

**A METHODOLOGY FOR ASSESSING THE FEASIBILITY OF DEVELOPING AND TRANSFERRING NEW ENERGY TECHNOLOGY TO THE MARKETPLACE.** Dr. H. M. Kosstrin and Dr. B. E. Levie, R. W. Beck and Associates, 1125 17th Street, Suite 1900, Denver, Colorado 80202.

Any new process intended to produce clean energy from waste should be characterized for its ultimate feasibility of becoming commercially successful. A four-phase strategy to analyze the process and plan for scaleup is presented. First, the new technology is assessed in terms of its market potential based on laboratory, bench scale or pilot data. A comparison with competing commercial technology is performed to compare the technology with its competition by estimations of factors such as life cycle cost, public acceptance, and adaptability to changing conditions and fuels. Second, the current status is reviewed with respect to theory, laboratory or pilot scale results, and available cost data. Third, the path to commercialization is outlined. The stages of scaleup and data required to prove the concept and remove risks of commercialization are identified. Finally, the financing needs for the various stages of scaleup and for a commercial unit are determined.

Introduction

Development of any new technology has traditionally been a controversial subject due to high expectations shared by proponents and results which many times fall short of these expectations. Solid and liquid waste management has seen both success and failure in the implementation of new technology. For example, promises to commercially produce liquid or gaseous fuels and/or chemicals from municipal solid waste (MSW) or refuse derived fuel (RDF) have so far been unfulfilled after several attempts at demonstrating various technologies. These failures encourage us to examine new and undeveloped technology in a more sophisticated and step-wise manner than has been previously done. By learning from past failures and taking a methodical and proactive approach to scaling-up suitable technology, we can better direct development so that realistic expectations can be made and met. The approach discussed here will increase chances for successful development of new waste management technologies.

The following phases outline the approach to be presented:

- I. Determine if a technology at its current state of development, either conceptual, bench, or pilot scale can be potentially competitive with commercial technologies today.
- II. Establish the current status of the technology and what needs to be better understood before progressing.
- III. Establish the path which would most logically be taken to result in commercializing the technology.
- IV. Identify the requirements of different financing options necessary to commercialize the technology.

These phases follow a progression in which the results of each builds on the results from the preceding phases. This review can be started at any time in the development process and should be updated to account for new data on the technology, the competition, or the market as they become available.

Review and analysis of new technology can be biased according to the perspective of the reviewer. The investigators, developers, and sponsors all have vested interests in the technology which may prevent a balanced view of the technology, its development, or its commercialization. Investors and lenders typically look for independent reviews of the technology prior to committing large amounts of capital. This can best be accomplished by persons without conflicts of interest and with an adequate background reviewing development of the technology.

#### Review of the Concept

In this initial stage of analysis, the technology is looked at objectively to assess its niche in current markets. The first step is to identify the market or markets where the technology would most likely be competing and to broadly establish a range of competitive pricing for the service provided or product produced. It is important to consider all areas where the technology could potentially compete, including those outside the primary field of interest. High value chemicals, resins, and plastics, for instance, may be more economically feasible to produce than fuels from certain feedstocks.

Questions to resolve before proceeding are those which would be important to an investor. These generally will establish if the market is potentially strong and lasting. In the area of solid waste management, the following questions can be used as guidelines to ascertain the market's potential. Similar questions can be developed for any particular field.

- Is market expanding?
- Is it monopolistic or controlled by a few companies?
- What are the minimum or maximum requirements for waste needed to be processed?
- Is the waste composition changing due to recycling, composting, changes in consumption, etc.?
- Are markets localized, where are they located?
- Do long-term contracts either for feedstocks or products already exist which would interfere with this technology?
- What are the standards for the product produced?
- Can environmental permits be obtained?
- What are the characteristics of markets for byproducts of the process?

The next step in reviewing a new technology is to compare the technology with those commercial technologies currently in the identified market(s). This comparison can be as brief or extensive as is desired, depending on if we are considering a revolutionary change or just an evolutionary advance in the market. At a minimum, cost and environmental comparison should be made between the new technology and what is available in the market. The cost should be assessed on a life-cycle basis, accounting for capital, operation and maintenance, disposal of residue costs, and revenues from tipping fees, the primary product and any byproducts. The general environmental assessment could include a number of considerations including impacts on air, water, workers, noise, and flora and fauna.

There are many other considerations in performing this initial assessment. The feedstock must be compatible with the technology, and the product(s) compatible with the existing markets. Flexibility can be quite advantageous in the waste management industry, as the quantities and composition of waste is rarely fixed. While some technologies might only be competitive for a certain type and quantity of waste, others could take many types of waste, in a range of quantities. Effects on other related technologies should be assessed, as today municipalities and other organizations are interested in integrated solid waste management. Generally no one technology can solve the waste problems for a given location. Thus, technologies which can work effectively together may be more desirable than those which prevent other technologies and strategies from being employed successfully.

In order to compare the new technology with existing ones, it must be emphasized that the new technology should be judged on a realistic basis. A conservative estimate for costs, revenues and efficiency of the new process should be used for comparison purposes. Often a new technology assessment under estimates commercialization costs and greatly over estimates potential revenues from products.

#### Establishing Current Status of the Technology

The second phase of this review is to establish the current status of the new technology, providing a baseline or framework from which further development can be compared. The initial limited economic feasibility developed in Phase I, can be updated with new information gained in this phase. Technical and economic gaps in knowledge should be identified in this phase and either resolved now or targeted for later development work and/or analysis.

#### Existing Data Review

This stage of review is many times performed by the researchers in order to propose further expenditures or justify previous funding. Therefore, some data may already exist for this analysis.

The first part of establishing the current status is to verify that the process proposed is physically possible and practically attainable. This will require checking previous assumptions, reviewing theory and obtaining

correct parameter values for thermodynamic, kinetic and mass and heat transfer. Mass and energy balances should be done to check process feasibility. A second law analysis could be performed on the process to identify inefficiencies.

Once the theory has been reviewed, operational data from the lab, bench, and/or pilot facility should be assessed to determine the deviation from theory. This will allow a better estimate of expected yields as the process is scaled-up further. It will also serve to highlight areas where the process can be improved or is not performing as well as expected. In some cases, it will point to the fact that the data is inaccurate or insufficient for reasonable analysis and that additional and more accurate data must be obtained before further progress can be made. It is important in this review that sufficient data be available to determine the precision of the data. Furthermore, there should be an adequate review of the instrumentation and data acquisition system to determine any measurement biases which exist. For example, biases occur in high temperature measurements, and when measurements are made close to the detection limit of the instrumentation.

Once a thorough review of the available data has been accomplished, we need to update our original economic model. Existing cost data should be reviewed to better establish costs of the technology at its present state of development. These costs should be segregated as much as possible into standard technologies and developmental technologies to identify which areas need more accurate estimates as development proceeds. If possible, costs for each piece of equipment or unit operation should be tabulated.

Many costs will not be available based on pilot plant data, such as upstream and downstream equipment which may not be implemented at this stage of development. But this equipment can be estimated if standard technology is used. Equipment in this category may include material waste recovery systems, gas cleaning, liquid cleaning, heat recovery equipment, and emissions, effluent and residue treatment systems.

Costs for operation and maintenance (O&M) are difficult to determine as pilot scale or smaller equipment will rarely run for long continuous periods of time. Some costs may be determined such as on energy requirements, energy losses, and other requirements of the process such as gases, water, or other utilities. Costs associated with running the process for long periods of time will generally not be available. But preliminary estimates can be made, and ranges input to the economic model to establish a current economic status.

#### Technical and Economic Questions

The review of the current status will raise various questions on both a technical and cost basis. Technical questions which are easily resolved with current equipment should be addressed as soon as possible prior to going on to Phase III.

It is generally far less expensive to acquire data at the initial stages of development than later on, and this data can provide many benefits. The additional data taken may indicate unusual phenomena occurring which need to be understood for successful scale-up. Extra information may point to flaws in the technology such as larger heats of reaction than calculated, poor kinetic rates, or poor catalytic activity. Such results might be indicated using extra thermocouples, calorimetry, gravimetric monitoring, etc. These may be economical to measure at this stage of development, but not once the technology is scaled-up. Discrepancies between actual operating data and theoretical projections may indicate poorly understood phenomena, inaccurate data, or invalid assumptions in the theory. These technical data gaps may need to be filled before further progress should be attempted.

Technical questions which may be unanswerable include environmental impacts, reliability of equipment over time, labor necessary to run and maintain operations full time, and degradation of process over time due to unknown phenomena. These questions will need to be revisited in later phases of development, and should be noted to trigger later activity.

Economic questions which may not yet be answered should be identified at this point and noted for later resolution. These may include questions of costs for upgrading the products and byproducts for sale, prices for the products and byproducts, and disposal costs for residues and effluents. Some of these questions are best left for later stages in development, when more representative products and residues will be produced. By initially establishing costs of upgrading or treating products or residues, it may be revealed that further consideration needs to be given to different methods of treatment. This may need to be worked on before, or concurrent to scaling-up.

#### Establishing a Path to Commercialization

Now that the current status of the emerging technology has been established and we have updated the economic model with new information, which still projects a competitive product, we can establish how to proceed. This third phase of development can consume fairly large amounts of capital, so a critical assessment should be conducted to establish a deliberate agenda so that an investor may be convinced to fund this phase.

The initial task of this phase is a risk assessment to identify any technical flaws in the concept, and establish a plan to address and overcome any obstacles. As an example, the process data from bench scale operations has confirmed the kinetic viability of the process but has left unanswered certain mechanical questions. For instance, we know the reactor works but we have assumed in our model a feeder that can use unprocessed feedstock. The problem identified is, how do we introduce the solid feedstock in a uniform, continuous manner without excessive preprocessing. This risk assessment, which should include all components, is intended to identify components of the process that either require further development prior to proceeding to the first scale-up or to find an acceptable alternative.

The final piece of the risk assessment is to critically look at the question of scale-up. One may ask the question, how far can we proceed, in this initial step from bench scale? But the right question is, what is the maximum scale-up possible from the final development unit to the commercial demonstration? Answering this question is a key to determining the total path to commercialization. We can then decide on how many scale-up steps to take and when critical components should be scaled-up. These steps may include any or all of the following: an integrated pilot plant, a semi-works to prove out critical components or a complete demonstration system.

After planning the global technical approach, and the required component development has been identified, we need to feed any revisions to our overall cost model to reconfirm feasibility. The next stage is to determine the additional technical data, whether mechanical or process, that is required.

Typical questions which help identify such data include:

- Does each component work as intended?
- Does the system as a whole work together in a safe manner?
- Does proper selection of materials take into consideration "corrosive and erosive elements in the process and can I maintain product specifications?

In addition, the duration of acquiring the answers to these questions should be established. Typical goals of this first scale-up may be 5,000 hours of total test time with perhaps 1,000 hours of continuous operation under design conditions. The purpose of this scale-up is to work through the operational and process problems, confirm yields and product quality, and obtain an indication of reliability. The "other" objective is to be able to again refine the economic model with the data obtained from this first scale-up for both capital and operations costs. We will need this information, since we are approaching the time that additional capital will be needed for the next scale-up or for a continuously operational demonstration facility.

Once we have established technically what type of data and scaled-up system the technology requires, we need to establish a cost of this phase of the work and raise additional capital. At this stage, it is important to consider if any revenue can be derived from the operation of the development unit to offset the operational costs. This may not be realistic, but an investor typically likes to see some "pay as you go" operation while development is progressing.

After the development unit has completed the technical data acquisition, it is again time to refine our feasibility model with new cost data, operational data and reliability data. The level of success of the

development unit will at times determine the type of financing that the process developer can consider. The final section discusses the various options.

### The First Commercial Unit - How Can It Be Financed

As we complete Phase III, the additional data collected from the scaled-up operation is again fed back into the economic model to reconfirm feasibility. A positive result will now enable the project to proceed to raise the capital necessary to build a full scale facility which, by definition, when successful will be the first commercial unit.

Financing can be obtained from a variety of sources, ranging from total equity, where the investor assumes all the risk, to non-recourse project financing where the risk of failure is divided between the lender and the equity participant. Technologies concerned with the disposal or processing of solid waste are currently eligible to obtain tax exempt bonding authority. The lower cost of capital by using tax exempt bonds is a commonly used method to enhance the overall economics of a project.

Funding a new technology using non-recourse project financing, typically requires either some level of equity participation or a guarantee to pay back the debt, or some combination of the two. The level of equity participation or debt guarantee depends on the characteristics of the project and the projected economics as determined by an Independent Engineering Study. This Independent Engineering Review is critical to both lenders and equity participants, since it is intended to confirm both the technical and economic viability of the technology.

From a lender's point of view, the typical characteristics of a strong project include some or all of the following:

- A turnkey construction contract including a fixed price, fixed completion date, detailed performance test and penalties for nonperformance.
- An operations and maintenance contract with a fixed price and incentives for positive performance and penalties for poor performance.
- Independent projections based on the technology and contract structure which show adequate cash flow to cover all expenses and debt service. These projections should be done for both the expected operational scenarios and in cases where potential problems may arise that are either technical or economical in nature.

Raising the capital for a new technology can be as challenging as completing the technical development. However, this job is easier when the proper groundwork has been laid by following the methodology presented here.