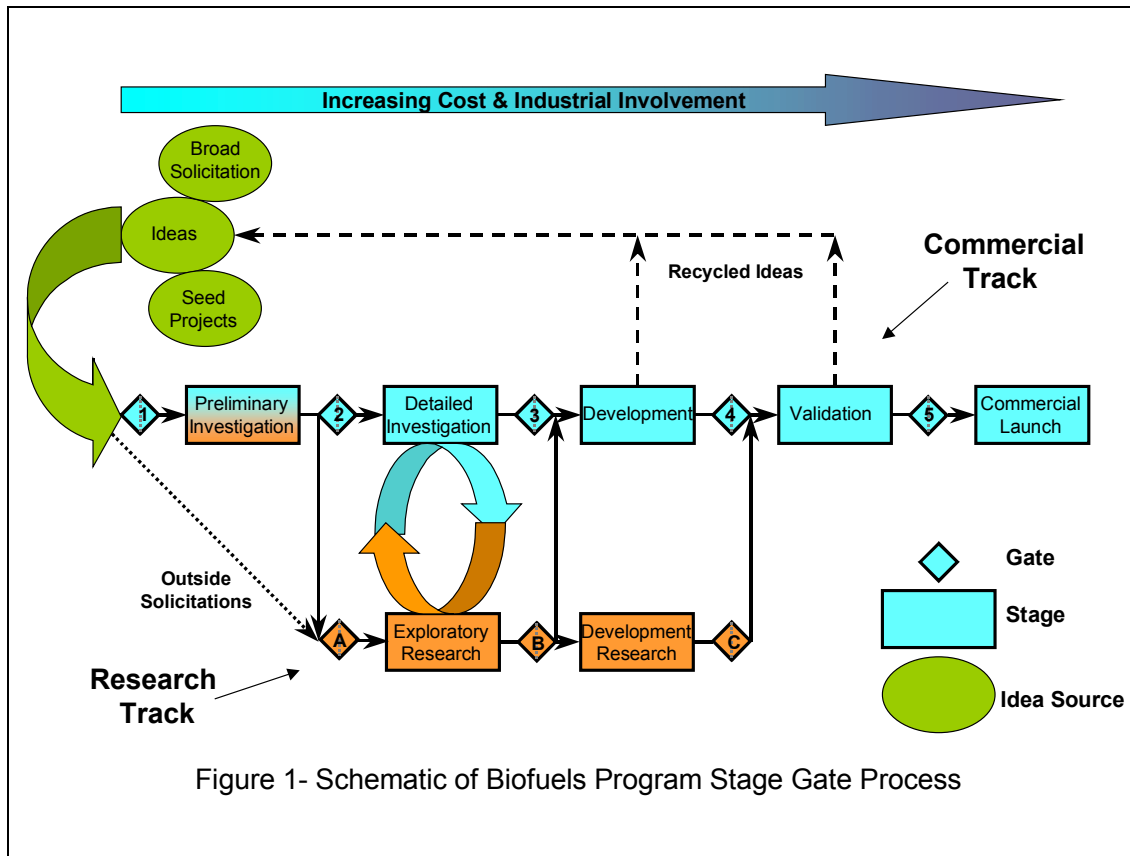
Overview

Stage Gate Management

Stage Gate management of Biofuels Program research and development activities was introduced in 1998. The Stage Gate process is an approach for making disciplined decisions about research and development that lead to focused process and/or product development efforts. Specifically, we use it to:

- Guide decisions on which projects to include in the Program's portfolio,
- Align R&D project objectives with Program objectives,
- Provide guidance on project definition including scope, quality, outputs and integration, and
- Review projects to evaluate progress and continuing fit in the Program portfolio.

The current Stage Gate process used by the Program is shown schematically in Figure 1. The basic approach is that there is a series of "Gates" to review projects and a series of "Stages" to accomplish the work necessary to move the project forward. There are two paths, or tracks, that a project can take depending on the planned outcomes from the project. The commercial track is for projects where the outcome is a commercial process or product. The research track is for more fundamental scientific projects. The two tracks are described in more detail below.



The overarching goal of the Biofuels Program is to support the commercialization of Biofuels technology - that is technology development through Commercial Launch (Stage 5). However, since NREL and DOE, as government organizations, will not commercialize technology directly it is imperative that we not only map routes to develop new technology, but we must also encourage and enable industrial partners to undertake the final development stages through to commercial launch. The Stage Gate process invokes a sense of purpose and direction to all aspects of technology development while at the same time inviting and encouraging a constant flow of new ideas into the system. These characteristics are essential if we are to have a chance of achieving our goal.

One of the advantages of this process is that the commitment of funding on a project is low to start and increases as more work is done and everyone becomes more confident (through the Gate reviews) that the project will be ultimately successful. Efforts are focused on the most critical and uncertain elements early in the life of a project thereby minimizing spending. By doing thorough background study of the potential for the technology, who will use it, its expected economics and the anticipated effort to develop, Gate Keepers (reviewers along the development path) can make the best judgment calls regarding spending greater and greater sums on money on the best projects. The expectation is that projects with significant technical and market problems are weeded out from the Program portfolio sooner rather than later, so that the "big" spending is reserved for those projects that have the greatest potential for success.

The stage gate process was originally proposed by Cooper¹ as a model for product development projects to reduce costs and time to market. The model was then adapted and extended by research and development organizations in the process industries, such as Exxon², Rohm and Haas³, and Eastman Chemicals for process technology development. We have adopted a version of the extended stage gate process used by Exxon Research and Engineering⁴ which is an integrated "basic - exploratory research - development" stage gate system. The expected effect is to bring science and technology to application sooner, at lower cost, and with improved probability of success. This extended stage gate process has added both clarity and flexibility in the application of this decision making model to our Program. By applying the Stage Gate process we hope to better integrate our R&D knowledge and successes with those of industrial partners who we, NREL and DOE, must rely upon for successful commercialization of Biofuels technologies.

Stage Gate Process and Long Range Strategic Program Planning

The Bioethanol Multi-year Technical Plan⁵ (MYTP) is organized to reflect the stage gate decision process. Activities in the plan are organized in three broad categories of,

¹ Cooper, R.G., *Winning at New Products: Accelerating the Process from Idea to Launch* 2nd Edition. 1993, New York: Addison-Wesley Publishing Co.

² Eidt, C.M., jr. and R.W. Cohen, *'Reinventing' Industrial Basic Research*. Research Technology Management, 1997: p. 29-36.

³ Sheasley, W.D., *Leading the Technology Development Process*. Research Technology Management, 1999: p. 49-55.

⁴ Cohen, L.Y., P.W. Kamienski, and R.L. Espino, *Gate System Focuses Industrial Basic Research*. Research Technology Management, 1998: p. 34-37.

⁵ *Bioethanol Multi-Year Technical Plan: Fiscal Year 2002 and Beyond*. 2001, National Renewable Energy Laboratory: Golden, CO. (Download at <http://www.afdc.doe.gov/bcfcdoc/5242.pdf>)

“commercial track” projects, “research track” activities, and “capabilities development”. The activities in the plan are explicitly labeled as to what stage the activity belongs. There is an immediate problem that should become apparent in trying to write the plan in this manner. The plan artificially makes gate decisions a priori. This leaves the impression that the gates themselves are only formalities that will capture the pre-determined decisions reflected in the MYTP. Nothing could be further from the truth. Every plan that has ever been written is merely a sequence of guesses and prognostications, many of which will turn out to be wrong. The fact that we must guess and will often be wrong should not stop us from planning. Thus, what appears in this plan is our best guess about future stage gate decisions for projects and research activities for the Program.

Gate Reviews

In front of each stage is a gate, or decision point, which must be passed through before the work on the next stage can begin. Gate reviews are conducted by a combination of internal management and outside experts, the Gate Keepers. The purpose of each gate is two fold. First the project must demonstrate that it met the objectives identified in the previous gate and stage plan and that it satisfies the criteria for the current Gate. We have developed a set of seven types of criteria against which a project is judged at each gate including:

- Strategic Fit
- Market/Customer
- Technical Feasibility and Risks
- Competitive Advantage
- Legal/Regulatory Compliance
- Critical Success Factors and Show Stoppers
- Plan to Proceed

Specific criteria are different for each gate and become more rigorous as the project moves along the development pathway.

The possible outcomes of this portion of the review could be 1) pass, 2) recycle, 3) hold, or 4) stop.

- **Passing** a project implies that the goals for the previous stage were met and everything looks good, including the market and customers and the projected economics.
- **Recycle** refers to working longer in the current stage because all goals have not been accomplished and the project still has a high priority and everything looks promising.
- **Hold** is suspending a project because the need for it appears to have gone away. There is an implication that the market demand could come back and the project would be restarted.
- **Stopping** a project might occur because the technology development is not progressing as it should, or because the market appears to have shifted permanently, or the technology has become obsolete or the economic advantage is no longer there. In this case the best ideas from the project are salvaged, but the project is permanently halted.

The second half of the gate review involves the plan to proceed. If the decision is made that project "passes" the gate. The project leader must propose a project definition and

preliminary plan for the next stage including objectives, major milestones, high level work breakdown structure, schedule, and resource requirements. The plan must be presented in sufficient detail for the reviewers to comment on the accomplishments necessary for the next stage and goals for completion of the next gate. Once the plan is accepted, the project can move to the next stage. Since the stakes get higher with each stage, the decision process becomes more complex and demanding as a project proceeds along this development path. If the decision is made to "recycle" the project the review panel will provide suggestions to the project leader on work that needs to be completed satisfactorily before the next gate review is held. If the decision is the either "hold" or "stop" the project, the plan to proceed is not needed.

Idea Generation And Evaluation

New ideas are critical to successful technology development. In our implementation of the stage gate process, we envision a number of specific ways in which new ideas can be brought into the program. The first is through regular broad based, competitive solicitations to industry and academia aimed explicitly at providing initial funding of new concepts. The Technology Manager may also elect to fund a seed project for investigating a new technological tool or approach that may offer as yet unspecified applications in bioconversion, and about which we may want to learn more. Examples of this include the general area of plant genetics or new tools for genetic manipulation. Such a seed project could lead to competitive solicitations or generate ideas directly for consideration in the stage gate process. Finally, individual researchers can submit new ideas for research or product development for consideration. An idea submission form is available to suggest ideas (See Appendix A). All ideas are subjected to a Gate 1 review, the outcome of which is a decision to place the project in the commercial track, the research track, or to do nothing with the project idea.

- **Gate 1:** The Gate 1 reviewers include the NREL Technology Manager, the NREL Division Director, and the Strategic Planning Leader.
- **Stage 1: Preliminary Investigation.** This is a purposefully "inexpensive" step that involves a preliminary technical and market assessment of the project idea based on literature, internal knowledge, and customer contacts. Economic projections are "back of the envelope" and no laboratory work is included. The stage is intended to make a nominal amount of funding available for development of an idea to the point where a decision can be made on whether or not to include the project in the portfolio and fund the next stage. If the project idea looks favorable then a project plan, or proposal, is developed and presented at either a Gate A or a Gate 2 review, depending on the type of project idea.

The Commercial Track

Any project (idea) suggested for the commercial track must be able to clearly envision how and where the technology would be commercialized from the outset. However, since NREL and DOE will not commercialize technology, industrial involvement increases dramatically as the project moves forward. Starting after Stage 1, the commercial development pathway includes four more gates and stages:

- **Gate 2:** Gate keepers include NREL Biofuels management, DOE management, and outside experts. The review criteria focus on market and customers,

economic feasibility, technology feasibility, legal aspects, environmental issues, and others.

- **Stage 2: Detailed Investigation.** This is the critical homework stage where investigation and planning are the emphasis. Work must show the unique capabilities of the technology and demonstrate unproven steps in a laboratory setting. In Figure 1, the recycle arrow between Stage 2 and Stage A implies the kind of interaction that may be required when experiments to prove feasibility raise new and important scientific questions. A business plan should be developed that fully illustrates the market and route to commercialization. This will require assessments of customers, competitive technology, technical details, and financial evaluation based on process modeling. The technical assessment requires identification of routes and solutions to problems as well as what risks will be involved. Stage 2 might cost \$150,000 or so and last about 6 months.
- **Gate 3:** This Gate review must confirm that the project homework in Stage 2 has been adequately done. Gate 3 keepers will always include external, industry expert reviewers along with DOE and NREL.
- **Stage 3: Development.** If the project gets this far, it is ready for significant spending on the technical development of the process or product. Stage 3 will be the highest level of direct research spending that DOE would likely invest in a project, potentially multimillion dollars and multiple years. Stage 3 needs to convert Stage 2's business plan to concrete deliverables and demonstrate or develop convincing data that the issues identified in the earlier stages can be or are resolved. Integrated, crosscutting technical work is the emphasis including prototype demonstration of unit operations, demonstration of simulated integration at real processing conditions, and development of engineering scale-up data. From the outset, a Stage 3 project must have a detailed plan with milestones and checkpoints for progress. For multiyear projects there will be thorough annual reviews to insure that the project is progressing per the original plan. If problems are identified a new plan will likely be required and potentially even a new Gate review. This stage requires serious industrial involvement. This could be as advisors or actual partners with or without cost sharing. At the end of this stage the technology should be developed to the point where industry is ready to assume leadership and control of the project.
- **Gate 4:** This gate review will be lead by the prospective Industrial Partners and will meet their requirements. Industry must accept that sufficient laboratory and prototype work has been completed to establish a project that they will carry forth to Stage 4 (Validation) and Stage 5 (Commercialization). NREL/DOE will not carry the technology development effort past Gate 4 into Stage 4 without a partner who is willing and has the ability to commercialize the technology.
- **Stage 4: Testing and Validation.** Spending at this point takes a much bigger step as demonstration scale testing of the product/process begins. The information created in this stage must be sufficient to support a decision for making the investment in commercial scale production. Once a project has reached this stage, DOE expects to have an industrial partner leading the work and financing the project. The Energy Policy Act (EPACT) requires 50% non-Federal government cost share for demonstration projects.

- **Gate 5:** The decision to commercialize a technology belongs with the industrial partner.
- **Stage 5: Full Production and Market Launch.** This level of effort is, clearly, almost exclusively the domain of an industrial partner. The Program can provide some technical support, but the lion's share of the effort and financing is expected to come from the private sector.

Conceptual process design and techno-economic analysis is used extensively in projects on the commercial track. The 1999 report entitled "Lignocellulosic Biomass to Ethanol Process Design and Economics, Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis, Current and Futuristic Scenarios" is a good example of the level of rigor used in the evaluation of projects on the commercial track in the Biofuels Program. The report includes a complete design basis including a discussion of all design assumptions and economic evaluation parameters, material and energy balances, equipment sizes and costs, and process flow diagrams. The report can be found at <http://www.ott.doe.gov/biofuels/PEdownload.html> - 3957.

The Research Track

Since the scope of the Program includes fundamental and applied research, not all projects are clearly acceptable for the commercial track from the start. Many times the feasibility of ideas or the capability to conduct a line of research must be proven before application in a commercial project can be visualized. Recognizing this, we implemented the research track in order to ensure that more fundamental scientific projects remain aligned with Program goals and objectives. There are two stages and three gates in the research track, Stages A and B, and Gates A, B, and C. Stage 1 is still employed for preliminary investigation of an idea, but following Stage 1, Gate A is used to review projects determined to be appropriate for the research track.

Expectations and milestones for projects in the research track are very different from those for projects in the commercial track. Milestones are "learning-oriented", a term coined by Rohm and Haas in their discussion of the differences between goals associated with commercial product development and those associated with "technology development"⁶. Exxon Research calls the work that goes on in research stages "business driven science" as opposed to "science driven research."⁷ In other words, when it is working properly, the research track on the Stage Gate process will allow the Program to fulfill its role as a high-risk technology developer, while avoiding the pitfalls of addressing "interesting scientific questions" that don't have a sufficiently practical focus. The ultimate success of projects in the research track will be measured by the degree to which this new knowledge or capability is used in new or existing commercially focused projects.

- **Gate A:** Gate keepers include NREL Biofuels management, and DOE management, and outside experts. The review criteria focus on market and customers, technology feasibility, and others.

⁶ Sheasley, W.D., *Leading the Technology Development Process*. Research Technology Management, 1999: p. 49

⁷ Eidt, C.M., jr. and R.W. Cohen, *'Reinventing' Industrial Basic Research*. Research Technology Management, 1997: p. 34.

- **Stage A: Exploratory Research.** This stage is where we are investing in developing the scientific knowledge or capability that will enable us to ask the "right" questions in the future. A thorough literature review supported by exploratory experimental work on key scientific questions is the emphasis with the focus on gaining an understanding of the potential importance of being able to answer these questions. The Stage A project will consult with related commercial track projects and potential industrial partners to confirm the importance of these scientific questions. The goals and objectives are focused on gaining knowledge about the problems at hand. Stage A will narrow down the list of possible options to one or two feasible lines of investigation.
- **Gate B:** It is possible that Stage A could identify a solution to the problem that could immediately move to the commercial line. If so, the project would move to Stage 2 or 3. However, if the solution is still too loosely defined and a more concerted effort is necessary on the one or two possible solutions identified in Stage A, then a Stage B is envisioned.
- **Stage B: Development Research.** This stage builds upon the exploratory knowledge or capability gained in Stage A in a focused, detailed experimental program. We are investing in developing the scientific knowledge or capability that will enable us to answer important scientific and technical questions in the future. The major difference between Stage B and Stage 3 is that in Stage B the route to solution to the problem is still not clear, even though there are customers and a market for the solution if it is ever found. More fundamental research is needed and therefore the outcome is unclear. This is in contrast to Stage 3 activities (and experimentation) where the path (and confidence in accomplishing the solution) has a higher probability of success.
- **Gate C:** Upon completion of Stage B either the problem will have been solved and the solution available for commercialization projects, or there is no workable solution and the project is ended. The plan to proceed in the Gate C review is focused on transfer of the newly developed technology or scientific capability to those projects or partners who can use it.

Support Activities

Some activities in our Program provide general ongoing support to all projects and do not fall neatly into a commercial track or a research track activity. These activities are not discretely managed using the stage gate process. However, the support activities are modified and improved based on the needs of the projects in the Program. Support activities include:

- Program Management
- Process Engineering and Analysis
- Industrial Partnership Development
- Centralized Capability Maintenance and External Analytical Services
- Communications and Outreach

When individual projects need specific work in any of these areas, then that work is planned as part of the individual project. For example, the process engineering and analysis support activity may purchase and/or develop a new level of modeling capability for the benefit of the entire Program, but when a project required use of the modeling

capability to create a project specific model, that work would be included as part of that project, not the support activity.

Expected Improvements by Using the Stage Gate Process

Sharper focus, better prioritization

- Weed out poor projects
- Focus resources on the best projects

We use the Stage Gate Process to manage the portfolio of projects in the Biofuels Program. Portfolio management is a critical area of Program Management because it integrates a number of key decision areas, all of which are difficult: project selection and prioritization, resource allocation across projects, and implementation of the business strategy. The gates and gate reviews allow us to weed out poor projects and reassign resources. This will allow more resources for the best projects and/or open the way for new projects to get started. Recent investigations into how businesses manage their R&D portfolios⁸ have shown that the most successful companies screen projects against a number of criteria very similar to those used in our system including strategic fit, financial competitiveness, commercialization capability, technological capability, and risk.

Quality of Execution

- Focus on quality – do it right the first time
- Focus on important – devote resources to pivotal and weak steps
- Focus on completeness – key activities are central to success, no gaps, no omissions

The execution of the work must focus on quality. Doing the work right the first time eliminates the need to waste resources redoing. By focusing on the most important steps, the “showstoppers” help to determine quickly and with the fewest resources whether or not the project is possible. Finally, make sure that all key activities are addressed. We need to be aware of all issues with no omissions. This is the only way to enable the identification of the most important items.

Fast-paced, parallel processing with a multifunctional team approach

- Undertake multiple activities in parallel (technical, safety, economic, environmental, etc.) not series

All projects need to be assessed, evaluated and researched in multiple areas. This might include market assessment, financial, safety, environmental characteristics, and technical performance. By the incorporation of a multifunctional team many aspects of the projects can be addressed simultaneously. Each of these assessments will be appropriate to the stage the project is in. This keeps on function (such as technical research) from getting too far along, if there is a serious concern in a different area, such as environment or marketing.

⁸ Cooper, R.G., S.J. Edgett, and E.J. Kleinschmidt, *Best Practices for Managing R&D Portfolios*. Research Technology Management, July-August 1998: p.20-33.

Strong customer/competition orientation

- Assess customer needs in all stages
- Assess other technologies for the same purpose (prioritization)

The greatest measure of success is that the technology is commercially launched in a profitable venture. To accomplish this, we (the government) must be able to transfer the technology no later than Gate 4. Realistically, to understand if the project has the potential to be transferred, potential partners must be identified very early in the overall technology development process. There will be requirements in the first stage that these customers of the technology be identified, with more and more input on their needs and desires coming in to help direct the project as moves forward. If we don't develop the project to the needs and concerns of the potential partners, they won't be interested in it when we are ready to hand it off. As we develop a new technology we must be ever aware of the competing technologies for the same process. These technologies could be new developments from universities and private industries or could be other projects currently underway within NREL and DOE. If the current project doesn't have the potential to be superior to others in most areas (such as technical performance, financial, environmental, safety, etc.) then the project should probably be ended.

Better homework up-front

- Insure that early stages are carried out
- Considerable insight to success from lowest investment

Homework is cheap! Looking at the market, competing technologies, past literature, financial analysis because they are generally paper analyses they are less expensive than laboratory or pilot plant activities. In addition, much can be learned from these types of studies about the probability of success of the current project. Because of this, the early stages (1 and 2), call for considerable homework to help clarify the project's position.

Roles and Responsibilities in the Stage Gate Process

Program Management

Strategic Context for Project Selection and Review

- Provide information of Program strategic analysis and planning in the form of written documentation.
 - Annual Bioethanol Outlook Fiscal Year 2001 - <http://www.afdc.doe.gov/bcfcdoc/5569.pdf>
 - Bioethanol Multi Year Technical Plan Fiscal Year 2002 and Beyond - <http://www.afdc.doe.gov/bcfcdoc/5242.pdf>
- Provide guidance on project priorities within the Program.

Gate Reviews

- Lead efforts of Gate Keepers in review meetings
- Provide clear decisions and recommendations during and after review meeting.

Review Detailed Project Plans

- Review, comment on, and approve detailed stage plans.
- Allocate funding for approved projects as part of AOP process.

Review Project Status

- Hold regular Program meetings that include project status reviews.
- Assist project leader as necessary with project issues or problems.

Division Management

Gate Reviews

- Participate as a Gate Keeper in review meetings.

Review Detailed Project Plans

- Review, comment on, and approve detailed stage plans.
- Allocate personnel resources for approved projects as part of AOP process.

Review Project Status

- Participate in regular Program meetings that include project status reviews.
- Assist project leader as necessary with project or personnel issues or problems.

Project Leader

Planning Gate Review Meeting

- Set Preliminary Target Date for the Next Gate Review Meeting
 - Have Project Assistant add date to Intranet
- Determine External Gate Keepers
 - Identify possible external reviewers
 - Recommend external reviewer(s) to Technology Manger and get agreement
 - Invite external reviewer for specified date and location
 - Arrange for Technology Manger to send follow-up letters if necessary

- Arrange with Administrative Assistant to handle travel expenses of external participants
- Invite all Gate Keepers and meeting participants to Gate Review Meeting
 - Provide background information to gate keepers prior to the meeting including current Stage Plan and summaries of important deliverables or milestone reports.
- Hold dry run of Gate Review Meeting
 - At least two weeks prior to scheduled Gate Review
 - Dry Run Audience: NREL Biofuels Program Management

Gate Review Meeting

- Present accomplishments from current stage
 - Clearly describe progress compared to the plan including goals, deliverables and milestones
 - Address all the gate criteria
- Present plan for the next stage
 - Show work breakdown structure; major goals, deliverables and milestones; preliminary schedule and budget
- Capture and review reviewer comments

After the Gate Review Meeting

- Summarize reviewer comments, revise plan per reviewer comments and distribute both to reviewers
- Provide presentation(s), reviewer comments, and revised plan to Project Assistant for posting on Intranet.

Proceed with Project

- Develop detailed project plan covering entire stage.
- Review detailed plan with Program and Division Management and get their approval.
- Execute and control the project.

Stage Descriptions and Gate Review Criteria

Stage 1: Preliminary Investigation

Goals:

- Spend a little money in order to gather information to explain project technical merits and customer prospects.
- Investigate major aspects of background.
- Identify critical elements that require feasibility demonstration.

Stage 1 Work Activities:

Homework, building insight, and planning is the major emphasis. There is no experimental work included. Projects in Stage 1 may go to either a Gate 2 review or a Gate A review at the end of Stage 1. It all depends on whether or not the project develops a commercial focus (Gate 2) or a research focus (Gate A) during Stage 1. Therefore, Stage 1 activities may be somewhat unique depending on the ultimate project focus. However, in general, the activities should include looking at the market needs, reviewing past literature, identifying competing technologies, and for an idea with a commercial focus, carrying out a rough financial analyses or "paper study".

- **Market Assessment**
 - Library research
 - Contacts with key potential customers (concentrate on real users) to develop general customer assessment of wants and needs.
 - Focus groups (organizations of potential users, if applicable and reasonable)
 - Determine market size, potential, time frame for implementation
- **Research Activities**
 - No laboratory research is included.
- **Develop Competitive Technology Assessment**
 - Conduct literature and patent reviews
 - Quick assessment of alternative technical solutions and routes based on literature and previous NREL work.
- **Detailed Technical Assessment**
 - Assess technical feasibility of proposed process.
 - Identify technical risks and showstoppers.
 - Identify possible legal or regulatory issues.
- **Financial Assessment** (for projects with a commercial focus)
 - Develop plausible process route for commercialization and identify preliminary economic advantages.

Stage 1 Outputs:

- **Market Assessment**
 - General understanding of customer needs and wants and confirmation that proposed project is on target to meet those needs.
- **Research Results**
 - None
- **Competitive Technology/Detailed Technical Assessment**
 - Summary of literature search results.
 - Description of competing technologies and assessment of the relative advantage of this process/product.
 - List of relevant patents.
 - Address any identified legal or regulatory issues or concerns.
- **Financial Assessment**
 - For projects with a commercial focus:
 - Process concept and preliminary estimate of economic advantage.
 - Detailed plan for Stage 2, and general plan for Stage 3. The Stage 2 plan should address the technical risks identified and the legal and regulatory concerns. The Stage 3 plan should identify expected partner involvement and support.
 - For projects with a research focus:
 - Detailed plan for Stage A, and general plan for Stage B.

Gate 2 Review Criteria

➤ **Strategic Fit**

- Does technology identified have the potential to address a business need?

➤ **Market/Customer**

- Is market potential of technology attractive?
- Need to describe specific situations where it is attractive, in addition to near term readiness.
- Identify what needs to be investigated for commercial partners to be willing to participate in Stage 3 technology development activities.
- What are business risks to develop the technology?
- What are the business showstoppers?

➤ **Technical Feasibility and Risks**

- Is technology feasible?
 - Describe how technology is a departure from current technology and the associated risks. Describing new process steps is critical to estimating technical risks.
- What are the technical showstoppers?

➤ **Competitive Advantage**

- Does proposed technology have an advantage?
- What are expected ranges of technical improvements and rough estimate of relative impact on economics? If NREL process models exist for similar technology options include results from preliminary process engineering economic analysis
- How long is advantage expected to exist? i.e. What is duration of window of opportunity?

➤ **Legal/Regulatory Compliance**

- Patent positions
- Waste streams, emissions, safety, permitting issues
- Are issues surmountable?

➤ **Critical Success Factors and Showstoppers**

- Need to provide prepared list of success factors and showstoppers.
- Have critical success factors been addressed?
- Plans to address potential business and technical showstoppers.

➤ **Plan to Proceed**

- What are detailed plans for Stage 2 (with milestones and resource estimates)?
- What are general plans for Stage 3, including partner involvement and support?

Gate 2 Keepers

- NREL Technical Manager
- DOE Program Manager
- NREL Technical Lead
- NREL Marketing Representative
- Industry Representative

Stage 2: Detailed Investigation

Goals:

- Critically investigate all aspects of background.
- Demonstrate process feasibility.
- Develop a business plan.

Stage 2 Work Activities:

Investigation and planning is the emphasis. Stage 2 must show the unique capabilities of the process and demonstrate unproven steps in a laboratory setting. The business plan should fully illustrate the market and route to commercialization.

- **Market Assessment**
 - Detailed customer assessment of wants and needs (product specifications), requires direct interaction with potential customers.
 - Probably requires participation of outside marketing firms specializing in the specific area.
- **Research Activities**
 - Demonstrate unique, cost critical and untried process steps in minimum scale laboratory setting.
 - Produce only enough material to prove necessary properties of product.
- **Develop Competitive Technology Assessment**
 - Review patent literature
 - Compare this process to other known processes and products (not just NREL technology).
- **Detailed Technical Assessment**
 - Investigate alternative technical solutions and routes.
 - Investigate and document technical risks.
 - Review patent literature.
 - Review legal, regulatory and safety issues applicable to this process. Address potential impacts of any of these issues on the proposed process.
- **Financial Assessment**
 - Develop plausible process route for commercialization and evaluate economics.
 - Use results of critical experiments to help substantiate cost critical operations.
 - Use cost sensitivities to illustrate the criticality of various process steps and estimate risk of various assumptions and unproven steps. This will aid in risk assessment of the business plan.

Stage 2 Outputs:

- **Market Assessment**
 - Clear understanding of customer needs and wants (specifications). Market size and ease of penetration should be assessed.
- **Research Results**
 - Detailed documentation of all relevant experimental work.
 - Added confidence (or feasibility) in unique process steps.

- Possible sample quantities of key products for preliminary evaluations.
- **Competitive Technology/Detailed Technical Assessment**
 - Clearly documented description of all competitive technologies and what is advantageous to this process/product.
 - Assessment of other routes to this technology and why this one should be pursued.
 - Address any identified legal, regulatory, environmental or safety concerns that this process will possibly face.
- **Financial Assessment**
 - Conceptual process design and economics. This should include sensitivity study of key process steps and variables.
 - Business plan for Stages 3 through 5. This plan should address the technical risks identified and the legal, regulatory, environmental and safety concerns.

Gate 3 Review Criteria

➤ **Strategic Fit**

- Does technology identified address the business need?

➤ **Market/Customer**

- Is market potential of technology attractive?
- Need to describe specific situations where it is attractive, in addition to near term readiness.
- Identify what needs to be developed for commercial partners to be willing to proceed to Stage 4.
- What are business risks to develop the technology?
- What are the business showstoppers?

➤ **Technical Feasibility and Risks**

- Is technology feasible?
 - Describe how technology is a departure from current technology and equipment and the associated risks. Describing new process steps is critical to estimating technical risks.
- What are the technical showstoppers? How does all data collected to date relate to conceptual process design?

➤ **Competitive Advantage**

- Does proposed technology have an advantage?
- What are preliminary economics? Results from process engineering economic analysis, compare to other process options.
- How long is advantage expected to exist? What is duration of window of opportunity?

➤ **Legal/Regulatory Compliance**

- Patent positions
- Waste streams, emissions, safety, permitting issues
- Are issues surmountable?

➤ **Critical Success Factors and Showstoppers**

- Need to provide prepared list of success factors and showstoppers.
- Have critical success factors been addressed?
- Plans to address potential business and technical showstoppers.

➤ **Plan to Proceed**

- What are detailed plans for Stage 3 (with milestones and resource estimates)?
- What are partner's general plans for Stage 4?

Gate 3 Keepers

- NREL Technical Manager
- DOE Program Manager
- NREL Technical Lead
- NREL Marketing Representative
- NREL Process Engineering Lead
- Industry Partner(s)

Stage 3: Development

Goals:

- Demonstrate or develop convincing data that issues identified in Stage 2 can be resolved.
- Convert Business Plan from (Stage 2) into Concrete Deliverables that can be evaluated.

Stage 3 Work Activities:

Technical work is the emphasis. Stage 3 is the most costly stage performed at NREL but led by industry partner(s).

- **Market Assessment**
 - Check market and potential customers to determine continued need, or if end product or time to market changes.
- **Research Activities**
 - **Prototype demonstration of process unit operations**
 - Equipment should be large enough and similar enough to envisioned commercial equipment that risk in scaling to demonstration scale (Stage 4) is minimized or at least well understood.
 - **Demonstration of simulated integration at real processing conditions**
 - Consideration of pseudo-steady state operation with appropriate recycle, accumulation, contamination, losses, waste streams, etc. and their impact on subsequent scale-up.
 - **Development of Engineering Scale-up Data**
 - Consideration should be given to kinetic and physical property data that will be needed to scale-up to demonstration sized equipment.
- **Detailed Technical Assessment**
 - More detailed process design with partner providing leadership (potentially involving outside consultants).
 - Continue to compare to other known processes
- **Financial Assessment**
 - Economic evaluation, and business plan refinement (from Stage 2) with partner providing leadership as appropriate (potentially involving outside consultants).

Stage 3 Outputs:

- **Market Assessment**
 - Updated customer assessment of needs and wants.
- **Research Results**
 - Detailed documentation of all relevant experimental work.
 - Mathematical models of key operations, cause and effect relationships including reaction kinetics, particularly for hydrolysis and fermentation
 - Scale up information from lab or bench scale to prototype, with understanding of subsequent scale-up steps and needs through demonstration (Stage 4) and commercialization (Stage 5).

- **Detailed Technical Assessment**
 - Initial process selection (including process flow sheet with material and energy balances, equipment lists, utility balances, process control philosophy, etc.)
 - Updated knowledge gaps with plan of action.
 - List of potential commercial design options and demonstration plans appropriate for each serious design.
 - Recommendation for suitable demonstration facility. This should include the size of the next facility, requirements for data to be collected (completely or partially integrated) and expectations for what is to be determined (e.g., gain experience in the operation of a larger scale unit operation and obtain intermediate scale-up information, test complete integration on accumulation of impurities, produce large quantities of product or by-product for customer or outside vendor testing, etc.)

- **Financial Assessment**
 - Economic models constructed for both experimentally verified case and most likely commercial case (the most likely commercial case may rely on additional knowledge to be developed in Stage 4).
 - Business plans for Stages 4 and 5.

Gate 4 Review Criteria

Must have a partner that will lead the Stage 4 effort.

➤ **Strategic Fit**

- Does process identified address the business need of the industrial partner?

➤ **Market/Customer**

- Is the market potential of process attractive?
- Is the partner willing, prepared and able to lead the Stage-4 validation effort?
- What are estimated business risks associated with the technology?

➤ **Technical Feasibility and Risks**

- Is process still feasible, considering the new testing of a more integrated, real system?
- Are there any technical showstoppers that still need to be resolved?

➤ **Competitive Advantage**

- Are the economics, with the new data and more detailed design, still compelling?
- Have any competing processes come to light that are better?
- Does this process still possess a competitive advantage?

➤ **Legal/Regulatory Compliance**

- Have legal and regulatory issues been addressed?
- Are there remaining issues that would have to be resolved during stage 4, i.e. site specific permitting issues?

➤ **Critical Success Factors and Showstoppers**

- Have critical success factors been addressed?
- Have all the showstoppers identified in Gate 3 been overcome? If so, how?
- What are plans to address remaining potential business and technical showstoppers?

➤ **Plan to Proceed**

- What are detailed plans for Stage 4 (with milestones)?
- What are industrial partner's general plans for Stage 5?

Gate 4 Keepers

- DOE Program Manager
- NREL Technical Manager
- Industry Partner Manager/Technical Lead
- NREL Technical Lead
- NREL Marketing Representative
- NREL Process Engineering and Economics Lead
- Outside Engineering/Scientific Experts
- Legal/Regulatory
- Environmental/Safety

Stage 4: Validation

Goals:

- Scale-up the process identified in Stage 3 sufficiently to support the design and construction of a commercial unit.
- Develop convincing process design data to enable process equipment guarantees.
- Produce sufficient quantities of products to satisfy customer evaluations.

Stage 4 Work Activities:

Scale-up work is the emphasis. Stage 4 requires an industrial partner leading and funding the effort. NREL would only serve as a technical consultant to the partner in the kinds of activities described below.

- **Market Assessment**
 - Identify specific customers and work with them to develop and test the process or products with their feedstock or process. If dealing with a product rather than a process, produce sufficient quantities to establish the product quality over the range of feedstock envisioned.
 - Check market and potential customers to determine continued need, or if end product or time to market changes.
- **Research Activities**
 - **Market development demonstration of process**
 - Equipment should be large enough and similar enough to envisioned commercial equipment that risk in scaling to commercial scale (Stage 5) is eliminated.
 - **Demonstration of integration at real processing conditions**
 - Process should be integrated as much as possible to identify any problems arising from feedstock quality and recycle (accumulation, contamination, losses). Waste streams should be closely monitored and proper designs made for their remediation.
 - **Development of Equipment Guarantees**
 - By testing in the demonstration unit or off-site at vendor locations sufficient data should be developed under process conditions (temperature, pressure, actual process streams) to support vendor guarantees for critical pieces of equipment.
 - **Development of Engineering Scale-up Data**
 - Any data found missing from the scale-up to this demonstration should be developed, either at the demonstration scale or back in a laboratory.
- **Detailed Technical Assessment**
 - Final commercial scale process flow diagrams and equipment specifications should be developed from demonstration scale data or other appropriate information.
 - Continue to compare to other known processes
- **Financial Assessment**
 - Economic evaluation, and business plan refinement (from Stage 3) with partner providing leadership.

Gate A Review Criteria

➤ **Strategic Fit**

- Does proposed research build knowledge or capability in alignment with program strategic direction?

➤ **Customer**

- Who are the customers for the new knowledge or capability?
- How will the knowledge or capability developed be valuable to the customer, or essential to future commercialization?
- What are business risks to investing in this line of research or developing this capability?

➤ **Technical Feasibility and Risks**

- Is research approach feasible?
- Describe how proposed work is a departure and is an improvement from current research pathways, including work outside of NREL.
- What are the technical risks in carrying out this line of research or developing this capability?

➤ **Competitive Advantage**

- How will proposed knowledge or capability improve the chances of commercial success?
- What other research or development routes exist and what are their relative advantages and disadvantages?
- What could happen to make this area of exploratory research, or capability obsolete?

➤ **Legal/Regulatory Compliance**

- Patent positions
- Waste streams, emissions, safety, permitting
- Are issues surmountable?

➤ **Critical Success Factors and Showstoppers**

- Provide prepared list of success factors and showstoppers.
- Have critical success factors been addressed?
- Plans to address potential business and technical showstoppers.

➤ **Plan to Proceed**

- What are detailed plans for Stage A (with knowledge milestones, schedule, and resource estimates)?
- What are general plans for Stage B?

Gate A Keepers

- NREL Technical Manager
- DOE Program Manager
- NREL Technical Lead
- Industry Partner(s)

Stage A: Exploratory Research

Goals:

1. Explore key scientific questions in order to gain an understanding of the potential importance of answering these questions to Program success.
2. Develop technical, scientific and/or engineering capability critical to the success of the Program.

Stage A Work Activities:

Exploratory technical work is the emphasis. Stage A is where we are investing in developing the scientific knowledge that will enable us to ask and solve the "right" questions in the future. Success will be measured by the degree to which this new knowledge or capability is used in new or existing commercially focused projects.

- **Market Assessment**
 - Confirm importance of scientific questions to be explored, or capabilities to be developed, through discussions with other project teams and/or potential industrial partners.
- **Research Activities**
 - **Conduct exhaustive literature review**
 - Investigate how similar experimental programs have been conducted and evaluate their relative levels of success.
 - **Identify and investigate multiple research strategies**
 - Since there may be multiple routes to reach the desired outcome, some experimental investigation will likely be needed before a research strategy can be selected for further development.
 - **Select and conduct preliminary validation of research strategy to be used for further work**
 - Prove that the strategy selected has a reasonable chance of success if it were applied to a Stage B project.
- **Detailed Technical Assessment**
 - Capture value of gained knowledge or capability developed in milestone reports.
 - Continue to compare progress to other known activities in the area.

Stage A Outputs:

- **Market Assessment**
 - Updated customer assessment of relevance and importance of working on the specific scientific question(s), or developing the new capabilities.
- **Research Results**
 - Detailed documentation of all relevant experimental work.
 - Publication and dissemination of information gained to the widest possible audience.
- **Detailed Technical Assessment**
 - Review impact of new information on program research activities to identify possible changes to ongoing or planned activities and/or shifts in program emphasis.

- Updated knowledge gaps with plan of action if appropriate.
- Recommendation for next step. If continuation onto Stage B, then a plan should be prepared including objectives, milestones, resource estimate, and schedule. Stage B would include work that answers the key questions established in Stage A with the research strategy selected in Stage A.

Gate B Review Criteria

➤ **Strategic Fit**

- Does proposed research build knowledge or capability in alignment with program strategic direction?

➤ **Customer**

- Who are the customers for the new knowledge or capability?
- How will the knowledge or capability developed be valuable to the customer, or essential to future commercialization?
- What is the customer's perception regarding the relevant "window of opportunity" for this work?
- What are business risks to investing in this line of research or developing this capability?

➤ **Technical Feasibility and Risks**

- Is research approach feasible for the specific problem identified?
- Describe how proposed work is a departure and is an improvement from current research pathways, including work outside of NREL.
- What are the technical risks in investing in this line of research or developing this capability?

➤ **Competitive Advantage**

- How will proposed knowledge or capability improve the chances of commercial success?
- What other research or development routes exist and what are their relative advantages and disadvantages?
- What could happen to make this area of development research, or capability obsolete?

➤ **Legal/Regulatory Compliance**

- Patent positions
- Waste streams, emissions, safety, permitting
- Are issues surmountable?

➤ **Critical Success Factors and Showstoppers**

- Provide prepared list of success factors and showstoppers.
- Have critical success factors been addressed?
- Plans to address potential business and technical showstoppers.

➤ **Plan to Proceed**

- What are detailed plans for Stage B (with knowledge milestones, schedule, and resource estimates)?
 - What are general plans for use of the knowledge gained or capability developed by customers or commercially focused projects?

Gate B Keepers

- NREL Technical Manager
- DOE Program Manager
- NREL Technical Lead
- Customers, Industry Partner(s)

Stage B: Development Research

Goals:

- Answer key technical questions in order to gain an understanding how to best tackle the major scientific challenges in developing program technologies.
- Develop technical, scientific and/or engineering capability critical to the success of the commercializing technologies under development by the Program.

Stage B Work Activities:

Stage B will build upon the exploratory knowledge or capability gained in Stage A in a focused, detailed experimental program. We are investing in developing the scientific knowledge and capability that will enable us to answer important scientific and technical questions in the future. While the work is not directly related to commercialization objectives, ultimate success will be measured by the degree to which this new knowledge or capability is used in new or existing commercially focused projects.

- **Market Assessment**
 - Reconfirm importance of scientific questions to be answered or capabilities to be developed, and focus the efforts to solve the specific problems or issues identified through discussions with other project teams and/or potential industrial partners.
- **Research Activities**
 - **Validation of selected research strategy**
 - Validate that the research strategy has an excellent chance of success when applied to the specific problem to be solved.
 - **Carry out planned work to solve specific problem(s) identified**
 - Since it is the intention that the results of this research benefit a defined (Blue Line) project, involvement with a partner involved in a defined project is appropriate.
 - Monitor progress in knowledge milestones that yield key pieces of the information necessary to meet the ultimate goal. In many cases, it should be possible to attach a specific performance objective to a knowledge milestone
- **Detailed Technical Assessment**
 - Capture value of gained knowledge or capability developed in milestone reports.
 - Continue to compare progress to other known activities in the area.

Stage B Outputs:

- **Market Assessment**
 - Updated customer assessment of relevance and importance of working on the specific scientific question(s), or developing the new capabilities.
- **Research Results**
 - Detailed documentation of all relevant experimental work.
 - Publication and dissemination of information gained to the widest possible audience.
- **Detailed Technical Assessment**
 - Summary of how the understanding or capability can be applied to commercially focused projects, including updated knowledge gaps with plan of action if appropriate.

- Review of the new information to determine impact on other program research activities to identify possible changes to ongoing or planned activities and/or shifts in program emphasis.
- Identification of "lessons learned" from the project. What went well and what did not? etc.
- Recommended next steps. This would be covered in a Gate C review in which the primary focus is the plan to transfer the newly developed technology or scientific capability to those projects or partners who can use it.

Technical and Financial Assessments in the Stage Gate Process

Conceptual process engineering design and techno-economic analysis is used extensively in the Program to carry out the detailed technical and financial assessments that are integral parts of the Stage Gate process. We practice a graded approach to these assessments meaning that as the projects move along the development pathway, the assessments become more robust and hopefully, more accurate. The Program has developed a series of detailed process models and assessment tools for the main process concepts under development. These tools are used where appropriate. However, when new ideas or process concepts are being considered, these models and tools must be developed. The information below describes the level of robustness appropriate for the assessments at each gate in the process.

New Ideas

Gate 1 – Idea to Preliminary Investigation

Objective: Process engineering validates research direction and provides engineering perspective.

New Idea Not Existing in an Available Process Concept Tool

1. Talk to engineering team about idea and any alternatives– get engineering perspective.
2. Possible profit margin calculation (value – feed costs=margin for process costs).
3. Possible simple fraction of revenue for feedstock (FRF) calculation
4. Determine what questions need to be answered in Stage 1.

New Idea Relates to Improving Existing Process

1. Talk to engineering team about potential cost reductions and design impact.
2. Possible calculation of best case cost reduction - total elimination of the associated cost, or use of previous sensitivity studies.
3. Determine what questions need to be answered in Stage 1.

Commercial Track

Gate 2 – into Detailed Investigation

Objective: Process engineering develops a Block Flow Diagram (BFD) and gross production cost.

New Idea Not Existing in an Available Process Concept Tool

1. BFD
2. Inside Battery Limits (ISBL) equipment only for process model
3. Preliminary modeling - Non-rigorous mass and energy balance (i.e. lignin model or transgenic cellulase from plant calculations)
4. Economic analysis capturing gross operating and capital costs (large ticket items)
5. Operating cost calculations use standard utility costs (need to determine standard)
6. Capital costs from database
7. Fixed costs as a percentage of capital costs
8. Use Lang factor to go from purchased equipment cost to Total Project Investment
9. Use Capital Charge Factor (a certain ROI embedded) to go from TPI to \$/production unit for capital

10. Add Capital and Operating Costs for Initial Minimum Selling Price Estimate

New Idea Relates to Improving Existing Process

1. Use existing models to evaluate impact of improvement
2. Perform sensitivity on uncertain data/costs to direct research

Gate 3 - into Development

Objective: Develop Process Flow Diagrams (PFDs) and detailed production cost. New ideas and process improvements to otherwise existing processes are handled the same way at this stage.

1. PFDs
2. Add Outside Battery Limits (OSBL) equipment in process model
3. Detailed modeling - detailed mass and energy balance (i.e. enzyme and two-stage models) using data from Stage 2.
4. Economic analysis with all capital and operating costs to +/- 30 to 50%.
5. Capital costs from vendors, Engineering and Construction firms
6. Fixed costs broken out.
7. Break out installation, contingency and other indirect costs. Determine what contingency should be used.
8. Break out ROI, equity into inputted numbers.
9. Perform sensitivity analysis with more defined ranges to direct research.
10. Additional analyses as indicated by potential customer representatives.

Gate 4 – into Validation

Objective: Develop a detailed engineering and economic design report. Since it is expected that by Gate 4 an industrial partner will be very involved and positioned to take over project leadership, the technical and financial assessments carried in support of Gate 4 are at a minimum conducted jointly by NREL and the industrial partner.

1. Refine model using site-specific data if available.
2. Use customer or industry accepted financial parameters.
3. Generate design report.
4. Perform kinetic modeling on key reactions to verify scale up.
5. Perform risk analysis to support customer in seeking process guarantees, funding.
6. Transfer information to industrial partner.
7. Support detailed design development by industrial partner.

Research Track

The technical and financial assessments of projects on the research track are very different from the assessments for commercial track projects. The emphasis is on identifying the relative importance of the scientific questions and problems to be explored by estimating the kinds of benefits or improvements in technology that could accrue if we had answers to the scientific questions.

Gate A - into Exploratory Research

Related to a commercial track project

Use existing models to run sensitivities on possible technology improvements enabled by the research.

New and unrelated to a commercial track project

Develop new process concept sufficiently to determine potential cost savings compared to existing process concepts.

Gate B - into Development Research

In Gate B the project must be related to a commercial track project so existing models can be employed to run sensitivities on possible technology improvements enabled by the research.

Appendix A - Project Idea Submission Form and Gate 1 Evaluation Criteria

Project Idea Submission Form

[Items 1-8 – Limited to 2 pages, Item 9 – Limited to 2 pages]

Title:

Submitter:

Submission Date:

Reviewers:

Review Date:

Review Outcome:

Revision Date:

Revision #:

Idea Description:

Strategic Alignment (describe how the project fits with the mission of the Biofuels Program):

Intended Customers (who will probably be interested in this technology if it is developed):

Technical Feasibility (describe the probability of success of the project. This could be based on the success of previous work, other projects or literature):

Competitive Advantage (describe what technology will this technology be competing with and why this technology will be better):

Legal and Regulatory Issues (describe any anticipated legal (patent or licensing requirements) or regulatory (emissions or waste) issues that will need to be resolved):

Critical Issues (describe the most important issues that must be addressed in order for the project to be successful):

Critical Success Factors (what will be necessary to pass Gate 2?):

Key success factors include:

Potential showstoppers:

Plan and Deliverables (describe the Stage 1 work to be accomplished and deliverables):

Gate 1 Evaluation

Project Title _____
 Submitter _____
 Reviewers _____

Submission Date _____
 Review Date _____

Recommendation:

Criteria	Objective	Key Inputs	Evaluation Criteria	Rating (0-10)	Weight Factor	Score	Comments
1. Strategic Fit	Ideas address needs of both Biofuels Program and Business Partners.	Objectives and expected results (process/product) of ideas	Evaluation if the results fit Program (MYTP or AOP) and business partners needs.		15.0%	0	
2. Market/Customer	Show the market potential of ideas is attractive. Identify potential showstoppers.	Potential market size and value of products. Competitive products. Customer's capability to commercialize ideas.	Identify major barriers or showstoppers for commercialization, e.g., SWOT analysis.		10.0%	0	
3. Technical Feasibility and Risks	Show ideas are feasible and risks are manageable. Identify potential showstoppers.	Technical objectives and expected results.	Show that key technical objectives are feasible. Identify potential technical showstoppers.		20.0%	0	
4. Competitive Advantages	Show ideas have more advantages than competitive methods.	Key technical features of proposed ideas and competitive processes/products.	Comparison of proposed technology/ideas with alternatives.		30.0%	0	
5. Legal/Regulatory Compliance	List all potential legal/reg. issues and show that they are surmountable.	Intellectual property position of proposed technology. Identify any environmental issues/benefits.	Identify any legal, regulations, and environmental issues regarding the proposed technology or products		10.0%	0	
6. Critical Success Factors	Identify all critical success factors.	Outputs of objectives #2 and #3.	A list of all critical success factors (technical and business)		15.0%	0	
7. Work Plan and Deliverables	Develop an effective plan to address critical success factors and technical/business show stoppers.	Critical success factors. Resources available.	A preliminary work plan which will accomplish all key success factors and include estimated schedule and resource requirements. A general plan for Stage 2.		+/-		

Total 100.0% (Maximum score = 10)

Other General Comments: _____

Appendix B - Recommended Project Management Approaches

From a project management perspective, each stage of a project is treated as an individual project with a discrete beginning and end. However, since by design the efforts start out at a relatively low level of complexity and spending we adjust our project management approach accordingly, that is we practice a graded approach to project management in the Biofuels Program.

Below is general guidance on appropriate project management approaches and tools for projects in different stages. More information on these approaches and tools can be found in the guide to Project Management in the Biofuels Program available in the BCFC Valuable Documents Database and on the Biofuels Intranet.

Stage 1 Project Management

This stage is a relatively low level of effort involving only a few people. It is generally defined as doing the homework and thinking required to turn an idea into a project proposal. Therefore the project management needs in Stage 1 are minimal.

Defining and Planning

- Idea submission form provides guidance for the definition of a Stage 1 project. Once approved a more detailed plan for the Stage 1 effort may be needed as described below, if not already part of the idea submission.
- Objectives, Deliverables, Milestones
 - Objectives, deliverables and milestones are generally determined by the kinds of questions that need to be answered in the Gate A or 2 review. All should be clearly defined.
- Work Breakdown Structure (WBS)
 - May just be a list of activities if planned work does not need to be broken down into discrete subunits.
- Simple schedule and budget
- Roles and Responsibilities Chart (RACI - Responsible, Accountable, Consult, Inform) if more than a few people involved.

Executing and Controlling

- Project meetings as needed
- Quarterly cost reports and technical reviews with management

Close-Out

- Gate A or Gate 2 review
- Complete Stage documentation of findings

Stages 2, A and B Project Management

These stages are likely to be similar in terms of project size, complexity, and need for integration. The level of project management is significantly greater than a Stage 1 project but less than a Stage 3 project.

Defining and Planning

- Gate 2, A or B Review meeting
 - Confirm satisfactory achievement of Gate 2, A, or B criteria including customer/program alignment based on Stage results
 - Provide overview of Stage 2, A, or B plan including preliminary WBS, objectives, milestones, budget, and schedule. Once approved, a more detailed plan will need to be developed by the Project Team as described below.
- Work Breakdown Structure (WBS)
 - Divide the project into logical subunits that will enable definition of quality, cost and schedule as well as connectivity between the subunits. The goal is to identify discrete units of work, each of which advances the project toward its completion.
- Objectives, Milestones, Deliverables
 - Each subunit in the WBS should have objectives, activities, milestones and deliverables clearly defined, including quality expectations and definition of successful completion.
- Project Team Alignment & Integration
 - Roles and Responsibilities Chart (RACI) including subcontractor roles
- Measures/Metrics
 - Budget developed with Brio/financial analyst
 - Schedule developed including milestones in Microsoft Project

Executing and Controlling

- Routine project meetings as needed, but held at least monthly.
- Bi-monthly progress reviews with management including cost reports, corrective actions and modifications to plans as needed.
- Experimental plans that clearly specify the questions to be answered by the experiments and criteria addressing data quality and measures of success.
- Experimental reports that document the work carried out and draw conclusions relative to the objectives of the experiment, data quality, and assessment of success.
- Modify RACI's as necessary during the project.

Close-Out

- Gate 3, Gate B, or Gate C review
- Complete Stage documentation including experimental work, assessments, and findings.

Stage 3 Project Management

Stage 3 Projects are the largest and most complex projects that NREL leads for the Biofuels Program and therefore have the highest levels of project management.

Defining and Planning

- Gate 3 Review Meeting
 - Confirm satisfactory achievement of Gate 3 criteria including customer/program alignment based on Stage 2 results
 - Provide overview of Stage 3 plan including preliminary WBS, objectives, milestones, budget, and schedule. Once Stage 3 work is approved, a more detailed plan will need to be developed by the Project Team as described below.
- Work Breakdown Structure (WBS)
 - Divide the project into logical subunits that will enable definition of quality, cost and schedule as well as connectivity between the subunits. The goal is to identify discrete units of work, each of which advances the project toward its completion.
- Objectives, Milestones, Deliverables
 - Each subunit in the WBS should have objectives, activities, milestones and deliverables clearly defined, including quality expectations and definition of successful completion.
- Project Team Alignment & Integration
 - RACI including partner and subcontractor roles
- Measures/Metrics
 - Budget developed with Brio/financial analyst
 - Schedule developed including milestones in Microsoft Project

Executing and Controlling

- Weekly to monthly project meetings with progress reviews including corrective actions.
- Monthly to Bi-monthly progress reviews with management including cost reports, corrective actions and modifications to plans as needed.
- Measures/Metrics
 - Budget/Cost Tracking (monthly Brio data in Biofuels project reporting format)
 - Schedule Tracking with Gantt charts and Milestones, % complete estimation
- Continued development of detailed WBS subunit definition including Gantt charts and Milestones
- Experimental plans that clearly specify the questions to be answered by the experiments and criteria addressing data quality and measures of success
- Experimental reports that document the work carried out and draw conclusions relative to the objectives of the experiment, data quality, and assessment of success.
- RACIs modified as needed during the project

Close-Out

- Gate 4 review
- Complete Stage documentation including partner development, experimental work, technical and financial assessments, and findings.