U.S. Department of Energy
Energy Efficiency and Renewable Energy
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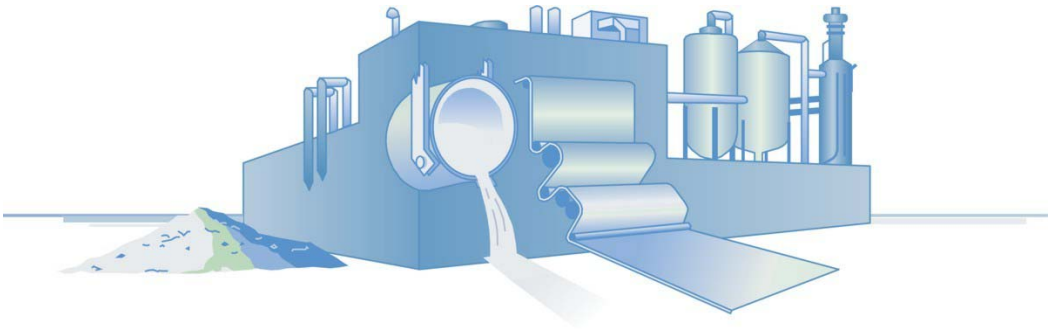
Industrial Technologies Program



Stage-Gate Innovation Management Guidelines

Managing risk through structured project decision-making

February 2007

Version 1.3

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Overview of ITP Stage-Gate Innovation Management

Background

The Industrial Technologies Program (ITP) manages a diverse research portfolio (Figure 1) with the overarching goal of accelerating the use of innovative, energy-efficient, industrial technologies. It is critical, therefore, that there is an effective pathway for innovative technology and new technical information to reach the end-user. The Stage-Gate Innovation Management Guidelines map out this pathway.

Figure 1. ITP Core Research

Industry Sector-Specific: Aluminum, Chemicals, Forest Products, Glass, Metal-casting, Mining, Steel

Cross-cutting Technology: Combustion, sensors and controls, materials, energy systems

Technology Delivery: Best energy management practices, Industrial Assessment Centers, emerging technologies

Stage-Gate Guidelines are a tool for ITP Technology Managers, Field Office Project Managers, and ITP partners to evaluate the progress of projects in the research portfolio and to guide disciplined decision-making throughout the course of an R&D project. The Guidelines are intended to be applied to projects at the Agreement level (individual technology) in EERE's Corporate Planning System (CPS).

To broadly accomplish its energy efficiency mission, ITP has designed the Stage-Gate process with flexibility to accommodate its various types of research projects. Whether the project is basic science or technology development, the Stage-Gate process contains the guidance that increases the probability of successfully bringing new energy technologies to U.S. industry.

Process Overview

ITP's Stage-Gate process is a multi-step approach of logical thought and decision making for use by ITP managers and their partners in conceptualizing and developing new processes and products. It is a project-based process that aids in the delivery of energy saving technologies to U.S. industrial energy users. Stage-Gate is an enabler of effective R&D and a guide to best practices, not a rigid set of rules to be followed without exception.

ITP's process is built on a foundation of *EERE RDD&D* practices combined with best methods from general business. ITP Stage-Gate Innovation Management Guidelines are based on Stage Gate™ principles (a registered trademark of R.G. Cooper & Associates), a methodology which has been successfully applied throughout industry and government (Cooper 2002, Cooper 1998, GRI 1995).

Stage-Gate is a phased project management approach that produces fact-based funding decisions based on a set of defined evaluation criteria. Specifically, the Stage-Gate approach will be used by ITP to:

- Provide consistent program and project management guidelines
- Characterize projects in terms of scope, quality, performance, and program integration
- Evaluate and monitor project progress against milestones
- Assess viability of technology commercialization
- Guide decisions on project funding (e.g., Go Forward, Stop, Hold, Return)

A key tenant of the Stage-Gate model is that R&D is inherently risky and only a small percentage of new ideas will find commercial use. Therefore, funding commitments for projects are initially low and typically focus on uncertain technical elements. Research to show the technical and economic potential for a technology in successive project stages provides important information for making judgments about the project and for committing funding in the long-term. The expectation is that projects with serious technical or other issues will be identified and resolved early-on, enabling greater investment in the projects with the greatest probability for success in later stages.

Stages and Gates

General Description

The Stage-Gate process is comprised of a series of stages and gates, as shown in Figure 2. Each stage is defined by a set of specific research activities; gates are checkpoints where decisions are made based on pre-determined criteria.

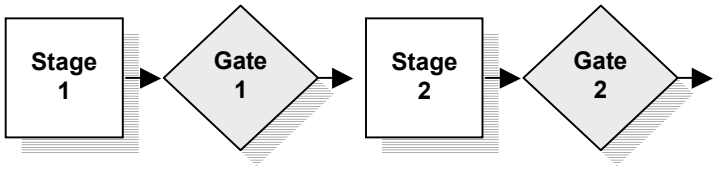


Figure 2. Simplified Stage-Gate Flow Diagram

Stages

Stages are the elements of a project where analytical research and technology development are performed. The near term objective of each stage is to make technical progress and gather the information needed to move the project through the next gate. Information accumulated during each stage is used to reduce levels of technical uncertainty and economic risk. With this knowledge, researchers can make informed decisions that address both technical and business challenges and reduce the overall uncertainty of the project. Early stages of research and development typically encounter the highest technical risks; the resources in later stages are most often dedicated to overcoming economic barriers to project success.

The Stage-Gate process provides flexibility to gather information, manage risks, and address end-user needs in the timeliest manner. ITP projects may be initiated at whatever stage is most appropriate. For example, projects may be well past preliminary analysis or idea generation, and ready for concept definition when funding is awarded by ITP. Wherever a project begins, however, it can only be in one stage at a time. Therefore, it is critical that a plan be in place to define the work to be accomplished in each subsequent stage.

Project funding may also end at the most appropriate stage. For example, industry may want to undertake portions of the technology development stage on their own without Federal funding due to proprietary or intellectual property issues. In some cases, DOE funding on an individual project may be for one select stage in the R&D cycle, with the private sector funding the remaining stages.

Gates

Gates are decision points for initiating funding or moving forward with a project. At each gate the following occurs:

- A set of criteria is used to judge the progress of the project
- A decision is made as to whether the project should go ahead, be delayed, or stopped
- Approval of funding is made for the next stage
- A path forward for the next stage is presented and approved

Each gate has a unique set of quantitative and/or qualitative criteria for determining whether ITP should initiate funding or approve the project into the next stage. Criteria are designed to answer salient questions such as:

- Have critical technical milestones been met?
- Is project on time and within budget?
- Does the concept still have potential to provide benefits to the end-user?
- Does the concept continue to fit with ITP goals and strategies?

The current stage of the project is determined by whether it has met all the criteria for preceding gates. As stated earlier, a project may enter the process at whatever stage is most appropriate. However, all previous gate criteria must have been met. For example, a proposal may be submitted where the criteria for Gate 2 have already been met. In this case the project could enter the process at Stage 3.

Progression through each gate is determined by gatekeepers who are identified at the time the project begins. The gatekeepers determine whether the project moves forward given the information developed in the preceding stage.

The ITP Stage-Gate Model

ITP's model for the Stage-Gate process focuses project management activities on the delivery of energy saving technologies and information to U.S. industrial energy users. The Process directs ITP and its partners to consider the prospects for commercialization from the start of a project to its conclusion. Planning for commercialization cannot wait until the end of a project. Studies have repeatedly demonstrated that a major reason for R&D failing to produce a market impact is the neglect of market, business and financial factors early in the R&D process.

Within ITP's research and development program, successfully completed projects result in one of two outputs that make an impact: Products or Information. Products, in general, are hardware, software, or process designs that are sold by equipment manufacturers, engineering design firms, or other commercial entities to energy users. Information is a knowledge-based result (e.g., database development, properties and behavior characterization, and modeling and simulations), which ITP disseminates to technology developers or the industrial sector; this new knowledge ultimately leads to reduced energy intensity. R&D activities designed to address a technical problem within an ITP product development effort should be integrated into a single Stage-Gate project. *Whether the output is a technology product or information, a successful project always delivers benefits to the end-user.*

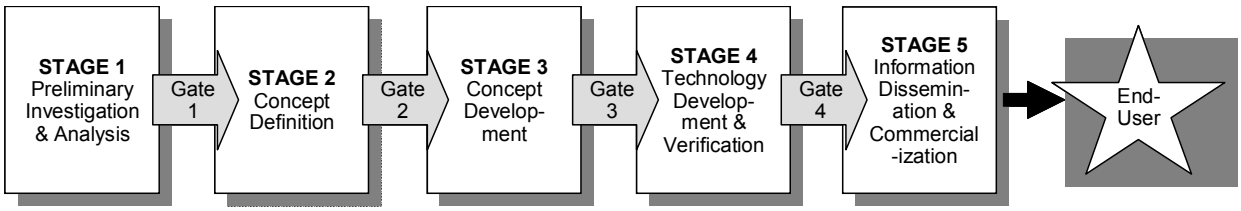


Figure 3. Stage-Gate Process Flow

Figure 3 is intended as process outline only. ITP technology development projects are not required to enter the process at Stage 1 and exit at Stage 5; project funding may begin at any stage and end at any stage in the five stage process. Stages may not be skipped, however, and should be followed in sequence. A typical DOE R&D commercialization project may begin at Stage 2, Concept Definition, and end after Stage 3, Concept Development, with the intent that the private sector will continue with Stages 4 and 5, Technology Development and Commercialization.

Stage	Gate
1. *Preliminary Investigation and Analysis*: Scoping studies to identify research topics; technical and market assessments; idea generation.	1. *Research Project Selection*
2. *Concept Definition*: Early stage research to explore and define technical concept or to answer a specific technical question; laboratory scale research.	2. *Research Approval*
3. *Concept Development*: Development and testing of prototype technology or process; development of models and informational databases; predictive modeling or simulation of process or equipment performance; evaluation of system scalability and end-user acceptability; demonstration of concept feasibility at prototype or bench scale.	3. *Proof of Technical Feasibility*
4. *Technology Development and Verification*: Pilot scale development of technology or process; verification and documentation of technical performance and validation of economic potential in field test(s).	4. *Proof of Commercial Feasibility*
5. *Information Dissemination and Commercialization*: All activities necessary for information delivery and commercial launch (production scale technology manufacture and installation; development of market infrastructure; demonstrated commercial operation).	

Stage and gate criteria have been developed that are uniquely suited to the type of projects funded by ITP. The section on Stage Descriptions and Gate Review Criteria beginning on Page 9 provides more details on suggested activities and decision-points.

Benefits of Structured Project Decision-Making

A consistent set of management guidelines, which can be followed throughout ITP, will improve accountability and pave the way for timely, fact-based decision-making. Stage-Gate Guidelines lead to a higher percentage of successful projects in the R&D portfolio by enabling effective communication among technology managers, project managers, contractors, equipment manufacturers, end-users and other project participants. Specifically, a structured innovation management process provides ITP with a tool for:

- Risk management through enhanced project prioritization
- Improved quality of execution
- Fact-based decision-making
- Parallel, multi-functional R&D
- Effective end-user involvement
- Idea generation

Risk management through enhanced project prioritization

Most of the projects funded by ITP are inherently high-risk ventures that industry is unable to undertake independently. The Stage-Gate process manages R&D risks by prioritizing the use of resources and ensuring they are properly allocated, based on the potential for successful research outcomes. For example, Stage-Gate identifies poorly performing projects and those that will not meet expected technical objectives. If appropriate, resources can then be diverted to entirely new projects or to projects with greater promise for success, expediting the path to commercialization. A well-implemented project decision process can shorten the time to market by 30% or more*.

Improved quality of execution

By anticipating and focusing on "road-blocks" early in the process, project decision-makers can monitor research and technical development and assess commercial feasibility while minimizing the use of resources. Quality of results is also improved by defining goals, activities and outputs ahead of time; ensuring that all key issues have been addressed.

Fact-based decision making

When stages and gates are clearly defined with pre-specified goals and outputs, decision-makers are able to quickly and factually formulate judgments based on the performance of the project. Gate criteria are based on current technical, market, financial and operations information in order to make well-informed decisions.

Parallel, multi-functional approach to R&D

To address and resolve interdependent issues such as technical performance, energy savings, market potential, economics, safety and environmental impacts, each stage of the Stage-Gate process requires multiple kinds of functional expertise. When technical research is conducted in parallel with other important studies and information is shared frequently, impediments to overall project success are addressed as early as possible.

Effective end user involvement

Identifying the needs and concerns of end-users, equipment manufacturers, and other potential partners early in the process helps ensure that private industry will be interested in partnering once the project reaches the production and commercialization stage. The level of industry involvement will become greater and more focused as the project moves though the stages, but their input must never be absent in defining the concept, and in developing, testing, and validating the technology.

Idea Generation

Stage-Gate incorporates a "homework" stage to gain insights on potential research and development areas. Preliminary, early-stage analysis is less expensive than laboratory or pilot-scale activities and provides insights on the future commercial potential of the technology. It is an effective way to prioritize various project options.

* www.stage-gate.dk/product-development-process.html

Alignment of Stage-Gate with ITP's Portfolio/Agreement Review Process

The Stage-Gate Innovation Management Guidelines have been developed to complement ITP's current decision-making processes and enhance its effectiveness. Stage-Gate Guidelines are not intended to replace existing project management and funding review approaches, rather to provide structure so that funding decisions are consistent and that the potential for success of the entire ITP portfolio is increased.

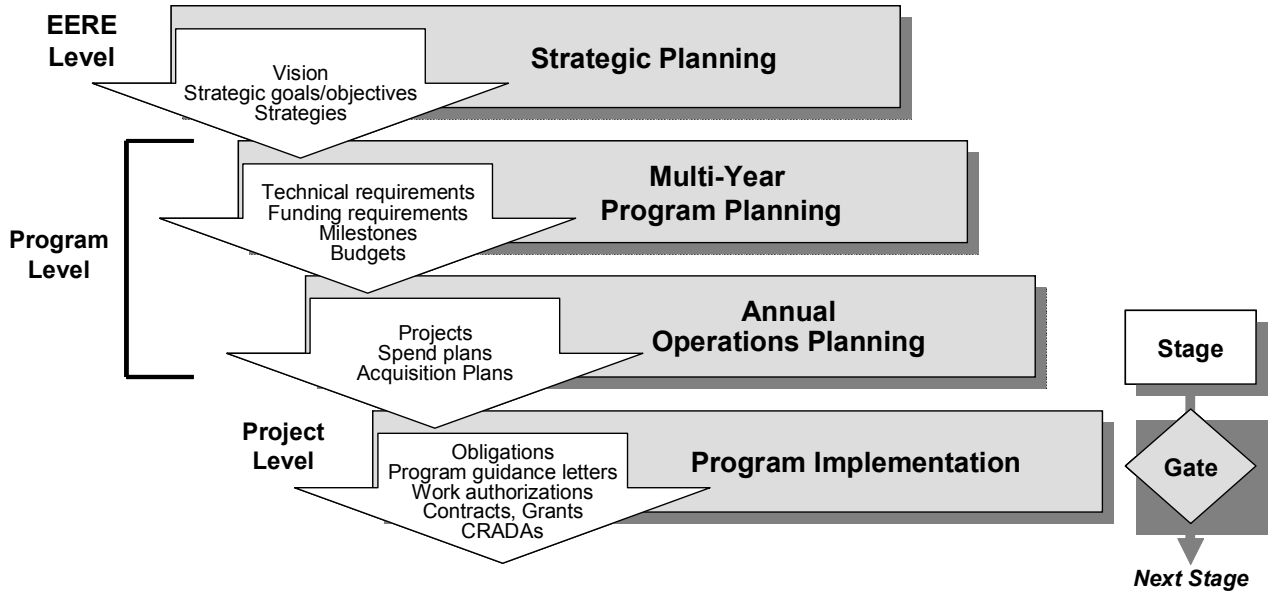


Figure 4. Stage-Gate aligns with AOP and Implementation steps of EERE's Program Management Cycle

Contracting and budget allocation are two key management controls in ITP's program. Using Stage-Gate guidelines in combination with proven management practices within ITP help optimize the allocation of funds within of the R&D portfolio. A clear link between Gate decision criteria and overall project objectives – in solicitations, proposals, and financial awards – leads to focused, fact-based, and balanced project decision-making.

Financial awards should follow Stage-Gate guidelines to the fullest extent possible, including appropriate references to stage activities and gate review criteria during the solicitation and proposal process. Some financial assistance awards, including the contractual agreements overseen by the DOE Field Offices, are currently structured according to budget periods to aid decision-making. Budget periods provide a convenient timeframe for the DOE Project Management Centers (PMC) to decide if a project is meeting its objectives and to discontinue if warranted. As a project approaches the end of a budget period, the PMC typically asks the project team to provide a continuation application that details the progress of the project to date. The continuation application process is one mechanism to integrate stage-gate principles into existing projects by aligning go/no-go decision points with Stage-Gate decision criteria. New awards embody Stage-Gate management approaches when the guidelines are incorporated into solicitations and gate criteria are part of the merit review process.

ITP regularly appraises program activities in merit reviews, project reviews and portfolio reviews in order to ensure that the program is focusing its scarce resources on the most important technical opportunities. ITP Technology Managers are currently responsible for arranging annual or biannual portfolio review meetings. While portfolio review meetings may not always coincide with Stage-Gate gate decision points because of the project timeline or the size of the project, Stage-Gate methods and terminology should be integral in planning and executing the reviews.

Depending on project timing, gate review meetings may be conducted concurrently with other project/agreement review meetings. Gate review meetings may also be more informal, possibly in the form of a conference call.

Implementation of the Stage-Gate Process

The basic Stage-Gate process (Figure 5) is comprised of a series of gates where individual projects are reviewed, and a series of stages to accomplish the work necessary to move the project forward. Essentially, the Stage-Gate process restricts investment in the next stage until management is comfortable with the outcome of the current stage.

Implementation of the process requires a project team with clearly delineated roles and responsibilities. These are outlined in the following sections.

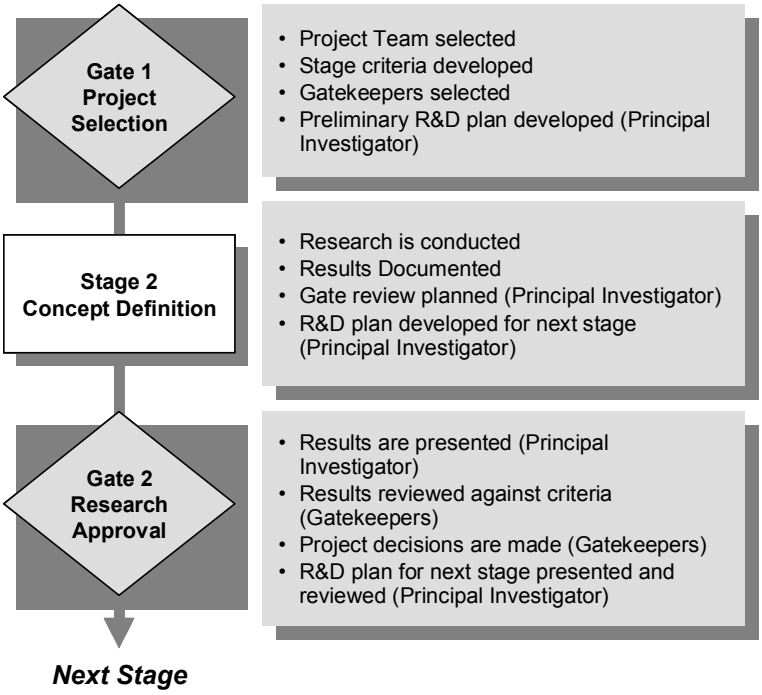


Figure 5. Representative Stage-Gate Process Implementation

Project Team

Upon project award, the first step is to establish a Project Team and to identify gatekeepers. Gatekeepers, typically ITP Technology Managers and DOE Field Office staff, are responsible for deciding whether the project goes forward to the next stage. Project Teams vary in composition depending on the nature, size and stage of the project. Outside experts may be called on at various gates to provide input in specific technical or business areas. Every project team has a Principal Investigator who is responsible for project execution and interaction with gatekeepers. The Principal Investigator should remain unchanged during the ITP Stage-Gate process. If a change in Principal Investigator is unavoidable, the DOE Field Office Project Manager, in consultation with the ITP Technology Manager, must approve the change.

Roles and Responsibilities

DOE Headquarters/ITP Technology Managers

ITP Technology Managers are responsible for all funding decisions and ensuring that DOE Field Office Project Managers apply Stage-Gate guidelines appropriately. Technology Manager responsibilities include:

- Strategic context for project selection and review
  - ◊ Providing documentation of ITP program strategic planning and analysis
  - ◊ Guidance on ITP program priorities and mission
  - ◊ Guidance on solicitation objectives
- Gate Decisions and Project Planning
  - ◊ Providing input to Gate decision criteria development
  - ◊ Participating in Gate reviews for large, high profile projects
  - ◊ Providing clear decisions and recommendations during/after Gate reviews
  - ◊ Allocating funding for approved projects
  - ◊ Reviewing R&D stage plans for larger R&D efforts
  - ◊ Verifying that gatekeeper comments have been documented and addressed
- Project status and review
  - ◊ Holding program/portfolio review meetings that cover project status reviews
  - ◊ Interacting with Principal Investigator and Field Office Project Manager to resolve project issues

DOE Field Office Project Managers

DOE Field Office Project Managers are responsible for applying the Stage-Gate guidelines to projects under their purview. Specific responsibilities include:

- Gate reviews
  - ◊ Providing input to criteria development
  - ◊ Identifying external gatekeepers as necessary
  - ◊ Setting target dates for review meetings
  - ◊ Participating as a gatekeeper
  - ◊ Reviewing and approving detailed R&D stage plans
  - ◊ Reviewing results and making recommendations for funding decisions
  - ◊ Verifying that gatekeeper comments have been documented and addressed
- Project status and review
  - ◊ Participating in program/portfolio review meetings where project status is reviewed
  - ◊ Interacting with Principal Investigator to resolve project issues as appropriate
- Stage management
  - ◊ Contracting/arranging resources
  - ◊ Tracking progress versus budgets, schedules and scope
  - ◊ Facilitating task execution
  - ◊ Communicating status, results and accomplishments

Principal Investigator

The Principal Investigator is a member of the team conducting the R&D and heads up the Project Team. He/she is generally responsible for planning and running the Gate review meetings and other tasks. Specific responsibilities of the Principal Investigator include:

- Executing and controlling the project stages
  - ◊ Gathering and analyzing information
  - ◊ Researching and developing technology
  - ◊ Documenting results and progress
  - ◊ Monitoring budget and schedules
  - ◊ Communicating with ITP managers and end-users
- Distributing outputs and stage plans to the Project Team in advance of review meetings
- Holding dry runs of prior to Gate review
- Developing materials for the review meeting
  - ◊ Presenting stage accomplishments
  - ◊ Addressing review criteria
  - ◊ Presenting the plan for next stage
- Revising and distributing Stage plans
- Documenting gatekeeper comments

Gatekeepers

Gatekeepers are individuals or groups of individuals that are responsible for deciding whether a project should continue and receive funding for the next stage. Gatekeepers are typically internal DOE managers and outside experts and may vary gate by gate. ITP project gatekeepers will typically be DOE Field Office Project Managers, and for large, complex projects, may include ITP Technology Managers. Final gate decisions and funding allocations are made by ITP Technology Managers. DOE Field Managers are responsible for making recommendations to the ITP Technology Managers regarding continuation of projects. Specific responsibilities for gatekeepers include:

- Review of results against preset gate criteria
- Gate decisions and funding allocations (ITP Technology Managers)
- Recommendations for revisions to the R&D plan going forward

Gate Reviews

Gate reviews are held to evaluate the progress of each project against a set of criteria that are defined at the outset of each stage. Work completed during a stage produces the information needed for decision-making regarding continued funding of a project. Other key outputs from the Gate review include pre-determined deliverables (e.g., R&D stage plan, testing results).

Criteria are different for each gate and become more rigorous as the project progresses. The criteria are preset and a list of rules are agreed upon to keep the review process unbiased. The needs of a particular project determine when and how gate reviews take place. The Principal Investigator and DOE Field Office Project Manager usually collaborate in setting target dates for gate reviews.

R&D Stage Plan

A Stage-Gate management plan should be developed for each project upon award, with input from the entire project team. In addition, the R&D stage plan should be updated by the Principal Investigator prior to moving on to subsequent stages. At a minimum, this plan should include:

- Research objectives for the individual stage
- Major technical milestones
- Commercialization or information dissemination objectives
- Work breakdown structure and schedule
- Resource requirements

At each gate review, the R&D stage plan for the next stage must be presented in sufficient detail for the reviewers to comment on the goals, activities and outputs. This plan may also be revised by gatekeepers at the gate review to better reflect technical objectives and funding levels.

Gate Decisions

Gates must have clear, well-understood criteria so that gatekeepers can make objective and timely decisions. Criteria must be specific enough to engage management in the decision process and enable them to ascertain the risks and benefits of going forward. Gate scorecards may be used by gatekeepers to compare projects within a program area as appropriate.

Gate decisions are made by ITP Technology Managers during or following each gate review. DOE Field Project Managers and other gatekeepers will provide input and recommendations for the decision-making process.

Figure 6. Possible Gate Review Decisions

GO FORWARD – goals for the previous stage were met; technical, market, financial and operational information has met expectations; and funding is approved for the next stage (dependent on annual funding appropriation by Congress).

STOP – project is not progressing as it should because the market has shifted permanently, the technology is obsolete, or desired technical objectives cannot be met.

HOLD – project has been suspended for a specified period of time and the criteria will be re-evaluated at a future date.

RETURN – goals have not been accomplished or the criteria have not been met, but because the project is still a high priority, the team will return to the previous stage to complete the work.

Possible gate decisions are shown in Figure 6. If a *go forward* decision has been reached the Project Team will be asked to present the R&D stage plan for the next stage. If the decision is made to *return* the project, the Gatekeepers will provide suggestions to the Principal Investigator on work that needs to be completed satisfactorily before the next gate review is held.

If the decision is to *hold* or *stop* the project, an R&D stage plan is not needed. A project on hold may be re-evaluated and continue at a future date, depending upon the circumstances. However, a stop decision indicates that the project will not receive funding for the next stage.

Stage Descriptions and Gate Review Criteria

For projects that are expected to result in a commercial process or product, stages and gates are designed to facilitate the development of new technology and enable industrial partners to take it forward to commercial launch. Projects that focus on information generation, which may range from fundamental scientific research to the dissemination of information about technology developments, similarly use the Stage-Gate process to ensure outcomes are valuable to end-users. In either case, emphasis is placed on developing effective R&D plans for each stage, and thoroughly understanding the technical and economic risks and benefits associated with new science and technology. Analytical and developmental work is performed during five *stages,* and decisions to continue with the project after completion of each stage are made at four gates (see Figure 7). Examples of activities within each stage and gate are given on the following pages.

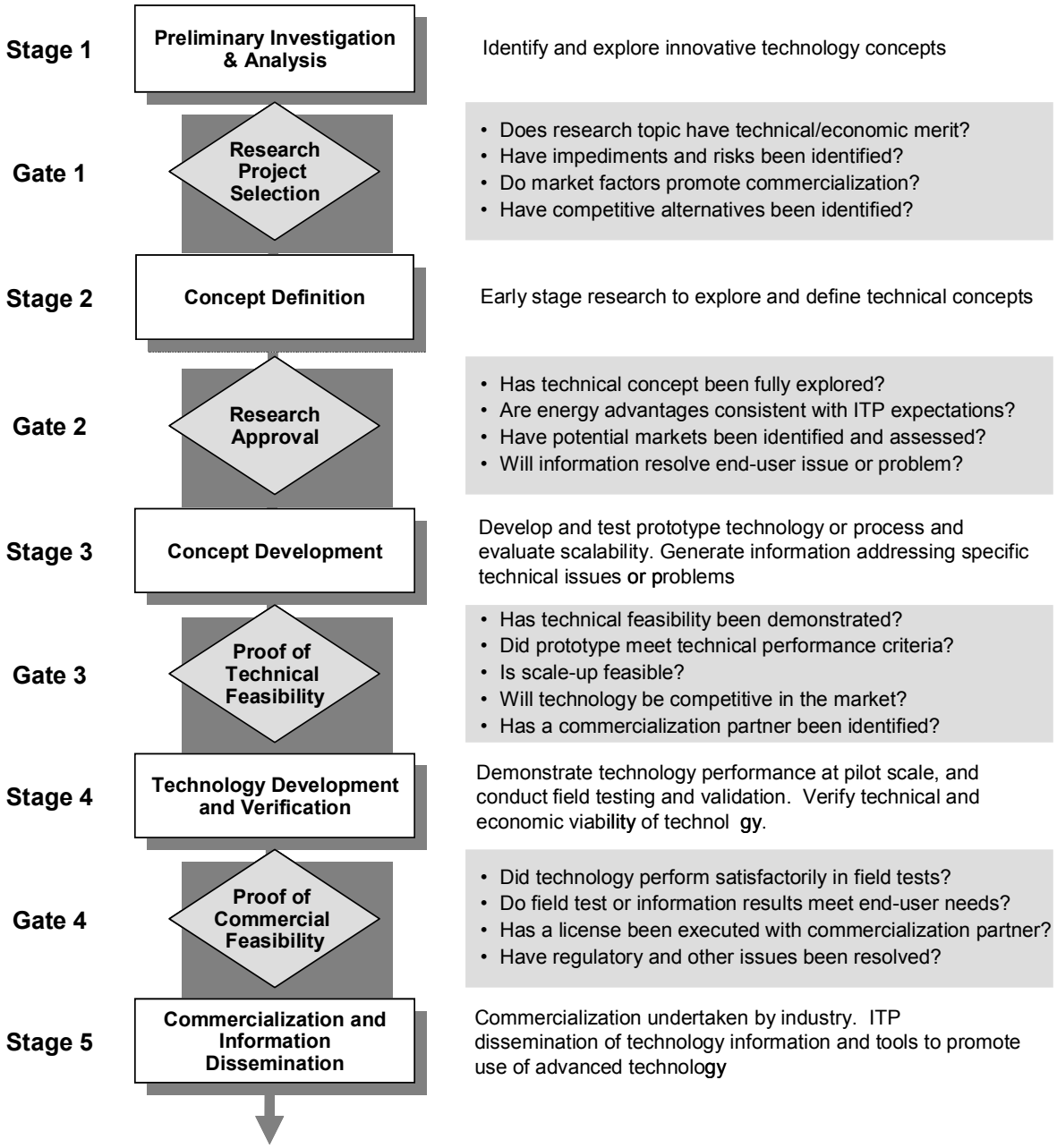


Figure 7. Stages and Gates

Stage 1 – Preliminary Investigation and Analysis

This is the "ideation" phase. It includes assessments of end-users' current and future issues as well as initial scoping studies that identify research to solve these problems. The objective is to prioritize important research topics whose results have the potential to provide energy and economic benefits to U.S. industry and the nation, and that fit within the mission of ITP. Specific goals, activities and deliverables for this stage are shown on the next page.

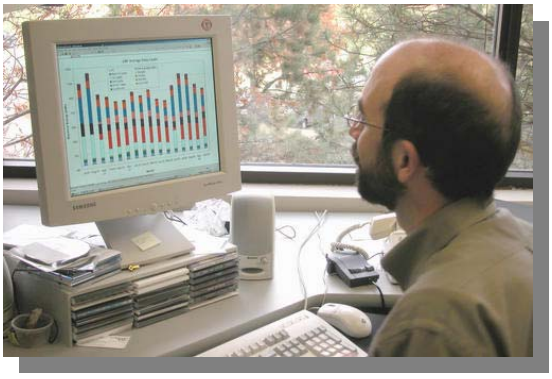
To help uncover the most promising research topics, technical analyses and economic assessments are conducted during this stage. These investigations may draw upon basic research results, literature searches, field research, and discussions with industry experts and technology-users. Technical analysis may involve evaluation of current technology options and limitations, assessment of possible innovative approaches, and identification of information gaps. Market assessments should include a preliminary analysis of market segments and commercialization potential. When this stage is complete, it is expected that one or more research topics will be identified for future funding.

Gate 1 – Research Project Selection

This is a decision point where new concepts and research ideas are screened for further development based on the technical and market information developed in Stage 1. It is anticipated that the results of the analysis of multiple topics from technical and market viewpoints will provide justification for the selection of some projects and elimination of others. Those research projects or topics that are selected will pass to the next stage. Specific review criteria for this gate are shown on the next page.

Gatekeepers must review initial technology requirements, potential technical and other impediments, benefits, costs and risks, and then make an informed decision as to the merit of the project or topic. If the decision is to "go forward" the criteria for the next gate are mutually agreed upon by the project team and gatekeepers. At this time, initial funding commitments will also be determined for selected projects.

Information gathering and analysis early-on fuels the research process and identifies important topics for study.



Stage 1: Preliminary Analysis

Goals

- Identify research topics with greatest potential to realize significant energy benefits through technology implementation
- Understand potential future benefits of identified research topics – energy, financial and other
- Gain enough knowledge on technical requirements, markets, impediments, and commercialization paths to be able to select specific R&D projects

Related Activities

- Develop a list of research ideas and concepts based on current understanding
- Conduct technical scoping studies on selected technology areas (current/prior research, competing technologies, end-user needs, technical barriers and specifications, potential benefits)
- Conduct market assessments (market segmentation, market risks, potential obstacles)
- Evaluate potential for commercialization and associated risks

Deliverables

- Potential research topics
- Reports/studies/assessments that demonstrate the potential benefits and technical barriers for individual research topics
- Prospective technical solutions that could be addressed by R&D projects within individual topics

Gate 1: Project Selection

Review Criteria

- Are the energy savings and other benefits consistent with ITP expectations and mission?
- Does the research project meet technical and financial criteria for selection?
- Have technical knowledge gaps been identified?
- Have competing technologies been identified and compared?
- Does the new technology offer significant advantages in comparison to the alternatives?
- Have technical, market and other risks and impediments been identified? Do these barriers represent potential "show stoppers"?
- Have market segments been identified for which the new technology provides a solution to an existing or anticipated problem?
- Has the potential for commercialization or information dissemination been examined?
- Has a project scope been developed? Does it include approach, timing and cost estimates, and address barriers?

Stage 2 – Concept Definition

Concept definition involves the early stage research needed to explore and define technical concepts. Activities in this stage are focused on thoroughly understanding and describing the capabilities of the technology. Concept definition research may include laboratory scale experiments, exploration of fundamental scientific concepts associated with the technology, data generation and analysis, and other exploratory methods. Specific goals, activities and deliverables for this stage are shown on the next page.

At the completion of this stage, the project concept needs to be clearly defined and justified. The technical performance specifications or information requirements of the end-users are to be identified. There should be a discussion of potential markets, as well as an assessment of expected financial, legal and regulatory issues. A stage plan is written describing the strategy and tactics to overcome obstacles and mitigate risks of new technology development. If Gate 2 criteria have been met, approval is given for research to go forward to further development at the prototype level.

Gate 2 – Research Approval

At this decision point, gatekeepers will determine if the technical aspects of the project concept have been fully defined, based on specific pre-determined criteria. They will review research results and establish that barriers have been appropriately identified and that a plan has been developed to adequately address those barriers. A key aspect of the Gate 2 decision is identification and evaluation of the key performance requirements for meeting end-user needs, as this will facilitate future commercialization and information dissemination. Specific criteria for this stage are shown on the following pages.

Gatekeepers must also review the results of more in-depth analysis of market, regulatory and other issues to ensure they have been adequately addressed and that market potential is clearly justified. The research plan going forward should include tasks to address technical as well as cost or economic issues, and recommendations for a possible commercialization path for new products or processes. Funding for projects meeting the criteria for approval will be determined at this point, based on the Stage 3 R&D plan.

Laboratory research, data generation and other fundamental research tools are used to fully define the technical concept.

Stage 2: Concept Definition

Goals

- Fully understand technical requirements and impediments
- Identify critical elements that require feasibility demonstration
- Translate end user needs into preliminary technical specifications
- Understand the market and technical risks
- Understand the technology's energy, environmental and economic advantages

Related Activities

- Research and evaluate key specifications: design, performance, energy use, and cost
- Identify current technology options and limitations, patents, and alternative technical solutions
- Conduct necessary data gathering, technology analysis, modeling, and experimentation
- Investigate and document technical risks, and any legal, regulatory or safety issues
- Contact potential customers or organizations to gain understanding of end user needs
- Research market size, geography, and potential growth
- Research the energy, environmental and economic advantages
- Prepare R&D plan for Stage 3

Deliverables

- Written results, models, or a laboratory -scale process that demonstrates the technical concept and its benefits
- Preliminary technology specifications, including assessment of competing technologies
- Preliminary market assessment
- Preliminary energy and economic assessment
- Stage 3 R&D plan

Gate 2: Research Approval

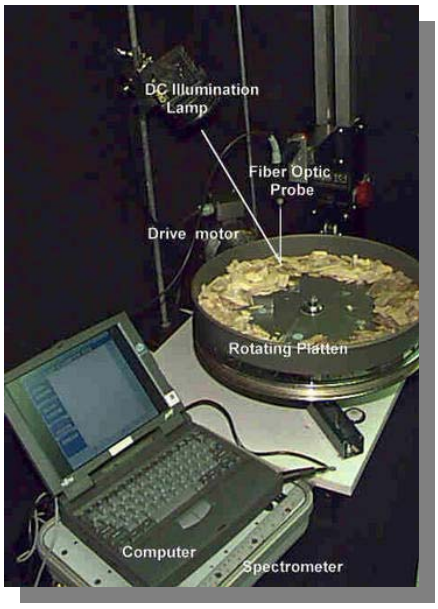
Review Criteria

- Have technical specifications of the concept and expected performance of the resulting product or process been fully defined?
- Have credible estimates been made for energy and other benefits? Are the energy advantages consistent with ITP expectations and mission?
- Have competing technologies and previous work in this area been sufficiently studied and does the project offer a significant advantage?
- Have all the challenges to developing the technology been identified? Do any of the identified risks and barriers represent potential "roadblocks"?
- Has a specific market segment been identified? Is the market potential of the project attractive?
- Have legal and regulatory issues been identified and addressed?
- Is Stage 3 R&D plan consistent with the scope, approach, timing and cost of the project?
- Does the Stage 3 R&D plan identify how risks will be managed?
- Will new knowledge generated meet the information needs of the end-users?

Stage 3 – Concept Development

During this stage, research, development and testing of prototype technology or processes are conducted. Stage 3 work may include predictive modeling or simulation of performance, engineering studies to assess scale-up, and demonstration of concept feasibility at the prototype or bench scale. Specific goals, activities and deliverables for this stage are shown on the following page.

Outcomes of this stage focus on how the concept's performance compares with preliminary technical requirements and objectives. Meeting these expectations indicates proof of feasibility of the technical concept. Experimental results from the product or process development show that it is theoretically possible to scale-up to commercial operation. Positive results lead to a plan to translate prototype-scale results into a full-scale design. Experimental projects designed to answer specific technical questions will result in computer models or databases.



Gate 3 – Proof of Technical Feasibility

At this gate review, gatekeepers assess development efforts and prototype testing results to determine whether the technical feasibility of the concept has been proven or not. The decision is made based on pre-determined criteria. Specific criteria for this stage are shown on the following pages. One important criterion in product or process development is the scalability of the concept from prototype- or bench-scale to pilot- or field testing-scale. Stage 3 results must provide sufficient evidence to demonstrate that scaling up the concept is feasible. At this point the competitive advantages of the technology should be well-understood and documented in a preliminary commercialization plan.

If a project is approved to move to the Technology Development and Information Verification stage, it means that work completed to date has removed significant technical risks. Reduced risk encourages industry participation and substantial industry funding in subsequent stages. ITP funding going forward is, therefore, expected to be greatly reduced. Criteria and information required for the next gate are determined by the gatekeepers and project team.

Prototypes enable testing and evaluation of performance at a smaller scale and identify potential scale-up issues.

Stage 3: Concept Development

Goals

- Qualify technology through prototype testing
- Refine technology specifications or information requirements
- Identify issues related to scale-up of prototype design to field test unit
- Assess end user feedback
- Understand all potential financial, legal and regulatory issues

Related Activities

- Develop a prototype according to technical specifications and cost goals
- Test prototype, including individual critical components, under simulated operating conditions
- Identify data gaps for scale-up, and determine feasibility of scale-up through models or other analysis
- Obtain feedback from end users and incorporate results into revised technical specifications
- Review market information (e.g., end user needs, market potential) and refine market impact as necessary
- Explore critical financial, legal and regulatory issues in more depth
- Identify technology production partners for next stage
- Prepare field test and information verification plans for Stage 4

Deliverables

- Test results, including all relevant experimental work and simulation results
- Modeling or other results demonstrating theoretical scalability to commercial operation
- Computer models, data bases or other information to be verified by end-users
- Commercial/partner agreements as appropriate
- Refined technology specifications and Stage 4 Plans

Gate 3: Proof of Technical Feasibility

Review Criteria

- Has prototype testing met proof of feasibility criteria and achieved desired technical and performance specifications?
- Have energy benefits been recalculated as necessary?
- Are scale-up requirements feasible? Have impediments to scale-up been identified?
- Has the market been clearly identified and quantified? Are the market demand and size still valid?
- Have technology specifications and/or costs been revised following prototype testing? Does technology still possess a competitive advantage?
- Have legal and regulatory issues been addressed?
- Has a project partner been selected to field test the technology?
- Has a commercial partner been identified? Does the commercial partner have a business plan?
- If applicable, is the Stage 4 R&D Plan consistent with the scope, timing and cost of the project? How will technology be field tested? Are scale-up issues being addressed satisfactorily?
- Has ITP's information dissemination role been defined?

Stage 4 – Technology Development and Verification

This is the final stage of R&D that would be undertaken with ITP funding. ITP's financial commitment during Stage 4 would be relatively small compared with the industrial cost-share. The objective of this stage is to overcome remaining technical issues and market concerns prior to commercialization of the product or process. Scale-up engineering is a major emphasis of this stage, which is expected to result in the final design of a saleable technology. Appropriately, the effort in Stage 4 involves pilot scale development and validation of technology through field tests. Involvement of ITP gatekeepers at this point may be reduced, in conjunction with lowered ITP funding and a commercialization partner's desire to protect intellectual property. Specific goals, activities and deliverables for this stage are shown on the next page.

Whether the results from this stage are a product or information, the effort focuses on end-user acceptance of the project outcomes. Part of this work, therefore, will address development of marketing plans, resolution of legal and regulatory issues, and elimination of other roadblocks to the use of project results. When this stage is complete, proof of concept for the product or process at a commercial scale will have been demonstrated and the usability of information will be verified.

Demonstration and field testing of technology provides real operating data and enhances potential for successful commercial launch.

Gate 4 – Proof of Commercial Feasibility

At this gate, the Project Team is responsible for demonstrating the commercial feasibility of the project; is there a market for the new product or process, or does new information fill a knowledge gap? All energy, economic, regulatory and legal issues and barriers should be resolved before entering this gate review. While ITP gatekeepers will continue to be involved through the completion of this stage, the decision to go forward to commercial launch will lie almost entirely with the industrial partners. Specific criteria for this gate are shown on the following pages.

In some cases, the industrial partner may decline the participation of Federal involvement during Stage 4 and at Gate 4 to protect intellectual property. Under these circumstances, Federal gatekeepers will decide if their commitment to the project is complete, or if additional activities to disseminate useful information should be pursued. Potential dissemination activities might include support for information flow about the new technology, but would not include any other activities related to commercial launch.

Stage 4: Technology Development and Verification

Goals

- Scale-up the technology sufficiently to support the design and construction of a commercial unit
- Develop design data for full scale equipment specifications
- Gauge end-user reaction to full scale performance
- Verify the usability of technical information
- Develop sufficient testing and validation data to satisfy end-user evaluations and demonstrate that earlier issues have been resolved

Related Activities

- Field test the technology (select candidate plant sites for testing, build a field test demonstration unit)
- Identify data gaps from scale-up of technology, and develop new specifications through prototype development and field testing
- Compare field test results to project technology specifications and end user needs to validate performance
- Obtain feedback from potential end-users on project performance and assess continued need
- Revise project cost estimates based on inputs, and finalize design specifications
- Identify production partners, conceive production schedule, and complete commercialization plan

Deliverables

- Field testing results and validation of performance capabilities
- Verified computer models, databases, and technical reports
- Final technology specifications (e.g. process flow diagrams, instrumentation diagrams, equipment specifications)
- Stage 5 Commercialization Plan or Information Dissemination Plan
- Revised estimated cost-to-completion

Gate 4: Proof of Commercial Feasibility

Review Criteria

- Are the results of the full-scale field testing satisfactory? Has the field test met proof of concept criteria?
- Was the performance of the scaled-up technology successfully validated?
- Have all technical milestones been met?
- Have energy benefits been recalculated as necessary?
- Are potential end users satisfied with the technology performance and information usability?
- Have project costs been revised following field testing?
- Have technology specifications or costs been revised after field testing? Does technology still have a competitive advantage?
- Has a license been executed with a commercial partner?
- Have all legal, regulatory and compliance issues been resolved?
- What are potential mechanisms for disseminating information?

Stage 5 – Information Dissemination and Commercialization

Commercialization is the conclusion of the Stage-Gate process. It is when the product or process is readied for end-user application and is successfully brought to the marketplace. This stage is undertaken entirely by ITP's industrial partners. ITP may, however, participate by disseminating information about technology and its impact to industry, end-users, the technical community, and the general public.

Even though ITP does not lead commercialization activities, it is important to be aware of how commercialization partners organize their commercialization activities and make business decisions. A partner's commercialization approach may influence how an R&D project is designed and implemented. Studies have shown that commercialization success in collaborative R&D depends on a shared, disciplined process such as Stage-Gate during technology development and commercialization, and that a more open, creative set of rules is appropriate during the ideation and research stages (Brown and Hagel 2006).

Commercialization typically involves all the activities necessary for commercial launch, including:

- Releasing engineering designs
- Documenting quality and manufacturability
- Developing engineering and technical support infrastructure
- Development of supply and distribution support infrastructure
- Meeting with lead customers
- Conducting customer workshops
- Developing and distributing product literature
- Completing sales staff training
- Acquiring financing and allocating funds for manufacturing plant, materials, and marketing
- Manufacturing and installing new technology
- Tracking sales and profitability
- Assessing customer satisfaction with product or process.

Once new technology is introduced in the marketplace, the industrial partner makes decisions about continuing investments in the technology, expanding sales to new markets, discontinuing product sales, and so on. Some of the key questions an industrial partner asks after they commercialize a product or process include:

- Have cost goals been met?
- Have sales goals been met?
- Have profit targets been met?
- Is return on investment criteria being met?
- To what degree has the product achieved estimated market penetration?
- To what degree are existing customer needs being met by the product?
- Were the ultimate benefits realized by the customer consistent with our estimates?
- What new needs or markets can be addressed by product spin-offs?

The social and economic impact of ITP's R&D results depends on the acceptance and ongoing implementation of knowledge, hardware, software, and processes generated by ITP.

Summary

The Stage-Gate process is an effective innovation management tool and will be used by ITP to incorporate structured decision-making into the research-portfolio investment process. The Stage-Gate process is flexible to accommodate the various types of projects that are funded by ITP, and is designed to optimize return on investments. Projects may enter the process at different stages as appropriate, depending on work that has been conducted.

Overall objectives are to:

- integrate uniform guidelines into portfolio management
- optimize research investments
- control project quality and maximize outcomes
- standardize decision-making

The Stage-Gate process has many benefits. Most important, the process will provide a consistent set of guidelines and definitions for each stage of research that can be communicated across ITP for project decision-making. This will ultimately enable better control of project quality as well as research outcomes. The process encourages meaningful end-user involvement and provides a parallel multi-functional approach to R&D where projects are evaluated in multiple areas such as technical performance, market potential, economics, and environmental impacts.

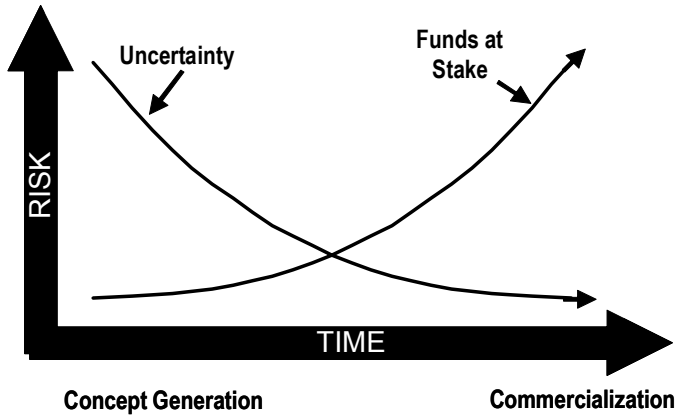


Figure 8. Project Risk Over Time

A key advantage of using the Stage-Gate process is the management of the risk that is inherent to research. Each stage is designed to reduce levels of uncertainty and risk. As information and data is assimilated at each stage of research, risk and uncertainty are lowered. With sufficient information, ITP Technology Managers as well as the project team can make sound technical and business decisions to control or eliminate risks. As shown in Figure 8, the highest technical risk is encountered in the early stages of research and development, when ITP has the most important role. The greatest business risks are faced in the later stages of development. At this time, the commercialization partner takes the lead. The project team must address both technical and business risks to reduce project uncertainty, even as the investments at stake continue to increase.

Implementation of the Stage-Gate process begins immediately after project award. The first step is the forming of a project team that will follow the project throughout the process. From the start, the team develops mutually-accepted criteria for measuring progress that will be used for the duration of the project. A uniform decision making structure is provided early-on and throughout the project.

Gatekeepers are selected as soon as practicable and, if possible, will remain with the project until completion to provide consistency. Gate decisions are carefully weighed based on the information provided by project team. This disciplined approach ensures accountability and integrity in the project-decision process, and uniformity for decisions across ITP.

ITP's primary objectives are to invest research dollars wisely, and to conduct research that will accelerate the development of advanced, energy-efficient industrial technology. The Stage-Gate process strongly supports these objectives by standardizing decision-making process and by providing the right information for timely decisions, ultimately reducing risk and targeting funds appropriately.

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Glossary of Terms

Business Plan

A documented scheme developed by a commercializing agent for a strategic business unit, product category, product, or target market of the commercializing agent to accomplish its organizational goals.

Commercialization

Stage 5 in the Stage-Gate process. Includes all activities related to commercial launch of the technology. This stage is undertaken by industry.

Commercialization Partner

An organizational entity which has the desire and ability to make, market, distribute, and sell a product to customers.

Commercialization Plan

A documented scheme which describes and integrates all functional activities required for the commercialization of a product. Functions typically addressed include: technical specifications, marketing, engineering, manufacturing, distribution, sales, finance, human resources and legal.

Concept Definition

Early stage research to explore and define technical concepts; laboratory scale research.

Concept Development

Stage 3 in the Stage-Gate process. This stage focuses on development and testing of small-scale prototypes, early stage R&D, modeling and analysis.

Dissemination

Includes technology transfer, information dissemination, and tools for encouraging use of advanced technologies.

Exploratory Research

Includes fundamental research conducted to develop scientific knowledge or capability, such as literature surveys, data gathering, analysis, basic experimentation, and modeling.

Field Project Manager

Manager working at a DOE Field Office who has the responsibility for individual or groups of projects funded by DOE HQ.

Gate

A checkpoint, or point in time, where a decision is made to "Go forward" with a project, "Return" to a previous stage to obtain more information or "Stop" it permanently.

Gate Decision

Project decisions made by gatekeepers at each gate; may include Go Forward, Stop, Hold, or Return.

Gatekeeper

The individual or group responsible for making a decision as to whether a project goes forward to the next stage, returns to a previous stage to obtain more information, or is stopped permanently. Depending on the gate, the gatekeeper may also be responsible for allocating funds. Gatekeepers may include Field Project Managers, ITP Technology Managers, and outside experts.

Gate Review

A meeting held with gatekeepers and project team at each gate to review results, assess them against criteria, and make project decisions.

Impact

The specific quantitative effect of a technology introduction measured in financial or technical units.

Information

Research outcomes that fill a knowledge gap of end-users. Information solves a specific technical problem or helps to promote the acceptance of new technology.

Information Projects

Includes more focused experimental or other work conducted to answer a specific technical question and fill knowledge gaps.

Market

That part of the economy or industry sector that will be impacted by the technology being developed.

Performance Goals

Quantification of the factors that are key to the technical and commercial success of a product.

Portfolio

The group of projects managed by the ITP Technology Manager. A portfolio is constructed to spread and reduce risk and uncertainty. Each project in the portfolio is managed separately. The results of these projects collectively achieve ITP goals.

Preliminary Investigation and Analysis

Stage 1 in the Stage-Gate process. Includes studies to identify research topics, and technical and market assessments.

Principal Investigator

Field researcher who is responsible for planning, allocating resources, and executing an individual project. Also responsible for working with gatekeepers to plan gate reviews, develop criteria, and report on results.

Product

Hardware, software, processes, or information offered to customers by ITP's partners.

Product/Process Projects

Projects that are expected to result in the commercial launch and ongoing use of new technology after completion of research.

Project

Coordinated efforts that are designed to result in the development and successful commercialization of a single technology. A project may include analysis, data generation, modeling or other knowledge based work to meet the information needs of the end-user.

Project Team

A group of persons assembled for the purpose of conducting research, development, and commercialization work for a project. These contributors encompass key resources, contractors, and commercialization partners.

Proof of Concept

Gate 4 in the Stage-Gate process. When this Gate is passed, the commercial feasibility of the technology has been proven.

Proof-of-Feasibility

Gate 3 in the *process*. The point in time at which technology performance has been confirmed through experimentation and/or accepted engineering analysis, and at which time it appears there are no technical or economic barriers to implementation that cannot be overcome in development.

Prototype

A pre-production version of a technology that has characteristics (e.g., specifications, scale, quality, reliability) representative of the expected final technology in commercial operation.

R&D Stage Plan

Research plan written to outline the various technical aspects of research during an individual stage. Includes milestones, objectives, and other pertinent information.

Research Approval

Gate 2 in the process. The point in time at which the criteria have been met for Stage 2, and funding is approved for Stage 3.

Research Project Selection

Gate 1 in the Stage-Gate process. A decision point where projects are selected based on merit and technical and programmatic needs.

Risk

The possibility of suffering loss. The Stage-Gate process helps to reduce three types of risk: technical, business, and market risk.

Stage

A period of time between gates in the Stage-Gate process where activities are performed with the objective of gathering information to pass through a future gate.

Stakeholder

A group or individual with a vested interest in the activities and outputs of an organization – e.g., industrial energy users, customers for new technology, suppliers (contractors), manufacturing partners, trade organizations, Federal and State organizations, and other public entities.

Technology Development

Pilot scale development and testing of technology or process, including field testing and demonstration.

Appendix A: Gate Review Templates

Gate 1, Research Project Selection – Evaluation Form

Project Title _____ **Date of Evaluation** _____

Submitter _____

Reviewers _____

Category	Goals	Key Inputs	Evaluation Criteria	Yes/No	Comments
1. Strategic Fit	Benefits and scope are consistent with ITP mission and expectations	Technical objectives and preliminary estimates of expected results/impacts	Are the energy savings and other benefits consistent with ITP expectations and mission?		
2. Technical Merit	Evaluate potential of the topic to create technological change	Scoping studies on current/prior research, end-user needs	Does the topic meet technical criteria for selection? Have technical gaps been identified?		
3. Market Potential	Understand potential markets	Market assessments	Has a specific market segment been identified and potential for commercialization examined? Has the potential for information acceptance been assessed?		
4. Risks	Identify technical, market and other risks and barriers	Prior research, scoping studies, financial and market assessments, environmental issues analysis	Have technical, market and other risks and impediments been identified? Do they represent potential "showstoppers?"		
5. Competitive Advantage	Compare with competing technologies and assess advantages	Competing technologies; key features of proposed technology	Have competing technologies been identified and compared? Does technology offer significant advantages? Will new information improve competitive advantages for industry?		
6. Technical Project Scope	Develop a technical project scope that addresses barriers and proposes an approach to research	Key technical elements, goals for research, research approach, timelines, estimated costs	Has a project scope been developed? Does it include approach, timing and cost estimates, and address barriers?		

Gate 2, Research Approval – Evaluation Form

Project Title _____ **Date of Evaluation** _____

Submitter _____

Reviewers _____

Category	Goals	Key Inputs	Evaluation Criteria	Yes/No	Comments
1. Strategic Fit	Benefits and scope are consistent with ITP mission and expectations	Objectives and expected results	Are the energy advantages consistent with ITP mission and expectations?		
2. Markets	Understand potential markets	Potential market size and value; competition; potential for commercialization	Has a specific market segment been identified? What is the size of the potential market? Is the market potential attractive?		
3. Technical Feasibility	Define performance criteria, end-user specifications	Technical specifications and objectives; performance measures	Have technical specifications and expected performance of the concept been fully defined? Have energy savings and other benefits been estimated?		
4. Technical Risk	Identify technical risks and barriers	Technical impediments and showstoppers	Have all the challenges been identified? Do any of the risks and barriers represent potential "showstoppers?"		
5. Competitive Advantage	Compare with competing technologies and assess advantages	Competing technologies; key features of proposed technology	Have competing technologies been sufficiently studied and results presented? Does technology offer significant advantages?		
6. Legal/ Regulatory Issues	Understand key legal and regulatory issues	Environmental benefits or issues; regulatory incentives; intellectual property issues	Have legal/regulatory issues been identified and addressed?		
7. Work Plan and Deliverables	Develop an effective plan to address barriers and complete goals for research	Technical milestones; key goals and objectives; work schedules and resources	Is Stage R&D Plan consistent with scope, approach, timing and cost of project? Does it identify how risks will be managed? Will an information project be warranted?		

Gate 3, Proof of Technical Feasibility – Evaluation Form

Project Title _____ **Date of Evaluation** _____

Submitter _____

Reviewers _____

Category	Goals	Key Inputs	Evaluation Criteria	Yes/No	Comments
1. Technical Feasibility	Build and test prototype to evaluate performance and refine approach to meet end-user specifications	Prototype specifications and test results	Has prototype testing met with proof of feasibility criteria? Has prototype met desired technical and performance specifications? Have technical milestones been met? Have energy benefits been recalculated as necessary?		
2. Scalability	Demonstrate feasibility of scaling-up prototype to commercial scale	Engineering analysis, predictive modeling at larger scales	Are scale-up requirements feasible? Have impediments to scale-up been identified?		
3. Markets and Commercial-ization	Define specific market impacts; develop preliminary path to commercialization; select site for demonstration or field testing at larger scale	Market segmentation studies; potential for commercialization; performance results	Has a specific market segment been clearly identified and quantified? Is market still valid? Has it been expanded or downsized following testing? Has a project partner been selected to field test the technology? Has a commercialization planning been addressed? Has a commercialization partner been identified? Does the commercialization partner have a business plan? Has a partner/site been selected for demonstration?		
4. Competitive Advantage	Make informed comparison with competing technologies	Prototype performance and preliminary technology/ equipment cost analysis	Have technology specifications or costs been revised following prototype testing? Does technology still have a competitive advantage?		
5. Legal/ Regulatory Issues	Address key legal and regulatory issues	Environmental benefits or issues; regulatory incentives; intellectual property issues	Have legal/regulatory issues been identified and addressed? Are there any remaining impediments to commercialization?		
6. Dissemination	Determine ITP technology transfer or dissemination role.	End-user feedback, commercialization plan	Is there a tech transfer or information dissemination role for ITP? What are potential mechanisms? Has information dissemination plan been developed?		
7. Work Plan and Deliverables	Develop plan to address barriers and complete goals for research	Technical milestones; key goals and objectives; work schedules and resources	Is Stage R&D Plan consistent with scope, timing and cost of project? Does it identify how technology will be field-tested? Are impediments to scale-up being addressed?		

Gate 4, Proof of Commercial Feasibility – Evaluation Form

Project Title _____ **Date of Evaluation** _____

Submitter _____

Reviewers _____

Category	Goals	Key Inputs	Evaluation Criteria	Yes/No	Comments
1. Concept Field Test and Demonstration	Build and test pilot or field-scale unit to evaluate performance against end-user expectations	Field test specifications and test results	Has field testing met with proof of concept criteria? Are the results of the full-scale field testing satisfactory? Was performance of technology successfully validated? Have all technical milestones been met? Have energy benefits been recalculated as necessary?		
2. Commercial-ization	Industry partner commitment to launch of new product or process	End-user inputs; performance results from field tests; commercialization plan	Are end-users satisfied with technology performance? Has a license been executed with a commercial partner? Have project costs been revised following field testing? Is commercialization planning complete?		
3. Competitive Advantage	Make informed comparison with competing technologies	Prototype performance and preliminary technology/ equipment cost analysis	Have technology specifications or costs been revised following field testing? Does technology still have a competitive advantage?		
4. Legal/ Regulatory Issues	Address key legal and regulatory issues	Environmental benefits or issues; regulatory incentives; intellectual property issues	Have all legal, regulatory and compliance issues been resolved?		
5. Dissemination	Determine continuing needs for ITP technology transfer or information dissemination activities	End-user feedback, commercialization plan, information dissemination plan	Is there a technology transfer or information dissemination role for ITP? What are potential mechanisms for technology transfer?		