Road Map to the Commercialization of
Next-Generation Biofuels – Part I

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Background

First-generation ethanol and biodiesel production in the U.S. expanded significantly during the period from 2000 to 2008, with ethanol production capacity tripling, according to the Renewable Fuels Association, while the National Biodiesel Board notes that production of biodiesel grew to more than 450 million gallons per year (MMGPY) in 2008 from less than 10 MMGPY in 2000. This dramatic growth of production capacity was possible as the projects met some of the key criteria for rapid commercialization; their technology was well-known with a proven operating history, vendors were able to provide a turnkey plant with a performance guarantee, and the project development process was something banks and investors were accustomed to financing. All of these factors led to projects that traditional financing institutions were comfortable funding.

By contrast, the factors that allowed first-generation renewable fuels to grow at a historic rate have limited the commercialization of next-generation technologies. Many second-generation technologies have been operated at pilot scale but not at commercial scale. There are no vendors that can provide a commercial-scale technology with a performance guarantee adequate to get standard commercial financing. As commodity prices for corn and vegetable oil limited first-generation biofuels' economic viability, growth of non-food-based biofuels was expected to increase at a similar rate. However, a large portion of the companies remain in the development and pilot operating stages.

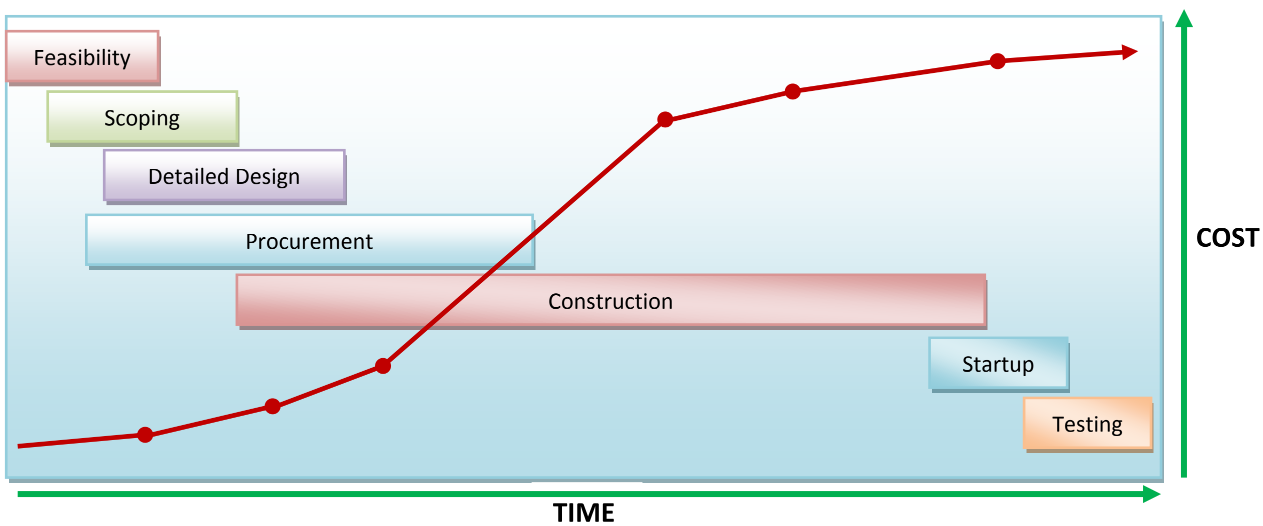
Capital Cost of Commercialization

A major limiting factor for the second-generation biofuel processes comes from the fact that their capital construction cost is significantly higher than the first-generation projects. Traditional corn-based ethanol plants typically have a capital construction cost of around $1.5 to $2 per gallon of annual capacity (a 100,000-MMGPY plant would cost between $150 and $200 million). Cellulosic ethanol facilities are generally projected with a capital construction cost of $5 to $10 per gallon of annual capacity. This represents about a five-fold increase in capital cost for facilities that do not have a proven operating history.

The significantly increased capital costs are generally offset by much better operating economics, driven primarily from second-generation biofuel facilities utilizing raw materials that have a significantly lower cost than the corn and vegetable oil commodities that have seen such dramatic price increases in recent years. As an example, a cellulosic ethanol plant utilizing biomass or municipal solid waste will generally have a much higher projected rate of return but with a significantly higher up-front capital cost.

Traditional Development Approach

Development of large capital projects has evolved into a standardized process that is expected by most traditional financial institutions and includes a feasibility study, project scoping, detailed design, procurement, construction, start-up, and performance testing. These are shown graphically on the figure below, along with a generalization of project spending.



The purpose of this process is to define scope and cost as early as possible, before significant amounts of capital are committed. Each of these processes is detailed as follows:

> <u>Feasibility Study</u>
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> A feasibility study is an early-phase study that vets a business model under a given set of assumptions, identifies major risks, and helps management or investors decide if the project is investment-worthy. For a new-generation biofuel, a feasibility study would involve a review of the technology (including heat and material balances), use of industry factors to determine a rough estimate of the project's capital cost, and a pro forma calculating projected costs and revenues.

Project Scoping

Often referred to in the industry as front-end loading (FEL) or front-end engineering design (FEED), the project scope phase of the project takes the feasibility study and expands the detail to a specific site. It defines the key process equipment, utilities, infrastructure (roads, docks, rail, etc.), and other major factors of the project. Basic capabilities of the project are defined and fixed during this phase of the project. For unique or long-lead equipment such as a distillation tower, the scoping phase would determine the size of the tower, materials of construction, internal packing material and other factors to lock down how the specific piece of equipment will function. This would be enough information to place a purchase order for the specific piece of engineered equipment. The work product includes a cost estimate that generally has an accuracy of +/- 10% of the capital cost of the project.

Detailed Design

In this phase of the project, the scoping documents are refined so that a contractor can construct the facility. In the previous example of a distillation tower, the scoping documents would have outlined enough information to enable the purchase of the piece of equipment, but the vendor will need to supply detailed shop drawings of the equipment for the detailed design team. This team would use these to design foundations, instruments, building structures, electrical supply, and other ancillary equipment that, when added to the engineered equipment, form a fully functional operating facility. The work product at the end of detailed design is a set of specifications and construction drawings.

Procurement

Key engineered equipment must be specified and purchased early in the process to allow the detailed design to be completed. Items such as gasifiers, reactors, distillation towers, heat exchanger, large tanks, distributed control systems, and other items that are not "off the shelf" items are part of this procurement cycle. A significant down payment is required with an engineered equipment order, with milestone payments along the way. The timeline of the project is often driven by the vendors' ability to supply the shop drawings previously noted, as they are necessary for detailed design to move forward. Other key construction materials (concrete, structural steel, pipe, valves, etc.) are typically purchased by the construction contractor within their scope of work.

Construction

On large-scale projects, it is common to use a general contractor who will be responsible for the overall project, even though their company may sub-contract major portions of the work. This allows the owner to have one point of responsibility for construction. There are multiple methods of contracting that will vary the alignment of risk and responsibility, which are discussed later. The construction phase of the project ends in "mechanical completion." This is the point when the facility is fully constructed and operable, but has not been charged with raw materials or tested.

Start-up

When the project is mechanically complete, responsibility is passed to the start-up crew. Initial efforts are called commissioning, where equipment is often tested with water and inert gasses to make sure basic functions are confirmed (pumps are able to pump, tanks do not leak, boilers produce steam, etc.) and instruments are calibrated. Once each of the systems has been commissioned, raw materials will be introduced and the plant begins operation. The first few months of operation are referred to as the "shakedown" period, when product is being made but usually at less than the nameplate capacity of the plant.

Performance Testing

A formalized, third-party-administered performance test is generally required by financial institutions to confirm that the key operating parameters within the project pro-forma are justified. These parameters include demonstration of plant production capacity, along with usage of key raw materials and utilities. This test is normally run for a seven-day period and is overseen by an independent engineering firm.

While these stages of project development are largely the same from project to project, the specifics of how they are contracted and financed varies. Construction contracting methods and financing options will be addressed in Part II of this series.

About Harris Group

Harris Group Inc. provides full-service engineering and consulting services in the production of fuels and chemicals from renewable feedstocks through sustainable technologies. Our experience encompasses conventional and emerging technologies for conversion of biomass into ethanol, biodiesel, biogas (methane), commodity chemicals, and other saleable products and byproducts. Harris Group Inc. provides both technical and program management services, with specific services to meet the needs of each customer.

Harris Group Inc.'s history in biorefining dates back to 1994 and the development of a process for conversion of municipal solid waste to ethanol. Since then, we have worked alongside entrepreneurs, researchers, and project developers on a variety of projects, from traditional corn ethanol and biodiesel to cellulosic ethanol and renewable diesel. Harris Group is a recognized leader in next generation biofuels technologies and was selected by the U.S. Department of Energy to provide independent oversight on some of America's first biorefineries, which are being partially funded by the DOE. Harris Group is familiar with established biofuels technologies and provides balance-of-plant engineering for providers of traditional biofuels processes. Harris Group Inc. provides strategic support from project definition and feasibility studies through construction management and start-up in both greenfield and retro-fit applications with core services of engineering and plant design. Specialty services include process conceptualization and development, research management and coordination, basic and detailed engineering, owner's engineering, due diligence and independent engineering, process improvement and control systems integration.

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