

Alternative Fuels: How can Aviation Cross the "Valley of Death"

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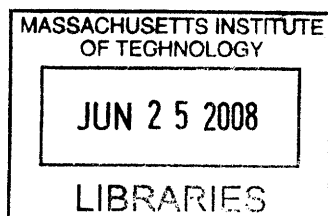
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Abstract

Aviation has used petroleum-derived fuels for over 100 years. With the rapidly rising price of oil and concerns about supply, the military and the commercial airlines are fostering the development of an alternative aviation fuel industry. In the U.S., coal, oil shale and biomass offer great promise as alternatives to petroleum for the production of aviation fuels. For the alternative fuel to be viable, the fuel must be price competitive, offer environmental benefits compared to petroleum, and must be qualified and certified for use in aviation. This thesis explores the barriers and risks associated with the technology adoption life cycle for alternative aviation fuels as viewed through the lenses of the technology developer, the early adopter, the early majority user, and the financial community. The challenges related to crossing the “Valley of Death” between technology development and deployment, and bridging the “Chasm” between the early adopters and the early majority of users are explored and a series of evaluation frameworks, tools, models, and recommendations are presented. The suggestions and recommendations provide potential actions that the military and the civil aviation sector could implement to reduce the risks and barriers for an alternative aviation fuel industry to commence and be sustainable both financially and environmentally.

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List of Abbreviations and Acronyms

AF	U.S. Air Force
APU	Auxiliary Power Unit
AS&C	Advanced Systems and Concepts
ASTM	American Society of Testing and Materials
ATA	Air Transport Association
B-1B	U.S. Air Force Supersonic Bomber
B-52	U.S. Air Force Heavy Bomber
Bbls	Barrels
BLM	Bureau of Land Management
BUFF	Battlefield Use Fuels of the Future
C-17	U.S. Air Force Cargo Aircraft
CAFE	Corporate Average Fuel Economy
CAFFI	Civil Aviation Alternative Fuel Initiative
CAPEX	Capital Expenses
CO₂	Carbon Dioxide
CRAF	Civil Reserve Air Fleet
CTL	Coal-to-Liquids
CRC	Coordinating Research Council
DARPA	Defense Advanced Research Projects Agency
DESC	Defense Energy Support Center

DEFStan 91-91UK Defense Standard for Aviation Fuels

DoD	Department of Defense
DOE	Department of Energy
E-85	Gasoline blend with 85% ethanol blended with 15% gasoline
EA	Environmental Assessment
EERC	Energy and Environment Research Center
EC	European Community
e.g.	For example
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPAct 2005	Energy Policy Act of 2005
EPC	Engineering, Procurement, and Contracting
FAA	Federal Aviation Administration
FT	Fischer-Tropsch Fuel
GDP	Gross Domestic Product
GE	General Electric
GSE	Ground Support Equipment
HAP's	Hazardous Air Pollutants

IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IPCC	Intergovernmental Panel on Climate Change
JP-4	Standard naphtha kerosene fuel used by the U.S. Air Force
JP-5	Standard high flash point kerosene fuel used by the U.S. Navy
JP-8	Standard kerosene fuel used by the U.S. Air Force
MIT	Massachusetts Institute of Technology
MOGAS	Motor gasoline used by the U.S. Department of Defense
MTBE	Methyl-tertiary-butyl-ether
N ₂ O	Nitrous Oxide
NAFRC	National Aerospace Fuels Research Complex
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NIMBY	Not In My Back Yard
NGO	Non-Government Organization
NO _x	Nitrogen Oxides
OECD	Organization for Economic Co-Operation and Development
OEM	Original Equipment Manufacturer
OPEC	Organization of Petroleum Exporting Countries
OPEX	Operating Expenses

OSD	Office of the Secretary of Defense
R&D	Research and Development
RP-1	Standard kerosene rocket fuel
RR	Rolls Royce
SBIR	Small Business Innovative Research
SOx	Sulfur Oxides
SWOT	Strengths, Weaknesses, Opportunities, Threats
T-39	U.S. Air Force Executive Transport Aircraft
TED	Total Energy Development
TRB	Transportation Research Board
U.S.	United States

1.0 Introduction

This thesis explores the risks and uncertainties related to the development of an industry to produce alternative aviation fuels for the military and commercial airlines in the United States. The methodology I used was a technology adoption lifecycle analysis, from the innovator of the technology to the establishment of an early majority of users. I explored the lifecycle through the lenses of the alternative fuel innovators, potential early adopters, the early majority of users and the financial community. The technology adoption lifecycle has two main regions of risk and uncertainty, the “Valley of Death,” the region between the technology development phase and the early adoption by users, and the “Chasm,” the region between the early adopters and the early majority of users. In the chapters of this thesis, I describe the risks and uncertainties associated with the “Valley of Death” and the “Chasm” using business frameworks, scenarios, and systems dynamics models based on research from the literature as well as interviews with industrial representatives. Lessons learned from the analysis were used to offer tools, suggestions, and recommendations on how the “Valley” can be crossed and the “Chasm” can be bridged. A brief summary of each chapter in the thesis is as follows:

In Chapter 2, I describe the history of alternative aviation fuels in the context of national security and the roles the Department of Defense and the Air Force have played to foster alternative fuel innovation. For over 100 years, petroleum derived fuels have been the only source of supply to the military and the airlines, and as we look into the future, petroleum will be the dominant resource used for many decades. Alternative fuels produced from resources other than petroleum offer the military and the aviation industry choices that may

improve security, supply, economic stability, and/or environmental footprint. Early in the chapter, I discuss the first wave of innovation that started in the 1970's to develop alternatives from oil shale, and the second wave that started in the late 1990's to develop a wide range of alternative fuels produced from resources such as coal, biomass and oil shale. I describe how Air Force and Department of Defense leadership is critical for the success of these efforts and report on recent progress on programs to foster the development of alternative fuels. I explore the benefits of the partnership between the Air Force and the commercial sector through the Commercial Aviation Alternative Fuel Initiative to help technology innovators cross the "Valley of Death." Finally, I summarize the chapter with some thoughts on how the collaboration of the military and the commercial sector could help develop a market for alternative aviation fuels and help industry bridge the "Valley of Death."

In Chapter 3, I explored the technology adoption lifecycle through the viewpoints of the developer of the alternative fuel innovation, through the early adopters, and early majority of users. I used business strategy frameworks from Michael Porter of Harvard Business School and Arnaldo Hax of MIT to illustrate the factors that are critical to an alternative aviation fuel business strategy and the role the U.S. military and the FAA play in terms of influencing the market. I explore in more depth the two breaks in the technology innovation adoption life cycle, the "Valley of Death" and the "Chasm" that define the barriers and risks that alternative aviation fuel innovators must bridge to secure early adopters and an early majority of airlines to use the alternative fuels. Finally I illustrate how government policies and environmental activists influence may influence the strategy of an alternative fuel developer.

In Chapter 4, I provide the results of the research I conducted to understand the issues facing technology innovators, early adopters and the early majority of users of alternative fuels for aviation. The research consisted of a literature review and a series of phone interviews using questionnaires that were sent to the interviewees prior to the interview. The results are aggregated into set of key phrases that characterize the issues for each segment of the technology adoption lifecycle and the results of the research are summarized for each segment.

In Chapter 5, I discuss the key issues that create risk and uncertainty for alternative fuel developers based on the literature review and interview responses. The main categories of risk and uncertainty include financial, environmental, market, regulatory and sociological. To explore the impact of these risk and uncertainties, I provide analysis of the strengths, weaknesses, threats, and opportunities for oil shale, coal, and biomass as resources for alternative aviation fuels. Using the information from the literature and interviews, I present some example scenarios based on the barriers and risks identified and a discussion of some of the first steps the military and the commercial airlines could foster to reduce the risks.

In Chapter 6, I explore the dynamics related to crossing the “Valley of Death” and bridging the “Chasm” in respect to the key variables that will control the early adopter and early majority adoption rates for alternative fuels for aviation. The models show that an industry can be started by the airlines and military approving the use of the fuel, and that the adoption rate will progress by airlines acting as a cluster at a given airport purchasing the fuel. As the demand for the fuel increases, the alternative fuel production industry will respond by building plants to match the demand as long as the plant utilization capacity is high and they are profitable. The

demand by airlines will be controlled by the relative price of the alternative compared to petroleum, with fuels that cost the same or are lower in price driving the dynamic. The price of the alternative also includes the attractiveness of the product from an environmental standpoint. The dynamics will self-perpetuate until all the airlines and airports adopt the fuel and market demand is satisfied. The dynamics will stall if the price exceeds the market price of petroleum-derived fuels or if the fuels do not offer significant environmental benefits.

In Chapter 7, I discuss the growing worldwide demand for energy and the concerns associated with global warming due to fossil fuel use. However, since there are no alternative fuels for aviation, greenhouse gas emissions from aviation will likely continue to grow unless sustainable, environmentally friendly alternatives are made available for the industry to use. One of the issues with alternative fuels is the lack of tools to assess the sustainability (financial and environmental) of an alternative fuel candidate and there is little methodology to compare alternatives on an equal basis. In this chapter, I present a balanced scorecard approach to compare the sustainability of alternative aviation fuels, and a risk analysis worksheet to help qualitatively define the risks associated with the alternative. By combining the scores from the balanced scorecard and the risk analysis worksheet, one can compare risk versus return and build a portfolio of alternative fuel options. I extend this approach in a comparative manner to stock market portfolio theory and describe a methodology to compare alternatives to the “low risk option,” petroleum-derived fuels. I conclude the chapter with a brief discussion on the natural hedging that arises from processes that produce several products in addition to aviation fuel and how this may enhance the overall commercial viability of a project.

In Chapter 8, I provide some final analysis of the key issues that are critical to helping technology developers cross the “Valley of Death” and provide some scenarios and recommendations to facilitate the crossing. I also show how the military and civil airlines can work collaboratively to help start the dynamics of an alternative fuel industry and how with federal and state government support help build an industry. I describe how this collaboration bridges the “Chasm” increasing demand and spurs on the new entrants to the industry.

In Chapter 9, I summarize the key finding of the thesis and review a series of recommendations that if executed could help the alternative aviation fuel industry start and prosper.

2.0 Alternative Fuels for Aviation: History and Issues

2.1 Chapter Overview

In this chapter, I describe the history of alternative aviation fuels in the context of national security and the roles the Department of Defense and the Air Force have played to foster alternative fuel innovation. For over 100 years, petroleum derived fuels have been the only source of supply to the military and the airlines, and as we look into the future, petroleum will be the dominant resource used for many decades. Alternative fuels produced from resources other than petroleum offer the military and the aviation industry choices that may improve security, supply, economic stability, and/or environmental footprint. Early in the chapter, I discuss the first wave of innovation that started in the 1970's to develop alternatives from oil shale, and the second wave that started in the late 1990's to develop a wide range of alternative fuels produced from resources such as coal, biomass and oil shale. I describe how Air Force and Department of Defense leadership is critical for the success of these efforts and report on recent progress on programs to foster the development of alternative fuels. I explore the benefits of the partnership between the Air Force and the commercial sector through the Commercial Aviation Alternative Fuel Initiative to help technology innovators cross the "Valley of Death." Finally, I summarize the chapter with some thoughts on how the collaboration of the military and the commercial sector could help develop a market for alternative aviation fuels and help industry bridge the "Valley of Death."

2.2 The Military as a Consumer

The Department of Defense (DoD) is the largest energy consumer in the United States (U.S.) government and requires a diverse slate of energy resources, including jet fuel, electricity, ethanol, biodiesel, gasoline, diesel fuel, natural gas, propane, and coal. The U.S. Air Force (AF) is the largest energy consumer in the DoD, and consumed 2.26 billion gallons of jet fuel costing \$5 billion in 2006 to protect national security interests. Jet fuel is the largest single energy expense for the AF and constitutes 82% of the total annual energy consumption. For every \$10 increase in the price of oil, the AF fuel bill is increased by \$600 million. Facility energy costs are continuing to increase even though the AF has an aggressive program to improve efficiency and reduce energy use energy use still cost the AF over \$1.1 billion in 2006. The rising cost of energy has required the AF to take action at all levels, including conserving energy, using energy more efficiently, and fostering development of alternatives. The AF strategy is to “make energy a consideration in all we do.” To This end, the AF is attacking the supply side of domestic availability by investigating alternative fuels for aviation and renewable energy for installations as well as the demand side by enhancing energy efficiency in aviation and infrastructure.¹

2.3 The History of Alternative Aviation Fuels

Energy security and availability has been a concern for the US military throughout history and the U.S. Air Force has been a leader in demonstrating alternative energy technologies and a willing first adopter of new technologies. One of the earliest examples was

¹ Michael Aimone, Briefing: “Air Force Energy Strategy for the 21st Century,” February 2006.

the flight by Major Arthur Hyde of the Civil Air Patrol (affiliated with the Army Air Corps) from Morgantown West Virginia to Washington National Airport on November 6, 1943 in a Stinson aircraft fueled with gasoline derived from coal. A Congressional Representative, Jennings Randolph greeted Major Hyde at National airport and congratulated him on his flight. It is interesting to note that representative Randolph was an early advocate of renewable fuels and warned against dependence on foreign energy.²

Furman et al (2007) point out that energy security has been a concern for the U.S. since 1970's and has created economic issues, including recessions, reduced consumer confidence, and reduced consumer spending. In addition, higher oil prices impact the prices of other goods and governmental monetary policy. Furman cites the writings of Thomas Friedman that present evidence that oil wealthy states increasingly resist international norms and conventions as their oil wealth increases, limiting U.S. foreign policy as the governments of these oil states could withhold oil from world markets, thereby creating shortages and price spikes. In addition, oil dependence has required a U.S. military presence in the Middle East for over 50 years.³ Continued dependence on imported oil could negatively affect future roles and missions of the Department of Defense, thus hampering our ability to react to contingencies, terrorist threats, and humanitarian operations or to provide support to U.S. allies and friends.⁴

² Picture and article of the flight of Major Hyde, November 6, 1943 from an unknown published source. Article presented to author by Judith Pensabene and Colin Hayes, DOE/NETL, 2007.

³ Jason Furman, J. E. B., Manasi Deshpande, and Pascal J. Noel (2007). Overcoming the Economic Barriers to Climate Change and Energy Security.

⁴ Unpublished paper, Theodore Barna, Assistant Deputy Under Secretary of Defense/Advanced Systems and Concepts, October 2005.

As a response to the national security threats of the 1970's the DoD and the AF took a leadership position to identify, test, certify, and be a first user of alternative fuels. Under Project: Rivet Shale, the U.S. Air Force took a leadership role to validate the use of shale oil derived JP-4 fuel in operational aircraft. An AF pamphlet dated October 3, 1983 states:

“Despite reports of a world oil glut, the U.S. still imports a big percentage of its petroleum energy requirements. In fact, if we project out through the year 2000, we see existing conventional petroleum production will meet only one-half our energy needs.” “To the extent we fail to develop domestic energy alternatives to conventional petroleum, the U. S. will become increasingly reliant on imported oil whose sources cannot be guaranteed.” “Twice in the past 10 years Air Force stocks of jet fuel were seriously depleted because of curtailed oil supply to the U. S.” “In addition, (oil) shale is abundant in this country.” “80% of the world’s recoverable (oil) shale (over 1 trillion barrels) is here in the U. S.” The pamphlet goes on to say “The Air Force Systems Command, through the Aero Propulsion Laboratory at Wright Patterson AFB, is conducting the ground test phase of the R&D program.” “Basically, each system that is fuel wetted on board an aircraft is being examined to ensure performance, material compatibility, and endurance standards.” “The second and final portion of our program consists of validating the long term use of shale derived JP-4 in operational Air Force aircraft.” “Rivet Shale⁵ will validate the safe and effective use of shale derived jet fuel while helping unlock an abundant and secure source of energy here in the United States.”⁶

⁵ Rivit Shale was the name of the Air Force program to work with industry to develop jet fuel from oil shale and certify the use of specification quality shale-derived fuels for use in Air Force aircraft.

⁶ Air Force Pamphlet, “Project Rivet Shale, Air Force Synfuel Shale Oil Program, 3 October 1983.

The first wave of alternative fuel innovation started as a result of the Organization of Petroleum Exporting Countries (OPEC) oil embargo of September 1973. At this time, the DoD consumed approximately 500,000 barrels per day (bbls/day) of diesel fuel marine, JP-4 jet fuel, JP-5 jet fuel, and motor gasoline (MOGAS). To counter the challenges presented by the embargo, the DoD initiated three strategies: conservation, supply assurance and technology applications. The supply assurance strategy was based on the assumption that in the time of a crisis, the DoD would be given priority access to all the petroleum resources required to defend the nation. During peace time, the DoD would purchase petroleum products on the open market and during an energy crisis where there was not military threat the DoD would reduce its demand by reducing sustainment and readiness.⁷ This philosophy continues to be offered by some segments in the DoD as a reason not to engage in alternative fuels. The line of thinking is that because oil is a global fungible product, there will always be suppliers willing to provide oil to the U.S. if the U. S. is willing to pay for the product. Also, because the military has priority over other consumers when it comes to purchasing such products, there is no need to consider alternative fuels.

The first barrier that must be overcome by the military is the belief that petroleum derived fuels will always be available and that there is therefore no need for alternatives.

The wave of innovation in alternative fuels triggered by the OPEC embargo was started in the early 1970's by the Navy and Naval Petroleum and Oil Shale Reserves Office. Under agreements between the Federal Energy Administration (now the Department of Energy), the DoD agreed to test products from synthetic crude oils using DoD equipment as long they met

⁷ James Carnes, Unpublished report, "History of DESC's Synthetic Fuel Purchases," 2006.

DoD fuel standards. DoD would pay market price for the products and the Federal Energy Administration would pay R&D costs above market price through the Synthetic Fuels Corporation.⁸ Although the first production samples of shale-derived jet fuel showed promise, refining technologies at the time were challenged by the characteristics of the shale oil including a high nitrogen content requiring innovation in catalysts and refining techniques. Since the initial production was not suitable for use in an aircraft, the fuel was re-refined until it met the specifications. Even with re-refining, issues related to corrosion and the lubricity of the fuel were identified as technical area's requiring additional research. Since the fuel met specifications the first test flight of a shale-derived JP-4 occurred in 1976 in an Air Force T-39 aircraft.⁹

Realizing the technical challenges of refining shale oil into specification military fuels, the Air Force established research programs with Sun Oil, UOP, and Ashland Research and Development to develop improved technologies to produce shale derived fuels and through the Defense Energy Supply Center (now the Defense Energy Support Center) to purchase large volumes of fuel produced from Geokinetics retorted shale oil at the Caribou Four Corners Refinery in Woods Cross, Utah. The Air Force also conducted research with the aviation industry to study the effect of shale derived fuels on all aircraft fuel wetted systems and subsystems and aircraft engines. Plans were put in place to purchase large quantities of shale-derived fuel from major shale oil projects including Geokinetics, Paraho, Occidental and Unocal and to convert to shale-derived fuel all the fighter aircraft stationed at Hill AFB Utah and

⁸ James Carnes, Unpublished report, "History of DESC's Synthetic Fuel Purchases," 2007.

⁹ William Harrison, Unpublished report, "Oil Shale History," October 2005.

Mountain Home AFB Idaho.¹⁰ By the early 1980's, the price of oil began to plummet and the major oil shale programs started to fail following the announcement on May 2, 1982, by Exxon to cancel the Colony project. This date was dubbed Black Sunday and it marks the beginning of the end of large scale alternative energy projects in the U. S.,¹¹ The Air Force continued to conduct research on shale derived fuels as well as other unconventional fuels, including oil sands, heavy oils, coal liquids produced at the Great Plains Gasification Plant and even tires into the late 1980's when all research on alternative fuels was terminated.

The first wave of innovation on alternative fuels started in the military in the mid-1970's and ended when the price of oil collapsed in the 1980's. The military must consider the barrier to the development and sustainment of alternative fuels created by the cyclic nature of cost of petroleum.

2.4 The Clean Fuel Initiative

In 2002 the DoD Office of the Secretary of Defense (OSD) Advanced Systems and Concepts Office (AS&C) started the Clean Fuels Initiative to begin evaluating unconventional transportation fuels for military applications. The vision statement for the initiative declared that the DoD intended to catalyze the commercial industry to produce clean fuels for the military from secure domestic resources using environmentally sensitive processes that create jobs and wealth in the United States. The Clean Fuels Initiative consisted of two parts: Total Energy Development (TED) and Battlefield Use Fuels of the Future (BUFF). The TED program

¹⁰ William Harrison, Unpublished report, "Oil Shale History," October 2005.

¹¹ James T. Bartis, Tom LaTourrette, Lloyd Dixon, D. J. Peterson and Gary Cecchine, "Oil Shale Development in the United States: Prospects and Policy Issues," Rand, 2005.

was designed to conduct outreach to industry, other government agencies, consortia, think tanks, and academia to assess the resource base available in the U. S. and the technical maturity to recover the resource. More specifically the outreach was designed to assess all secure indigenous sources of energy including coal, oil shale, oil sands, and biomass and to determine the technical feasibility and economic viability of producing jet fuels for the military. The focus was to find ways to minimize government funding, meet existing government mandates and executive orders especially in regard to environmental compliance, couple the program with emerging technology programs in the DoD, and produce a cleaner, more environmentally friendly fuel. The BUFF program was designed to facilitate the OSD's work with the military services to evaluate, demonstrate, and certify fuels from alternative energy resources for use in tactical vehicles, aircraft and ships.¹²

In addition, there was a technical research portion of the Clean Fuels Program dedicated to investigating the potential of Fischer-Tropsch (FT) fuels produced by a small Oklahoma company, Syntroleum. The technical program, based on a Congressional addition to the defense budget, was managed by the Army's National Automotive Research Center, which coordinated collaborative research with the Air Force and Navy. I became involved with this initiative in 2003, as my research group in the Air Force at the National Aerospace Fuels Research Complex (NAFRC), Turbine Engine Division, Propulsion Directorate, Air Force Research Laboratory, was asked to collaborate with the Army to evaluate the potential of Fisher-Tropsch fuels for aircraft. Research conducted by NAFRC personnel found that the Syntroleum FT fuel produced from natural gas offered superior properties when compared to most petroleum

¹² Briefing by Dr. Theodore Barna, "OSD Clean Fuel Initiative, March 2005.

derived fuels. The fuel was 100% isoparaffinic in nature, which allowed it to burn cleaner and produce less soot.¹³ In addition, the fuel could be manufactured to have superior low temperature properties which could increase the flight envelop of some Air Force aircraft. The fuel also had superior thermal stability, enabling cooling for advanced propulsion systems. Moreover, the fuel could be produced not only from natural gas, but from coal as demonstrated by SASOL in South Africa and biomass. As research continued, the fuel was found to be a direct use fuel for solid oxide fuel cells, to work as well as RP-1 in hydrocarbon rockets, and to be beneficial for hypersonic propulsion. It could also be used in the existing fleet of gas turbine engines and provide advantages to advanced fuel efficient gas turbine engines.¹⁴ The Army conducted tests in diesel engines and the Navy conducted an assessment of the fuel for shipboard applications. In all tests, the FT fuel was demonstrated to be the first fuel that could be used in multiple applications and had the potential to be used as not only a single battlefield fuel today but to enable use as a single battlespace fuel in the future.¹⁵

2.5 Introduction to the “Valley of Death”

In November 2004 I was detailed from my job as Chief, Fuels Branch, Turbine Engine Division, Propulsion Directorate, Air Force Research Laboratory to OSD AS&C to be a senior advisor to the Assistant Deputy Under Secretary of Defense managing the Clean Fuels Initiative, Dr. Theodore Barna. As a member of the staff working on this initiative, it became clear to me

¹³ Edwin Corporan, Matthew DeWitt, Orvin Monroig, David Ostdiek, Ben Mortimer, and Matt Wagner, “Reduction of Turbine Engine Particulate Emissions using Synthetic Fuels,” ACS Preprints, 2005.

¹⁴ William Harrison and Steven Zabarnick, “The OSD Assured Fuels Initiative – Military Fuels Produced from Coal,” Department of Energy Clearwater Coal Conference, 2005.

¹⁵ Coryne Forest and Patsy Muzzell, “Fischer-Tropsch Fuels: Why are they of Interest to the United States Military,” AIAA paper 2005-01-1807, 2005.

that there was a gap between technology development and technology deployment. Many technologies are available to provide alternative energy resources to the U.S. and the technology readiness ranges from small lab experiments to commercially available technologies that have been deployed in other countries. The Department of Energy (DOE) had provided support for a number of technologies that had never been commercialized although they were technical successes. In discussions with colleagues in the International Policy Office in the DOE they dubbed this problem as the “Valley of Death.”¹⁶ The more I looked at the needs of the DoD, the more it became apparent that the DoD needed to help foster a strategy to cross the “Valley of Death” as the DoD is a customer of products that would rely on the deployment of the alternative fuel technology. The technology innovator must be able to show that the technology is proven at a representative scale for construction of a commercial plant for the DoD to consider being a first adopter. The innovator must provide sample in sufficient quantity for the DoD to evaluate, qualify and certify the fuel. With representative fuel samples produced from a representative scale process, the DoD can begin the necessary steps to become a first adopter of the technology. To tackle this problem may require the actions of many government agencies and each could contribute a plank to help bridge the “Valley of Death.” Figure 2.1 illustrates some of the potential players and actions that could bridge the “Valley of Death.”

¹⁶ The term “Valley of Death” is attributed to my friend and colleague David Berg of the Department of Energy. He coined the term in a report entitled “The U.S. Environmental Industry” for the Office of Technology Policy, Technology Administration, U.S. Department of Commerce, 1998.

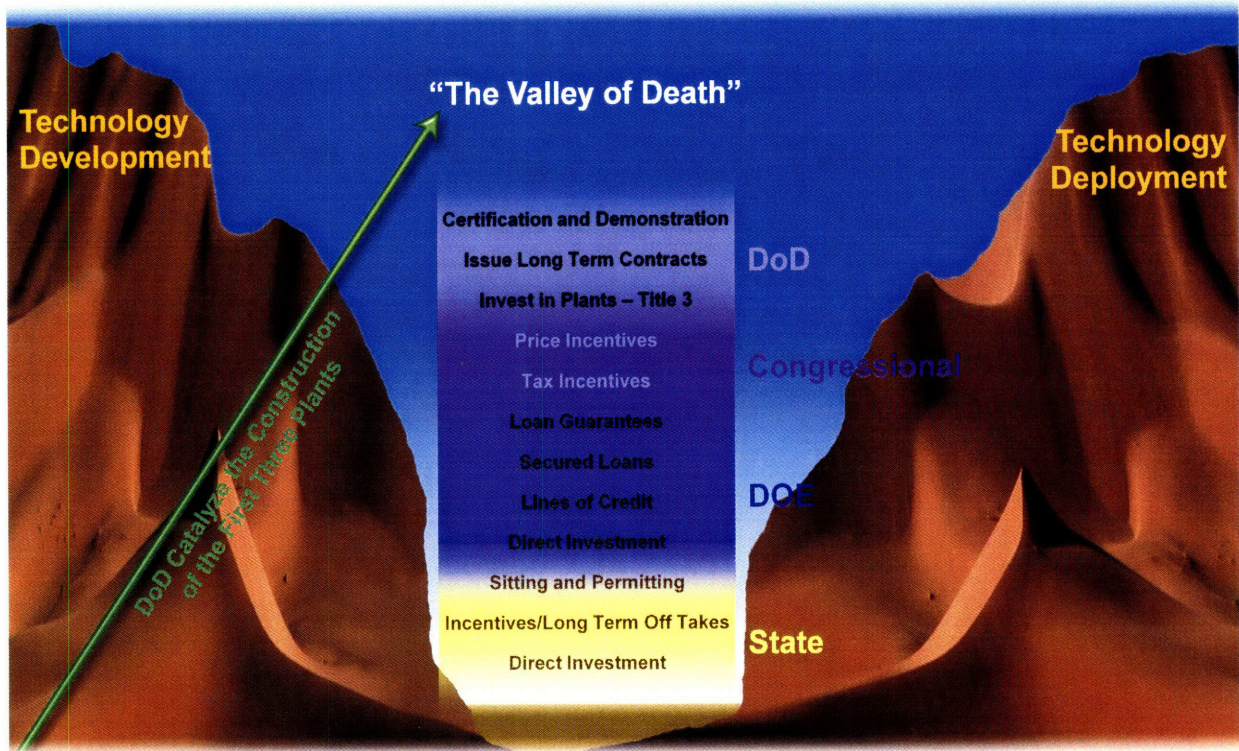


Figure 2.1 Bridging the “Valley of Death”¹⁷ Potential players and actions.

Bridging the “Valley of Death” was one of the projects I worked on while in OSD. As part of the TED outreach, my colleagues and I learned that there were many alternative energy technologies that could be used to produce fuel for the military that had been developed and deployed outside the U. S. In addition, the Department of Energy (DOE) had matured technologies with demonstration projects that had never been commercialized. Other innovative technologies were at the laboratory level at universities, government laboratories and industry laboratories. The challenge became determining how the government could help move these technologies forward to commercial enterprises that could sell fuel to the DoD. It also became apparent that no one entity could provide all the pieces needed to bridge the “Valley.”

¹⁷ William Harrison, Lecture, Purdue University, 2006.

In one of the first series of outreach meetings, my colleagues and I met with the Western Governors Association. Dr. Theodore Barna, the OSD lead for the Clean Fuel Initiative, was asked to speak at their annual conference. This outreach generated a series of discussions with state governments in the East, West, and Mid-west that demonstrated the power that states have in bridging the “Valley.” For example, states have the authority to provide direct investment, utilize bonding authority, issue state contracts, provide tax incentives and use other financial tools to help develop commerce within the state. In addition, state environmental protection agencies play a critical role in the siting and permitting of alternative energy projects. As any new alternative energy project must comply with all state and federal environmental laws, the state is the first line of approvals to assure environmentally friendly projects. Another key issue for siting plants is local resistance to some alternative energy technologies. “Not in my back yard” (NIMBY) sentiment can stop any business project in its tracks. Finding locations in states that embrace an alternative fuel project is a key step toward producing fuel and reducing dependence on foreign oil. For the state, a new project provides jobs and revenue and creates wealth within the state boundaries. The role of the state is even more critical as the issue of greenhouse gases is addressed. An energy project must satisfy the local requirements and interests as well as global issues. In some cases, these interests are not aligned. For example, the costs emissions reduction projects in the power industry may be passed on to the rate payers in the state where the power plant is located.¹⁸ These costs may not be able to be passed on to transmission customers outside the state, even if the power is

¹⁸ Private communication, Kim Wissman, Ohio PUCO, January 2008.

sold outside the state. This type of disconnect will be increasingly amplified as global warming issues are raised, as the local good and the global good must be properly aligned.

The Department of Energy (DOE) offers many programs to help bridge the “Valley.” For example, the Energy Act of 2005 (EPAAct 2005) made provisions for loan guarantees. Although limited in funds, the use of loan guarantees provides a level of risk reduction for capital expensive projects. The DOE can also provide direct investment in demonstration plants and provide direct loans, and lines of credit. The DOE should be commended for its support of R&D and technology demonstrations. The DOE in collaboration with industry has fostered many energy technologies. Collaboration with other agencies such as DoD would reinforce the technology provider/technology user relationship and provide a strengthening truss for bridging the “Valley.”

In EPAAct 2005 and other legislation there are a number of other incentives for developers of alternative energy projects. The incentives include tax credits, accelerated depreciation schedules, price incentives, direct mandates, research and development credits, and job credits. One challenge for alternative fuel developers is that all the incentives are spread over multiple pieces of legislation. In many cases the incentives are authorized but no companion legislation that provides an appropriation has been passed. In these cases, the ability to provide the incentive is there, but it cannot be used by the industry as no financial resources have been allocated. Government incentives have provided enable alternative energy projects for transportation and power generation. Mandates have been effectively used to spur alternative fuels such as corn ethanol for automobiles and tax credits have used effectively to

spur development of wind energy. Mandates, incentives and sound energy policy are key parts of an effective bridging strategy.

Since the DoD is a customer, we explored the options that were available within DoD to help bridge the “Valley.” One of the key barriers to the use of alternative fuels is the complex and costly certification process required for aircraft, ground vehicles and equipment and ships. In many ways the approval barrier has been an effective deterrent to alternative energy developers. This situation is often coupled with the added expense that is required in the processing of aviation fuels to meet specification and fit for use criteria. Many projects economically favor the production of other middle distillate fuels such as diesel fuel, further driving developers away from the aviation fuel market. One way the DoD could help bridge the “Valley” is by qualifying and certifying alternative fuels. Another potential bridging technique would be to issue long term contracts for the fuel purchase. Currently fuel is purchased via competitive contracts awarded to the lowest bidder on an annual basis. Although this strategy benefits the DoD when oil prices fall, it complicates the budgeting process when oil prices rise. For example, if Congress does not add money to the DoD budget to cover the fuel price increases in a market where oil prices are rising, the services must make trade-offs such as decreasing operations, training, maintenance, or other critical requirements. In some cases, acquisitions of new equipment are downsized or delayed. DoD is limited in its ability to issue long-term contracts, although discussions with legislators are continuing on this subject. One last tool the DoD can use in a crisis is to enact the Defense Production Act, Title 3 legislation. This legislation, which was last updated during the energy crisis in the 1970’s, provides the DoD full authority to build, own, and operate an alternative energy industry to provide fuel for the

military as necessary for national defense. Although the authority exists, the current energy challenges are not a crisis and it is unlikely that the military would ever pursue this option.

Another option is for the military to use its abilities to catalyze the commercial industry to build some demonstration plants that would reduce risk to the industry, move the industry forward on the learning curve and provide alternative fuels for the military. Proper alignment of tools and incentives could make this vision a reality.

2.6 Air Force Leadership to Help Industry Cross the “Valley of Death”

In late 2005, the Honorable Michael Wynn, Secretary of the Air Force, stated that the Air Force should take a leadership role and he issued strong guidance to the Air Force to “make energy a consideration in all you do.” The guidance also declares that the Air Force should use 50% alternative fuels by 2016, if economical. To facilitate this effort, Mr. Wynne authorized, and was a strong supporter of the demonstration of Fischer-Tropsch (FT) fuels in a B-52 aircraft, which occurred in late 2006. He also sponsored the development of a new military handbook to stream-line and clearly delineate a process to certify jet fuel in all Air Force systems and across all enterprises that included safety, training and environmental considerations. I had the privilege of being one of the co-leaders of the B-52 flight demonstration and the team that developed the new handbook. The systems engineering process that frames the handbook is currently being employed by a new office established at the Aeronautical Systems Center at Wright Patterson AFB Ohio to certify all Air Force systems. Recently a C-17 aircraft made a transcontinental flight on a 50/50 blend of FT fuels and in the near future a supersonic engine from a B-1B aircraft will be tested at the Arnold Engineering Center.

The second wave of innovation on alternative fuels in the military was started by an initiative in the Office of the Secretary of Defense in 2002 and continues to progress with strong leadership by the Air Force.

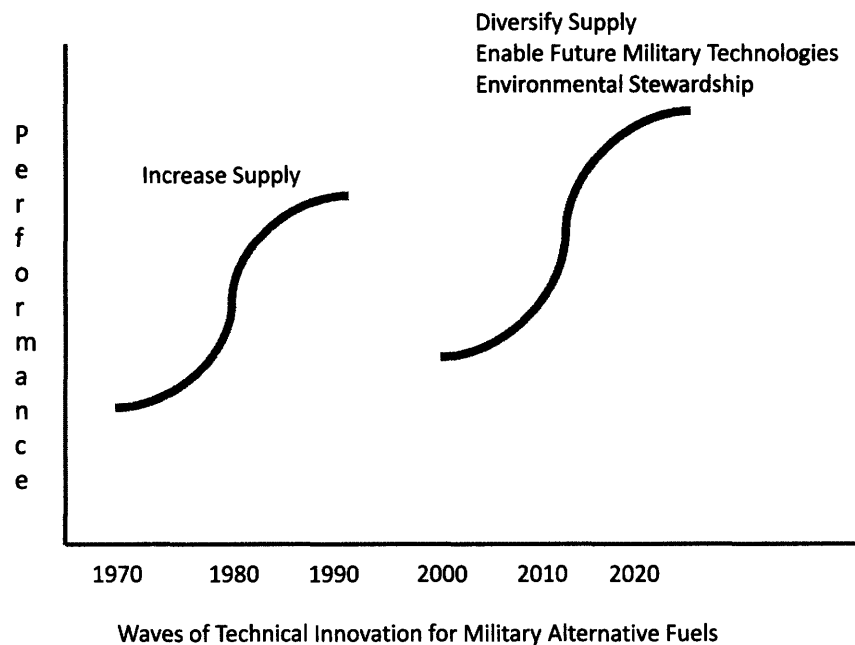


Figure 2.2. Waves of Technical Innovation for Military Alternative Fuels

One might question why the Air Force should be enabling innovation in alternative fuels. In 2005, R. James Woolsey and George Schultz discussed the present danger of the risks of petroleum dependency and the vulnerability of the petroleum infrastructure in their paper on "Oil and Security." They recommended policy for improved modern diesel engines, hybrid gasoline-electric vehicles, plug in hybrids, constructing light weight vehicles using carbon fiber composites, as well as encouraging the commercialization of alternative transportation fuels including cellulosic ethanol, biodiesel, coal gasification, natural gas to

liquids, and oil sands. The main focus of their paper was targeted at automotive solutions and there were not recommendations for aviation.¹⁹ John Deutch and James R. Schlesinger in their task force report on the “National Security Consequences of U. S. Oil Dependency,” comment on the increased strategic vulnerability and the international constraints that occur to pursue foreign policy and national security objectives. Deutch and Schlesinger argue that oil dependency places the U.S. in direct competition with the expanding economies of India and China, potentially compromising U. S. future foreign policy. They also state that the U. S. must integrate energy issues into foreign policy.²⁰ Clearly, the linkage between energy issues and foreign policy should be viewed by the military as a rallying call to integrate energy and worldwide energy concerns into its planning cycles. Deutch and Schlesinger recommend that the U. S. should support a strong military posture that permits rapid deployment to the Persian Gulf to protect U.S. interests in a reliable oil supply, nonproliferation, and combating terrorism. Their report recommends increasing energy efficiency, expanded use of alternative fuels such as ethanol, and greater use of nuclear power. In addition, they encourage increased supplies of alternatives from the substantial U. S. reserves of unconventional resources.²¹ The National Science and Technology Council in their report on National Aeronautics Research and Development Policy state that the U. S. Government has played a leading role in advancing scientific principles and technologies for flight. They state that in order for the U. S. to maintain its technical leadership in aeronautics, the U. S. should be guided by the following principles: 1) Mobility through the air is vital to economic stability, growth, and security; 2) Aviation is vital to

¹⁹ R. James Woolsey, and George P. Shultz, “Oil and Security,” The Committee on the Present Danger, August 2005.

²⁰ James Deutch and James R. Schlesinger, “National Security Consequences of U. S. Oil Dependency, Report of Independent Task Force Report 58, Council on Foreign Relations, 2006.

²¹ James Deutch and James R. Schlesinger, “National Security Consequences of U. S. Oil Dependency, Report of Independent Task Force Report 58, Council on Foreign Relations, 2006.

national security and homeland defense; 3) Aviation safety is paramount; and 4) Security of and within the aeronautics enterprise must be maintained. They recommend that in some instances when other market factors may limit private sector investment, the federal government should decide that investment is required.²² With all the above mentioned drivers, the Air Force should take a leadership role in alternative fuels for aviation. The national security implications may create situations in the future that require military operations, and those thinking about alternative fuels for national security are only focused on the ground transportation sector. Furthermore, since the aviation industry in general is suffering from financial difficulties, the AF should fill the gaps and spur alternative fuel innovation.

2.7 Global Climate Change Implications

A new challenge facing aviation and the military is the recognized impact of global warming. The Intergovernmental Panel on Climate Change (IPCC) in 2007 linked the effect of human activities with global warming. As the temperature of the earth increases, climatic shifts, including rising sea levels, more frequent and severe storms, increased floods, increased droughts and other shifts in normal weather patterns occur.²³ Clearly, climate change and the resulting natural catastrophes could increase the need for Air Force operations in the future to provide security to troubled area's as well as the delivery of humanitarian relief. In 2006, 42% of the energy used by the AF (almost 1 billion gallons) was used for mobility operations.²⁴ this suggest that climate change could become a dominant issue in future Air Force operations and

²² John Marburger, "National Aeronautics Research and Development Policy," National Science and Technology Council, December 2006.

²³ Jason Furman, J. E. B., Manasi Deshpande, and Pascal J. Noel (2007). Overcoming the Economic Barriers to Climate Change and Energy Security.

²⁴ Michael Aimone, Briefing: "Air Force Energy Strategy for the 21st Century," February 2006.

costs. Furman (2007) discussed three key economic barriers related to climate change: 1) the large gap between the cost of energy to individual consumers and producers and the cost to society as a whole; 2) the private sector's underinvestment in research and development, primarily speculative long range research and 3) the fact that consumers may not have all the information they need to make informed choices.²⁵ Furman's observations are significant in regards to alternative fuel choices for aviation. Many environmental groups such as the Sierra Club and the National Defense Resources Council are drawing broad conclusions in regards to what resources should be used for transportation and which resources may contribute to global warming. Some groups paint fossil sources as bad and biological sources as good. However, from an overall environmental standpoint it is not that simple. To better assess environmental impact a careful analysis from ground to aircraft wake is needed. The analysis needs to include not only energy and greenhouse gas production associated with producing the resource and converting it to fuel but also the emissions from the tailpipe of the aircraft. This topic can be controversial and is often a source of heated scientific debate. For example, corn-based ethanol may require more energy to grow, harvest and produce than it yields, and some biological crops may actually create more environmental damage if they are destroying rain forests or other environmentally sensitive land masses.²⁶ Coal and other fossil resources do contribute to high levels of CO₂, but these levels can be mitigated with carbon capture and sequestration. The challenge is how to develop a balanced approach that considers at all the key issues related to an alternative fuel and weight the pro's and con's. This approach will be

²⁵ Jason Furman, J. E. B., Manasi Deshpande, and Pascal J. Noel (2007). Overcoming the Economic Barriers to Climate Change and Energy Security.

²⁶ William Schulz, "The Cost of Biofuels," Chemical and Engineering News, Dec 2007.

described in more detail in Chapter 6. An approach that is environmentally sustainable and economically sustainable for commercial airlines and the military is the prudent way to move forward.

2.8 The Need for Government Support for Alternative Energy to Succeed

Ogden, Podesta, and Deutch (2008) state that the U.S. must begin a process of transforming the economy from one of oil dependence and polluting coal-fired power generation to one of energy efficiency, alternative fuels, and electricity with low carbon emissions. The rate at which the U. S. develops new energy technology will determine the speed and cost of this economic transformation. In addition, public investment has not been sufficient to meet the urgency and scale of the energy challenges. The authors point out that in some cases direct federal support has led to projects that have failed and they cite the many large synthetic fuel projects of the 1970's and 1980's. To better steward public funds, we need to differentiate between projects that will define technical performance, cost and environmental effects and those that are undertaken to increase production either with federal financial support or in response to federal mandates. In general Ogden et al. believe that government agencies are not equipped with the personnel or operational freedom to permit the agency to pursue the first-of-a-kind project that demonstrates the economic prospects of a new technology. They believe that indirect financial incentives such as loan guarantees, guaranteed purchase, tax credits and equity investment allow innovation to mature in a commercially viable and sustainable manner. They further state that guaranteed purchase is

one way of bringing down the unit cost of a new technology.²⁷ As the military functions as an informed consumer and a large purchaser of fuel, guaranteed purchases of a negotiated volume of fuel from an alternative energy plant could simultaneously meet the AF goals of 50% alternative fuels by 2016 and provide economic benefits to the developer of the new technology. If the AF acts as an early adopter of the alternative fuel technology, it will provide the first beach head for the technology innovator to gain technical credibility and long-term insight into the performance of the product and the overall impact on the environment of the process. Ogden et al's view supports one of the potential planks the AF can use to help bridge the "Valley of Death."

Indirect financial incentives such as guaranteed purchase agreements are one tool the military can use to bridge the "Valley of Death"

2.9 The Commercial Aviation Alternative Fuel Initiative

Ogden et al. state that energy innovation needs a market-driven rather than technology-driven approach to R&D as new energy technologies are beneficial only if they are adopted and deployed by private industry.²⁸ Since the Air Force purchases only approximately 10% of the jet fuel in the U.S., alternative fuel solutions that benefit the commercial sector will offer significant leverage to the producers and help control the price of the alternative fuel. When the Air Force stepped forward with aggressive leadership on alternative fuels, the Civil Airline sector quickly followed suit with the Civil Aviation Alternative Fuel Initiative (CAFFI). The

²⁷ Peter Ogden, John Podesta, and John Deutch, "A New Strategy to Spur Energy Innovation," Center for American Progress, 2008.

²⁸ Peter Ogden, John Podesta, and John Deutch, "A New Strategy to Spur Energy Innovation," Center for American Progress, 2008.

Federal Aviation Administration's (FAA) Environment and Energy board was prompted by its advisory board to fund activities related to alternative fuels. CAAFI was born in 2006 from the efforts of the Transportation Research Board (TRB) Committee on the effects of aviation on the environment. The TRB is a forum where airlines, airports, manufacturers, and the FAA come together to discuss new and emerging issues. CAAFI is a forum of U. S. commercial aviation representatives that work to enhance energy security and environmental sustainability with alternative fuels. CAAFI includes the trade associations for airports, U.S. aircraft and engine manufacturers, and U.S. airlines. CAAFI members also include federal agencies, fuel suppliers, the international aviation community, and academia.²⁹The group held its first meeting in May 2006 and formed four teams: 1) R&D, 2) certification/qualification, 3) environmental, and 4) business and economics. In October 2008, the group met to develop the first set of industry/government roadmaps. The formation of CAAFI and the development of industry sets a new direction for aviation fuels. As Altman (2006) stated, alternatives to jet petroleum based aviation for commercial aircraft were, at best, an afterthought of energy suppliers. The collective wisdom of the airlines, airports, aircraft manufacturers and the FAA had been that aviation would consume the last drop of oil used in transportation. The new wisdom asks an important question: is there a better future possible with a more secure supply, and a better environmental footprint?³⁰

Commercial aviation capacity is expected to grow by a factor of 1.8 – 2.4 folds by 2025.

The challenge is how to control emissions and greenhouse gases and meet sustained growth.

²⁹ CAAFI Factsheet, "Commercial Aviation Alternative Fuels Initiative: Supporting Solutions for Secure and Sustainable Aviation", 2007.

³⁰ Richard Altman, "Alternative Fuels For Aviation: the CAAFI Process," International Airport Review, 2007.

Boeing projects a 5% growth in emissions per year that can be offset by only 1% per year in efficiency improvements.³¹ In 2005 the cost of fuel surpassed the cost of labor in civil aviation and became the largest expense faced by the industry.³² The market volatility of fuel costs creates uncertainty in an industry characterized by low profitability and bankruptcy. The current price of fuel that the airline industry pays on average is a function of long-term contracts, spot market prices, and the location of the sale. Fuel accounts for 25 – 40 percent of the airlines' operating expenses. The Air Transport Association (ATA) reports that the airlines consume 19 to 20 billion gallons of jet fuel per year and for every one cent increase in the price of fuel the industry faces increased costs of between \$190 and \$200 million annually. Since 2000, the average cost of jet fuel for the industry has risen by 140%. To counter the escalating prices, the airline have embarked on a strong campaign to increase fuel conservation and efficiency, achieving a 36 percent increase in fuel efficiency for passenger carriers and a 24 percent increase in efficiency for cargo carriers. In addition, some aircraft carry extra fuel on certain flights to avoid the need to refuel at locations where fuel costs are very high. Improving efficiency also reduces greenhouse gas emissions. Aviation as a whole only produces 2 – 3 percent of all manmade greenhouses. The ATA reports that overall greenhouse gas emissions for civil aviation have been reduced 103 percent since 1978. One of the tools used by the airline industry to improve fuel efficiency and thereby reduce greenhouse gas emissions is to modernize aircraft fleets and to modify aircraft with winglets. In addition, the ATA board of directors has adopted a goal to increase fuel efficiency by 30 percent by 2025.³³ Efforts have

³¹ Private Communication, David Daggett, Boeing Company, November 2007.

³² Lourdes Maurice, "Alternative Fuels," FAA, Presentation to the ATA Energy Council Meeting, September 2006.

³³ Air Transport Association, (2008). "Energy/Fuel." from <http://www.airlines.org/economics/energy/>.

also been made to reduce unnecessary weight from all aircraft. The military has followed suit with similar efforts to reduce weight from current aircraft, but has not been able to make significant changes to modify aircraft or purchase new aircraft to improve overall fuel efficiency.

The CAFFI approach achieves one of the recommendations by Ogden et al. that the government to work closely with private sector and environmental regulators to develop and demonstrate technologies that can be profitable within existing and anticipated market conditions and environmental regulations.³⁴ Recently there has been growing interest both on the civil side and the military side to form a similar group in Europe. The formation of a European CAFFI would be a positive step towards a global solution for alternative fuels for aviation.

Would the administration support military leadership in alternative fuels? In 2006, The President's Council of Advisors on Science and Technology made several overarching recommendations 1) increase federal support for science and technology research, 2) promote EAct 2005 incentives, 3) support state incentives, and 4) position the federal government as an early adopter of new technology.³⁵ The military, led by the Air Force, can fulfill this charge and become one of the early adopters of alternative fuel.

³⁴ Peter Ogden, John Podesta, and John Deutch, "A New Strategy to Spur Energy Innovation," Center for American Progress, 2008.

³⁵ John Marburger, "The Energy Imperative: Technology and the Role of Emerging Companies," President's Council of Advisors on Science and Technology.

2.10 Chapter Summary

The DoD is a large consumer of energy, primarily jet fuel. The U.S. Air Force is the single largest user of jet fuel in the DoD. The energy shocks of the 1970's propelled the DoD to start the first wave of innovation on alternative energy, but this wave ended with the cyclic price slide of oil in the 1980's. The Air Force played a significant role in the first wave of innovation by conducting research and development, conducting evaluations and certification of alternative fuels, and developing plans and strategy to be a first adopter. In 2002, the DoD started the second wave of innovation with the Clean Fuels Initiative (renamed Assured Fuels Initiative in 2005). The Air Force, led by the Honorary Michael Wynne has demonstrated a leadership role for alternative fuels in this second wave of innovation by fostering research and development, fuel evaluation and certification, and locking in a plan to certify the entire Air Force fleet for the use of a 50/50 blend of Fischer Tropsch fuels by 2010. This action not only provides a bridging strategy to help industry cross the "Valley of Death" and allow the Air Force to be an early adopter of the technology, but does so in a way that balances national security interests, economic security interests, and environmental stewardship. Efforts are underway in the second wave of innovation not only to consider clean technologies for fuels derived from fossil sources, but to develop renewable resources for aviation fuels. Increasing the number of alternatives allows the Air Force to be an early adopter in several fuel markets.

As an early adopter of alternative fuel technologies, the Air Force helps bridge the "Valley of Death," but as a single entity the bridging is weak and probably not sustainable. Collaboration with the civil sector significantly strengthens the bridge, however, issues of

availability, cost, infrastructure, and environmental effects may create barriers to sustainability of the innovation. This thesis will explore the innovation technology adoption life cycle in Chapter 2 and use a series of business frameworks to explore the challenges, barriers, and issues related to a sustainable future for alternative fuels.

3.0 Business Strategy Frameworks

3.1 Chapter Overview

In this chapter, I explored the technology adoption lifecycle through the viewpoints of the developer of the alternative fuel innovation, through the early adopters, and early majority of users. I used business strategy frameworks from Michael Porter of Harvard Business School and Arnaldo Hax of MIT to illustrate the factors that are critical to an alternative aviation fuel business strategy and the role the U.S. military and the FAA play in terms of influencing the market. I explore in more depth the two breaks in the technology innovation adoption life cycle, the “Valley of Death” and the “Chasm” that define the barriers and risks that alternative aviation fuel innovators must bridge to secure early adopters and an early majority of airlines to use the alternative fuels. Finally I illustrate how government policies and environmental activists influence may influence the strategy of an alternative fuel developer

3.2 The Technology Adoption Lifecycle

Developing energy strategy is an extremely challenging undertaking. The dominant standards for the energy we use today, petroleum for transportation and coal for electricity production evolved over the past 100 years based on cost, resource availability, product commoditization and the collaborations of partners across value chains. Consumers are so accustomed to turning on a switch and the lights coming on or easily finding gasoline all over the U.S. that alternative energy may have little if any impact on their daily lives. Energy, unlike consumer goods is an entity that is difficult to materialize. It has limited impact on consumer behavior and limited consumer brand loyalty. In fact, energy products in general, other than

gasoline, have no brands, are fully commoditized, fungible in the distribution system, and in many cases it is impossible to identify who produced them. In limited cases, a consumer may be able to materialize an aspect of energy, such as pride in owning solar cells or driving a fuel efficient hybrid car. But in most cases consumers react negatively to energy, their responses relegated to water cooler discussions of how high the price of gasoline has risen or how astronomical their electricity bill was the previous month.

Geoffrey Moore (1999) in his book *Crossing the Chasm* describes the technology adoption life cycle for consumer goods. (see Figure 3.1.)³⁶ Energy consumers, accustomed to purchasing a commoditized product, may be considered laggards when it comes to any new or alternative energy product and they may be inclined to wait until the product is proven or available everywhere. In addition, the prime driver in a purchasing situation where consumers have choices will be lowest cost product.

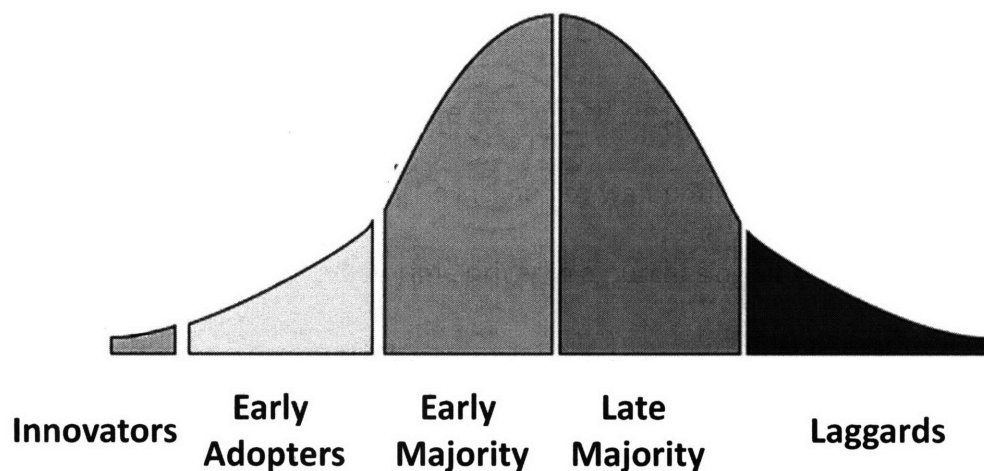


Figure 3.1. Technology Adoption Lifecycle

³⁶ Moore, Geoffrey. *Crossing the Chasm*, Collins Business Essentials, 3003.

There are few alternative fuel technologies that have been commercialized and the cost implications studied. Ethanol for automotive use (a product that will be explored in many segments of this thesis) provides a good case study to look at the technology through both the technology innovator's lens and the end consumer's lens and can provide insight for other energy products. Consumers' attitudes toward adoption of energy technology may be strongly influenced by political policies, mandates, and regulations geared to the public good rather than to the materialization and desire for the product itself. Moreover, issues related to the local impact of energy projects may be polarized against the global impacts of energy. This is especially true in terms of environmental issues such as greenhouse gases and global warming. Therefore, in addition to public policy, corporate social responsibility is critical to any sound energy strategy. Energy corporate CEO's must address the issue of sustainability in terms of many dimensions, including local, global, environmental issues and, most importantly, financial sustainability. Energy strategy that does not adequately address financial sustainability will quickly go into the red trying to be green. To narrow the focus of energy sectors and types, the focus of this thesis will be transportation fuels with an emphasis on fuels for aviation. As discussed in Chapter 2, the military is a major user of jet fuels and can therefore play a role in assisting innovators entering the market. Although many of the concepts discussed in this thesis should have broad energy sector applications, it will concentrate on fuels for aviation.

Novel changes to energy production and use will likely come from new entrants in the market rather than the established energy companies. The business literature has documented waves of disruptive innovation in consumer electronics and shown how dominant players were focused on incremental technology evolution while new entrants, unconstrained

by entrenched corporate norms such as current customers, market share or profit margin, came forth with a new technology that displaced the current one.³⁷ For example, manufactures of mainframe computers were ill equipped to counter desk top computers. Or manufactures of large disk drives were replaced by new companies that made smaller, less expensive models.³⁸ New energy technology innovators may face more challenges than those that encountered in consumer electronics or software market. These markets have users that are brand loyal or have a strong producer /customer relationship and are willing to make new alliances as technology advances. The non-linear advantages of new consumer electronic technologies make it easier for customers along the value chain to embrace change and buy a new product and benefit from its use. They can materialize the product, take advantage of its new capabilities, and in the case of business customers rapidly use the technology to increase corporate profitability.

3.3 Market Disruptions

The energy industry will be more difficult to penetrate with disruptive technologies, unless these technologies offer clear cost or other significant advantages to the users. New entrants face many barriers when entering a global commoditized market with established producers such as petroleum refiners who have amortized the cost of equipment and facilities over many decades. Most have made incremental improvements to keep pace with demand and government regulation and to adapt to the changes in the crude oil market. Petroleum refiners, distributors, and marketers have done their job so well; that the general public takes

³⁷ James Utterback, Mastering the Dynamics of Innovation, Harvard Business School Press, 1996.

³⁸ James Utterback, Mastering the Dynamics of Innovation, Harvard Business School Press, 1996.

them for granted and will take an aggressive action only when there is a disruption. For example, the series of oil shocks in the 1970's left consumers waiting in gas lines and in some cases without gasoline when they needed it. The shock of disruption drove customer behavior to buy more fuel efficient cars, and because of the high prices, to focus more closely on energy efficiency purchases as a whole. Disruption in supply drives the desire for alternative fuels. The perceived possibility of disruption today is driven by the instability of many of the nations that provide oil, the fear that oil has peaked and is in decline, increased world demand by expanding economies in India and China, and the physical disruptions that can occur when hurricanes such as Rita and Katrina hit. Another emerging driver for alternative fuels is climate change and the aggressive stance of environmental groups. As environmental activists brand fossil fuels as one of the deadly sins of mankind, these activists seek to change consumer behavior and demand non-fossil based forms of energy. Disruption of supply or the perceptions of disruption, as well as climate change, are the drivers for new innovation in energy, not the consumer materialization of energy itself.

3.4 Business Strategy Frameworks

One way to analyze the energy business is through a series of business strategy frameworks. Michael Porter of the Harvard Business School developed models and frameworks to look at the dimensions a new entrant should consider when deciding to enter a market.³⁹ Applying his framework in the energy arena requires the addition of three externalities: 1) the global thirst for energy that creates an inelastic global market; 2) the impact of environmental activists concerned with climate change, and 2) government mandates, legislation and

³⁹ Michael Porter, The Competitive Advantage of Nations, New York Free Press, 1990.

regulations that skew the energy market away from true free market dynamics. Another externality that must be considered is the boom and bust cycles of the energy industry over the last 100 years. The fear of a market collapse of the price of oil will always be an externality that could force the end of an alternative energy project. The ramifications of Black Sunday when ExxonMobil cancelled the Colony oil shale project in the 1980's due to the collapse of world oil prices will always remain a vivid reminder of this externality.⁴⁰ Porter (1990) recommends that a firm evaluate many factors when considering entering a market as illustrated in Figure 3.2. These include the availability of human, physical, knowledge and capital resources as well as the positioning of the firm in the vertical and horizontal value chains. Rivalry between new entrants and existing competitors will drive innovation to reduce costs and improve quality and service. The advantage of entering the energy business is the almost limitless markets and thus the opportunity externality shown in Figure 3.3. Michael Porter might characterize this externality as the role of chance.⁴¹

Hax and Majluf (1996) describe modifications of Michael Porter's Five Forces Model as a tool to assess the competitive position of a business entering a new market. Hax recommends that a firm look at the barriers to entry, government actions, the rivalry among competitors, barriers to exit, the power of suppliers, the power of buyers and the availability of substitutes.

⁴² Figure 3.4 illustrates the relationships between factor conditions; demand conditions, the firm's strategy, structure and competitors, as well as related and supporting industries define the overall strategy of the firm. In addition, environmental groups' influences, governmental

⁴⁰ James Bartis et al., Oil Shale Development in the United States: Prospects and Policy Issues, Rand, 2005.

⁴¹ Michael Porter, The Competitive Advantage of Nations, New York Free Press, 1990.

⁴² Arnaldo Hax and Nicholas Mujlaf, The Strategy Concept and Process: A Pragmatic Approach, Prentice Hall, 1996.

policies and regulations also define the overall strategy of the firm. However, in the energy sector, these factors and influences open opportunities for new innovative technologies.

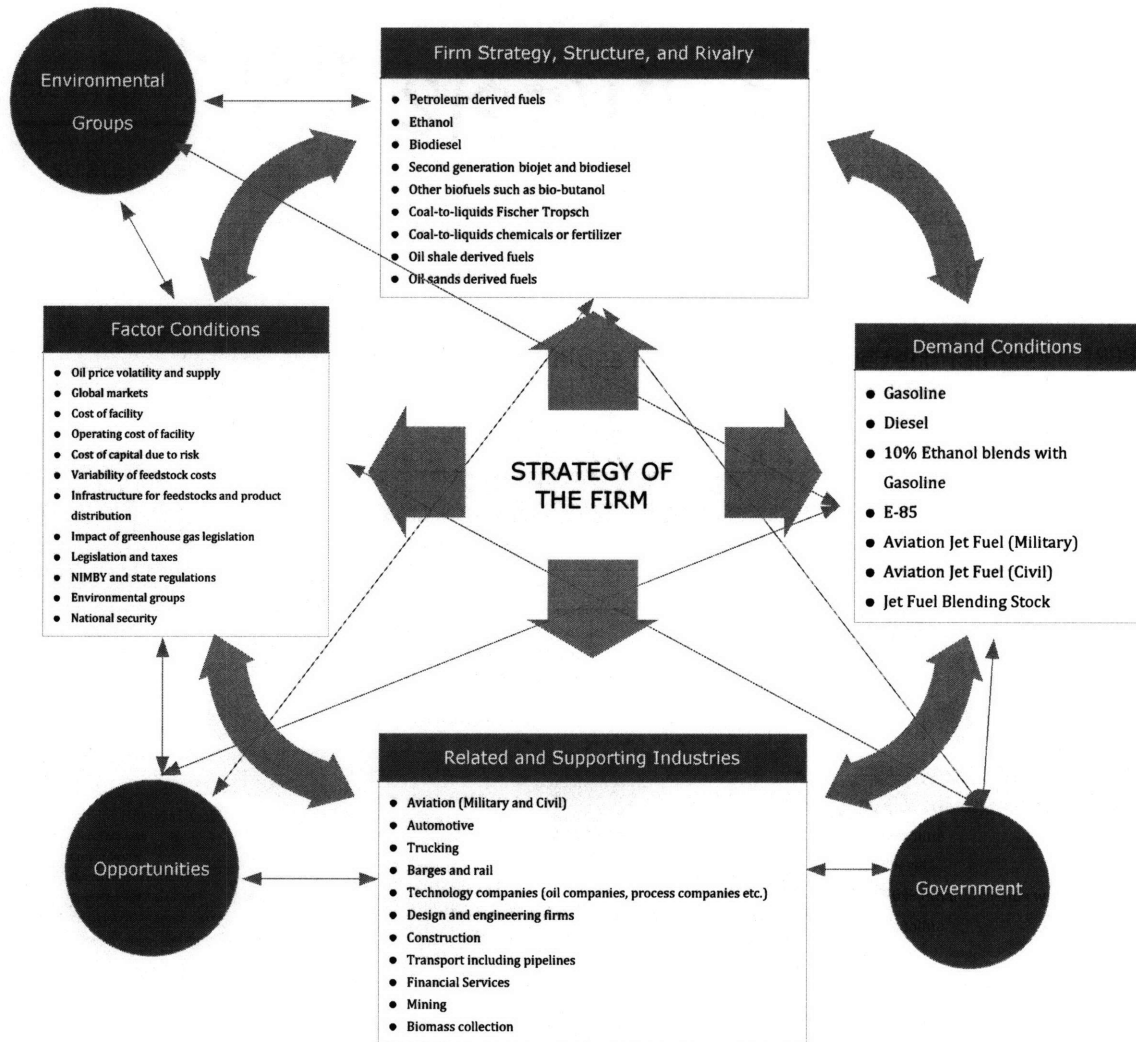


Figure 3.2. Market considerations of an alternative transportation fuel production firm

The role of the government has a strong influence over the new entrants. For example government mandates, tax incentives, and other subsidies were needed to start a corn ethanol industry in the U.S., and combined with R&D investment, were critical for cellulosic ethanol. The ethanol industry is protected by tariffs against the import of product from countries such as

Brazil. In addition, government environmental laws and regulations are obligatory compliance requirements for a firm. When producing product for the military, federal procurement regulations, certification and qualification requirements and executive orders can also influence the marketability of new products.

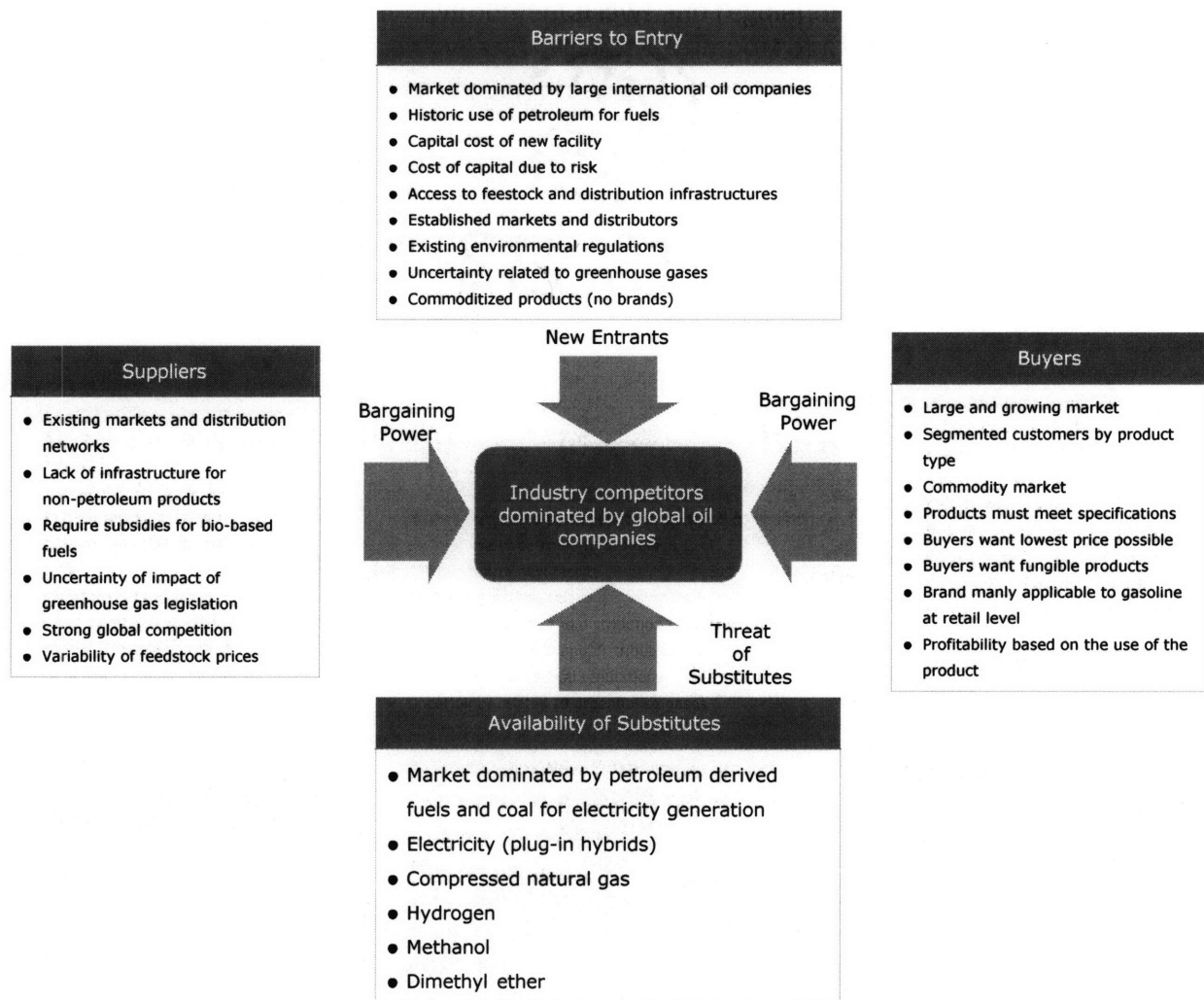


Figure 3.3. Porter's Five Forces Framework (modified) for alternative fuel production firms

Hax points out two other key considerations, the challenge of intermittent overcapacity (such as currently being experienced by the corn ethanol industry) and exit barriers such as the cost of site reclamation.

3.5 The “Valley of Death” and the “Chasm”

Alternative energy developers are the innovators in the technology adoption lifecycle shown in Figure 3.1. The challenge for these innovators is to cross the “Valley of Death” described in Chapter 2. Moore (2006) describes the first group of customers to purchase a new product as the early adopters. In alternative energy, the early adopters can also be agents that help cross the “Valley of Death” by setting up a beach head for the new product. Moore points out that these early adopters play a significant role in establishing a market for the innovator, but the innovator faces a second challenge to move to the early majority of users.⁴³ In alternative energy, unless the new product is a direct drop in to the equipment that will use it and the transportation infrastructure that will move it, it will take significant efforts to move from the early adopters to the early majority. A direct drop-in replacement is one that can be used interchangeably with the original. In the case of alternative aviation fuels, a direct drop-in is fully interchangeable and has the same or better overall performance characteristics. Even for products that are direct drop-ins, the equipment manufactures and transportation infrastructure must be convinced it will do no harm. Thus, there is a “Chasm” to cross when moving from early adopters to the early majority, as illustrated in Figure 3.4.

⁴³ Moore, Geoffrey. Crossing the Chasm, Collins Business Essentials, 2003.

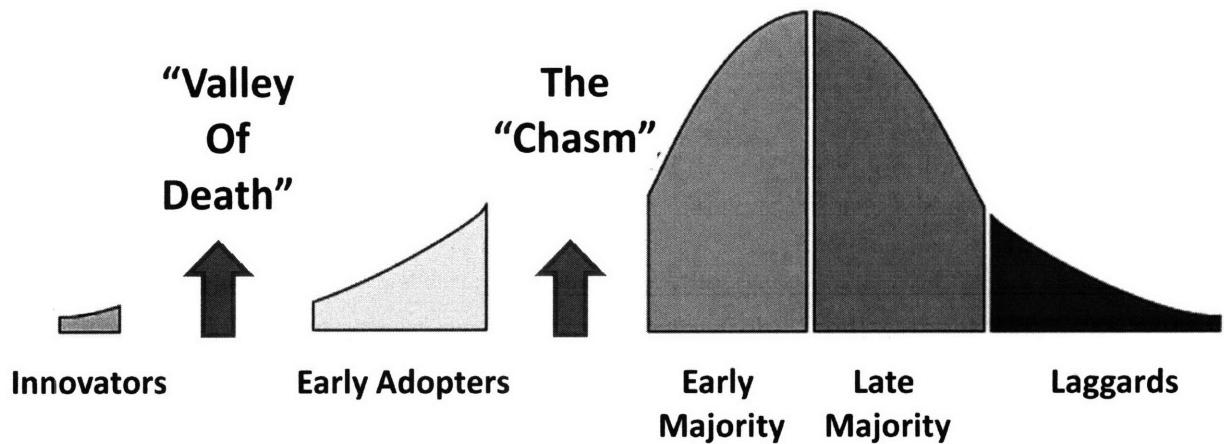


Figure 3.4. Alternative Energy Technology Adoption Life Cycle

Chapter 2 discussed some of the barriers and potential solutions for crossing the “Valley of Death,” and the leadership role of the Air Force in being an early adopter of Fischer-Tropsch fuels. However, since this work started in 2005, little movement has occurred in terms of moving the innovators across the “Valley.” Recent initiatives by The Boeing Company and Richard Branson to demonstrate biojet fuels demonstrate the willingness of the commercial aviation sector to establish a beach head market for fuels produced from oil seeds or algae and be early adopters of the technology.⁴⁴ Similarly, DARPA has established research programs on biojet to enable the military to evaluate the chemical and physical properties of the fuel and to conduct tests to determine its suitability for use. If the fuel proves to be technically viable, the military is likely to conduct demonstrations of the fuel and move towards being an early adopter of this technology as well.

⁴⁴ Murray, J. (2007). "Virgin Atlantic prepares biofuel test for early next year." Retrieved 22 January 2008, from <http://www.computing.co.uk/business-green/news/220262/virgin-prepares-biofuel-test>.

The challenge for the early adopters is that their efforts may end in the demonstration phase unless an early majority joins them. For example if the both the military and the civil sector can use fuels produced from coal, oil shale, and/or biomass, the market size would be increased 10-fold. To align the early majority, several barriers must be removed. Unlike the consumer electronics and other high tech industries, for the aviation transportation fuel industry crossing the chasm will require more than sound marketing strategies and careful customer segmentation to cross. Chasm barriers for transportation fuels include qualification and certification in all hardware, military approval for use, FAA approval for use, qualification and certification by the fuel infrastructure (e.g., tanks, hydrants, refueling trucks) owners and transportation fleets. The military and FAA control the dominant exchange of all new aviation fuels as they must assure technical compliance, performance, and flight safety.

3.6 Collaborators and Complimentors

As a technology developer develops strategy, collaborators and Complimentors should be considered. Hax and Wilde (2001) have developed the Delta Model, a series of frameworks and methodologies, to help managers develop and implement effective business strategies. Underpinning the model are the relationships between the firm and its customers. Hax states that classic strategy frameworks focus on the company's products where the competition in the marketplace determines the best product. Also, the nature of distribution channels present barriers that block the firm from reaching the end customer. The Delta Model helps a firm develop a bonding strategy with end customers and a set of strategic options.⁴⁵ One of the unique aspects of alternative fuels and alternative aviation fuels in particular is that the product

⁴⁵ Arnaldo Hax and Dean Wilde, The Delta Project, Palgrave, 2001.

is defined by specifications, must undergo extensive evaluation and testing, be qualified and certified for use in aircraft, and be constantly evaluated for quality and adherence to specifications. Aviation fuels in the military are also used in ground equipment and must be qualified and certified by the original equipment manufacturers (OEM's) for suitability. Once a fuel type is certified, any manufacturer can produce the product as long as it meets the specification. It should be noted that ethanol and biodiesel have been reluctantly accepted by the OEM's as the burden of qualification and certification was left to them. In addition, adherence to specifications has been a problem with biodiesel, resulting in problems in the field in some military non tactical systems. Failure to consistently meet standards and provide high quality product taints the whole fuel type, although the problem is an individual producer. From an industry standpoint, the military and civil aviation sectors become the apex of the Delta Model creating the system lock-in to a standard.⁴⁶ Figures 3.5 and 3.6 illustrate the element of the dominant exchange using the Delta Model. The current markets and buying practices drive the industry toward the commodization of the product and lowest possible costs.

⁴⁶ Arnaldo Hax and Dean Wilde, The Delta Project, Palgrave, 2001.

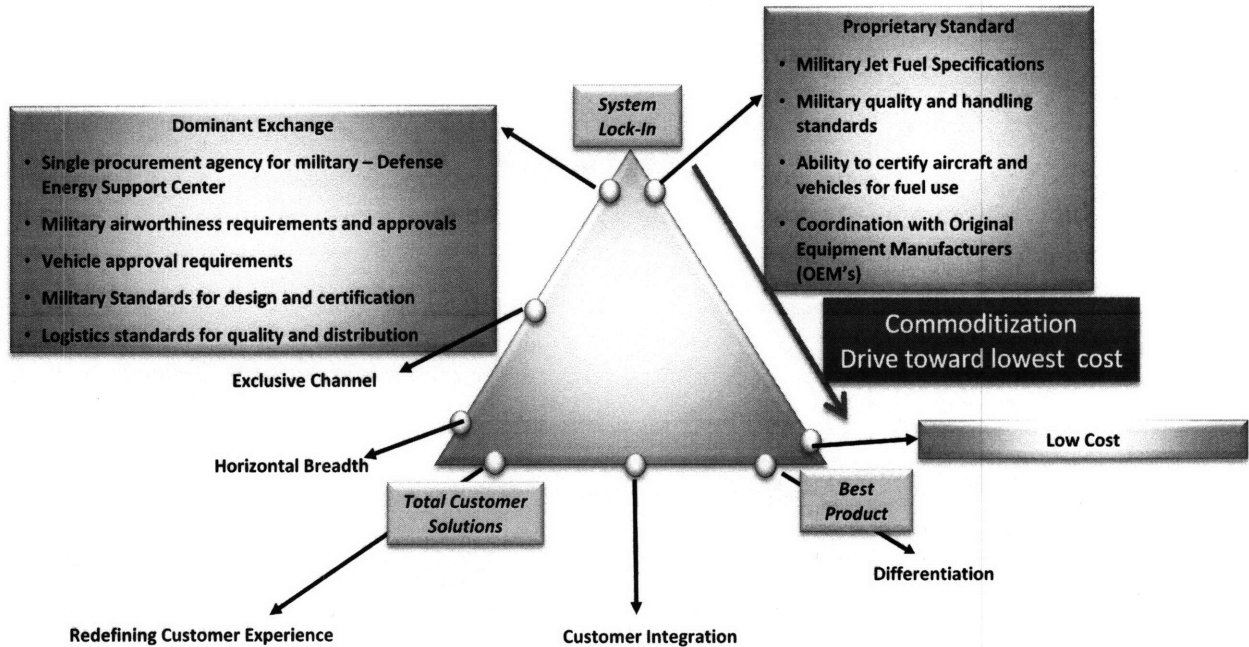


Figure 3.5. The military as a dominant exchange for the industry using the Delta Model

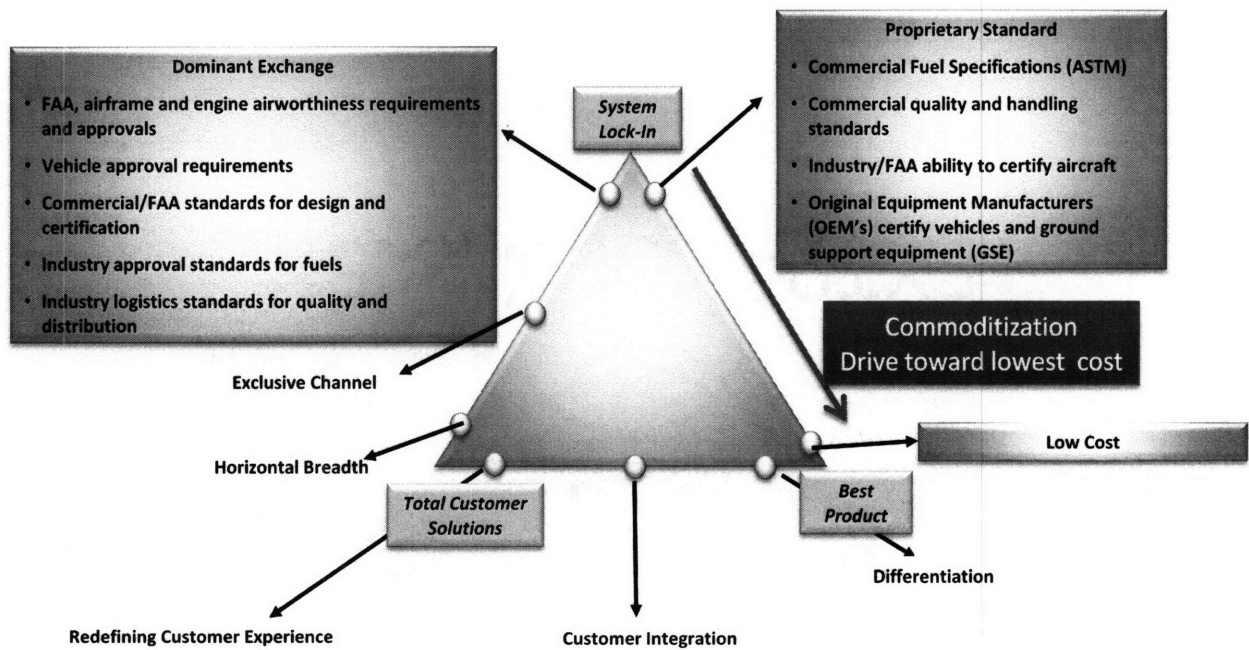


Figure 3.6 . The FAA as a dominant exchange for the industry using the Delta Model

The role of military and FAA as the dominant exchange provides stability for the aviation community in terms of the fuel's suitability for use and ensured safety of flight. Their role also acts as a barrier to disruptive innovation of an alternative fuel. For example, ethanol or biodiesel fuels do not meet current specifications and are therefore not fit for use as a drop-in replacement. Using these fuels would require modifications to aircraft and the entire aviation enterprise infrastructure, raising the cost hurdle, which could only be compensated by a significantly lower cost compared to petroleum. In addition, these fuels have severe disadvantages for use in aviation. For example the energy density of ethanol is approximately one-half the density of JP-8; thus, an aircraft would burn approximately twice the fuel to fly the same distance. In addition, the volatility of ethanol is such that aircraft fuel tanks would need to be redesigned. Biodiesel fuels lack sufficient high temperature stability and proper low temperature properties for use in aviation. Poor high temperature stability will significantly increase the operational costs and reduce the reliability of engines. Poor low temperature properties reduce the altitude at which an aircraft could fly without the fuel freezing causing the aircraft to operate at flight altitudes that will increase the amount of fuel used. The benefit of the dominant exchange is that it would enable the use of alternative fuels from coal, natural gas, oil shale or biomass that meet the current standards and specifications and can be used interchangeably with petroleum derived fuels.

The Delta Model strategy could be an effective tool for an innovator and alternative fuel producer to develop the marketing strategy for the product. Whereas petroleum derived fuels are a fully fungible commodity with no branding, an alternative fuel could provide a level of differentiation and attract customers. For example, biofuels have caught the interest of

Richard Branson at Virgin Atlantic as a way to reduce the impact the airline has on climate change.⁴⁷ Using a branded alternative fuel that reduces greenhouse gas emissions could be a marketing differentiator for both the fuel producer and Virgin Atlantic.

3.7 Global Climate Change Considerations

Many industrialized nations signed the Kyoto Agreement; thus, there currently exists segments of the airline industry that are concerned with their CO₂ footprint. If an airline were to become an early adopter of biojet, then it could become the rallying force for the industry to move toward the early majority and across the technology innovation life cycle. A producer of biojet could segment the industry and develop a brand for the product. Fossil derived alternatives could also be produced with lower carbon footprints. For example, coal derived FT fuels that were produced with carbon capture and sequestration could be cost competitive and have CO₂ footprints comparable to petroleum. If that same fuel were produced with the co-firing of biomass with coal, the CO₂ footprint would be lower than petroleum. If the fuel were produced from gasification of 100% biomass, the fuel would have a CO₂ footprint that is orders of magnitude lower than petroleum.^{48 49} Thus, the developers of different types of alternative fuels could develop customer segmentation based on greenhouse gas emissions and cost. The challenge to the alternative fuel project developer is the relationship of the company to the distribution value chain. If the differentiated customer is a single adopter, then distribution channels and infrastructure could prevent the early adopter from becoming a long term

⁴⁷ Murray, J. (2007). "Virgin Atlantic prepares biofuel test for early next year." Retrieved 22 January 2008, from <http://www.computing.co.uk/business-green/news/2201262/virgin-prepares-biofuel-test>.

⁴⁸ David Gray, Charles White, Glen Tomlinson, "Increasing Security and Reducing Carbon Emissions of the U.S. Transportation Sector: A Transformational Role for Coal with Biomass," DOE/NETL, 2007.

⁴⁹ Williams, R., Presentation: "Toward Ultra-Low GHG Emissions for Synfuels." US DOD/DOE Review Meeting, 2006.

customer. If the early adopter were to provide the leadership for a group of adopters to join forces, for example all the airlines at an airport, the distribution channels and infrastructure issues could be aligned as a whole and a whole airport could become the customer. If the product were fully fungible and interchangeable, then the alignment process would be minimal and the mode of airline operation would be as it is today. A similar case can be made for an entire military base becoming part of the early majority. This is possible when all the aircraft that operate out the location and all the ground support equipment is qualified and certified for the use of the fuel. Alternative energy innovators may be able to provide a group of clustered customers (such as an airport) with a total customer solution that balances cost, availability, and global environmental stewardship.

The business strategy models of Porter and Hax provide frameworks for the alternative fuel innovator to assess the market and develop sustained customer relationships. However, crossing the “Valley of Death” and bridging the chasm currently are significant barriers. Barron (1995) recommends that a firm develop an integrated strategy that includes market and nonmarket components.⁵⁰ Market strategies include the cost relationships of the price of the alternative to petroleum derived fuels, customer segmentation and relationships, and the relationship of the producer to the distribution channels. Non-market strategies evaluate the relationship of the project to the interactions of the public, the share-holders, the government the media, and non-governmental organizations (NGO’s). For alternative energy projects, non-market strategies are very important, especially in the area of global climate change, as no solid

⁵⁰ David Barron, “Integrated Strategy,” Market and Non-Market Components,” California Management Review, Vol 27. No. 2, 1995.

international framework of law for CO₂ exists. Even projects that are developed with strong corporate social responsibility to the environment face risk and potential opposition. In addition, solutions to global climate change may create problems within the current framework of environmental laws, primarily in the areas of local air quality and clean water. Any alternative that requires the modification of land (for example, mining or growing crops on land that is significantly altered in terms of its existing flora and fauna) could create opposition to a project. Even changes in current farming practices to grow crops on marginal land could change local ecosystems. Therefore, non-market strategies for fossil alternatives and renewable alternatives must include global air quality, local air quality, water quality, and land use and reclamation.

The problem for an airline or a government agency is how to access which alternative offers the best balance of market and non-market issues described in a format that enables direct comparison of choices. If customers cannot make an informed choice based on factual knowledge, there will be resistance to adopting the alternative or they will follow public pressure and pick the politically correct alternative which may actually be suboptimal for the overall balance needed for sustainability. Fortunately, the FAA has funded a team of researchers at the Massachusetts Institute of Technology (MIT) and the Rand Corporation to develop a ground to wake assessment of alternative fuels for aviation.⁵¹

⁵¹Private communication with Jim Hileman at MIT.

3.7 Chapter Summary

Alternative energy project developers face two major hurdles: the “Valley of Death” that must be crossed to get to early adopters and the “chasm” that must be bridged to gain the market of the early majority. Each chasm is characterized by barriers and challenges that need to be overcome to allow the company to achieve sustainable business. Market pressures related to the global petroleum market and non-market pressures such as the environment must be addressed as part of a firm’s overall strategy. The strategy frameworks of Porter and Hax provide insight into the issues that must be considered by the alternative energy industry as a whole and by each individual company. Since alternative energy strategy is complex, I have conducted a series of interviews with individuals from industry, trade organizations, financial institutions, academia and the government to explore in more detail the challenges and barriers faced by the industry and to synthesize the information into various scenarios and recommendations. In chapter 4, I will discuss the interview processes and the insights gained from the interviews, and also outline the major challenges and barriers facing the industry. In later chapters I will explore various scenarios for the government and industry to follow to assist the industry and provide recommendations and suggestions.

4.0 Research

4.1 Chapter Overview

In this chapter, I provide the results of the research I conducted to understand the issues facing technology innovators, early adopters and the early majority of users of alternative fuels for aviation. The research consisted of a literature review and a series of phone interviews using questionnaires that were sent to the interviewees prior to the interview. The results are aggregated into set of key phrases that characterize the issues for each segment of the technology adoption lifecycle and the results of the research are summarized for each segment.

4.2 Research Overview

To characterize the barriers preventing alternative energy innovators from attracting early adopters and to explore the issues associated with building a customer base from early adopters to an early majority, I conducted a review of the literature and a series of interviews. These interviews with key players included alternative energy developers, companies in the vertical supply chain, potential early adopters, financial investors, trade associations, government officials, and professors and researchers at MIT. This chapter will explore the barriers that face the industry along the innovation technology life cycle; first, based on observations from the literature and then using information obtained in the interviews. Interview questions can be found in Appendix A. A list of companies that were supportive to the interview process is provided in Appendix B. The questions were tailored to the interviewees and were sent to them in advance of the phone call or visit. Different sets of

questions were developed to probe each set of barriers and to solicit suggestions for potential solutions that the airline industry and the government could enact to help develop the industry. The interviewees were informed that I would not attribute specific comments to the person being interviewed but would collect a series of phrases that represent the industry's views. Chapter 5 of this thesis will analyze the results of the research and provide several potential scenarios to help explore solutions to crossing the "Valley of Death" and bridging the "Chasm."

4.3 Literature Review

A wide range of literature was explored to help gain an understanding of the barriers and challenges facing alternative energy innovators that would like to deploy technology. The literature also provided insight on some potential solutions. This review yielded the following observations:

1. The President's Council of Advisors on Science and Technology (2006) identified economic, political, and environmental challenges as key issues that will influence change in the nation's energy systems and infrastructure.⁵²
 - a. Barriers and Challenges:
 - i. Current regulations prohibit utilities from improving efficiency and environmental performance of legacy power plants
 - ii. Import tariffs on ethanol
 - iii. Current excise taxes promote biofuels such as ethanol but are not linked to the price of oil

⁵² John Marburger, "The Energy Imperative: Technology and the Role of Emerging Companies," President's Council of Advisors on Science and Technology, 2006.

- iv. Land use and land use policy related to energy crops
- v. National energy challenges are directly linked to the worldwide energy situation
- vi. Cost of alternative energy solutions compared to conventional energy sources
- vii. Competition of current sources of ethanol (corn) and biodiesel (soy beans) with food crops

b. Potential Solutions:

- i. Increase science and technology research and development to support future innovation and accelerate near-term commercialization of energy technologies
- ii. Use EPCRA 2005 incentives to assist commercialization including low-interest loans, tax incentives, capital contributions and price subsidies
- iii. Support state initiatives to improve competitiveness and encourage them to share best practices
- iv. Position of the federal government to be an adopter of new technology – expand the government’s role to be an early adopter to demonstrate the commercial feasibility of new energy technologies
- v. Expand the use of biofuel and vehicles suitable to use them in high concentrations

2. The Department of Energy National Technology Laboratory identified key challenges related to a coal-liquids-industry:⁵³

a. Barriers and Challenges:

- i. Economic risk – world oil volatility is an impediment to coal-to-liquids (CTL) facilities. Petroleum industry used for high profit oil and gas exploration and production
- ii. Technical uncertainty – technologies have been demonstrated at commercial scale , but the integration of these technologies poses significant risk
- iii. Investment in infrastructure – expanded use of coal will require investment into new mines, rail cars, and barges for transport, and pipelines to transport products
- iv. Availability of critical materials, resources, and skills – worldwide demand has created competitions for process equipment, labor, and materials
- v. Environmental concerns – capture and sequestration of CO₂ will be required and NIMBY issues must be addressed

b. Potential Solutions:

- i. Build and operate a few plants to facilitate early commercial learning related to process improvement and cost reduction. Demonstrate and learn from the capture and sequestration of CO₂

⁵³ Judith Pensabene, Colin Hayes, Joseph Strakey and Greg Kawalkin, Presentation: Coal-to-Liquids, DOE/NETL, May 2007.

- ii. Develop an R&D program to develop improved technologies based on the operation of the first plants
 - iii. Use financial incentives such as tax credits (EPACT 2005 Section 1307), loan guarantees, and guaranteed price floors
 - iv. Test FT fuels for use in early commercial markets such as DoD, Clean Cities program, and the Northeast Home Heating Oil Reserve
 - v. Establish collaborative exchange programs with foreign governments
3. The Sandia National Laboratory identified key challenges related to energy and national security due to oil dependency, climate change, and the vulnerability of existing infrastructures:⁵⁴
- a. Barriers and Challenges:
 - i. Sociological – energy and environmental threat complacency, selection of technology solutions that seem to be the right answer at the time, technologies needing to be presented in ways that address personal needs, technologies having to be adaptable and affordable for the society that will use the technology, energy projects needing to take into account diverse perspectives and culture
 - ii. Psychological – crisis reaction where people may over react to a dramatic event, resistance to change
 - iii. Political -- political systems that emphasize the short term, national sovereignty, oil produced in many countries with political instability,

⁵⁴ Thomas Karas, "Energy and National Security," Sandia National Laboratory, 2003.

economic recessions can trigger instability in exporting countries and increased demand increases their power, supplies can be interrupted by underinvestment in production capacity, political events, or logistical interruptions, armed conflict in energy-producing regions may cause disruptions

- iv. Economic – globalized economy creates interdependence between energy producers and consumers, efforts by China to secure energy supplies globally, disputes between industrialized countries and developing countries over climate change, trade imbalances

b. Potential solutions:

- i. Conservation -- direct federal agencies to conserve, increase funding for efficiency and renewable R&D, tax credits for hybrid and fuel cell vehicles, extend the Energy Star program, fund intelligent transportation systems, provide tax incentives, and stream-line permitting process for combined heat and power, improve CAFÉ standards
- ii. Modernize the energy infrastructure – improve pipeline safety and expedite permitting process, agencies expedite energy project permits, promote renewables, regulatory changes to improve electric reliability,
- iii. Increase energy supplies – increases supplies of oil, wind power, biomass, biomass co-firing, clean coal, hydropower and nuclear

- iv. **Protect the environment – base pollutant regulations on flexible market-based caps, export environmentally friendly technologies, use royalties to fund land conservation effort, reduce truck idling**
 - v. **Increase energy security – direct FEMA to prepare for potential energy-related emergencies, and support energy development with Mexico and Canada**
- 4. The Air Transport Association identified key challenges related to alternative fuels for aviation:⁵⁵**
- a. **Barriers and Challenges:**
 - i. **Compliance with regulations – requirement to get FAA certification for each particular aircraft and engine type**
 - ii. **Inadequate R&D funding for alternative fuels – public investment is required to develop cost effective alternative fuels that provide greenhouse gas emission reduction**
 - iii. **Lack of logistic infrastructure – alternative energy facilities are likely to be located away from existing distribution networks and thus require new infrastructure. Additional road and rail networks need to be upgraded to transport feedstocks and products. Pipeline construction is needed to transport new products. In addition, new storage capacity at airports may be required**
 - b. **Potential Solutions:**

⁵⁵ Air Transport Association, (2008). "Alternative Fuels Q&A." Retrieved 18 January 2008, from <http://www.airlines.org/economics/energy/altfuelsquanda.htm>.

- i. ATA supports efforts the Commercial Alternative Aviation Fuel Initiative (CAAFI) to bring together NASA, the FAA, the U. S Air Force, airframe and engine manufacturers, alternative energy providers and academia to advance the use of alternative fuels
- ii. ATA supports the efforts of the International Civil Aviation Organization (ICAO), the United Nations body for international aviation, to address the standards and recommended practices of aviation on global climate change
- iii. ATA has adopted goals to improve fuel efficiency by 30% between 2005 and 2025

5. The Rand Corporation identified key challenges related to alternative fuels for the military:⁵⁶

a. Barriers and Challenges:

- i. Uncertainty about the costs and performance of coal-to-liquid plants – limited knowledge on construction costs and environmental performance
- ii. Uncertainty about the future course of world oil prices
- iii. Uncertainty about how greenhouse gas emissions will be controlled in the U.S.

b. Potential recommendations:

⁵⁶ James Bartis, "Policy Issues for Alternative Fuels for Military Operations," Congressional Testimony to the House Armed Services Committee, Subcommittee on Readiness and the Subcommittee on Terrorism, Unconventional Threats and Capabilities, 2006.

- i. Congress should foster the construction of a limited number of commercial-scale plants to gain operating experience and reduce uncertainty
 - ii. The federal government should enter into purchase agreements for products that guarantee a minimum price to reduce the risk of project developers if the price of oil drops
 - iii. Increase R&D funding for CTL production
- 6. The Department of Energy sponsored a study with Scully Capital (2006) to investigate a business case for coal gasification with co-production. This report found the following.⁵⁷
 - a. Barriers and Challenges:
 - i. Information on coal-liquid-plants (CTL) is limited -- vendors and companies are reluctant to share information to the public domain as the cost and performance information is considered proprietary
 - ii. Commercial CTL plants require significant investment – cost of a 30,000 bbl/day plant can cost \$3.3 billion to \$3.7 billion with carbon capture and compression
 - iii. Lower grade coals such as lignite reduce the operating costs of the plant but increase the capital cost of a plant due to the need for additional coal handling and gasification equipment

⁵⁷ Scully Capital, “The Business Case for Coal Gasification with Co-Production”, 2006.

- iv. Carbon capture and compression increase the price of Fischer Tropsch fuels -- cost will be approximately \$3.50 - \$4.00 per barrel for capture and compression
- v. Plant location impact the value of co-products and the overall economics of the plant – plants must be located near feedstocks, distribution networks and locations for CO₂ sequestration
- vi. Limited construction contractor infrastructure and lack of standards for plant performance limits financeability -- the lack of standards, contractor track records for plant construction, and performance guarantee's create financing risk
- vii. Project scale is important – product prices can decrease with scale up to an asymptotic point. Plants that are too small cannot produce product at market prices
- viii. The historic volatility of the oil market creates risks about the long-term profitability of a new plant

b. Potential Solutions:

- i. Loan Guarantee's – reduce the risk of the success of the plant by providing federal backing of loans for the plant

7. In a Senate Energy and Natural Resources Committee hearing, David Hawkins of the NRDC outlined environmental concerns for coal-to-liquids:⁵⁸

a. Barriers and Challenges:

⁵⁸ David Hawkins, "Testimony of David G. Hawkins, Director, Climate Center, Natural Resources Defense Council," Senate Energy and Natural Resources Committee Hearing, 2006.

- i. Environmental concerns of the use of coal related to land, water, air, human health, and the environment
 - ii. Large amount of CO₂ emissions from a CTL plant using historic technology (27.5 lbs of CO₂ per gallon of petroleum fuel versus 49.5 pounds CO₂ per gallon from coal)
 - iii. Environmental impacts of mining coal from legacy mining including water pollution including with acid mine drainage
 - iv. Release of methane from coal seams
 - v. Historic impacts of mining on communities
 - vi. Impact of coal transportation
- b. Potential Solutions:
- i. Increased efficiency, renewable fuels, plug-in hybrid vehicles
 - ii. Establish tax credits for manufactures to retool existing factories to build fuel efficient vehicles
 - iii. Establish tax credits for consumers to buy fuel efficient vehicles
 - iv. Raise federal fuel economy standards
 - v. Improve oil saving in existing motor vehicles with requirements for tires and oils to be at least as efficient as original equipment
 - vi. Improve efficiency of heavy duty trucks
 - vii. Expand industrial efficiency programs that use oil
 - viii. Replace chemical feedstocks with biobased products
 - ix. Upgrade air traffic management

- x. Promote residential energy savings
 - xi. Expand the production of flex-fuel vehicles
8. The Western Governors' Association (2008) explored the potential of coal-to-liquids and other fuels from unconventional resources.⁵⁹ They stated the following:
- a. Barriers and Challenges:
 - i. Economic and financial challenges – economic challenges are due to the lack of experience in industry with commercial CTL plants. Large projects can strain the commodity and labor markets and significant uncertainty of material costs exist due to the large demands for construction materials from Asia. “This is an example of one of the primary financial challenges to entry into the CTL sector, which is primarily associated with high and volatile development and capital costs, as well as tangible and intangible risks perceived by potential lenders.”⁶⁰
 - ii. Lenders concerns about technology demonstrated in the US
 - iii. Engineering contractors reluctant to give performance guarantees on new technologies
 - iv. Forward market pricing of fuels
 - v. Uncertainty surrounding green house gas regulations
 - vi. Plant siting may be an issue -- CTL plants are neither a traditional chemical plant or a traditional power plant

⁵⁹ Western Governors Association, “Transportation Fuels for the Future,” 2008.

⁶⁰ Western Governors Association, “Transportation Fuels for the Future,” 2008.

- vii. Infrastructure availability for feedstocks, products, water and electricity -
- this is a limitation for plant locations
- viii. In the West, coal resources may be located at great distances from
biomass resources for use in co-firing
- ix. Socioeconomic impacts of expanded mining and new production plants –
compliance with Surface Mining Control and Reclamation Act (SMCRA),
impact of wealth distribution in the community, fugitive dust, water use,
and availability
- x. Current availability of trained construction crews, engineering and
contractors – high demand in India and China is challenging worldwide
resources. Some countries are paying premiums to the industry and
absolving them from performance liabilities
- xi. Limited federal investment in basic research

b. Potential Solutions:

- i. Federal incentives – self-pay loan guarantees, long-term off-take
agreements for products, floor pricing and caps, accelerated investment
tax credits, tax credits for the products, accelerated depreciation. Off
budget performance based incentives related to climate change such as
cap and trade, carbon taxes, CO₂ sequestration tax credits, fee-bate
systems, or mandatory standards
- ii. State incentives: bond financing, financial assistance, tax credits, timely
cost recovery

9. Furman (2008) in his paper on climate change and energy security has identified the following barriers and potential solutions:⁶¹

a. Barriers and Challenges:

- i. Economic barrier – there is a gap between the cost of energy to the producer, consumer and society as a whole primarily in the arena of greenhouse gases and global climate change.
- ii. Underinvestment by the private sector in long-term and speculative research -- in the energy sector innovation that generates social benefits may not be captured by a single company
- iii. Consumers do not have all the knowledge to make informed choices

b. Potential solutions:

- i. Price carbon and oil correctly to incentivize the private sector to reduce its use -- establish a cap and trade system or a carbon tax
- ii. Increase federal research on long-run and speculative energy technologies
- iii. Use pricing mechanisms for carbon mitigation rather than regulations and mandates

10. The Task Force on Strategic Unconventional Fuels (2007) identified the following barriers and challenges as well as potential solutions.⁶²

a. Barriers and Challenges:

⁶¹ Jason Furman, Jason Bordoff, Manasi Deshpande, and Pascal Noel, "Overcoming the Economic Barriers to Climate Change and Energy Security," 2008.

⁶² Task Force on Strategic Unconventional Fuels, "America's Strategic Unconventional Fuels," Vol I, 2007.

- i. Land use and ecological impacts – large portions of the resource are on federal and state lands
 - ii. Development economics – federal and state governments should create fiscal regimes to attract private development capital
 - iii. Environmental protection -- design and demonstrate commercial scale plant to demonstrate best available environmental control technologies. Include air quality and water quality as key parts of the design.
 - iv. Socio-economic impact – develop policies and procedures to help communities with industry development. Some communities have a history of boom and bust related to energy development in the region
 - v. Regulatory/permitting – develop streamlined but inclusive regulatory and review processes for alternative energy development
 - vi. Public infrastructure – develop public infrastructure at a pace commiserate with energy development
 - vii. Water resource management – assure adequate water supplies and protect surface and ground waters
 - viii. Identify target markets – target public fleets, commercial aviation, trucking, passenger vehicles and the military
- b. Potential solutions:
- i. Economic incentives – accelerated depreciation, investment tax credits, production tax credits, and price floors

- ii. Provide improved access to federal lands to develop unconventional resources in the western United States
- iii. Develop long-term contracting arrangement for products – DoD can be a market initiator for limited volumes
- iv. Build proper infrastructure at a pace in harmony with project development. Develop plans for affected communities and assist in finding resources necessary to improve infrastructure and services
- v. Develop sound strategy for water management. Understand water requirements for communities and projects. Identify ways to conserve water and manage the resource
- vi. Develop sound environmental strategy. Foster strategies that capture and sequester carbon as well as meet Clean Air Act and Clean Water Act regulations
- vii. Empower private financial investment to allow the development of commercially viable companies

11. The Department of Agriculture and the Department of Energy (2005) issued a report on the U.S. potential to use biomass as a feedstock for a bioenergy and bioproducts industry. The identified the following barriers and challenges and potential solutions:⁶³

a. Barriers and Challenges:

- i. Impact of large-scale forest and crop residue collection as well as perennial crops on traditional markets for agriculture and forest products

⁶³ U.S. Department of Energy and the U. S. Department of Agriculture, "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply," 2005.

- ii. **Accessibility of terrain to have some forest products. In addition, the removal of large trees can create unfavorable public opinion**
- iii. **Transportation cost of biomass may limit viability. The availability of markets and transport distances may limit production**
- iv. **Availability of skilled labor to harvest forest residues**
- v. **Impact of soil erosion and movement of sediments into surface waters**
- vi. **Need for more efficient and specialized equipment to harvest biomass**
- vii. **Seasonality of some biomass may affect the viability of the resource**
- viii. **Expanded use of agricultural biomass will require improvements in crop yield, tillage practices, harvest and collection technologies and transportation. In addition, crop disease issues should be considered.**
- ix. **Long-term economic and environmental concerns associated with the removal of plant residues from the fields. Removing residue may reduce soil quality and promote erosion which can reduce long-term crop productivity and profitability**
- x. **Increased requirements for fertilizer and the control of run-off**
- xi. **Variability of yields due to weather conditions**

b. Potential solutions:

- i. **Additional R&D to reduce costs**
- ii. **Demonstration projects to assess and mature technology**
- iii. **Financial incentives such as tax credits, price supports, and subsidies**

12. The Organization for Economic Co-Operation and Development (OECD) (2003) held a workshop on biomass and agriculture. Their report highlighted the following:⁶⁴

a. Barriers and challenges:

- i. Economics of biomass – currently in most situations, biomass is only competitive with government support including subsidies, tax exemptions, and other forms of support. Fossil fuel prices may not be high enough to drive the widespread use of biomass for energy. In comparing biomass to fossil fuels, the analysis should include externalities and subsidies for these resources. Efficiency and economies of scale may close the gap between biofuel costs and fossil prices. The markets for biofuels can be altered with markets for greenhouse gas emissions.
- ii. Environment soundness – cost and benefits of biomass compared to fossil fuels depend on environmental benefits and costs. Currently there are no suitable markets to determine the price of environmental benefits. Frameworks and assessment tools such as life-cycle analysis are needed. For example, a critical issue in sustainability is how the biomass relates to the interactions of other land uses. In addition, sustainability will also require the assessment of soil quality, nutrient content, and need to incorporate plant residues back into the soil

⁶⁴ Organization for Economic Co-Operation and Development, “Biomass and Agriculture,” Workshop Report, 2003.

- iii. **Social benefit -- the social benefits must include the effect on farm incomes, rural employment, and the economy as a whole. Increased education may be important, as there is a general lack of knowledge of the industry**
- iv. **Biomass is an infant industry – R&D is needed on energy crops and biomass conversion processes as many are in the experimental phase**
- v. **Greenhouse gases – carbon certification mechanisms are required to establish the net impact and benefits of biomass compared to fossil sources**

b. Potential solutions:

- i. **Financial incentives – use indirect production support to stimulate bio-energy markets. Use financial incentives to encourage innovation and reduce costs. Use market based approaches to stimulate the bio-industries. Carbon markets may be an effective tool**
- ii. **Establish goals and targets for bio-energy – goals and targets can be related to energy security, environmental effectiveness, rural development, economic efficiency and market innovation**

13. Cramer (2008) led a study for the Dutch government to develop a framework for sustainable biomass. In her report, she identified the following themes related to sustainability:⁶⁵

a. Sustainability themes:

⁶⁵ Jacqueline Cramer, "Testing Framework for Sustainable Biomass," Report to the Government of the Netherlands, 2007

- i. Greenhouse gas emissions – biomass must produce less greenhouse gas emissions on average compared to fossil and must be calculated over the whole value chain
- ii. Competition with food or other local uses – biomass must not damage food supplies or preclude other important uses for the land
- iii. Biodiversity – biomass must not affect protected biodiversity
- iv. Environment – when producing biomass, the quality of soil, surface and ground water, and air must to retained or improved
- v. Prosperity – biomass production must contribute to local prosperity
- vi. Social well-being – biomass production must contribute to the social well-being of the employees and local population

4.4 Summary of Literature Review

The literature review in this chapter highlights some of the key barriers and challenges to alternative energy projects. A wide range of perspectives was chosen to assure depth of perspectives and alternative views. The literature included selected papers and reports from The Presidential Council of Advisors, the Department of Energy, Sandia National Laboratory, the Air Transport Association, the Rand Corporation, Skully Financial Services, the National Resources Defense Council, the Western Governor Association, Academia, the Task Force on Unconventional Fuels, the Department of Agriculture, the Organization of Economic Development and the Dutch government. The key elements of this review are listed in Figure 4.1.

The barriers and challenges can be broken out into the following categories, financial, environmental, market, regulatory, and sociological. In most areas the issues are characterized by uncertainty, which creates risks for the development of a project. Some of the most pressing barriers include the lack of legislation for greenhouse gas emissions, technical uncertainty at the commercial scale for innovations, the historic volatility of oil, the historical boom and bust cycles associated with energy, and the uncertainty of project costs due to the rapid growth in India and China which is consuming construction materials and engineering.

Financial	Environmental	Market	Regulatory	Sociological
Economic Risk due to the Volatility of the Price of Oil	Lack of Legal Framework for Greenhouse Gases	Global Energy Markets - Commoditization	Outdated Regulations Related to Efficiency	Public Complacency and Resistance to Change
Technical Uncertainty of New Technologies and Lack of Commercial Experience	Clean Air Act	Infrastructure Constraints	Complexity of Permitting and Project Site Approval	Reaction to Crisis and Disruption
Short Term Financial Return Horizon	Clean Water Act	Availability of Critical Resources	Federal Mandates	Short Time Horizons for Political Decision Making
Under investment in Vertical Supply Chain	Water Requirements	Instability of Some Oil Producing Nations	Import Tariffs	Availability of Skilled Workers
Technology Performance Concerns	Land Use	Rapid Growth in Developing Nations	Qualification and Certification of Aviation Fuels	Pace of Industry Development
Escalating Cost of Construction	Carbon Capture and Sequestration	Logistic Infrastructure for Feed stocks and Products	Lack of Siting Criteria for Alternative Energy Plants	History of Boom and Bust Cycles in Energy
Uncertainty Regarding Greenhouse Gas Legislation	Need for Balanced Project Comparative Analysis Tools	Interrelationships between Diverse Markets	Lack of a Legal Framework for Greenhouse Gases	Job and Wealth Creation and Impact to Rural Communities
Pressure of Environmental Groups	Legacy Issues from Coal Mining	Competition of Energy and Food	Lack of a Carbon Tax of Cap and Trade System	NIMBY
High Cost of Large Facilities and Volatility of development and capital costs	Compliance with Surface Mining Reclamation Act	Alignment of Feedstock Prices to Price of Oil	Access to Federal Lands in the Western US	Slow Turnover Rate of Energy Consuming Products and Equipment
Availability of Federal and State Incentives	Soil Erosion, soil quality and sustainment	Inelasticity of Energy Demand	Lack of Standardized Life Cycle Analysis Tools	Historic Impact of Industry on Local Communities and Public Infrastructure
Historic Use of Subsidies For Biomass		Concerns with Foreign Developed Technologies	Under investment in R&D	Paralysis due to public debate

Figure 4.1. Technology Innovation Issues for Alternative Energy Identified in the Literature

One of the growing concerns identified in the literature is the lack of standardized frameworks and tools to assess life cycle analysis and sustainability. Life cycle analysis, from ground to exhaust, is a critical element to determine the benefit of any fuel derived from an alternative or unconventional source. The lack of standardized frameworks is best illustrated in the ethanol literature as there is a strong debate as to whether corn based ethanol is energy negative or energy positive when all factors are considered. From a greenhouse gas standpoint, the careful identification of all sources becomes critical. For example, corn based ethanol requires more fossil energy than can be recovered by burning the product, so the fuel actually contributed to global warming. Other studies show that it has a net positive energy balance and is reducing CO₂ emissions by 1.5 – 2% as a 10% blend or as much as 15% - 20% if it were used as a pure ethanol fuel.⁶⁶ Clearly the assumptions used in the analysis play a large role in the results. This issue could be resolved with by using standardized frameworks for analysis. The European Community (EC) has taken action regarding the lack of frameworks. Concerned about the increased generation of greenhouse gases caused by using palm oil produced in countries where rain forest is being destroyed to plant palm trees, the EC is developing a series of frameworks to look at a broader range of attributes that define the true sustainability of the resource. These attributes include greenhouse gas emissions, competition with food and other uses for the land, biodiversity, local environmental concerns, and the impact of prosperity and social well-being.⁶⁷

⁶⁶ David Rotman, "The Price of Biofuels," Technology Review, 2008.

⁶⁷ Jacqueline Cramer, "Testing Framework for Sustainable Biomass," Report to the Government of the Netherlands, 2007

The issues raised by Cramer (2007)⁶⁸ to define sustainability for alternative energy from biomass provide a good framework to look at the sustainability of other resources such as fossil. Fossil resources that are developed with careful attention to sustainability attributes, such as the use of innovative technologies to capture and sequester carbon, could be considered sustainable for the next 50 – 100 years if balanced appropriately with bio-based technologies to recycle and sequester carbon. Since it is unlikely that the world will be able to wean itself off of fossil fuels in the next 20 – 50 years, the deployment of bridging technologies could reduce the impact of global warming and sustain continuous global economic growth. Evaluation frameworks will be explored in more detail in Chapter 7.

In my review of the literature, I found that it lacked substantive references to the technology innovation development cycle for alternative energy. In addition, I found that the literature lacked any review of the barriers and challenges faced by innovators seeking early adopters and growth of an industry into substantial groups of the early majority of users. What I found, was that the primary markets for alternative sources were driven by regulations, mandates, and incentives. For example, the growth in ethanol in the U.S. was driven by the requirements for oxygenates in gasoline. When methyl-tertiary-butyl-ether (MTBE) was found to be polluting ground water, ethanol was advocated as a replacement. As concerns related to the need for more secure domestic sources of energy evolved, so did the federal mandate for the use of ethanol. Federal policy has focused on goals and mandates for the production of ethanol to displace oil for the next decade and longer. Similarly, the strong ethanol industry in

⁶⁸ Jacqueline Cramer, "Testing Framework for Sustainable Biomass," Report to the Government of the Netherlands, 2007

Brazil was developed by strong governmental investment and mandates for use. Renewable energy such as wind and solar also benefits from government mandates and incentives that create markets and allow these resources to compete against fossil and nuclear power generation. Currently these mechanisms are not in place to stimulate activities to produce alternative aviation fuels. In some ways they actually inhibit its development. For example, a biojet fuel produced from a seed crop such as soy would compete against corn for farm acreage and supply. Other food based seed crops compete against world food needs. Fuel produced for aviation from seed crops competes against the biodiesel market and the use of these fuels in the trucking industry. Unintended consequences of one biofuel may create barriers for another. In all, the literature revealed that fossil based biofuels face challenges due to the uncertainty of greenhouse gas emissions and the cautious approach the financial community is taking as they balance environmental issues with profitability, especially in the long term.

4.5 Interviews

To probe deeper into these issues, I conducted a series of telephone and face to face interviews. Targeted groups for the interviews were coal-to-liquid developers, biofuel developers, shale oil developers, airlines, financial institutions, consultants, and government officials. A technique similar to that used by Burchill (2005)⁶⁹ was employed to capture the key messages of the interviews. A series of interviews was conducted with representatives of airlines, the airline trade associations, aircraft builders, engine companies and the military to develop a series of views from potential early adopters and the airlines in general. Figures 4.2 and 4.3 show the key phrases that characterize the responses in terms of the first adopters, the

⁶⁹ Gary Burchill and Christina Hepner Brodie, Voices to Choices, Center for Quality of Management, 2005

early majority, the “Valley of Death,” the “Chasm” and other company’s issues. From the interviewees, it was not very clear that there could be any early adopter beyond the military. Several airlines such as Virgin, Air New Zealand, and Continental have conducted or will conduct in the near future demonstrations of alternative fuels in aircraft and specification bodies such as the American Society for Testing and Materials (ASTM) are developing modifications to specifications to allow the use of alternative fuels but none has committed to be the first users of an alternative fuel.

First users of alternative fuels must be assured that the fuel is safe for flight and that no harm will occur to the equipment. To achieve this aim, extensive testing in the laboratory, in actual equipment and in flight is required before the fuel can be used. The first group to accomplish this process with an alternative fuel was the airlines that operate out of Johannesburg South Africa that use fuel produced by SASOL from coal.

First Adopters	Early Majority	Valley of Death	The Chasm	Company Issues
Customer concerns about greenhouse gases	Cost Sensitive	Biofuel property technical issues	Aircraft and engine qualification and certification	Innovation is coming from small companies
Airlines Demo (Virgin, Air New Zealand, Continental)	Environmental concerns	Not able to pipeline biofuels	ASTM Fuel Specification	Smaller companies like to partner with a large user
Country specific conditions may drive early adopters	All aircraft at an airport must convert due to logistics	Aircraft qualification and Certification	Projected growth in air traffic	Large airframe company act as a catalyst
European Airlines	Drop-in fuel	Biofuels will need subsidies	Military Fuel Specification	US airlines are price sensitive
Resistance to change	Need for partnerships	Assure material compatibility	The effect of the fuel on range and payload needs to be examined and documented	European airlines are environmental and price sensitive
Off set emissions growth in the future	CAAFI efforts critical for early majority	Infrastructure concerns	Global acceptance and international standards	Early investors want certification in place
Early airline advocated may not be early adopters	Aviation in Europe is viewed like the tobacco industry	Volatility against disruptions	Identification of airport pairs to gain operational experience	Competition between diesel fuel and aviation fuel
Airlines use the same fuel resources at airports	Europeans believe aviation is the largest contributor to CO2 emissions	Fuel needs to be a drop-in and fungible	Need to convert entire airports	Airline buying consortium for alt fuels
Safety and reliability must be proven	Need some sort of an environmental spec	Proper government policies and procedures	Product needs to be fully interchangeable with petroleum fuels	Large companies not interested in biofuels
	Limited ability to pass on costs of alternative fuels	Need sustainable fuel sources		Need baseline lifecycle emissions for petroleum

Figure 4.2. Early Adopter Views

Since coal derived fuels were critical to meet the aviation fuel demand at Johannesburg, a collaborative effort was formed to evaluate, qualify, and certify the fuel for use. Since the fuel would supply only a single location with limited air traffic, the collaborative team forged new ground, obtained approvals and documented the suitability of the fuel produced from SASOL as suitable for use at Johannesburg. The DoD, led by the Air Force, conducted more extensive testing of Fischer Tropsch fuels produced from several sources including SASOL, Syntroleum, and Shell. The Air Force developed a new military handbook, MIL-HDBK-510 to

First Adopters	Early Majority	Valley of Death	The Chasm	Company Issues
Looking for cost stability and environmental benefit	OEM qualification and Certification	Shortage of sustainable biomass	Focus on the end fuel rather than technologies and feedstocks	Define operational impacts
Very difficult for a commercial airline to be an early adopter	Operational impacts defined	Following the ground transportation sector	Need drop-in fully fungible fuels and blends	Define environmental benefits
Must be a price advantage for a single company to step out	Security and stability	No star industry	Its a global problem that needs global solutions	Define total good in economic terms
Safety of flight must be proven	FAA certification	Infrastructure impacts are not acceptable	Take community awareness and acceptance into account	IATA is developing goals for sustainability
	Buying pool to reduce risk exposure	Cost and cost exposure if prices drop	Fuels are co-mingled at airports in tanks and hydrant systems	Long life of aircraft in system
	Need ASTM standard for qualification and certification	Qualification and certification	All or non approach at airports	Don't study things to death -- have positive progress
	Need ASTM specification for alternative fuels		Define impacts on range and payload	Airlines are a conduit for other industries to make money
	If fuel costs are too high the airlines will loose the discretionary passenger		Need harmonization between international standards and specification	Energy industry is not investing for the long term
	Need the industry or an association to lead		Industry needs to coordinate and cooperate	Should the industry use alternatives at all?
			Foster collaboration across the entire value chain	Look for environmental fuel economy
				Global companies versus domestic companies

Figure 4.3 Airline Views

document a streamlined approval process for new fuels across all Air Force enterprises (air, ground equipment, and infrastructure) and is currently qualifying all aircraft and equipment for a 50/50 blend of Fischer Tropsch fuels that is independent of suppliers to allow worldwide purchases. The JP-8 fuel standard allows the Fischer Tropsch fuels to be produced from coal, natural gas, biomass or other carbon based feedstock and is thus feedstock independent. The Air Force has conducted extensive flight testing in subsonic and supersonic aircraft and will complete the fleet certification by 2010.

Shale oil was tested and approved for use by both the military and commercial airlines in the 1980's and could be used today if the fuel meets the current specifications. Biomass

derived fuels (other than Fischer Tropsch) will require a complete evaluation, qualification and certification process. One challenge with biomass is that there is no single source or dominant production process that has been identified for fuel production. It is likely that many feedstocks and processes will be qualified in an iterative fashion.

Since it is unlikely a single airline will be an early adopter, it is possible that a cluster of airlines at a single location will adopt the use of an alternative fuel (similar to Johannesburg and coal derived fuels). Since all airlines in general use the same fueling infrastructure at airports, all equipment that operates out of the airport must be qualified and certified. All airlines at the location would need to agree to use the fuel. Since resistance to change is typical, there would need to be a motivation driven by environmental concerns or price to move forward. Initial locations for biomass derived fuels could be airports that service countries that have signed the Kyoto Protocol. Since the airlines would operate as a group, the formation of a buying consortium for alternative aviation fuels could help offset any risk exposure due to falling oil prices and potentially could issue long-term off-take contracts to stabilize price. For this to happen, the fuel must be proven safe for flight, be a drop-in and be fungible with petroleum derived fuels. However, biofuels have a history of not being compatible with infrastructure and require subsidies. Additional qualification and certification may be required to assure that biomass derived aviation fuels are fully fungible.

If a cluster of early adopters at an airport demonstrates suitability for use, other clusters are very likely to want to use the fuel and the early majority of users will start. For this to happen, all aircraft and engines will need to be qualified and certified, service bulletins will

need to be updated and the fuel specifications documented in the ASTM and military fuel specifications. Airline trade associations will need to work with their international counterparts to develop a global acceptance to the standards and approval for use.

In a sense, a chicken-and-egg situation exists. For early adopters to move forward they need commercial supplies of certified fuel. For innovators to secure financing to build a facility, they require contracts with a user. Smaller producers may need an equity partner like an airline; however, airlines may not have the financial stability to be an equity partner. In addition, the airlines are driven by fuel price and the alternative must be cost competitive with petroleum. These challenges frame some of the issues that need to be addressed to cross the “Valley of Death.”

I also interviewed alternative energy project developers. Oil shale developers (Figure 4.4) offer the potential of a large feedstock that can be refined using current refinery technology. In a sense it is just another type of oil. This feedstock has been part of the historic reserves for the military for almost 100 years but has remained virtually undeveloped except for a short period in the 1970's and 1980's. Oil shale can be used to make high quality jet fuels in a preferential slate due to the nature of the crude. The main problem with oil shale is that the vast reserves (approximately 1 trillion barrels) are primarily on federal lands and have been targeted by environmental groups not to be developed. The Bureau of Land Management (BLM) did issue several research and development leases as a result of the EPO Act 2005 but has yet to issue a commercial lease program. Most developers are using in-situ recovery processes that are environmentally friendlier than the projects of the 1970's and 1980's; however, they

do not have a pathway to pre-commercial or commercial scale demonstrations. Part of the reason is the lack of legislation related to greenhouse gases. Since Shale Oil is a fossil source, the lack of legal legislation for greenhouse gases poses a significant risk for investment. Also, political horizons in the region are short compared to the development time needed for commercial projects. This resource has lost significant support since the EPA Act 2005 but offers the federal government billions of dollars in potential tax and royalty revenues if developed.

Coal developers offer significant potential to be large scale suppliers to the military and airlines. Figure 4.5 show the phrases that characterize the conversations with coal-to-liquid developers. Coal can be gasified, and the syngas purified and converted into clean burning Fischer Tropsch fuels. Coal gasification creates CO₂ that must be captured and sequestered for these fuels to be on a par with petroleum derived fuels. With the qualification and certification work of SASOL and the U. S. Air Force, this is the most near term alternative that can be adopted by aviation as a whole. The main challenge with coal is that it is targeted by environmental groups due to its historic exploitation and the amount of CO₂ that it will generate. The industry is hampered by the lack of greenhouse gas legislation such that it cannot develop solid plans to meet environmental compliance. In addition, there are no legal frameworks in place for carbon sequestration. Airlines and the military will want to buy only a fuel with a measurable CO₂ lifecycle footprint that is equal to or less than the volume of CO₂ produced compared to the incremental barrel of petroleum that it displaces. Plants will be very large to gain scale efficiencies and will require large amounts of capital. For example a 30,000 barrel per day plant may cost \$3 - \$4 billion. This cost poses large financial risks, especially since these will be first-of-a-kind plants in the U.S.

First Adopters	Early Majority	Valley of Death	The Chasm	Company Issues
Airlines are not interested in oil shale	Can be mixed into existing refinery crude slate	Long term moratorium on oil shale development	Move from R&D leases to commercial leases	Individual ownership of some track -- value of track if better commercial leases are opened up
Military could create a market based on historical interests	Shale fuels approved in current specifications	Lack of a commercial leasing program		Access to federal lands
Significant momentum lost since the passage of the EPAct 2005	Need to buy product from commercial demonstration projects	Public needs education on oil shale and energy		Environmental permitting for spent shale tailings
Provide safety net for first-of-a-kind plants		Risk of technology failure		May want to restore land to better conditions than started
Balance public and private risk		No positive activity from the government		Lack of greenhouse gas legislation places a cloud over project economics
Support programmatic environmental impact statement		Need proven technology		
		Difficulty in obtaining permits		
		Politicians have short time horizons		
		Long cycle time for projects		

Figure 4.4 Oil Shale Developer Views

The advantage of coal fuels is that with oil at \$100 per barrel these plants may be very profitable and are likely to have lower price fluctuations due to the lower volatility of coal prices. In addition, it is very likely that biomass will be co-fired with the coal, producing a fuel that has a much lower CO₂ footprint than petroleum derived fuels and allowing the industry to find the most cost effective mix of feedstocks.

First Adopters	Early Majority	Valley of Death	The Chasm	Company Issues
Interested in biomass as a way to reduce CO2 footprint	Airlines need FAA certification	Technical concerns of combining FT technology with a gasifier	Industry expects a long slow process for adoption	Delays have significantly increased the cost of facility
Some airlines are interested as a way to stabilize fuel costs	DoD qualification and certification critical for commercial airlines	Technology has not been demonstrated in the US	CAAFI effort critical	Intellectual property issues with DOE
Air Force must take an active role in certification	Financial industry developing an alternative fuel market	Competition from China and India for materials	ASTM must develop specifications	Plants must be located near CO2 pipelines of sequestration sites
Need for long term off take agreements	Environmental groups targeting airlines	Volatility associated with the cost of oil and value of products	Pipeline companies must be able to accept the product	High risk of cost overruns due to escalating prices of materials
Long term off take agreements with provider of financial commodity market	Need to talk about product benefits not feedstocks	Biomass is logistically challenging and costly	Slow learning curve between projects	Limited selection of FT technology vendors
Culture change needed for military procurement	Environmental groups need to work with the industry not against it	Lack of legal structure for CO2	Can't put look back clauses in long term contracts	Difficult to get price information from vendors
Market dynamics drive to higher value diesel fuel	Early adopters must want CTL	Environmentalists want to stop the use of coal	Uncertainty of geological sequestration	Commodity markets no branding
Increased support with shortages or disruptions		Need to build large plants for economy of scale	Lack of legal framework for greenhouse gases	Advertising of a brand for early plants could lead to shortages
Stick toe in the water approach not full commitment		State governments killing coal projects		Developing linkage between crops and the price of oil
		Large CAPEX needed		Competition with producers that have paid off facilities
		EPC contractors are saturated with foreign construction and less stringent requirements		Product deliveries 4 - 5 years in the future from project start

Figure 4.5 Coal-to-Liquid Developers Views

All alternative energy plants face challenges in regards to finding engineering, procurement and contracting (EPC) contractors due to the worldwide demand for their services. EPC contractors should provide insurance (a wrap) for the performance of the plant. However, it is difficult in the current high demand environment and the challenges of first-of-kind plants for them to provide a wrap. The escalating costs of materials and construction combined with the difficulty of obtaining project wraps create significant financial risk. Coal-to-liquid projects are too costly for venture capital although this type of funding may have helped a company move through the pre-commercial demonstration phase. Other equity and debt partners are required, but they are looking for ways to reduce risk. Although these projects are

likely to be profitable, the long construction time line, the high capital expenditures (CAPEX), and the uncertainty of the oil market all add financial risk.

Compared to fossil fuel developers, biofuel developers face a different set of issues. Although biofuels are perceived as green, recent questions about sustainability and greenhouse gas footprints have surfaced. In general, biofuels are the hardest resource for which to come up with quantitative greenhouse gas life cycle measurements due to the challenges associated with land use change. Also as food crops are used the food versus energy debate creates long-term sustainability issues. However, if biofuels offer a reduction in greenhouse gas intensity, they will become a high priority for the development of alternative aviation fuels. Several Kyoto signatory countries have targeted aviation emissions as a top priority for reduction, and biofuels may offer the environmental incentive to propel them forward. In general, production facilities are likely to be much smaller than conventional fossil production facilities, which may create a higher production cost and lower margins, but are also in a cost range that are more likely to attract both equity and debt financing. Biomass has a long history of subsidies; thus, the cost of environmental benefits would be spread across the majority and not just the users of the product. This scenario is similar to the environmental subsidy for the wind power. Project sustainability that does not need subsidies will offer higher long-term value to investors.

Another major challenge for biofuels is that many sources are likely be used and the fuel produced via many production pathways. Without dominant standards, each fuel will require a separate aircraft qualification and certification process. Since this process is long and costly, it is likely that only a couple of dominant production pathways will be chosen for approval. With

the likelihood of small production facilities and potentially high feed stock gathering costs, production costs will need to be minimized to be competitive with petroleum. If greenhouse gas legislation is passed such that a cap and trade system or carbon tax is imposed, the cost gap between biomass and fossil source may be closed. Another issue with small plants (100 million gallons per year) is that several plants will be required to support one major airport such as Logan Airport in Boston. For a single cluster of airlines to move forward, they must look at the total cost impact of multiple small plants feeding a single location.

After interviewing the potential early adopters and various alternative energy developers it has become evident that there is no “silver bullet” for aviation; in fact, there is not even a silver BB. To better understand what the financial community thinks of alternative energy for aviation, I interviewed several venture capital firms and Wall Street investment banks. Figure 4.7 shows the key phrases from the financial community in regards to first adopters, the early majority of users, the “Valley of Death,” the “Chasm” and various company issues. The financial community in general is looking for opportunities in alternative energy but they see several significant challenges. All projects have risk due to the uncertainty surrounding greenhouse gas legislation and costs. They also are looking at the environmental cost of compliance situation in the U.S. compared to the global environment for alternative energy. If it becomes too costly for investment in the U.S., the companies will look to fund projects in other countries.

First Adopters	Early Majority	Valley of Death	The Chasm	Company Issues
International Airlines operating in Kyoto Signatory countries	Long term liability issues for pollutant emissions	Boom and bust of oil cycles and impact on alternative fuels	Need for FAA certification	Cost Plus Fixed Fee Contract Concept
Need long term contracts	Need biofuels that are fully fungible	Food versus Energy Debate	Lipids chemistry beat fermentation chemistry for fuels	Ethanol plant has 7 year payback period
Need ways to share risk with producers	Concern about the long time it takes to certify a fuel	Historic use of subsidies	Emerging fermentation chemistry produces high molecular weight liques	Petroleum Refineries have asset paid off
Domestic airlines are interested but not serious		Jet Fuel is more complex than most than ethanol	Need a variety of feedstocks and production facilities	Timeline 2 - 3 years for an operational plant
Develop supplier/user relationships		Uncertainty in cost of construction materials		Impact of commodity markets on food based feedstocks
Interest at the airframe company level primarily		Every barrier need 18 months to resolve		Biodiesel and corn ethanol are not cost effective
		Lower risk to blend into other transportation fuels or at the refinery		ASTM is not enough you need a industry quality assurance program
				Yearly crop switches by farmers
				Mandate are the only way currently to survive
				Do fuels need aromatics?
				Ethanol production draining acquifers

Figure 4.6 Biofuel Developers Views

The financial community is also anxious about the limited EPC resources and the current impact that worldwide energy demand is having on resources and the currently unaccountable escalating costs of large projects. They are also bothered that EPC contractors are working on projects where EPC wraps are not important and the potential lack of willingness to provide an EPC wrap to an alternative energy project in the U.S. Airlines are not considered credit worthy enough individually to be a strong project partner, although alliances for purchasing may be seen as helping reduce project risks. In general, the financial community is looking for project developers to have a large equity share to reduce risk and projects that have natural hedges such as producing a fuel and electricity. The industry as a whole will fund limited projects in the near future due to liquidity concerns in the financial markets.

The financial community would like to see some government backstops to help the industry get on its feet. Two key tools that they have suggested are loan guarantees and long term off-take agreements for the product. If a careful balance is struck such that the industry assumes enough risk to be competitive and efficient but is backstopped with government help for the first few first-of-a kind plants with loan guarantees and off take agreements, alternative energy for aviation could itself take off.

First Adopters	Early Majority	Valley of Death	The Chasm	Company Issues
Need to issue long term off-take contracts	Airlines in better shape today than 2 years ago	Environmental control is a rich country issue -- India and China don't care	Airline credit alone not enough to allow for funding of projects	The economy is being beaten up right now
Military is a natural -- a bankable user	Air traffic is likely to increase	Major wealth shift to developing countries	If all airlines can use the fuel it could be sold as a commodity into the market	Academics have given up on energy independence
Price support would be helpful	Industry will likely need to pool risk	Not enough money in the DOE loan guarantee program	Airlines need to tell world they want alternative fuels	CO2 trading for 10 - 12 Euros per tonne
DoD enhanced use leases might help developers		Cap and trade system expected		Lack of liquidity in the market at the current time
Need to demonstrate technology works		EPC growth of 30 - 40% due to demand		Lack of liquidity will slow down energy projects
		Need for EPC wraps on projects		Industry is skeptical of government energy programs
		Alternative energy projects need to be demonstrated at scale		Need a mix of equity and debt financing
		Need backstops for risk		All projects must have a carbon management plan
		No insurance company ready to insure project risks		Projects with natural hedges are more attractive
		Uncertainty over feedstock supplies		EPC contractor construction books are full at the present time
		Lock-in upstream and downstream costs -- market will suffer otherwise		Private risk spread to public like wind tax credits

Figure 4.7 Financial Community Views

4.6 Chapter Summary

In this section, I reviewed a selection of relevant literature and conducted interviews with key players in the alternative energy industry. Many barriers exist to the development of an alternative energy industry for aviation. Financial barriers are a main paralyzing force at the moment. First-of-a-kind plants create risk to investors with large projects such as oil shale and coal-to-liquids potentially requiring large amounts of capital. Projects require a rather large equity share and the cost of the debt will be high due to risk. Government intervention in the form of loan guarantees and long-term off-take agreements may help the industry move forward.

Environmental risk is high primarily due to the uncertainty of greenhouse gas legislation and legislation related to carbon sequestration. Lifecycle footprints for petroleum and all potential resources need to be determined and sustainability parameters defined and compared. Land use policy and the impact of land use changes on CO₂ lifecycle footprints also need to be resolved before the industry can move forward at a rapid pace.

Market risks relate to the volatility of feedstock markets, product markets, and the volatility of the oil market. Projects with minimal infrastructure costs have a higher likelihood of success compared to those that require significant infrastructure development. Social economic issue, especially in rural locations, must be factored into any analysis of market impacts. The debate over food versus energy will hamper projects using food crops as a feedstock. In addition, the lack of greenhouse gas legislation hampers the determination of the overall benefit of most biofuels.

Regulatory risks are another major factor of the uncertainty in the market today. Land use, greenhouse gases, subsidies, and federal mandates all contribute to uncertainty and create risks for project developers and financial investors.

Sociological risks must also be considered. The U.S. is dependent on foreign oil and is part of a global economy. Oil has had a history of booms and busts, and alternative energy projects have suffered through the bust periods. Rapid development of most alternative energy resources has significant impacts on rural communities. If managed properly, these issues can be minimized and wealth created in the U.S. through these projects.

In the next chapters in this thesis, I will explore many of these issues in more detail and provide some potential tools as well as recommendations that could be employed to help develop an alternative fuel industry to support aviation.

5.0 Data Analysis and Scenarios

5.1 Chapter Overview

In this chapter, I discuss the key issues that create risk and uncertainty for alternative fuel developers based on the literature review and interview responses. The main categories of risk and uncertainty include financial, environmental, market, regulatory and sociological. To explore the impact of these risk and uncertainties, I provide analysis of the strengths, weaknesses, threats, and opportunities for oil shale, coal, and biomass as resources for alternative aviation fuels. Using the information from the literature and interviews, I present some example scenarios based on the barriers and risks identified and a discussion of some of the first steps the military and the commercial airlines could foster to reduce the risks.

5.2 Data Analysis

Several strong themes emerged from the literature reviews and interviews:

- Financial -- alternative fuels must compete with petroleum derived fuels at market price. Financial uncertainty coupled with the production costs associated with alternatives creates risk.
- Environmental – life cycle greenhouse gas emissions, local air quality, water usage and pollution, and land use all drive the sustainability of any alternative

fuel. Assessments of carbon footprint are difficult due to lack of consensus on frameworks and benchmarks. No legal framework exists for CO₂ in the U.S.

Environmental uncertainty creates risk.

- **Market** -- fuels and the feedstocks to produce them are commodities and are subject to high volatility. External drivers such as political events, speculation, supply, demand, currency valuations, and global markets create uncertainty and risk. Energy has experienced boom and bust cycles in the past and this creates additional uncertainty.
- **Regulatory** – current regulations need to be revised to foster alternative energy. Regulations related to plant citing, permitting, environmental compliance, taxes, and tariffs at both the state and federal level create uncertainty and risk.
- **Sociological** – public acceptance of alternative energy sources is not universal and highly locational. Wealth creation and environmental tolerance as well as historical locational issues dominate the discussion. Impacts on local infrastructure and the concern over boom and bust cycles must be considered. Social-economic issues create uncertainty and risk.

Uncertainty and risk create opportunities. The challenge is to develop methodologies to assess these uncertainties and risks and weight the benefits and hazards associated with the new technologies. The uncertainties and risk characterize the “Valley of Death” between the development of an alternative energy innovation and the deployment of the innovation. In this chapter I will highlight some of the strengths, weaknesses, opportunities, and threats (SWOT) for various resources and consider them through the lenses of a technology innovator and an

early adopter. I will then look at the “chasm” between the early adopters and the early majority and the challenges for a sustainable industry. I will summarize my findings at the end of the chapter and list some key area’s that will be explored in more detail in later chapters of the thesis.

Three key domestic resources, oil shale, coal and biomass offer potential for the production of alternative aviation fuels. Oil shale is an unconventional resource with a long history. It is a vast US resource with over 1 trillion barrels of oil equivalent. As discussed in Chapter 2, this resource was the first alternative resource developed in the 1970’s and 1980’s and the source of the first wave of innovation on alternative fuels. The strengths, weaknesses, opportunities and threats for shale oil derived jet fuels are shown in Figure 5.1. Shale oil is attractive as it is most similar to petroleum and can be refined in conventional refineries and high quality fuel can be made to the existing commercial and military specifications. It is likely to be cost competitive with petroleum at today’s market prices. The challenge is that most of the resource is located on federal land and there is no commercial leasing program to allow industry to move from the R&D phase to the commercial phase.

	Opportunities	Threats
Weaknesses	<ul style="list-style-type: none"> ❑ Most oil shale is on Federal lands ❑ Oil shale located in area's with limited water ❑ Shale deposits located in regions with limited access and infrastructure ❑ Social impacts must be considered and solved due to boom and bust of the 1970's - 1980's ❑ Volatility of the price of oil ❑ Medium CAPEX for retort development 	<ul style="list-style-type: none"> ❑ Congress (with BLM as an agent) controls access to Federal oil shale lands ❑ Activism by environmental groups to prevent development ❑ Lack of support by the government of State of Colorado ❑ Minimal support for resource development in Congress
Strengths	<ul style="list-style-type: none"> ❑ Large known domestic resource ❑ Shale oil can be processed in existing refineries ❑ Similar crude oils are refined today ❑ Medium CAPEX to upgrade a refinery to process crude ❑ Cost competitive with crude oil \$50 per barrel 	<ul style="list-style-type: none"> ❑ Need for Federal government to develop a commercial oil shale lease program ❑ Availability of lower cost oil in other countries ❑ No excess refining capacity in the US ❑ Lack of infrastructure to move product from oil shale deposits to refineries ❑ No Federal or State Legislation on greenhouse gas

Figure 5.1 SWOT Analysis of Shale Oil

The oil shale is located in remote rural areas and will require the development of local infrastructures commensurate with the growth of the industry. Water availability and environmental compliance are key considerations but they can be managed with existing federal and state laws. The main threats are from environmental groups that do not want fossil fuel development or land changes and this obstacle is compounded by the lack of support by the federal government to develop the resource. There is a general lack of information on oil shale and the environmental impact especially in regards to greenhouse gas emissions. This lack of information supports efforts to keep the resource inaccessible.

Infrastructure is another challenge for the developer. Since the shale is located in remote regions, the infrastructure required to move the retorted oil to the market must be part of the overall development of a project. A network of crude oil pipelines that transport the oil to refineries to be processed will need to be constructed. Refineries that are located close to the resource may require additional hydroprocessing capability and associated refinery upgrades. The shale oil derived aviation fuel would be sold co-mingled with petroleum derived fuel thus eliminating problems related to additional product infrastructure. The price of the shale derived product would follow the volatility of the aviation fuel produced from petroleum.

Coal is a major resource in the U.S. that has a mature industry base for mining and transport but a limited resource base for the construction and operation of coal-to-liquid plants. The strengths, weaknesses, opportunities, and threats (SWOT) of coal are shown in Figure 5.2. Coal has been targeted by environmental groups due to its large greenhouse gas footprint and land change issues. Technology exists for coal gasification, carbon capture and sequestration, but because there is limited commercial experience in these technologies, the financial community requires more integrated demonstrations of the technology. Without sound legislation on greenhouse gas emissions, industry is unwilling to invest large amounts of capital in demonstration programs or initial commercial plants to gain knowledge. The benefit of coal over oil, oil shale or biomass is that its CO₂ footprint can be measured more accurately and measured over time and with carbon capture and sequestration, the fate of the CO₂ produced from the gasification can be monitored. Since the Fischer Tropsch jet fuel produced will have a lower CO₂ footprint when burned compared to conventional petroleum, the burning of these fuels would reduce the CO₂ intensity of aviation. From a financial standpoint, coal is attractive as there is limited volatility in the feedstock market and coal mine operators want long-term contracts to ensure the investments made in the mine. However, risk exists because high CAPEX and OPEX of the plant and value of the aviation fuels produced will follow the volatility of those produced from petroleum. One advantage of a

coal-to-liquid plant is the natural hedge provided by the sale of electricity to the grid. If an operator can get a long-term contract for this commodity, it will help reduce impact of the volatility of sale of aviation fuels. If the plant produces other products such as nitrogen fertilizer or naphtha these commodity materials may also provide additional natural hedges to the volatility of jet fuel prices. With the stability of feedstock prices, natural hedges, and measurable CO₂ emissions, long-term off-take contracts could reduce the volatility of the price the military or the airlines would pay for fuel. The challenge here is that the high cost of production could lead to cost exposure risk if the price of oil were to drop below the production cost of the coal-to-liquid fuel.

	Opportunities	Threats
Weaknesses	<ul style="list-style-type: none"> ☐ CO₂ footprint high compared to other fossil sources ☐ High CAPEX for a CTL plant ☐ Limited commercial experience for CTL ☐ Limited companies with commercial experience in Fischer Tropsch fuels ☐ Lack of legislation for CO₂ sequestration 	<ul style="list-style-type: none"> ☐ CO₂ cap and trade or carbon tax will increase costs of all energy resources ☐ Experience with technology will be demonstrated in China ☐ Land usage for biomass and rural social-economic impacts may drive need for fossil projects
Strengths	<ul style="list-style-type: none"> ☐ Large known domestic resource and well documented ☐ Existing legal framework for coal mining ☐ Mining is a mature industry ☐ Studies show cost competitiveness with current market prices of oil ☐ Technology for CTL has been demonstrated at commercial scale ☐ Clean fuels can be produced 	<ul style="list-style-type: none"> ☐ Pressure by environmentalists to eliminate coal as a resource ☐ No federal or state legislation on greenhouse gases emissions ☐ Cost of capital due to risk ☐ Competition for construction resources and manpower by developing countries ☐ Economic advantages of constructing plants outside the US first ☐ Potential for the price of oil to fall below threshold price for CTL with CO₂ capture and sequestration

Figure 5.2 SWOT analysis of coal for aviation fuel production

Biomass is a large potential resource that could be used to produce aviation fuels. The SWOT analysis for biomass is shown in Figure 5.3. Currently there is no preferred approach to

producing the fuel compared to the other alternatives: shale oil (e.g. conventional refining), coal-to-liquids (e.g. Fisher Tropsch). The experience in the production of biofuels has been to produce ethanol or biodiesel, both of which are unsuitable for aviation. DARPA and others are sponsoring research to develop second generation biofuels that are likely to be produced from oils that are hydroprocessed. These oils could come from food or non-food crops and algae. The advantage of using food crops such as soy bean oil is that there is an existing infrastructure to produce, harvest, and store the crop. The disadvantage is that the use of food crops for energy may create food shortages especially in developing nations. Food crops are a large source of U.S. exports and a balance between food exports and energy imports must be achieved. Non-food crops such as inedible oils (e.g. jatropha), salt water tolerant plants (e.g. halophytes), and algae offer potential as a sustainable feedstock. Fuels produced from biomass face the same land and water use issues of fossil fuels, as well as additional challenges such as CO₂ release from the soil, local water pollution from fertilizer, pesticide and herbicide run-off, and the lack of an industry to grow, harvest and store the crops. In addition, socio-economic issues affecting rural infrastructure such the need for road improvements to handle heavy truck traffic must be addressed.

To produce high quality fuels for aviation, the oils will require hydroprocessing to improve the stability, freeze point, and other properties. The hydrogen that is needed will have to be produced from natural gas, coal or the electrolysis of water. The CO₂ footprint associated with the hydrogen production must be included in the overall CO₂ footprint. In general, as demonstrated in the recent debate in the literature, determining the net CO₂ benefit of biofuels is difficult. Since the crops absorb and may sequester carbon, they offer a potential way to

stabilize greenhouse gases in the atmosphere. However, the CO₂ liberated as additional arable but underutilized land is converted to energy crops must be determined to evaluate the overall benefit. Tools to evaluate the overall impact of biofuels must be developed and a consensus on the boundaries of the analysis and the baseline conditions must be reached. As the industry moves towards standardizing the crops that will be used and the selection of processing technology to produce high quality fuels, the certainty of the resource will emerge and its net benefits will be determined.

	Opportunities	Threats
Weaknesses	<ul style="list-style-type: none"> ❑ Large land use changes required to shift to energy crop production ❑ Problems with water usage and water contamination due to runoff from fertilizers, herbicides and pesticides ❑ lack of infrastructure for collection and distribution of biomass ❑ Rural community impacts related to collection and distribution 	<ul style="list-style-type: none"> ❑ CO₂ cap and trade or carbon tax will increase costs of all energy resources ❑ Low carbon footprint fossil fuel technologies ❑ Crops that can grow in salt water or contaminated water environment (algae)
Strengths	<ul style="list-style-type: none"> ❑ Food crops have an existing infrastructure for storage and distribution ❑ Large amounts of cellulosic material available ❑ Crops recycle CO₂ and potentially can sequester it in the soil ❑ Benefit to farmers and reduction in oil imports 	<ul style="list-style-type: none"> ❑ Water usage required ❑ Lack of infrastructure to collect and transport cellulosic materials ❑ Rural socio-economic impacts due to land use changes ❑ Food crops salable on commodity markets for export ❑ Increases in food prices ❑ Debate over low cost food or low cost energy ❑ Need for hydrogen for processing biojet ❑ Lack of product transportation infrastructure

Figure 5.3 SWOT analysis of biomass for aviation fuels

Each alternative fuel resource has strengths, weaknesses, opportunities and threats and no one resource stands out as the best way forward. My research showed that uncertainties are slowing the adoption of any alternative fuel for aviation. These uncertainties are driven by the lack of tools to adequately compare alternative fuels in regards to financial and environmental sustainability, the lack of demonstrated technical maturity, the lack of greenhouse gas legislation, the uncertainty in the oil market, the financial strength of the airline industry, and the high barriers of qualification and certification. With uncertainty there is paralysis and the desire to retreat to the low risk option of using petroleum derived fuels. This view was expressed in the literature and in the interviews. For example, the “do nothing” option was mentioned by the DoD Defense Science Board, “... if needed for national security, DoD could exercise eminent domain over commercial energy contracts. Therefore, the Task Force finds it difficult to imagine a scenario where DoD would be unable to obtain the petroleum it needs to perform its mission from commercial sources.⁷⁰” The Task Force further advocates the development of technologies that focus on fuel efficiency rather than alternative energy sources. In this scenario fuel cost is not important in the short term.

Improvements in efficiency are very important for the long term; however, since the turnover rate of military hardware is measured in decades, efficiency improvements creating reductions of fuel consumption and emissions will occur gradually with significant benefits achieved approximately 20 – 30 years in the future. This is a reasonable long-term strategy and is low risk but it leaves the military vulnerable in the short and mid-term. Airlines have demonstrated much more agility in replacing aircraft and adopting fuel saving techniques when

⁷⁰ Defense Science Board, “Report of the Defense Science Board Task Force on DoD Energy Strategy,” 2008.

they are driven by the bottom line, and thus they can cope better in the short and mid-term.

The downside of this strategy is that the volatility of oil price dominates and any environmental benefits are pushed off to the future. Actual progress is contingent on budgetary cycles for new equipment and no new competition is established to provide downward pressure on the price of fuel. In emergency circumstances the military takes fuel from the commercial sector to conduct operations creating market impacts in that sector. In a sense this is a hope-based strategy – we hope the situation will not get too bad before long-term equipment replacement takes place to reduce fuel usage, cost and environmental effects.

A more aggressive strategy would be to look more carefully at the technology adoption lifecycle, identify the key elements required to cross the “Valley of Death” and bridge the “Chasm” and develop suggestions and recommendations for industry and the government. A technology innovator looking at the issues related to securing early adopters for alternative aviation fuels faces many barriers related to the alternative resource you are developing and the barriers faced by the early adopters. Figure 5.4 shows some of the key barriers faced by an alternative energy developer looking for an early adopter. The SWOT analysis earlier in this chapter highlighted the resource based barriers, but other issues such as fuel qualification and certification, price and environmental benefits also become dominant. If you are an early adopter your view is shown in Figure 5.5.

The challenge is how to evaluate each resource from both sides -- the early adopter and the technology innovator-- of the “Valley.” For example the resources could be compared to gauge the dominance of OPEX and CAPEX which will be strong drivers to the competitiveness of

the resource compared to petroleum. (Figure 5.6) Some resources have a history of subsidies. An evaluation of how likely the project is to be sustainable can be compared to the need for a subsidy as shown in Figure 5.7.

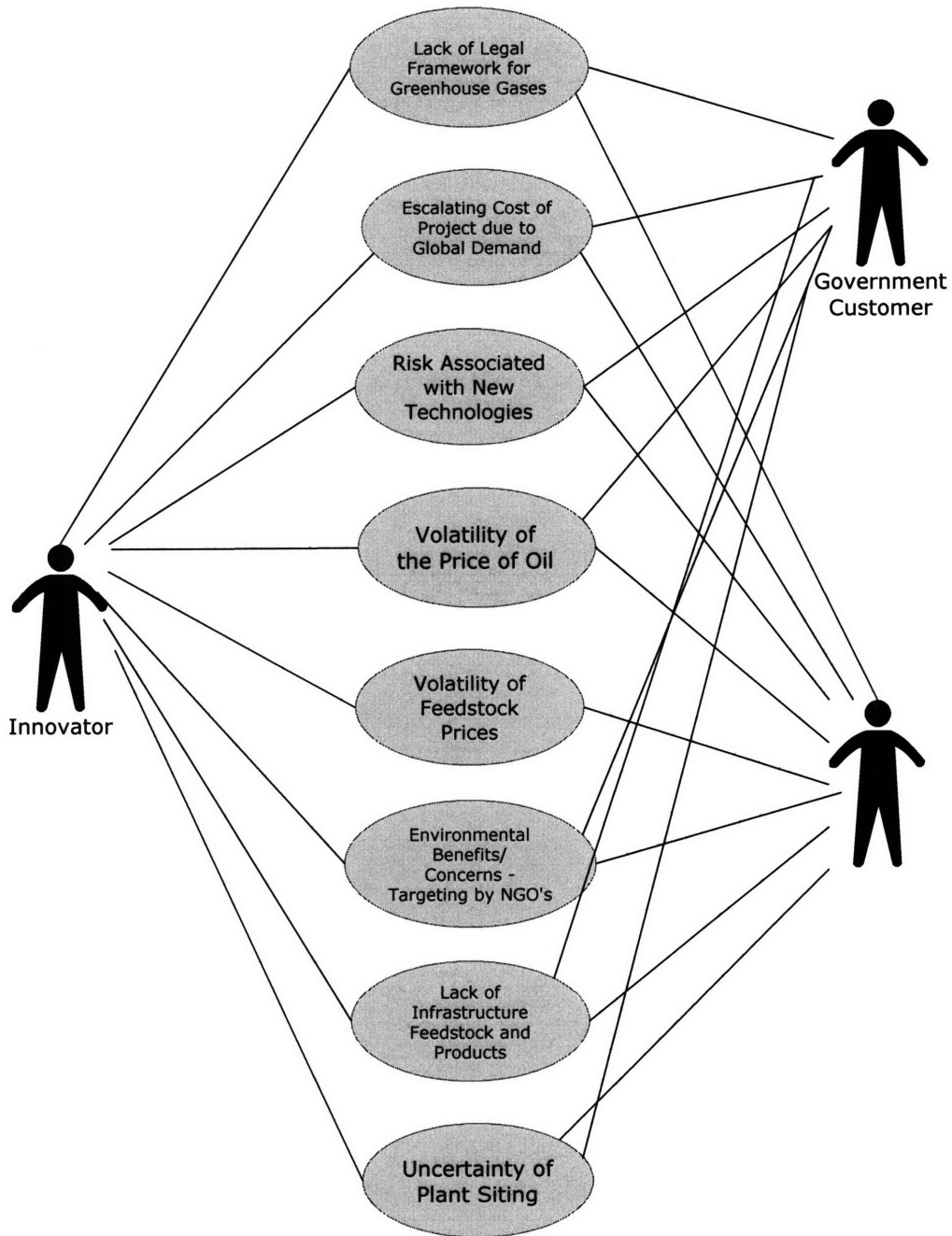


Figure 5.4 Innovators view of the "Valley of Death"

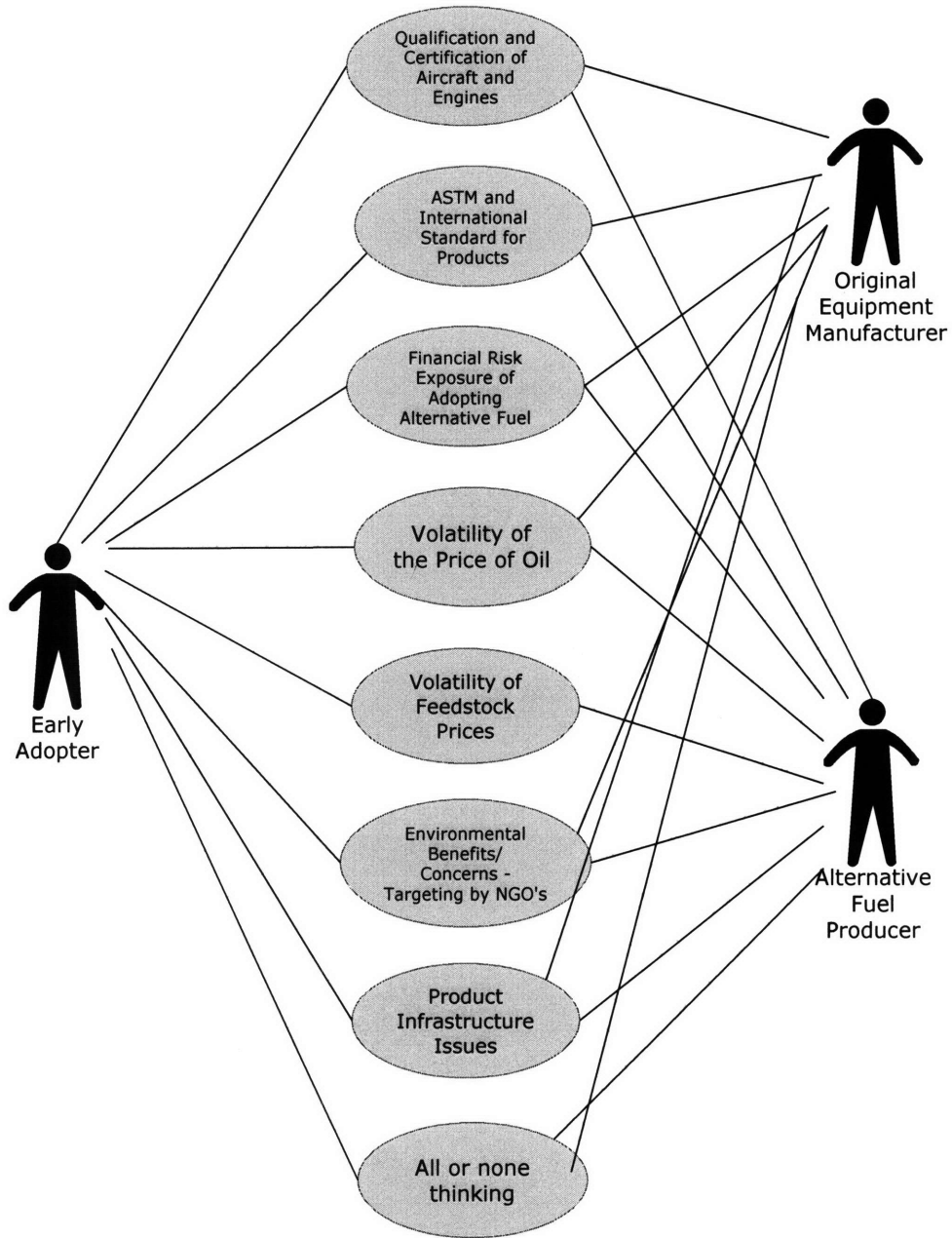


Figure 5.5. Early adopters view of the “Valley of Death”

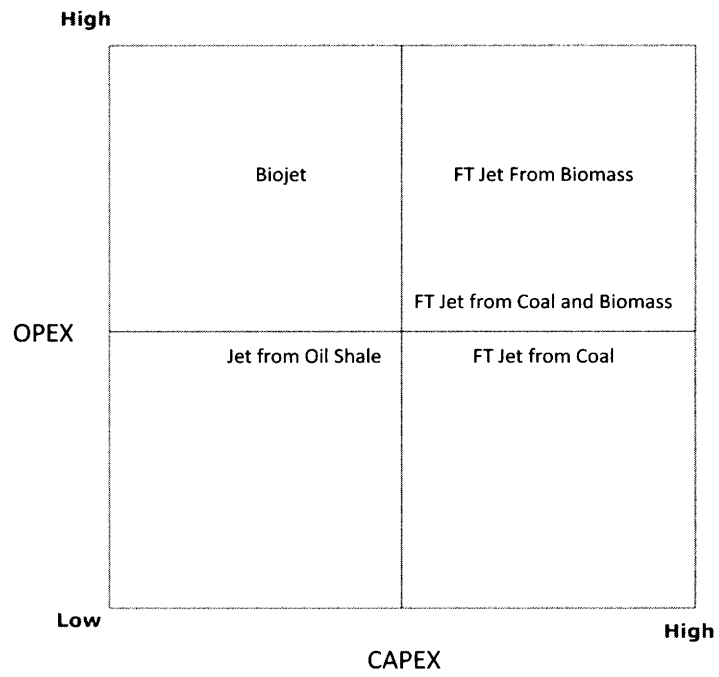


Figure 5.6 Evaluations of Alternative Fuels Based on Cost Drivers

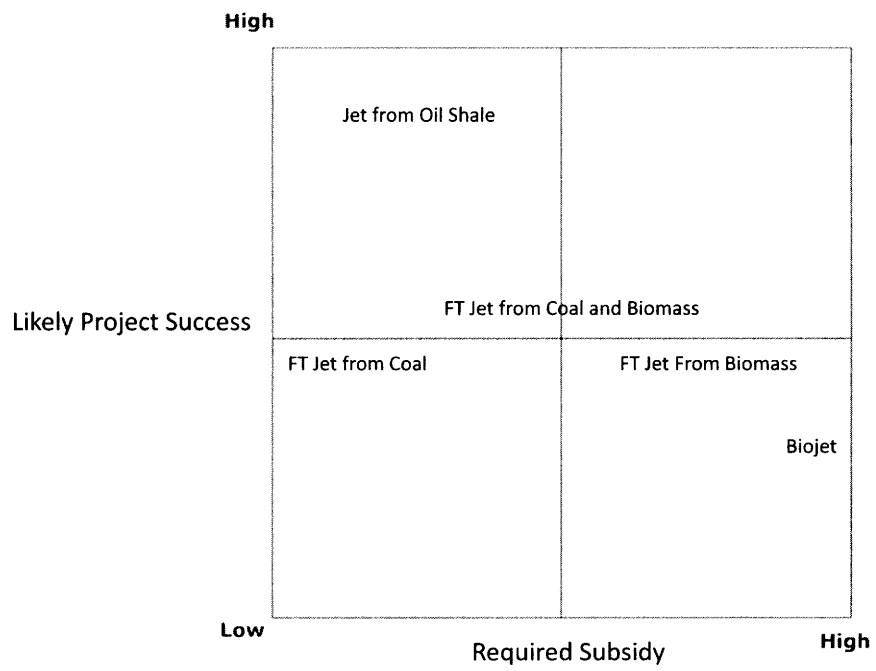


Figure 5.7 Evaluations of Alternative Fuels based on Subsidies

Environmental issues may be used as a tool to compare alternative fuels. The challenge is the lack of benchmarks, regulatory frameworks, and balancing local air and water quality to global environmental issues. However, one could compare projects based on the certainty of the CO₂ footprint and expected cost as shown in Figure 5.8.

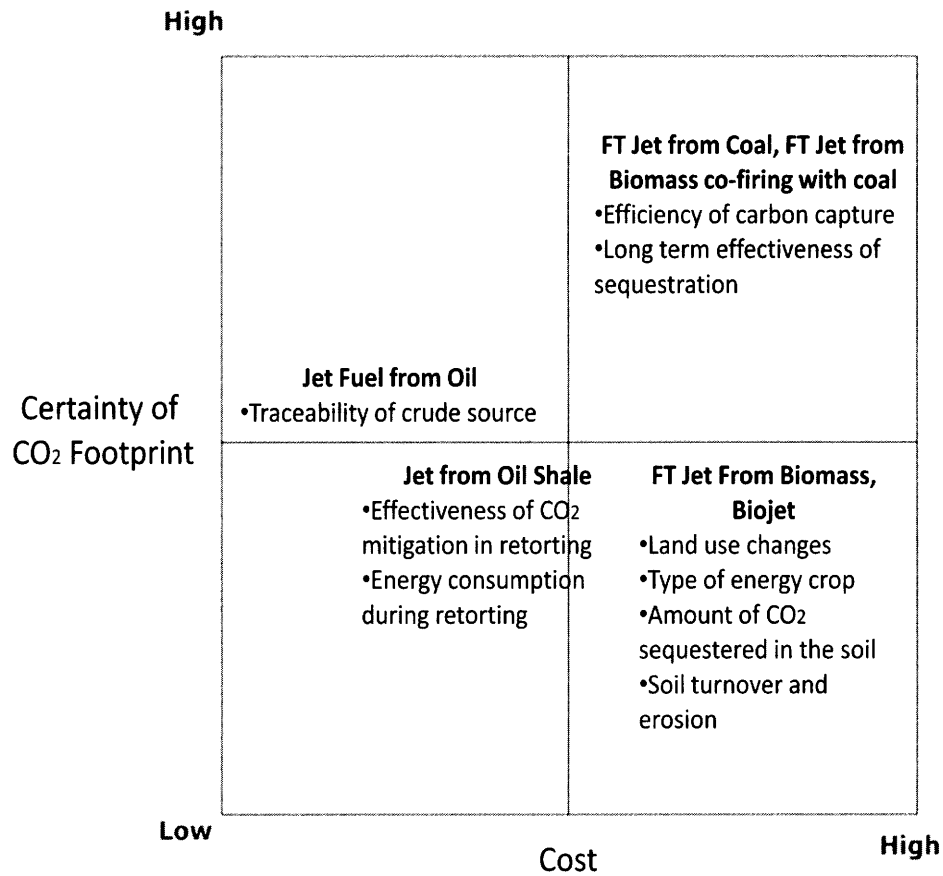


Figure 5.8 Certainty of CO₂ Footprint versus Cost

Other scenarios such as the success of the alternative fuel could be mapped against the need for the military or the commercial sector to be a first adopter. (see Figures 5.9 and 5.10) Industry has responded very favorably to the military as an early adopter and as an organization that can take greater

risks and develop tools and processes more effectively than the commercial sector. The early adoption of alternative fuels by the military helps the innovator secure a beach head market, provides financial security for the investment community, and reduces the perceived risk by the commercial airlines. My research has shown that the commercial airlines could be an early adopter, but this move would likely be driven by a clear cost advantage, or a locational issue such as the need to supply the airlines with coal derived Fischer Tropsch fuels in Johannesburg South Africa. Locational issues are very dominant when one looks at how airports fuel infrastructures are considered. At many airports, the fuel is purchased separately by the airlines, but distributed jointly. Many airlines use hydrant system for fueling, thus each airline attached to the system gets the same fuel, regardless of which airline actually purchased the gallon of fuel. Similar issues exist for airlines serviced by refueling trucks. At other airports, there may be multiple suppliers of fuel: at these airports, a single early adopter might be possible, but it would be more effective if all the airlines as a group moved to the alternative. In general, the military as an early adopter provides significant leverage to all stakeholders and the commercial airlines, whereas the airlines as an early adopter are more focused on locational issues and price competitiveness. The success of biomass based fuels increases with the commercial sector as an early adopter. Airlines that operate internationally are facing problems related to greenhouse gas emissions control in nations that signed the Kyoto Agreement. A locational advantage at airports with large numbers of international carriers may exist if the CO₂ levels of aviation in Europe are capped or a high CO₂ tax is levied on the operator. The equipment mix that operates from the location to the carbon constrained international location could drive a move to biobased fuels even if they are more expensive than petroleum based fuels. The challenge would be to appropriate this cost difference to carriers that do not operate at locations that are carbon constrained.

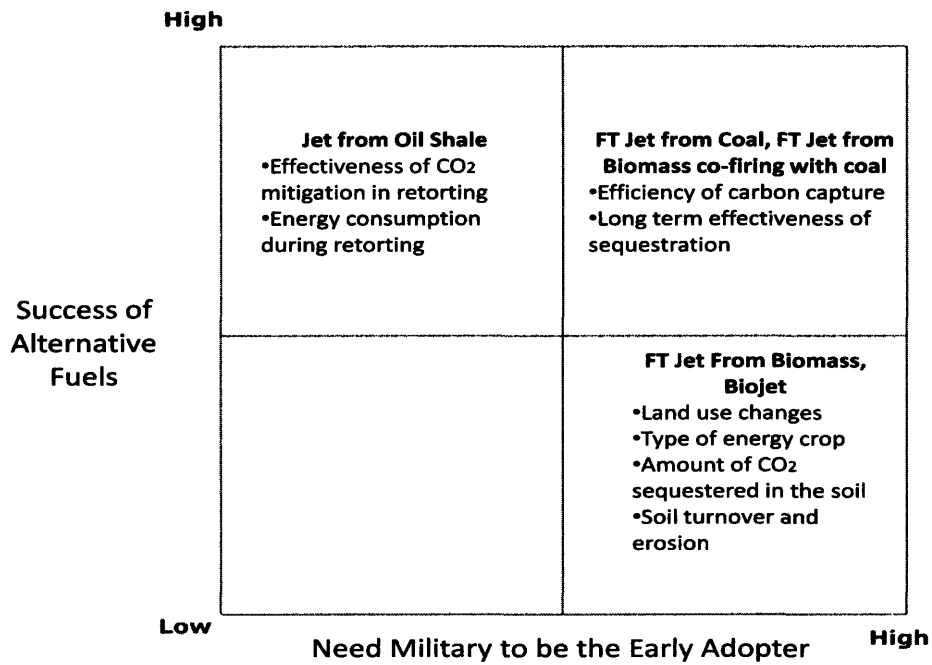


Figure 5.9. Success of alternative fuel type with the military as an early adopter

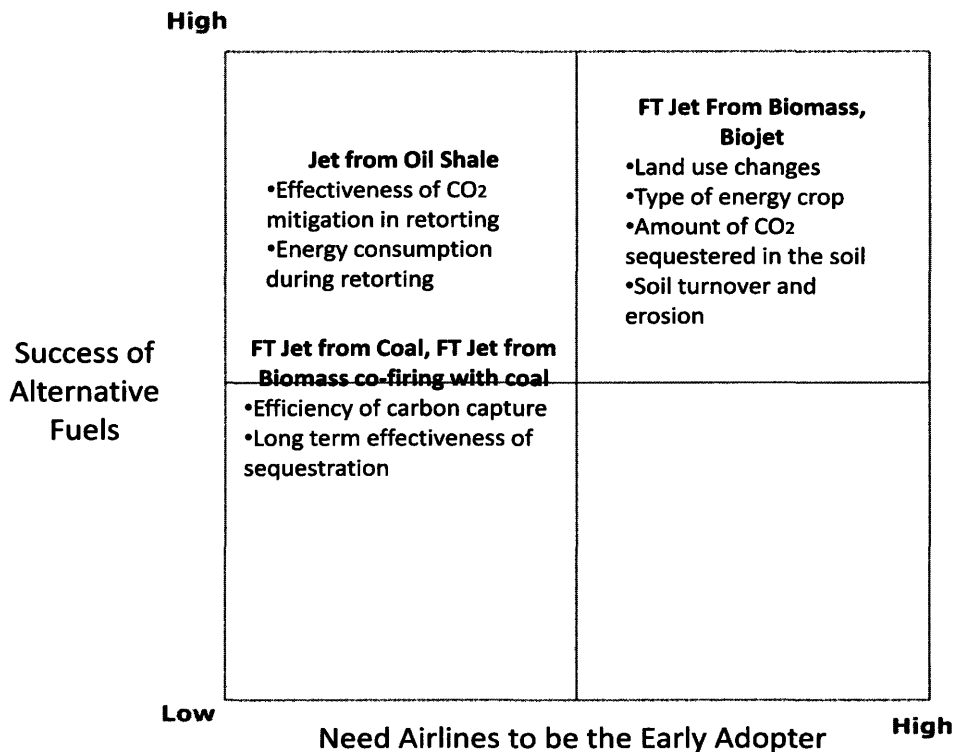


Figure 5.10 Success of alternative fuel type with a commercial airline first adopter

For each alternative fuel source to be used for aviation, government intervention is critical. Oil shale developers need the government to move forward with a federal lease program, as well as need clear legislation on greenhouse gas emissions, and support for rural infrastructure development. Coal developers need clear legislation on greenhouse gases and carbon sequestration and may also need support in developing rural infrastructure, especially if they choose to co-fire biomass to reduce CO₂ emissions. Biomass developers need guidance on land use and solid greenhouse gas legislation. Cellulosic materials may require investment in rural infrastructure and the feedstocks are likely to need government subsidies. All alternative fuel developers would benefit from government incentives such as loan guarantees, tax credits, price floors (and collars), purchase agreements and/or accelerated depreciation. The need for government intervention can be compared to the probability of project sustainability over a project's full life (30 years) as shown in Figure 5.11

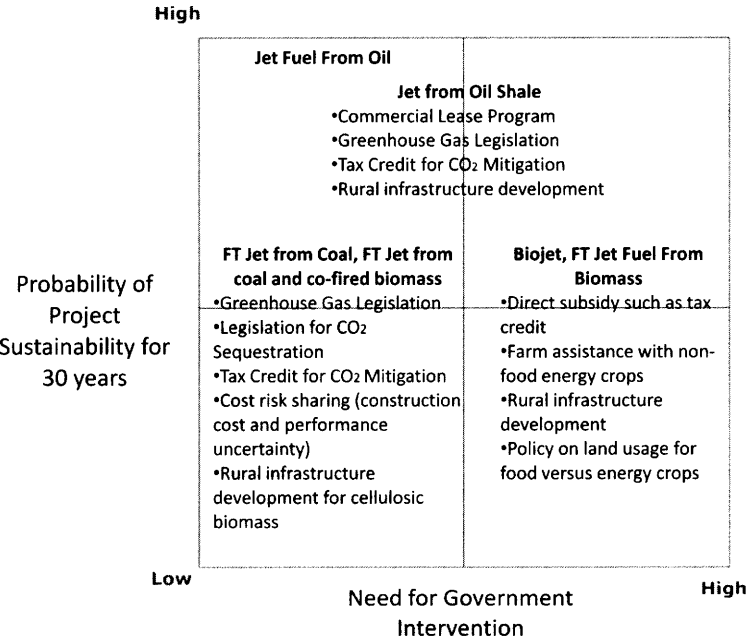


Figure 5.11 Need for government intervention for project sustainability

For the developer to cross the “Valley of Death” some level of government intervention is needed as well as a willing early adopter, and a carefully executed qualification and certification process. To bridge the “Chasm” to the early majority additional issues must be considered as illustrated in Figure 5.12

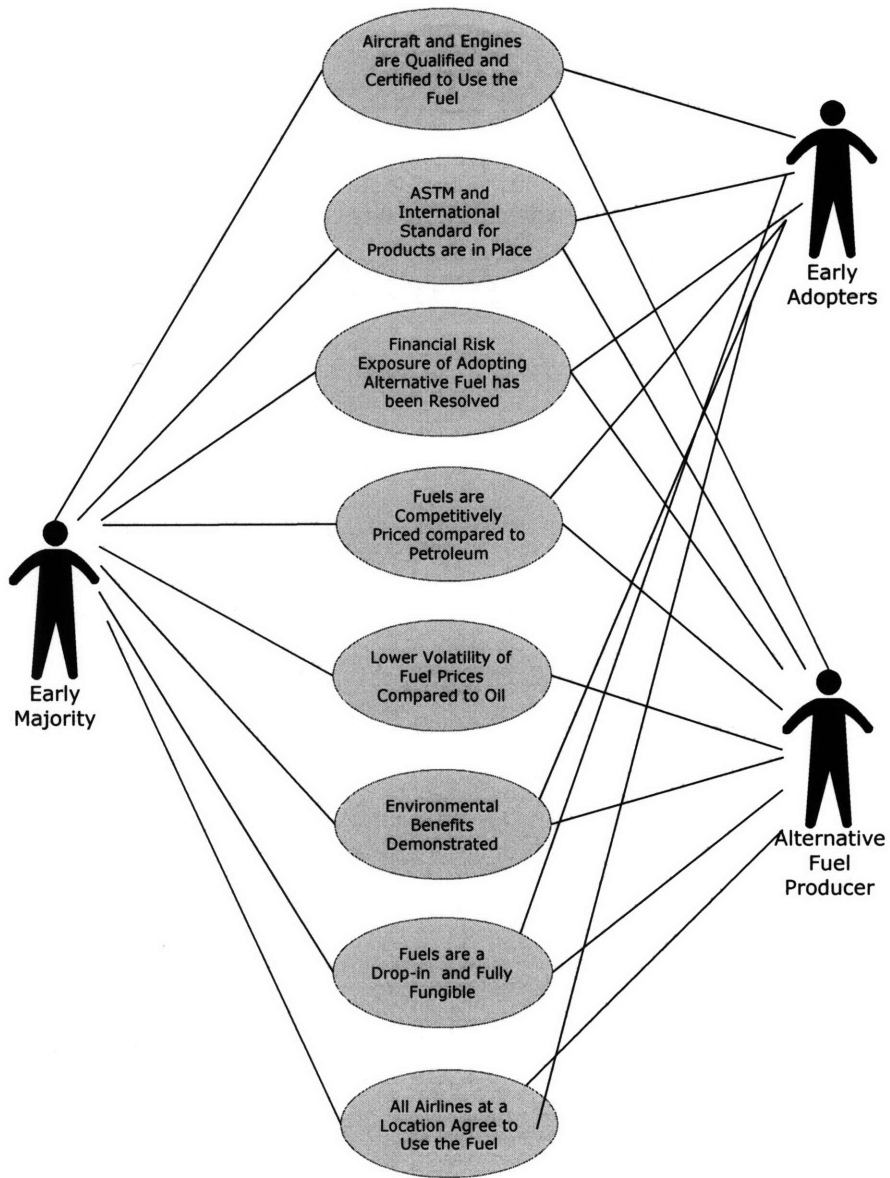


Figure 5.12 Early Majority View of the Crossing the Chasm

In my research with both the alternative energy developers and the airline industry two key elements emerged: cost and environmental benefit. The product must compete on price or environmental benefit, preferably both, to be sustainable in the long term. The cost of fuel over the last several years has become the most significant expense for the airlines.⁷¹ Since petroleum derived kerosene is the dominant standard and the producers have power in the distribution channel, alternative fuels must offer a lower price to displace the petroleum fuel to attract customers or some additional benefit at the same market price. Low price or best value will give the airlines the power to negotiate with the producers and the owners of the distribution networks to switch to the alternative fuel producer. Petroleum fuel suppliers will be forced to reduce price to compete, but the real market competition is based on the cost of the feedstocks and the volatility of feedstock price. For an alternative fuel to compete on price, the feedstock must be significantly less expensive than petroleum, as the processing of the feedstock will be equal to or more expensive than conventional petroleum and most alternatives lack the ability to aggregate production scale in a single location. Whether an alternative may offer a cost advantage is related to the volatility of the feedstock. If an alternative fuel producer could minimize feedstock and final product volatility, there could be an advantage for the airlines to switch to the alternative to control upward cost pressures. In a sense this would be a hedge against the volatility of oil prices. One tool to control the volatility would be the use of long-term contracts. However, the downside to long term contracts is the cost exposure of the airlines if the price of oil were to plummet. Risk exposure during times

⁷¹ Air Transport Association, <http://www.airlines.org>, 2008

when the price of oil falls must be considered; however, the ability to use an alternative may provide a mechanism to help control costs and provide downward price pressures.

The second way an alternative fuel can compete is based on environmental benefits, but the value of the benefits is difficult to quantify at this point. The environmental benefit area has two categories: 1) local air quality benefits and 2) global greenhouse gas reduction benefits. Local air quality is easier to define and is governed by existing legal frameworks for N₂O, SO_x, and fine particulates. Fuel composition can be tailored to control SO_x and particulates. Global greenhouse gas reduction mandates may be the issue that accelerates alternative fuels, but only if those fuels have a life-cycle greenhouse gas footprint that is less than petroleum. Recent concerns raised by the European Union over palm oil⁷² and more recently on corn based ethanol⁷³ show that biomass derived fuels will require as much scrutiny as those produced from fossil sources that include carbon capture and sequestration. A methodology to assess this factor will be described in Chapter 7. Greenhouse gas emissions are likely to be controlled by a cap and trade system or a carbon tax. Cap and trade systems already exist in some parts of the world such as the European Union but are only being discussed at this time in the U.S. When CO₂ emissions are applied to aviation, this mechanism could provide a premium for an alternative fuel that has a lower CO₂ footprint than petroleum. One of the challenges is the very definition of the CO₂ footprint of petroleum. For example a sweet light Saudi crude has a lower CO₂ footprint than an oil sand derived fuel or one produced from heavy oil. A clear definition of the baseline petroleum fuel and the premium associated with greenhouse gases

⁷² Jacqueline Cramer, "Testing Framework for Sustainable Biomass," 2007.

⁷³ Timothy Searchinger, Ralph Heimlich, R. A. Houghton, Fengxia Dong, Amani Elobeid, Jacinto Faiosa, Simla Tokgoz, Dermot Hayes and Tun-Hsiang Yu, "Use of US Croplands for Biofuels Increases Greenhouse Gases Through Emissions for Land Use Change, Scienceexpress, Feb 2008.

must be defined before the benefit of an alternative fuel for environmental reasons can be determined. Similarly, for the alternative fuel a clear definition of the life-cycle CO₂ footprint also must be established.

As we described early, the alternative fuel developer faced the “Valley of Death” and found a way to overcome the barriers associated with the gap between technology development and technology deployment and was able to secure early adopters. But what barriers exist to for this early developer to gain an early majority? How can the chasm between early adopters and the early majority be bridged? Based on the interviews, the following barriers were identified:

- Requirement for an American Society for Testing and Materials (ASTM) approval process to qualify and certify alternative fuels
 - Harmonization of the approval process with all international standardization bodies
- Requirement for clear definitions of a drop-in fuel and fit-for-purpose and use of these terms in a modified fuel specification
- Requirement for revisions to the international fuel specifications to allow for alternative fuels and blends
- Requirement to assess impacts on infrastructure (e.g., tanks, pipelines, hydrant systems, refueling trucks)
- Assessment of any impacts on aircraft range and payloads

- Requirement that all aircraft and engines be qualified and certified for the use of the fuel
- Requirement for all the airlines at a location to adopt the fuel at the same time so they can move as a group
- Assessment of changes required for quality surveillance programs

Unlike consumer goods, with alternative fuels the barriers to bridging the “Chasm” and securing an early majority cannot be overcome by advertising and the effective sales strategies. Education and documentation are critical elements that help drive the crossing but primarily it will take organizations outside the airline industry. These organizations include ASTM, CAAFI, and the FAA in the U.S. and international standardization groups such as International Air Transport Association (IATA) and the United Kingdom Ministry of Defense, which controls DEF STAN 91-91⁷⁴ which is used as the basis of a number of international fuel standards.

CAAFI and the FAA play an important role in helping ASTM clear the first hurdle. These organizations can provide information and open discussions between the fuel producer and equipment original equipment manufacturer (OEM) technical communities. This process will help ASTM develop and publish a process to qualify and certify fuels. This development combined with military handbook MIL-HDBK-510 which defines the military qualification and certification process can become the foundation for the crossing the chasm. These documents must provide clear definitions of the terms drop-in fuel and fit-for-purpose, which are key elements beyond the chemical and physical properties required by the specification that

⁷⁴ Ministry of Defense Standard 91-91, “Turbine Fuel, Aviation Kerosene Type, Jet A-1, Issue 5, February 2005.

actually define the suitability for use of the products. With definitions of the terms drop-in fuel and fit-for-purpose and a review of the technical data on the alternative fuels, the fuel specifications can be revised. The fuel specifications provide the critical contractual link related to properties and fuel quality between the producers and the users. With the qualification and certification procedures and the fuel specifications in place, the next barriers to be overcome relate to an assessment of infrastructure and range payload impacts. If the approval process and the specification have been developed in a robust fashion, then these analyses would be primarily checklist reviews. However, if the fuel properties are unique, such as the automotive industry has experienced with ethanol and biodiesel, these barriers could be significant and expensive. The cost of new infrastructure or significant range/payload penalties could negate any cost or environmental benefit.

The next barrier for a fuel producer to overcome is that all the airlines at the target airport must agree to use the fuel. Most fuel supplies at large airports are interconnected. For example the same fuel flows through a common hydrant system located near the passenger gates. Thus all the airlines on the same loop use the same fuel. In locations with truck refueling, all the trucks are refueled from common tanks and the trucks are dispatched to multiple airlines. To eliminate this barrier, the FAA and CAAFI must work closely with all the airlines so that they move in lock step. The rejection by a single airline at a location can terminate the ability of all the other users to access the alternative fuel. With an accepted qualification and certification process, this undertaking should be a relatively easy achievement. The final barrier is that a new quality surveillance program must be put in place at the airport. This is critical to assure safety of flight and to avert any aircraft problems that may occur due to

contamination or poor quality product. This component should not be overlooked. Biodiesel usage has been hampered by producers providing product that did not meet specifications or that was delivered with a fuel quality problem. Reports from the trucking industry and the military related to filter plugging and low temperature problems have created additional expense and the lack of enthusiastic support for the alternative.

Alternative fuels with an environmental benefit may have an early mover advantage at locations with large international fleets. The coordination at the airport between national and international airlines becomes more challenging as both need to move to the new fuel in lockstep, but there may be an advantage to the international carriers. If the U.S. lags behind other countries in the regulation of greenhouse gases for aviation, those airlines traveling to those locations from the U.S. may require a low CO₂ footprint fuel first. This location based first mover advantage should be considered by the alternative fuel producers as they develop their customer tiers.

The transition from the early majority to the late majority is primarily a function of the availability of the alternative fuel at multiple locations. If cost and environmental benefits are achievable at multiple locations, then the number of users will increase significantly.

5.3 Chapter Summary

Oil shale, coal, and biomass are candidates for alternative fuels for aviation. None stand out as a strong contender over the others as all are faced with issues that require government intervention. Oil shale requires the government to allow access to federal lands through commercial leasing programs. Coal faces challenges related to the lack of legal

frameworks for greenhouse gases and carbon sequestration. Biomass likely requires subsidies and policies on land use. In addition, there is no set of consensus-based tools to assess project sustainability from both an economic standpoint and an environmental standpoint. Beyond those environmental regulations covered in the Clean Air Act and Clean Water Act, there is no legislation and no benchmarks.

Alternative energy developers face many barriers related to crossing the “Valley of Death.” These barriers include financial, environmental, market, regulatory, and social-economic. The government can help reduce the barriers and provide tools to help developers build first-of-a-kind plants. The Air Force can play an important role as the lead adopter of the technology. The credit-worthiness of the Air Force combined with the risk reduction from qualification and certification provide critical bridges across both the “Valley of Death” and the “Chasm.” Without the Air Force as a leader, industry will progress at a significantly slower pace on a locational basis and only when the price becomes attractive for a long period of time.

Crossing the “Chasm” between early adopters requires collaboration between suppliers and users as well as the cooperation with national and international standardization organizations. Unlike consumer goods, all the users of alternative fuels must cross the chasm in lock step. To make this a viable proposition the product must provide a cost advantage or an environmental advantage. Moreover, the product must be certified for use and the entire airport enterprise considered. Only when all parties are in alignment, can the transition at a single location happen.

In Chapter 6, I will explore the interactions required between various collaborators to start a market based response to the supply of alternative fuels and the key initiating steps that will need support from both the government and the commercial airlines. Chapter 7 will use the data from the literature and interviews and provide a discussion of potential tools and strategies to help frame the nature of the support that is required. In Chapter 8, I will provide additional analysis and a series of recommendations.

6.0 System Dynamics Models

6.1 Chapter Overview

In this chapter, I explore the dynamics related to crossing the “Valley of Death” and bridging the “Chasm” in respect to the key variables that will control the early adopter and early majority adoption rates for alternative fuels for aviation. The basic models have been crafted and variables identified such that the relative impacts of the crossings will be explored, but the models are only illustrative. I will not run any simulations or present any detailed quantitative evaluation due to the limited time available to write this thesis. The models show that an industry can be started by the airlines and military approving the use of the fuel and that the adoption rate will progress by airlines acting as a cluster at a given airport to purchase fuel. As the demand for the fuel increases, the alternative fuel production industry will respond by building plants to match the demand as long as the plant utilization capacity is high and they are profitable. The demand will be controlled by the relative price of the alternative compared to petroleum, with fuels that cost the same or are lower in price driving the dynamic. The price of the alternative also includes the attractiveness of the product from an environmental standpoint. The dynamics will self-perpetuate until all the airlines and airports adopt the fuel or market demand is satisfied. The dynamics will stall if the price exceeds the market price of petroleum derived fuels or if the fuels do not offer significant environmental benefits.

6.2 Dynamics Associated with Fuel Qualification and Certification

In my research, I found three significant drivers for early adopters of alternative aviation fuels: price compared to oil, the environmental benefit of the fuel (which in turn depends on

how these benefits are priced), and the approval of the fuel as safe for use. In general, commercial early adopters were not likely to be individual airlines but clusters of airlines at a single location due to the joint use of fueling infrastructure by all the airlines at an airport. Airports in general have a single or a small group of fuel providers that all airlines at that airport use. In many airports, the aircraft are fueled via a hydrant system that runs from gate to gate and services all the airlines along that system. In some cases, the aircraft are fueled by trucks, which offer some level of flexibility, but in general the trucks are filled from central tanks that all airlines share. The cost of segregated fuels could be very high and would be attractive only if the price of the alternative was well below the market price of petroleum-derived fuel. In addition, if the alternative was a blended fuel, the cost of blending and managing two stocks of fuel (petroleum derived and the alternative) at an airport would be high. Blended fuels would need to be delivered to the airport and have an attractive price compared to petroleum derived fuels. In contrast to the military, could adopt the fuel as a single user converting an entire base to its use.

The dynamics of the acceptance of an alternative fuel starts with the approval process. The alternative fuel provider must be able to produce commercially representative samples for test and evaluation by the original equipment manufacturers (OEM's). This can be a challenging problem for the developer but one that proves the technical viability of the process and therefore a step that investors are seeking to reduce the risk associated with the cost of a full scale commercial plant. Based on recent qualifications by the Air Force of Fischer Tropsch fuels, quantities of between 100,000 to 250,000 gallons are required for all the airframe, engine, and auxiliary power unit (APU) qualifications. Fuels that are very different from

petroleum derived fuels will require larger volumes to ensure safety of flight. The scale up of fuel production to pre-commercial production levels can be very attractive to capital markets.

Most innovative alternative fuel research starts in the laboratory with small scale research to prove the concept. Funding for these efforts can come from the private side through equity investment from the founders, angel investors, or venture capital firms, or, if the company is large enough, through direct investment. The research is often supplemented by government investment for R&D by the Department of Energy or Department of Agriculture using competitive contracts, grants, or Small Business Innovative Research (SBIR) resources. Once laboratory results show promise, the challenge is to scale the process up to investigate the feasibility at a large scale, such as a process development unit scale. Most developers use either government R&D funds or equity funding such as venture capital to foster the development of the innovation at this stage. The challenge is conducting pre-commercial demonstrations to prove scalability to commercial scale and providing representative samples for qualification and certification. Since a pre-commercial scale project can be costly, and will probably not be economical for commercial operation, it may be difficult to attract the investment capital. Capital could be provided by government R&D organizations, equity capital through equity investors, or a public offering, or some combination of funding sources (see Figure 6.1).

If a developer can produce sufficient quantities through process development or pre-commercial demonstration scale, and provide the fuel to the OEM's for qualification, one of the key steps for crossing the "Valley of Death" can be initiated. The Coordinating Research Council

(CRC) has developed an approval protocol for alternative aviation fuels for the American Society of Testing and Materials (ASTM).⁷⁵ The process starts with the requirement of small samples of fuel to evaluate its chemical and physical properties in terms of the current ASTM D1655 Aviation Fuel Specification. If the fuel looks similar to a petroleum derived fuel, additional fit-for-purpose tests, such as bulk physical property versus temperature, fuel lubricity, water separation characteristics, and stability, are performed. The results are provided to the OEM's, which determine whether the fuel may be used without further evaluation, may be acceptable but requires further component and engine tests, or is rejected as unsuitable for use as shown in Figure 6.2.

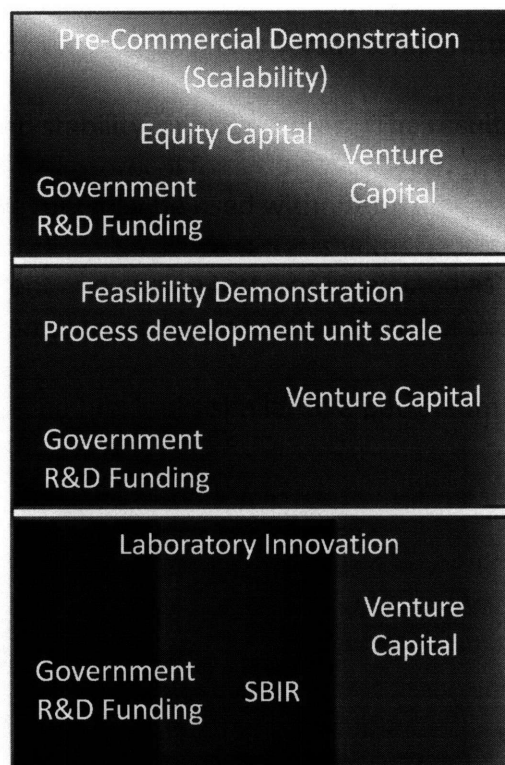


Figure 6.1 Technology Development Maturation Cycle.

⁷⁵ Clifford Moses, "Development of the Protocol for Acceptance of Synthetic Fuels Under Commercial Specification," Coordinating Research Council and the U.S. Army TACOM, 2007.

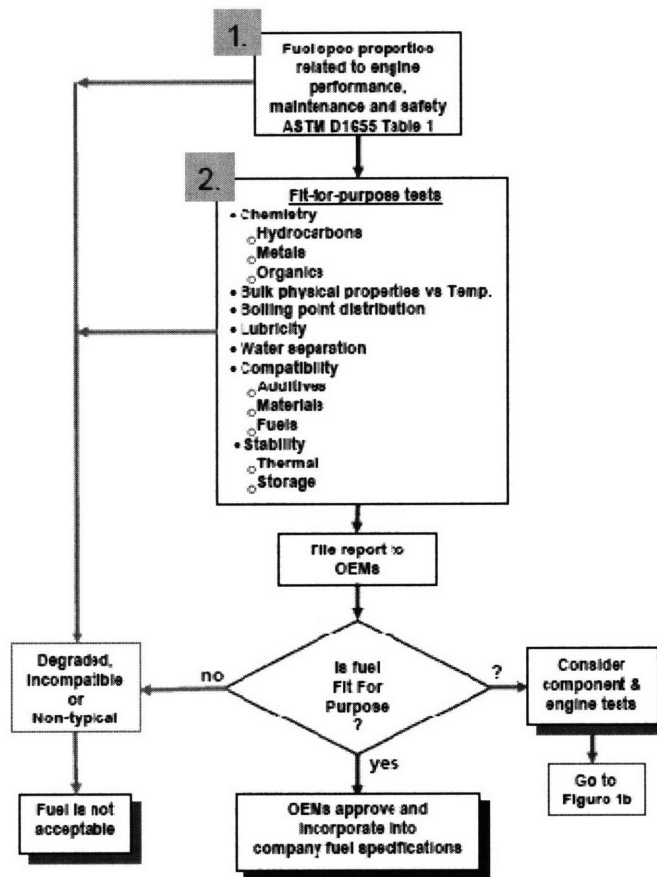


Figure 6.2. Approval Process for Alternative Aviation Fuels Part 1.⁷⁶

If the OEM's require additional evaluations, the second part of the process follows (see Figure 6.3). The qualification and certification will include component tests, such as fuel controls, fuel pumps, and combustor tests. In addition, full scale engine tests may be required for certification. If the fuel is acceptable for use, the OEM's will approve it and incorporate it into company fuel specifications. Large volumes of fuel, 100,000 to 250,000 gallons, are required for this phase of the evaluation.

⁷⁶ Clifford Moses, "Development of the Protocol for Acceptance of Synthetic Fuels Under Commercial Specification," Coordinating Research Council and the U.S. Army TACOM, 2007, Pg 6.

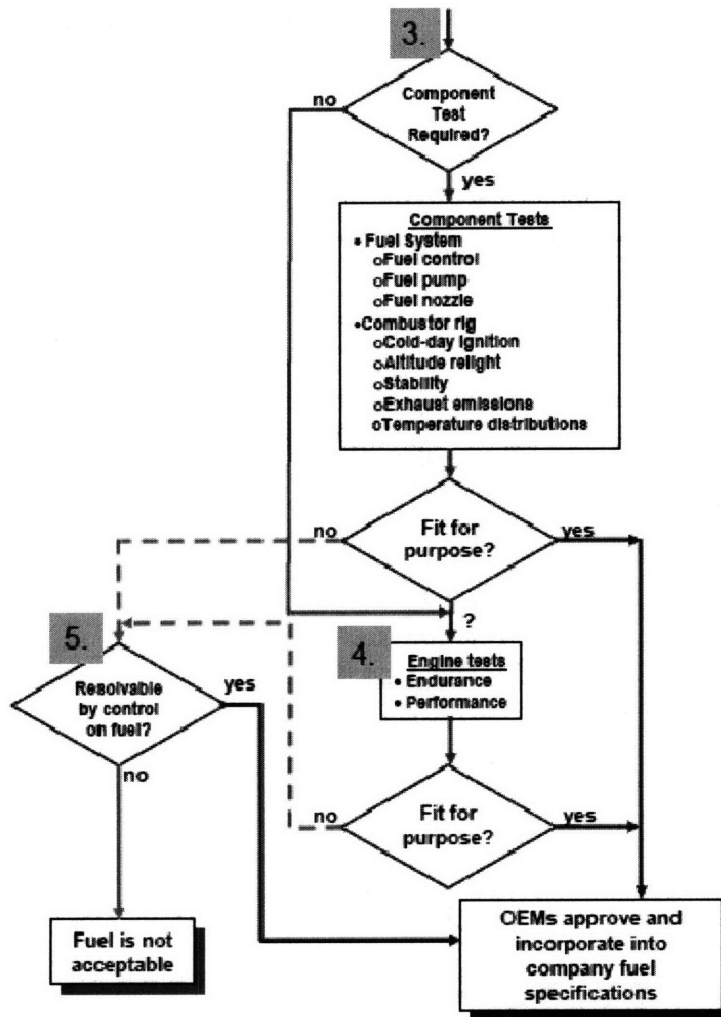


Figure 6.3 Approval Process for Alternative Aviation Fuels Part 2.⁷⁷

It should be noted that the Air Force certification process generally similar but requires additional testing for qualification and certification. The Air Force process is more comprehensive than the commercial process since the fuel is used not only in aviation equipment but group diesel equipment as well. In addition, the AF process considers all

⁷⁷ Clifford Moses, "Development of the Protocol for Acceptance of Synthetic Fuels Under Commercial Specification," Coordinating Research Council and the U.S. Army TACOM, 2007, Pg 7.

aspects of the enterprise, of which aviation is only one part. The more complete commercial process is shown in Figure 6.4, but it does not include any requirements for the fuel to be used in diesel equipment.

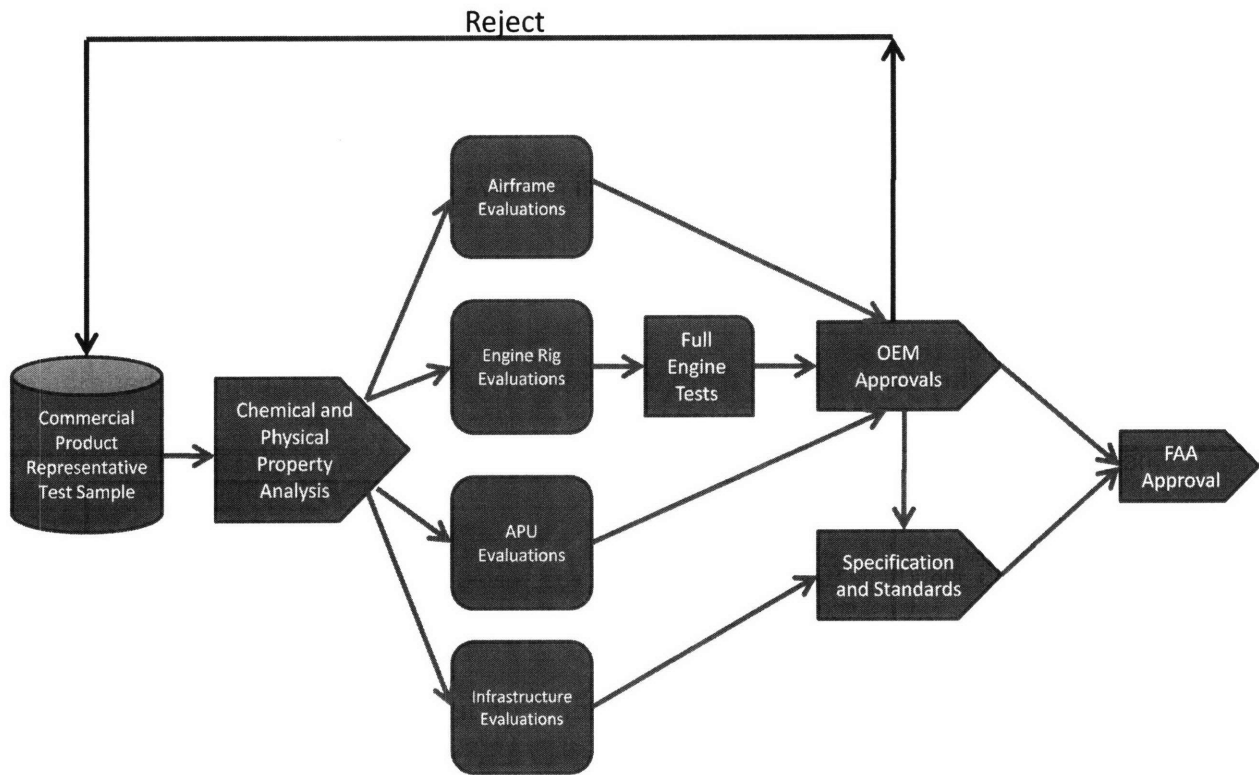


Figure 6.4 Approval Process for Alternative Fuels.

The qualification and certification of alternative fuels is one of the key steps to crossing the “Valley of Death” and the use of the fuel by early adopters, but many other issues must be addressed to cross the “Valley.” Most of the remaining challenges relate to construction, environmental concerns, and project financing, which will be covered in some depth in future chapters.

6.3 Initiating the Dynamics that Build an Industry

In this rest of this chapter, I will explore how the approval of a fuel can start the dynamics for its early adoption (the dynamics of crossing the “Valley of Death”) and how these dynamics spur multiple adopters (the early majority) and provide the necessary dynamics to build an industry. Once the industry starts, market effects will determine long-term sustainability. The basic systems dynamics model is shown in Figure 6.5.

Approval Process: To understand the dynamics, the first key steps are shown in the upper left hand part of the model, starting with the OEM approval. To help follow the model, the key parameters that describe the dynamic interaction loops are identified by **bold underlined comments**. Key variables that control the dynamics are linked by causal arrows that describe the direction of the impact of the variable on the next variable. The key steps to reach this entry point into the model were described earlier in the chapter, but, in general, to start the process, the OEM’s must approve the fuel for use. Once approved, the FAA can grant approval for use in the approved aircraft and individual airlines can use the FAA approval to begin using the fuel. Since aviation has many types of aircraft, both produced domestically and globally, adopting airlines may request additional OEM’s to approve the fuel for use expanding the number of potential aircraft that can use it. **Increase the Number of Users:** With airlines adopting the fuel, they can work with other airlines at an airport to approve its use and begin to work as a cluster at a single location to attract a producer. This dynamic continues to build until all types and models of aircraft approve the use of the alternative and all airports are in a position to use the fuel if they choose.

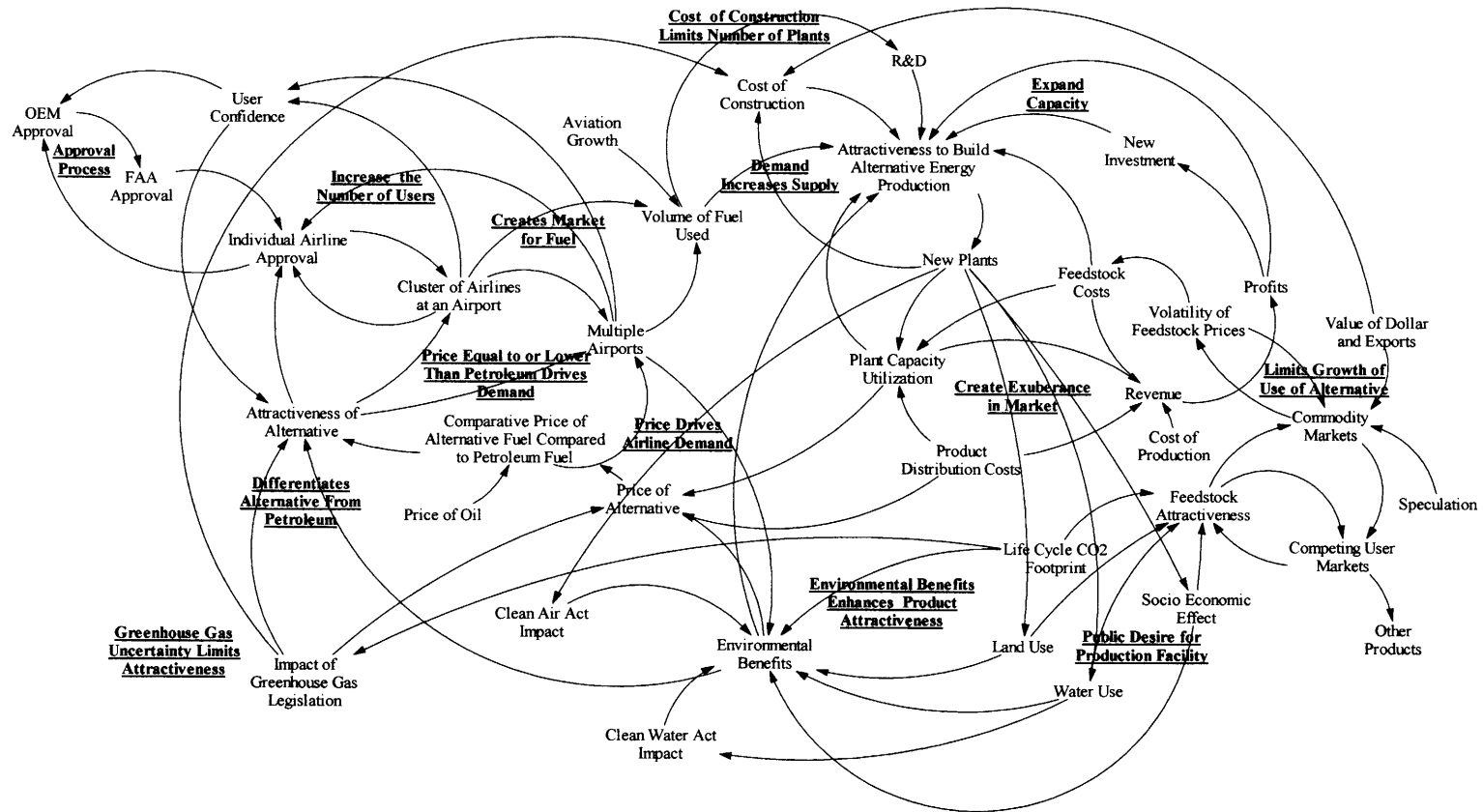


Figure 6.5 Alternative Aviation Fuel Systems Dynamic Model

Creates Market for Fuel: To gain producer interest, the volume of fuel used at a given airport demonstrates a potential demand, which creates attractiveness for the industry to build an alternative energy plant.

Demand Increases Supply: If the demand is strong and the first plants have high plant capacity utilization, additional plants will be built, which creates exuberance in the industry and can attract additional investment. Plant capacity utilization has an impact on the price of the fuel and the revenues generated by the plant. **Create Exuberance in Market:** Plant revenues are driven by the cost of production, the cost of the feedstocks, and the product distribution costs. **Limits Growth of the Use of Alternative:** Feedstock prices impact the attractiveness of building plants, but these prices are tempered by the volatility of the market. Alternative energy feedstocks such as coal, oil shale, or biomass, will be driven by commodity market dynamics such as the competition for these products by competing markets. For example, in corn ethanol production, the commodity market reacted to the value of the dollar, and competition in other markets, such as food production, thereby driving the costs up and increasing the volatility of the resource. These market dynamics drive the attractiveness for feedstock for use in alternative energy from a price standpoint. Speculation also will drive the market dynamics and volatility of feedstock costs and subsequently the price.

The plant revenues are determined by the amount and price of the product sold. Profits are determined by the revenues less the operating costs, the distribution costs, and the feedstock costs. **Expand Capacity:** The more profitable the venture, the more enthusiasm to build more plants by the companies in the market, and this enthusiasm draw in new investors.

The attractiveness of building more plants is enhanced by the profitability and by R&D that can be used in subsequent plants to reduce costs or improve efficiency. **Cost of Construction Limits**

Number of Plants: The main element that inhibits the initiation of this set of dynamics is a large hurdle for the first plants -- the cost of construction. This issue will be explored in more detail in later chapters, but the challenge to starting these dynamics is the construction of first-of-a-kind plants. First-of-a-kind plants have significant financial and technical risks, which may require government support. Very expensive plants may require companies with large balance sheets and access to large amounts of capital. But most alternative energy innovators are small to medium companies, so it may not be possible for them to build first-of-a-kind plants without some government intervention. The challenges of securing financing for the first plants will be a significant limiter, even if the airlines move to buy a large volume of fuel at an airport. The dynamic of the purchase requirement and the ability to offer long term off-take agreements by the user may be a key step in increasing the attractiveness of the construction of the plant.

Price Drives Airline Demand: The adoption rate by airlines drives the volumes of fuel that they are willing to purchase and this dynamic spurs investment in plants. **Price Equal to or Lower than Petroleum Drives Demand:** The adoption rate by airlines is primarily driven by the comparative price of the alternative to petroleum and secondarily by environmental concerns. The price of the alternative is driven by the cost of production and the plant capacity utilization. The price will be compared to petroleum and, if equal, especially if it has less volatility than oil, the fuel is likely to be adopted. If the price is less than petroleum, the adoption rate will be much more rapid. The price of the alternative compared to petroleum will drive the adoption of the cluster of airlines at a single location or the number of different airports that adopt the

fuel. In general, price will be the significant driver for the market. The sustainability of this dynamic will be based on the cost of petroleum derived fuels.

Differentiates Alternative From Petroleum: Environmental attractiveness will also increase the dynamics of the attractiveness of the alternative. **Public Desire for Production Facility:** Feedstock choice for production will create an environmental footprint that includes land use, water use, socio economic effects, lifecycle CO₂ footprints, local air quality impacts, and Clean Water Act impacts. In addition, the production of the fuel will also have an impact on all these issues, especially for fossil fuel plants. **Greenhouse Gas Uncertainty Limits Attractiveness:** Currently, there is uncertainty with regard to greenhouse gas emissions, as there are currently no legislative frameworks. However, if a cap and trade system or carbon tax is implemented, it will add significant cost drivers to the overall system dynamics shown in the model. The uncertainty causes stagnation, so it can be viewed as a critical point in the initiation of the industry.

When looking at the three alternative fuel feedstocks for aviation — coal, oil shale and biomass — all have potentially significant impacts on the environment. Resources that have the potential to significantly reduce greenhouse gases may create other environmental problems due to carbon liberation during land use changes (e.g., palm oil) or may require large amounts of energy for harvesting and production (e.g., ethanol). Fossil sources will require carbon capture and sequestration, adding additional costs to the construction and operation of production facilities. Water use and rural socio economic issues can overshadow the potential of each feedstock based on local issues. The problem is that there are no comprehensive

frameworks to evaluate the relative environmental benefits or hazards. Chapter 6 will provide some frameworks for evaluating these risks.

6.4 Chapter Summary:

The system dynamics model provides a framework to consider how the industry will develop if three key steps can be solved to begin the process and how the industry will respond to changes. The first step is that representative fuel samples be produced and approved for use. The approval starts the process of building clusters of airlines that want to buy the fuel. The second dynamic is the attractiveness of the fuel based on price. Many variables drive the price of the fuel, but if it can be produced and sold at the market price of petroleum derived fuel or below, the adoption rate will increase. The price is also influenced by environmental benefits and potential greenhouse gas legislation. There may be situations where the adoption of greenhouse gas mitigation overseas drives the adoption of less carbon intensive alternative fuels in the U.S. The environmental benefits can drive demand, but they also impact cost and the cost comparison to petroleum and this circumstance may limit adoption. This analysis reveals that it is essential to find ways to help the airline industry adopt alternative fuels and to help start the dynamics associated with first-of-a-kind plants. The remaining chapters of the thesis will explore the financial and environmental issues related to use of alternative fuels for aviation in more detail and provide recommendations to help start the dynamics of the adoption of alternative fuels.

7.0 Balanced Scorecards and Portfolio Management

7.1 Chapter Overview

In this chapter, I discuss the growing worldwide demand for energy and the concerns associated with global warming due to fossil fuel use. However, since there are no alternative fuels for aviation, greenhouse gas emissions from aviation will likely continue to grow unless sustainable, environmentally friendly alternatives are made available for the industry to use. One of the issues with alternative fuels is the lack of tools to assess the sustainability (financial and environmental) of an alternative and little methodology to compare alternatives on an equal basis. In this chapter, I present a balanced scorecard approach to compare the sustainability of alternative aviation fuels and a risk analysis worksheet to help qualitatively define risks associated with the alternative. By combining the scores from the balanced scorecard and the risk analysis worksheet, one can compare risk versus return and build a portfolio of alternative fuel options. I extend this approach in a comparative manner to stock market portfolio theory and describe a methodology to compare alternatives to the “low risk option,” petroleum derived fuels. I conclude the chapter with a brief discussion on the natural hedging that arises from processes that produce several products in addition to aviation fuel and how this may enhance the overall commercial viability of a project.

7.2 Energy Demand and Global Climate Change

Energy is critical to sustained economic growth, and the aviation industry is integral to the U.S. role in global markets. Lyon (2005) in his presentation of the ExxonMobil Energy Outlook states that oil and gas will remain the primary sources of energy through the middle of

the 21st century, with growth in coal primarily for power generation and growth in renewables in all energy sectors. However, their impact will remain small. He encourages continued development of all energy supplies and suggests that more groundbreaking research is needed. ExxonMobil predicts the annual growth rate for oil to be 1.6% per year through 2020 with higher growth for natural gas 2.4% per year and lower growth for coal 1.5% per year. Fuel demand for the transportation sector is projected to grow at 1.9% annually through 2020. The world has consumed approximately 1 trillion barrels of oil since the beginning of the oil age that started in the late 1800's and it is likely that we will consume another 500 billion barrels by 2020. Current worldwide oil reserves are estimated at 2 – 3 trillion barrels and conventional oil reserves are estimated at another 2 trillion barrels. Left to market conditions alone, oil will be the dominant source of energy for transportation for the next several decades.⁷⁸ The International Energy Agency (2006) stated that fossil energy will remain dominant until 2030 with an average projected growth rate of 1.6 and with over 70% of the growth coming from developing countries. Over 50% of the energy growth will be for generating electricity, and 20% will be used to meet transportation needs. Carbon dioxide (CO₂) levels are projected to climb at 1.7% per year, representing a 55% increase in the period from 2004 to 2030. Developing countries will account for 75% of the increase in global CO₂ emissions in this time period. The growth in energy consumption and CO₂ emissions can be slowed with global policy aimed at energy security and greenhouse emissions.⁷⁹

⁷⁸ John Lyon, "The Energy Outlook," ExxonMobil, 2005

⁷⁹ International Energy Agency, "World Energy Outlook," 2006.

While oil may be the dominant global resource for aviation fuels, national security issues, political actions, including regulations and mandates, and global climate change may necessitate aviation's use of alternative energy resources to produce fuel. The National Commission of Energy Policy (2004) state that the U.S. must address its contribution to climate change related to energy usage, but must do so in a manner that balances the global nature of the problem with the competitive position of the U. S. Sound U.S. policy would focus on improving the nation's energy security by reducing the vulnerability of high energy prices and supply disruptions. The Commission recommended expanding energy supplies, including natural gas, clean coal, nuclear power, and renewable energy. The commission also recognized that greenhouse gas emissions are a century-scale, global issue and the amount of greenhouse gases must slow, stop, and reverse over the next 3 – 5 decades. Uncertainty exists about the costs and benefits of mitigation, but the world must address climate change in an organized collaborative manner. For the U.S. to be successful in this undertaking, the nation's environmental objects must be carefully integrated into a broader energy policy that focuses on supply and national security. The Commission encourages the development of a suite of domestically produced transportation fuels to dampen the impact of high oil prices and oil supply disruptions. No single fuel or technology should be chosen; rather a diversity of low-carbon alternative fuels from a variety of domestic resources provides the will provide the best way forward. In addition, alternative fuels that can be successfully integrated into the existing infrastructure or vehicle fleet offer advantages over fuels that require new infrastructures or of new fleets of vehicles.⁸⁰

⁸⁰ The National Commission on Energy Policy, *Ending the Energy Stalemate: A Bipartisan Strategy to Meet*

7.3 Candidate Resources for Alternative Aviation Fuels

In the U. S., the three main resources with potential are shale oil derived fuels produced with conventional petroleum refining technology, coal-to-liquids fuel produced by gasification and Fischer-Tropsch technology, and biofuels produced various means, including gasification and Fischer-Tropsch technology, thermal chemical conversion followed by hydroprocessing, or the upgrading of oil seeds or algae oil with hydroprocessing. Advances in technology may offer other alternatives, including the conversion of CO₂ into fuels or other chemical processing techniques that are more cost effective and energy efficient.

As discussed in Chapter 2, the first wave of innovation by the military was in the 1970's with shale oil. The U.S. has significant reserves of oil shale that have been estimated at 1.8+ trillion barrels. Retorted shale yields liquid hydrocarbons in the middle distillate range, ideal for producing jet and diesel fuels. The EPAct of 2005 directed the Secretary of Defense to develop a strategy to use oil shale for defense purposes and national security.⁸¹ In consequence, the military partnered with the Departments of Energy and Interior, state governors, and official representatives and members of potentially impacted communities to form the Task Force on Strategic Unconventional Fuels.⁸² Oil shale historically has been one of the resources considered vital to the military and national security. In the early 20th century, oil shale reserves were set aside on federal land out of concern for the Navy's petroleum supply. The oil can be recovered by retorting or pyrolysis of the oil shale to crack the kerogen into

America's Energy Challenges, December 2004.

⁸¹ Anthony Andrews, "CRS Report for Congress: Oil Shale: History, Incentives, and Policy," Congressional Research Service, Library of Congress.

⁸² Task Force on Strategic Unconventional Fuels, "Development of America's Strategic Unconventional Resources: Initial Report to the President and Congress of the United States," September 2006.

hydrocarbons, which can be upgraded using conventional petroleum refining technology. Although shale oil challenged the processing technologies of the 1970's, aviation turbines fuels suitable for use in U.S. Air Force aircraft were produced.⁸³ With today's modern refining technology, oil shale can readily be processed into high quality aviation fuels. James Bartis of the Rand Corporation (2005) stated that the commercialization of oil shale should be supported and developed at a measured pace but policy should be crafted for oil shale development. This policy should address land use and ecological impact, air quality (local and regional), greenhouse gas emissions, water quality, socioeconomic impacts, federal leasing of oil shale tracts, production costs, market risks and water consumption.⁸⁴

As Chapter 2 has explained, the military has been leading the second wave of innovation on alternative fuels by evaluating, testing, and certifying fuels produced by the Fischer-Tropsch process. The benefit of these fuels is that they can be produced from a wide range of feedstocks including natural gas, petroleum coke and residues, coal, and biomass. SASOL in South Africa commercialized coal gasification and chemical production in the 1950's. To produce transportation fuels, SASOL employed the Fischer-Tropsch process, a technology that was pioneered in Germany in the 1920's. In the late 1990's, in response to shortages of jet fuel at Johannesburg International airport, they began working with the airline industry, aviation equipment manufactures, and Southwest Research Institute to qualify a blend of coal derived Fischer-Tropsch fuels for use in aviation. In 1999, airlines operating out of Johannesburg began using a blend of coal derived Fischer-Tropsch fuels and conventional petroleum derived fuels

⁸³ "Composition of Shale Derived Fuel Samples," W. E. Harrison and D. D. Potter, Chapter 13, Shale Oil Upgrading and Refining, Butterworth Publishers, 1983.

⁸⁴ James Bartis, Tom LaTourrette, Lloyd Dixon, D. J. Peterson, Gary Cecchine, "Oil Shale Development in the United States: Prospects and Policy Issues." Rand Corporation, 2005.

and continue to provide that product to the market today.⁸⁵ Several years later, as a result of the OSD Clean (latter named Assured) Fuel Initiative, the U.S. military began looking at Fischer-Tropsch fuels produced from natural gas by the Syntroleum Corp. The zero-sulfur, clean-burning fuels offered potential for use in all military systems and would reduce CO₂ emissions at the aircraft tailpipe by 2 – 3% (regardless of feedstock) if used in a 100% neat form or proportionally lower if blended with conventional petroleum.⁸⁶ The historic demonstration flights of the B-52 in 2006 and the transcontinental flight of the C-17 (2007) used fuel produced from natural gas. Syntroleum supplied fuel for the B-52 flight and Shell for the C-17 flight. With these uses by the commercial sector in South Africa and the military in the U. S., Fischer-Tropsch fuels from both coal and natural gas were demonstrated to be suitable for aviation, and when available, Fischer-Tropsch fuels from biomass will be suitable for use. In the U.S. the large resource base that is attractive for Fischer-Tropsch fuel production is coal. The U.S. has large supplies of coal that are secure and have lower price volatility than petroleum or natural gas. But environmentalists have raised concerns about the impact on global warming of coal-to-liquids (CTL) because the production of the fuel using conventional gasification and Fischer-Tropsch technology would have a CO₂ footprint double that of petroleum derived fuels. This footprint can be reduced to CO₂ parity with petroleum if the CO₂ produced in the processing is captured and sequestered, and a footprint lower than petroleum can be achieved if the coal is co-fired with biomass.⁸⁷⁸⁸ Other challenges faced by CTL include water consumption, the

⁸⁵ Cliff Moses, "Sasol Synthetic Jet Fuel Program," Presentation at the Fischer-Tropsch Turbine Engine Applications Conference, May 2006.

⁸⁶ Personal communication, Dr. James Edwards, Air Force Research Laboratory, Mar 2007.

⁸⁷ Robert Williams, Presentation: "Toward Ultra-Low GHG Emissions for Synfuels," Princeton University, March 2006.

impact of mining, uncertain production costs, and the relationship of coal with the volatile oil markets.⁸⁹

Recently, there has been increased interest in the use of biomass to produce jet fuels. Virgin Atlantic and Boeing pursued a joint collaboration to demonstrate biojet on a 747 aircraft. This historic flight took place on February 24, 2008. In addition, DARPA initiated research programs in 2006 with UOP, EERC, and GE to produce samples of biojet fuel that would meet the current military specification for jet fuel JP-8. The generally accepted approach to an acceptable biojet is to hydroprocess the oils from seed crops or algae oils. Although research is in the early stages, these fuels offer promise in terms of reducing greenhouse gas emissions. Biobased fuels, however, may create other problems. These include land use and erosion, energy required to produce the fuels compared to released when used, water pollution and runoff from fertilizers and pesticides, water use, and, if a food crop is used, the food versus energy issue. The World Resources Institute (2003) states that two different environmental impacts should be compared when analyzing biofuels: water quality issues and climate change mitigation.⁹⁰

7.4 Development of Sustainable Alternative Aviation Fuel Strategy

As there is no one resource that stands above the others for aviation fuel production, it is essential to develop a portfolio of alternative fuels based on a sustainable strategy that

⁸⁸ David Gray, Charles White, Glen Tomlinson, "Increasing Security and Reducing Carbon Emissions of the U.S. Transportation Sector: A Transformation Role for Coal with Biomass," DOE National Technology Energy Laboratory, August 2007.

⁸⁹ Jim Bartis and Frank Camm, "Project Update: Unconventional Fuels," Rand Corporation, December 2006.

⁹⁰ Suzie Greenhalgh and Amanda Sauer, "Awakening the Dead Zone: An Investment for Agriculture, Water Quality, and Climate Change," World Resources Institute, 2003.

balances user needs, cost, and availability with corporate social responsibility. From a government standpoint, how can we balance national security, economic security, and environmental stewardship? From an aviation industry standpoint, how can we balance cost and social responsibility? Figure 7.1 illustrates the interplay of these factors. The main challenge to develop a way forward is to synthesize complex sets of information with location specific issues into a balanced portfolios that will change over the next several decades as technology and innovation on alternative energy emerge. In this chapter, I will explore the development of balanced scorecards for alternative energy projects and how they may be analyzed using stock market portfolio theory.

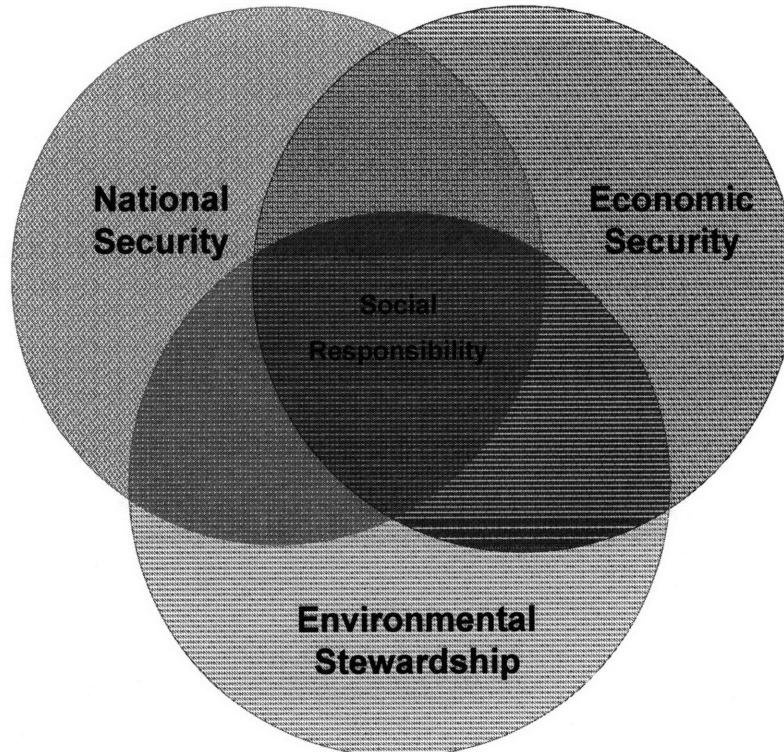


Figure 7.1. Balancing National and Economic Security with Environmental Stewardship

7.5 Balanced Scorecards

Balanced scorecards offer a method to systematically organize information about alternative energy projects and put them into a framework that the military and civil aviation industry can use to rate their relevance and potential for aviation. To build a balanced scorecard, the first perspective to be explored is the key elements of alternative energy strategy that a project developer would use. These elements include financial, local impacts, global impacts, and externalities and barriers, as shown in Figure 7.2.

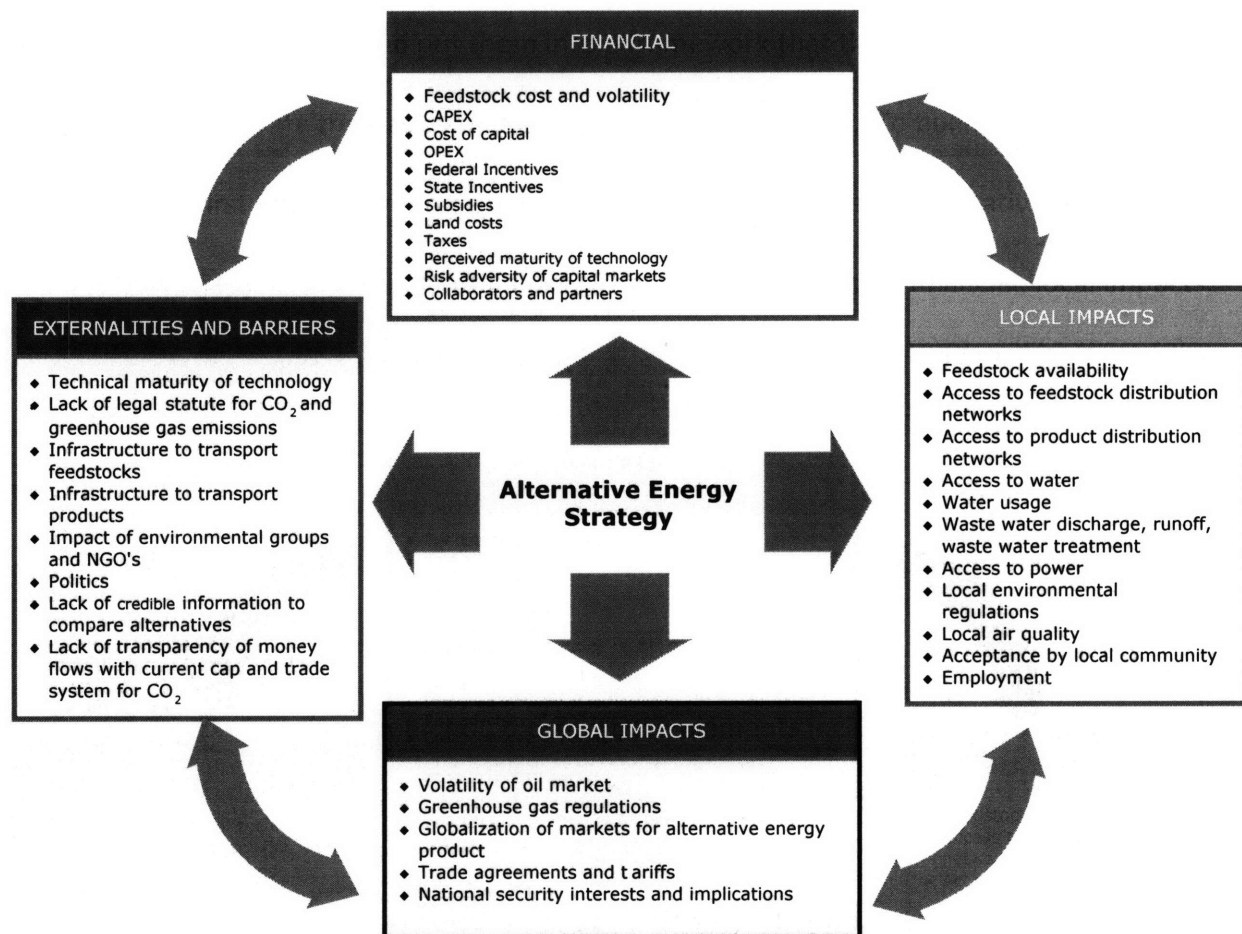


Figure 7.2. Elements of an Alternative Fuel Producer Balanced Scorecard

Financial viability is the key driver for an alternative fuel producer: a company must be able to produce profits and increase shareholder value to be a sustainable business venture. The challenge of alternative energy projects is that the more novel a technology, especially if the technology has not been demonstrated on a commercial scale, the higher the risk it will be perceived as having by the investment industry. Investors want high returns for high risks. This situation creates a challenge for a project that has to compete head-to-head with oil prices. Investors are also aware of the boom and bust cycles that have been part of the history of the oil age. Alternative energy blossomed in the 1970's and included massive efforts at developing shale oil, direct liquefaction of coal, and electric cars. All these technologies were later shelved in the 1980's and 1990's. Recently there has been exuberance in the market for the construction of ethanol plants, leading to a surplus of capacity and loss of margins.⁹¹ Even the enthusiasm behind the hydrogen economy and fuels cells has been tempered by high costs and technical barriers.

Given these uncertainties, a new alternative energy company must carefully evaluate the cost of the feedstocks it will use and the market volatility for the feedstock. Once a new feedstock is identified, it may create a price escalation until the market determines what the price should be. Currently corn futures are breaking new market price levels as the wisdom of the market determines the correct price for the commodity. Not only is the volatility of the market an issue, but there must be a stable infrastructure to transport the feedstock to the production facility and an infrastructure in place to continuously produce the feedstock.

⁹¹ David Rotman, "The Price of Biofuels," Technology Review, January 2008.

Locked in contracts for feedstocks maybe a less risky approach for new projects versus riding on the spot market for the material.

Capital Expenses (CAPEX) and the cost of capital is a key concern for many projects. A challenge in the energy business is scale. Larger facilities have traditionally been favored in the energy industry because the cost per unit production can be reduced with scale. Large scale projects usually require high CAPEX and if they are first-of-a-kind plants, a complimentary high cost of capital. This is can be a significant barrier for a small company that is trying to be a disruptor in the business sector, and it slows the entry of large firms that have established products and markets. In a sense, everyone wants to be second or third: let someone else take all the risk, and when the product is proven, buy the company and then grow. With the high CAPEX and high cost of capital barrier, developers are often driven to smaller, less cost intensive projects where operating expenses (OPEX) become a dominant factor since the margins are reduced because of the smaller scale. In some cases, such as biofuel projects, the high cost of transport of low energy density biomass or limited access to rail or barge networks, drives the down the size of a plant. Location becomes another factor in the size of the plant, driven primarily by the infrastructure needed to secure feedstocks and the infrastructure needed to distribute products. To sustain any size plant, the developer must build strong collaborations vertically in the supply chain in order to be successful. A key analysis of a new project should include a careful look at the supply chain and the position the new company will occupy. This position will dictate the power that the business has in the supply chain and its ability to negotiate with collaborators.

To help incentivize alternative fuel projects, the developer may need to look into federal and state incentives. These could include loan guarantees, tax credits, tax breaks, accelerated depreciation, direct investment, or other incentives. Berg and Paterson (2008)⁹² investigated several government incentives and the impacts they would have on a coal-to-liquids plant. These included purchase agreements that address key project risks and enhance the ability of the developer to attract capital, tax incentives to reduce output pricing, loan guarantees to address the high cost of capital, and a tax credit based on carbon dioxide sequestration. Based on their analysis, all these incentives have positive impacts on the development of the technology and the construction of first-of-a-kind plants. Berg and Paterson also demonstrate that state incentives, such as investment tax credits, grants, and improved permitting, and regulatory processes, have positive impacts of the transition from technology development to technology deployment. The challenge of federal and state incentives is that if they are means to make an alternative fuel business profitable, it is not a sustainable business as the incentives can change over time. In fact, most incentives in the energy bills of 2005 until the present have time limit clauses.⁹³ A sustainable business must have the ability to be profitable without significant federal or state incentives.

States play a critical role in determining the local impacts of a new alternative energy project: states permit the site of the plant and approve the environmental impact statement. Siting and permitting is the first step in the construction of a new facility and is one of the factors controlling the speed at which the plant can be constructed. The developer must work

⁹² David Berg and Andy Paterson, Briefing "The Business Case for Coal Gasification with Co-Production," DOE Briefing, January 2008.

⁹³ Incentives can be found in the EAct 2005 and the Safe, Accountable, Flexible, Efficient Transportation Act: A Legacy for Users.

with the state on locations that pass the “not in my back yard” or NIMBY test. No facility will ever break ground if the local residents do not want the plant. Sites must be chosen such that necessary infrastructure such as power, water, feedstock supply and product distribution are suitable for sustained operation, in locations where the local community supports the project. A new project must meet local and federal air quality standards and the requirements of the Clean Water Act. Care must be taken to consider the environmental issues surrounding the use of the feedstocks such as the impact of the mining of coal or impact on soil erosion and water pollution with biomass. Since the local community benefits through jobs and taxes, local support can be a major factor in site selection.

Project developers also must address the global impacts of their facility. Transportation fuels are part of global markets and therefore subject to the price volatility of oil. Projects that can compete in the global market are sustainable. In some cases, national interests and import tariffs provide a level of support for U.S. alternative energy projects. For example, the \$0.54 tariff on Brazilian ethanol provides a level of market protection to U.S. producers.⁹⁴

Another key consideration that must be considered for new projects is global climate change. Although legal frameworks are not currently in place for greenhouse gases, emerging legislation related to cap and trade programs or carbon taxes are likely. All new alternative energy projects must consider the impact of greenhouse gas legislation as part of their business model.

⁹⁴ http://www.associatedcontent.com/article/233100/ethanol_from_corn_vs_ethanol_from_sugarcane.html

A new alternative energy project developer must also consider other project externalities and barriers. Technical maturity reduces project risk, but aggregation of proven technologies into a new process may create a high risk for investors. Coal-to-liquid project developers are facing this dilemma. Although gasification technology is commercially proven as is Fischer-Tropsch technology, there is no operating plant in the U.S. that currently operates both a gasifier and a Fischer-Tropsch unit. The only global commercial entity is SASOL in South Africa. The externality of the risk of meshing proven technologies can be a significant challenge for the project developer. Other externalities related to the transport of feedstocks can also have significant impact. For example, rail capacity limitations can limit the delivery of coal or biomass. The transportation of products can also cause significant limitations. For example, the ethanol market in the U.S. is severely impacted by transportation limits of trucks and rail because there are no pipelines that will accept ethanol (or biodiesel) for transport. Other externalities that add uncertainty are the impact of environmental groups and NGO's. Although often such groups target fossil fuel projects, they have a track record of creating hurdles for renewable energy projects such as wind power. Many times the externalities are compounded by the lack of reliable information and limited ability to compare alternatives. Finally, emerging challenges for companies that are working toward strong corporate social responsibility (CSR) are hindered by the lack of transparency of their efforts especially in some of the current CO₂ cap and trade systems. If there is no clear traceability of how effective the funds spent on CSR impact their intended end users, companies become more reluctant to participate in these types of activities.

Government evaluators need a balanced scorecard to compare and contrast various alternative energy projects and to help them build a portfolio of choices. Balanced scorecards are used by government agencies and private industry as a tool to review complex projects and the sensitivity of the parameters to the overall project. For example, the Ohio Public Utilities Commission uses a balanced scorecard to evaluate the siting of projects. Their scorecard includes ecological, social, and constructability to develop numerical summary and a total weighted score.⁹⁵ For the government, all of the elements of the industrial scorecard are relevant, but additional area's must be explored that address overall sustainability issues. (see Figure 7.3).

⁹⁵ Ohio Public Utility Commission, Ohio Power Citing Board, Pre-Application Analysis, 2005.

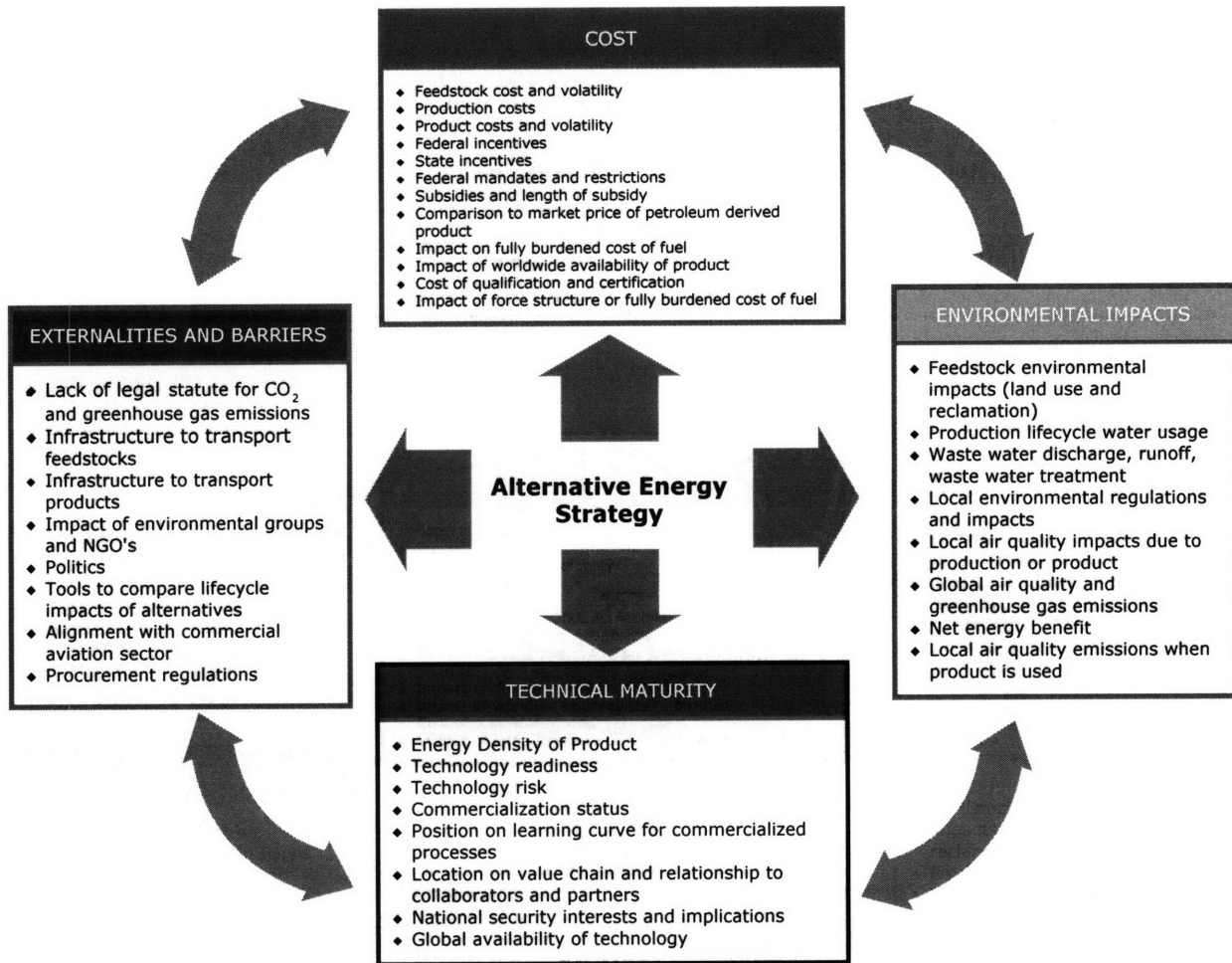


Figure 7.3. Elements of a government evaluator balanced scorecard

Cost and predictability of cost are key elements that a government evaluator should consider for alternative energy projects. Government agencies such as the DoD can benefit significantly if the price of fuel can be estimate accurately for several years into the future. A consideration for feedstock availability and potential price volatility should be part of the project consideration process. In addition, federal mandates and regulations may play a significant role for the military and create requirements that cost more than current products. The fully burdened price of the fuel should be a key consideration as well as the requirements related to new infrastructure as well as equipment qualification and certification. The military

has struggled with alternative fuels for non-tactical vehicles such as E-85 and biodiesel since there were no companion budget increases for new infrastructure for these products. A similar issue faces the civil sector because the industry is slow to adopt the installation of E-85 pumps in a comprehensive manner. On the cost side, one final consideration should be made related to global availability. Although a fuel might be more costly domestically, evaluators should ask whether it be bought globally at price consistent with petroleum market dynamics.

Environment impacts must be evaluated not only from a fuel production standpoint, but from an end use standpoint. A fuel that solves greenhouse gas emissions but creates local air quality impacts may cause significant problems to a base commander. For example, ethanol blends in some locations have created increased ground level ozone and local air quality problems. Alternative fuels with a high oxygenate content may also create other hazardous air pollutants when combusted. Some fuels may not have a net energy benefit. The literature is full of articles over the debate on ethanol as to whether it is energy positive or energy negative.

Technical maturity of the production process and the product must also be a consideration. The lowest risk projects are those where the technology has been commercialized and there has been a history of learning about the process and the products. Ethanol production is a good benchmark for this consideration. The challenge here is that to be more innovative, more risk will need to be realized. A balanced assessment of maturity and the impact on logistic supplies and operational performance should be conducted. Projects that provide national security benefits, coupled with environmental stewardship, should receive a high relative rating in any assessment.

The government also must consider other externalities such as procurement regulations, mandates, and executive orders. The political process and the will of Congress can provide direction to the military that is different from the civil sector. Emphasis should be placed on evaluating projects that provide benefit not only to the military but to the civil sector as well. Clear alignment with the civil sector adds strength to a project.

To assess a series of alternatives, a worksheet such as figure 7.4 could be used. The worksheet identifies key elements from the commercial developer and government evaluator balanced scorecards and a way to score compliance and weight the relevance to the evaluation. Projects with high scores in both compliance and relevance should be considered key projects for government/industry collaboration. The scoring mechanism chosen looks at the importance of the element and uses a 0 – 5 scale.

- 0 Not important
- 1 Low importance
- 2 Medium low importance
- 3 Medium importance
- 4 Medium high importance
- 5 High importance

The impact of each element is also evaluated on a scale from 0 to 3.

- 0 No impact
- 1 Low impact
- 2 Medium impact
- 3 High impact

Using both these scores and comparing them to the maximum value (highly important and high impact) gives a relative positioning for the project. The importance of these parameters over time can also be accessed. For example, I used the scorecard to evaluate oil shale in the 1970's compared to today. (see Figure 7.5) In the 1970's the oil crisis created strong social impacts. The government was therefore very motivated to increase supply at the expense of technology maturity and environmental concerns. Using the importance of the parameters in the scorecard the technical maturity was 18/40 or 45%, cost was 37/80 or 46%, environmental concerns were 13/50 or 26%, and the externalities (need for supply) were the dominant issue: 40/55 or 73%. Similarly, the impact of technical maturity was 11/24 or 46%, cost was 23/48 or 48%, environmental impact 11/30 or 37%, and the externalities 25/33 or 76%. This analysis shows that the impact of the externalities was the critical driver for the advancement of the technology.

If the analysis were conducted today, it would reveal the importance and impact of many factors have changed. As shown in Figure 7.6, Technical maturity is more important today as it relates to the cost of the fuel. The technology importance rating today is 25/40 or 63% and the impact is 15/24 or 63%. Technical maturity is focused on the retorting technology as the industry as a whole has made significant improvement in the processing of crudes similar to shale oil and the shale oil is likely to be viewed as just another refinery input, like oil sands from Canada. If it were not for the large resource base in the U.S. and the historical view of oil shale as an alternative, this resource would be categorized as heavy oil. Cost is a strong driver because the Office of Management and Budget (OMB) has stated that the military cannot pay a premium for an alternative fuel. The cost importance rating is now 57/80 or 71% and the

impact is 38/48 or 79%. Environmental impact is a key issue, as no project being developed in the 1970's would meet the criteria for commercialization today. Environmental impact is rated at 50/50 or 100% important and 30/30 as the impact. This is probably the most significant impact at the moment that will determine whether an alternative will be commercialized. Finally, in comparing the externalities of today, the strong governmental push of the 1970's is lacking. Language in the Energy Act of 2005 pushed for the development of this resource, but subsequent legislation and limited funding have made the language nearly non-executable. The externalities to oil shale today are rated at 41/55 or 75% for importance and 30/33 or 91% for impact.

The value of the balanced scorecard is that it can be used to explore the relative impacts of different scenarios or what will happen if different aspects are changed. As technologies mature the ratings can be updated and the impact of federal incentives and investment can be reevaluated and modified.

The best approach for the military is to build an alternative energy portfolio and compare it to the current use of petroleum. To build an alternative energy portfolio, stock market portfolio theory could provide a framework for ranking and comparing projects.

Balanced Scorecard Part 1

Technical Maturity	Importance (0 - 5)	Impact (0 - 3)
Technology Readiness Level		
Technology Risk		
Commercialization Readiness		
Position on the Learning Curve for Commercialized Process		
Correctly Positioned on Value Chain with Collaborators		
Technology Saleable Globally		
Feedstock Supply Infrastructure Readiness		
Product Distribution Infrastructure Readiness		
Score		

Cost	Importance (0 - 5)	Impact (0 - 3)
Feedstock Cost		
Feedstock Volatility		
Production Costs		
Product Cost		
Product Cost Volatility		
Cost of Production Facility \$/bbl basis		
Federal Incentives Required		
State Incentives Required		
Subsidies Required		
Subsidy Availability for first 5 - 10 Years of Plant Operation		
Estimated Price of Oil for Economic Viability		
Additional Infrastructure Required		
Cost Impact to Fully Burden Cost of Fuel		
Cost of Fuel Qualification and Certification		
Impact of Force Structure		
Contracting Mechanisms and Off-Take Agreements		
Score		

Figure 7.4 Balanced Scorecard

Balanced Scorecard Part 2

Environmental Impact	Importance (0 - 5)	Impact (0 - 3)
Feedstock Environmental Impact		
Land Use and Reclamation		
Water Use		
Soil Depletion and Erosion		
Life Cycle Run-Off and Treatment		
Local Environmental Impacts		
Local Air Quality (Clean Air Act)		
Local Water Quality (Clean Water Act)		
Socio Economic Considerations (e.g. NIMBY)		
Life Cycle Greenhouse Gas Footprint Compared to Petroleum		
Emissions Profile When Fuel is Burned (e.g. soot, HAP's)		
Net Energy Value		
Score		

Externalities and Barriers	Importance (0 - 5)	Impact (0 - 3)
Legal Statutes and Regulations		
Infrastructure Availability for Feedstock Transport		
Infrastructure Availability for Product Transport		
Compatibility with Existing Infrastructure for Transport and Storage		
National Security Impact		
Impact on Federal or State Mandates		
Environmentalists and NGO's Support		
Political Support		
Alignment with Commercial Aviation Sector		
Compliance with Executive Orders and other Mandates		
Perceived Risk By Financial Institutions		
Score		

Figure 7.4 Continued, Balanced Scorecard

Balanced Scorecard Part 1 (1970's)

Technical Maturity	Importance (0 - 5)	Impact (0 - 3)
Technology Readiness Level	3	2
Technology Risk	4	1
Commercialization Readiness	2	2
Position on the Learning Curve for Commercialized Process	1	1
Correctly Positioned on Value Chain with Collaborators	4	2
Technology Scalable Globally	1	0
Feedstock Supply Infrastructure Readiness	1	1
Product Distribution Infrastructure Readiness	2	2
Score	18	11
	(40 max)	(24 max)

Cost	Importance (0 - 5)	Impact (0 - 3)
Feedstock Cost	2	2
Feedstock Volatility	0	0
Production Costs	2	2
Product Cost	2	2
Product Cost Volatility	0	0
Cost of Production Facility \$/bbl basis	2	1
Federal Incentives Required	5	3
State Incentives Required	3	1
Subsidies Required	5	3
Subsidy Availability for first 5 - 10 Years of Plant Operation	5	3
Estimated Price of Oil for Economic Viability	1	1
Additional Infrastructure Required	1	1
Cost Impact to Fully Burden Cost of Fuel	0	0
Cost of Fuel Qualification and Certification	3	1
Impact of Force Structure	1	0
Contracting Mechanisms and Off-Take Agreements	5	3
Score	37	23
	(80 Max)	(48 Max)

Figure 7.5. Balanced Scorecard of Oil Shale in the 1970's

Balance Scorecard Part 2 (1970's)

Environmental Impact	Importance (0 - 5)	Impact (0 - 3)
Feedstock Environmental Impact		
Land Use and Reclamation	1	1
Water Use	1	2
Soil Depletion and Erosion	1	1
Life Cycle Run-Off and Treatment	1	1
Local Environmental Impacts		
Local Air Quality (Clean Air Act)	2	1
Local Water Quality (Clean Water Act)	2	2
Socio Economic Considerations (e.g. NIMBY)	2	1
Life Cycle Greenhouse Gas Footprint Compared to Petroleum	0	0
Emissions Profile When Fuel is Burned (e.g. soot, HAP's)	0	0
Net Energy Value	3	2
Score	13	11
	(50 Max)	(30 Max)

Externalities and Barriers	Importance (0 - 5)	Impact (0 - 3)
Legal Statutes and Regulations	4	3
Infrastructure Availability for Feedstock Transport	2	2
Infrastructure Availability for Product Transport	3	3
Compatibility with Existing Infrastructure for Transport and Storage	4	3
National Security Impact	5	3
Impact on Federal or State Mandates	5	3
Environmentalists and NGO's Support	1	0
Political Support	5	3
Alignment with Commercial Aviation Sector	3	1
Compliance with Executive Orders and other Mandates	5	3
Perceived Risk By Financial Institutions	3	1
Score	40	25
	(55 Max)	(33 Max)

Figure 7.5 Continued, Balanced Scorecard of Oil Shale in the 1970's

Balanced Scorecard Part 1 (Today)

Technical Maturity	Importance (0 - 5)	Impact (0 - 3)
Technology Readiness Level	4	2
Technology Risk	4	2
Commercialization Readiness	3	2
Position on the Learning Curve for Commercialized Process	1	2
Correctly Positioned on Value Chain with Collaborators	4	2
Technology Scalable Globally	3	1
Feedstock Supply Infrastructure Readiness	3	2
Product Distribution Infrastructure Readiness	3	2
Score	25	15
	(40 max)	(24 max)

Cost	Importance (0 - 5)	Impact (0 - 3)
Feedstock Cost	4	3
Feedstock Volatility	4	2
Production Costs	4	3
Product Cost	5	3
Product Cost Volatility	4	2
Cost of Production Facility \$/bbl basis	4	2
Federal Incentives Required	2	2
State Incentives Required	2	2
Subsidies Required	2	2
Subsidy Availability for first 5 - 10 Years of Plant Operation	2	2
Estimated Price of Oil for Economic Viability	4	3
Additional Infrastructure Required	4	3
Cost Impact to Fully Burden Cost of Fuel	5	3
Cost of Fuel Qualification and Certification	4	2
Impact of Force Structure	5	3
Contracting Mechanisms and Off-Take Agreements	2	1
Score	57	38
	(80 Max)	(48 Max)

Figure 7.6 Balanced Scorecard Oil Shale Today

Balance Scorecard Part 2 (Today)

Environmental Impact	Importance (0 – 5)	Impact (0 – 3)
Feedstock Environmental Impact		
Land Use and Reclamation	5	3
Water Use	5	3
Soil Depletion and Erosion	5	3
Life Cycle Run-Off and Treatment	5	3
Local Environmental Impacts		
Local Air Quality (Clean Air Act)	5	3
Local Water Quality (Clean Water Act)	5	3
Socio Economic Considerations (e.g. NIMBY)	5	3
Life Cycle Greenhouse Gas Footprint Compared to Petroleum	5	3
Emissions Profile When Fuel is Burned (e.g. soot, HAP's)	5	3
Net Energy Value	5	3
Score	50	30
	(50 Max)	(30 Max)

Externalities and Barriers	Importance (0 – 5)	Impact (0 – 3)
Legal Statutes and Regulations	4	3
Infrastructure Availability for Feedstock Transport	2	3
Infrastructure Availability for Product Transport	4	3
Compatibility with Existing Infrastructure for Transport and Storage	4	3
National Security Impact	2	2
Impact on Federal or State Mandates	3	2
Environmentalists and NGO's Support	4	2
Political Support	4	3
Alignment with Commercial Aviation Sector	5	3
Compliance with Executive Orders and other Mandates	5	3
Perceived Risk By Financial Institutions	4	3
Score	41	30
	(55 Max)	(33 Max)

Figure 7.6 Continued, Balanced Scorecard Oil Shale Today

7.6 Building and Alternative Aviation Fuel Portfolio

Stock market portfolio theory provides a methodology to rank expected return against risk as shown in Figure 7.7.

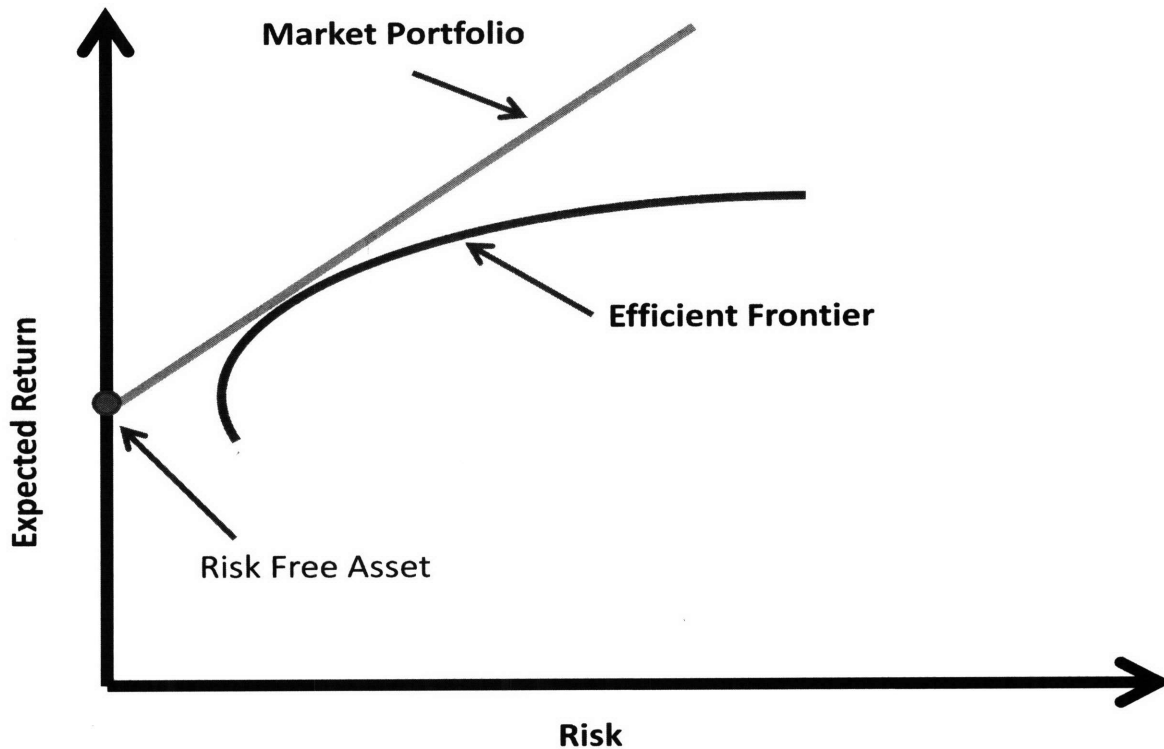


Figure 7.7. Stock market portfolio.⁹⁶

In the case of alternative energy projects, the balanced scorecard can be used to develop a score for the expected return in terms of technical maturity, cost, and environmental impact as well as externalities and barriers. A risk profile can be established based on project risk as viewed by the financial community, the impact on national security, the impact on

⁹⁶ Image: Capital Market Line.png - Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Image:Capital_Market_Line.png

economic security, and environmental stewardship as shown in Figure 7.8. Project finance risk is an area that provides a gauge for determining the level of government involvement.

Risk Analysis Worksheet Part 1

Project Risk (Financial Market)	Importance (0 - 5)	Impact (0 - 3)
Technology Risk		
Capital Cost of Project		
Cost Increases During Construction Cycle		
Engineering Capacity to Build Plants		
Operating Performance Guarantee/Start-up Time		
Crude Oil Price Slide		
Alternative Fuel Feedstock Price Increase		
Greenhouse Gas Legislation		
Score		
	(40 max)	(24 max)

National Security Issues	Importance (0 - 5)	Impact (0 - 3)
Domestic Versus Global Supply		
Diversity of Supplier Base		
Improve Global Availability of Fuel		
Supply Interruption Buffer		
Improve Fuel Critical Infrastructure		
Score		
	(25 Max)	(15 Max)

Figure 7.8 Risk Analysis Worksheet

Risk Analysis Worksheet Part 2

Economic Security Issues	Importance (0 - 5)	Impact (0 - 3)
Balance of Trade		
Domestic Tax Base		
Domestic Jobs		
Effect on GDP		
Score		

(20 Max) (12 Max)

Environmental Stewardship Issues	Importance (0 - 5)	Impact (0 - 3)
Local Air Quality		
Global Climate Change (Greenhouse Gases)		
International Operability		
Land Use Including Reclamation		
Water Pollution		
Water Demand		
Score		

(30 max) (18 Max)

Figure 7.8 Continued, Risk Analysis Worksheet

For example, low risk financial projects are easily managed by the financial community and require little government involvement or incentives. As the projects become more risky, especially for first-of-a-kind projects, the benefit of government involvement to share the risk increases markedly. There must be a clear win-win situation for the industry and the government. The government benefit is primarily driven by the how the project impacts national security and economic security. High risk projects for the financial community may be based primarily on the amount of capital required or the very short-time horizons that investors want for returns. Many times the timeline from project start through commissioning of the plant is longer than any investment firm wants to risk capital as the short-term opportunity cost is too high. The government may benefit in the long-term from tax revenues, job creation or changes to trade imbalances. Using a risk analysis that looks at both the financial short-term horizon and the government's long-term horizon can be beneficial. The final aspect of the risk profile is environmental stewardship. The risks in this arena are a mix of short-term (local air quality) and long-term effects (local air quality on health effects). The environmental challenges related to global climate change are very complex and will evolve. Since there is no complete international consensus (not all nations signed the Kyoto Protocol) nor is there a set of global legislative frameworks for greenhouse gases, the risk profile is likely to change over time. The long-term liability issue is a place where the government can help. For example, the government can construct legislation around best practices, or assume some of the environmental risk of the first few projects to increase the learning (for example, carbon sequestration). The government can also balance issues of water usage, long-term water pollution due to run-off, and the sometimes divergent concerns related to local air quality and

global air quality but policy and legislation. The development of the risk profile should be done in a collaborative fashion by the DoD, DOE, EPA, and the Department of Commerce, by think tanks, or from experts from the capital markets, and should be revised on a regular basis.

To build the portfolio of options, the value obtained from the balanced scorecard (expected return) can be plotted against the expected risk. Not only do the scores from the balanced scorecard and the risk assessment become important, but the relative weight of each alternative should be determined and a methodology for assigning weights developed. A good portfolio balances high risk but high reward projects with lower risk lower reward projects.

As in stock market portfolio development, the relative return versus the risk should be compared against a "risk free" investment, such as treasury bills. Similarly, the alternative energy portfolio should be compared against the "risk free" energy source oil. The challenge of using oil as the "risk free" point on the return versus risk diagram is the high volatility of the price of oil. The advantage of using the price of oil is that the return versus risk of any alternative is correctly aligned versus time; the disadvantage of the using oil is that the price of oil is based not on domestic values but on global markets. An alternative approach would be to use the price of a stable domestic resource such as bituminous coal. With the establishment of a risk free boundary that requires no government investment, the relationship between the risk free boundary and the efficient frontier of the portfolio could be explored. Alternative energy resources would be added to the energy portfolio based on a weighting related to the amount of government investment or incentives needed with 100% tallied by the amount of resources available. Once the portfolio is built, an efficient frontier can be graphed. A line drawn

tangential to the efficient frontier and connected to the “risk free” return would generate the equivalent to the best possible capital asset line. The dynamics of the investment of along this line could be used to compare against economic indicators such as GDP as shown in Figure 7.9.

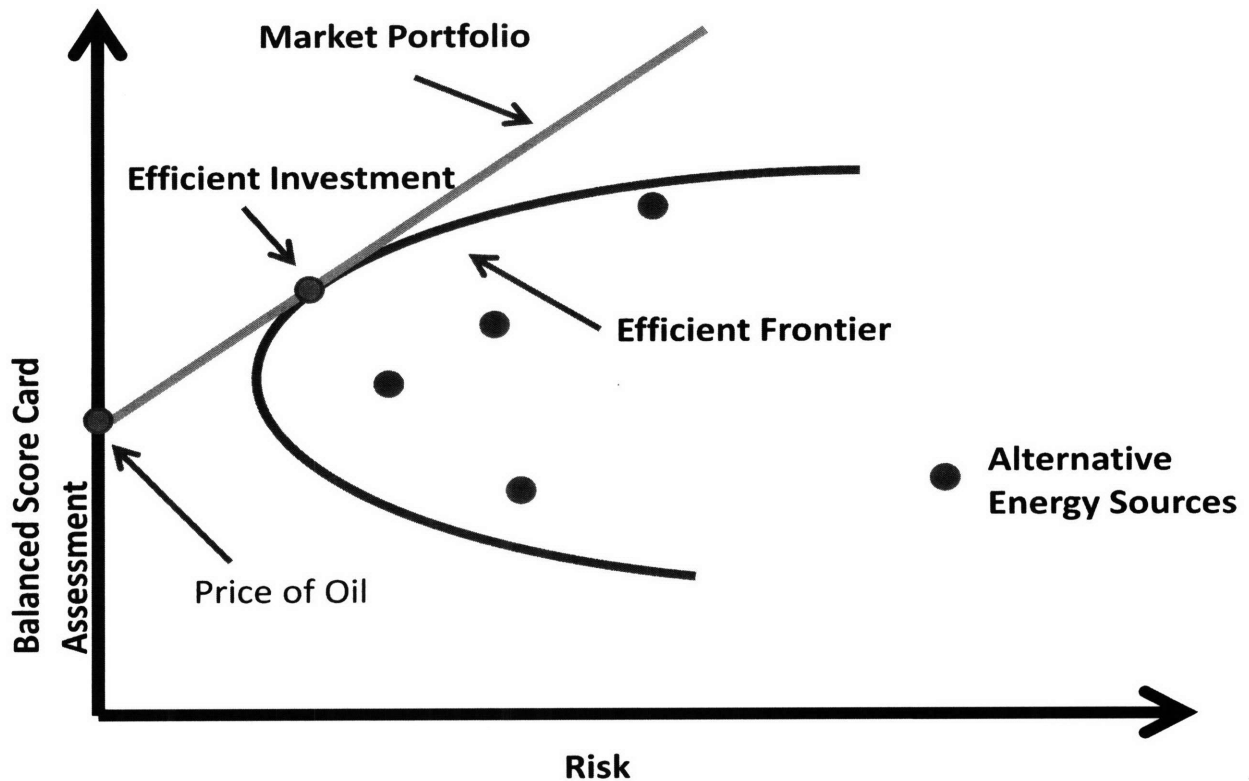


Figure 7.9. Development of an alternative energy investment portfolio

The basic premise of this concept could be used by commercial aviation as well as the military. For example, the investment requirements for alternative energy by the civil aviation sector could be compared to returns on the stability of the price of jet fuels, which would increase the profitability of the aviation industry and allow airlines to plan for future fleet upgrades that would improve efficiency and reduce emissions.

Using the balanced scorecard, the expected return can be determined. For example, does the cost of the alternative fuel exceed the cost of oil or fall within an expectation of oil volatility over a period of time? Do government incentives become the key driver for the project and are they sustainable for long periods of time? By using the importance and impact parameters, sensitivities can be explored. Since the first alternative energy projects are likely to be provided at higher costs than later plants that take advantage of the learning curve, the portfolio weighting for different projects can change over time. Over time, either the risk of alternative energy projects will decrease, or new risks will be found during operation. A periodic rebalancing of the portfolio could be accomplished based on return and risk. The key reward variable for comparison is the price of oil. Since the risk assessment tool is linked to the price of oil, it could be used to build sensitivity scenarios to provide additional insight into the relative weighting of the portfolio. At present, since these tools need further refinement, a balanced portfolio would include fossil and bio-based resources. Fossil-based resources provide scale and cost benefits and provide a way forward to reduce greenhouse gas emissions by demonstrating carbon capture and sequestration. Bio-based fuels offer the potential of carbon recycling and learning about land use and socio-economic issues. A final benefit of the portfolio approach is that the relationships between return and risk could be used as a tool for government agencies to use to allocate funding for R&D.

A project's financial sustainability can be enhanced by analyzing the project's covariance with other projects based on natural hedging that are created by producing products for multiple energy markets. Projects that optimize the scale of fossil with the environmental benefits of biomass may offer a strategy for long-term returns for both industry

and the government. For example a coal –to-liquids project will likely produce electricity as well as an aviation fuel. The project might also produce a naphtha product, diesel fuel, aggregate from the gasifier slag, CO₂ for enhanced oil production, or nitrogen fertilizers. Depending of the potential products and markets, the developer may have a natural hedging strategy that improves the long-term performance of the project compared to the short-term volatility of the oil market. For example, the sale of electricity can be a stabilizing long-term hedge compared to the production of aviation fuels which will be tied to the oil markets. For the majority of early users, alternative fuels that have products that are hedged via sales to multiple markets may reduce risk exposure for the investment. It may be beneficial to use portfolio theory to determine the covariance's off setting of overall project risk and use covariance as a tool for long-term strategies against the short-term volatility of the oil market. Another type of hedging may come from the flexibility of the production facility. To give an example, a current corn based ethanol plant might have the capability to be converted in the future to the production of high molecular weight hydrocarbons via fermentation when that technology is commercialized. This may offer a facility hedge in the future. The main driver for these types of hedges is the issues related to the length of time it would take for new technologies to come in and displace the existing technology. Again, a corn ethanol plant might be cannibalized and turned into a cellulosic conversion plant or converted to produce butanol. If market conditions are favorable, a later conversion could be to high molecular weight hydrocarbons. A balanced portfolio of support for various products could enable to sustainable long-term alternative energy options.

Hedging strategy should be considered in more detail by the government as an alternative to direct incentives. For example, if commercial hedging strategy to cover construction risk, such as a portfolio of futures related to cement, iron, copper and other construction products might reduce the impact of cost increases that are now being experienced by the rapid growth in China and India. If this strategy were combined with a government loan guarantee to cover the risk associated with the hedging strategy then the risk exposure by all parties could be minimized. A partnership with the investment community that balances commercial tools with government tools may be the best way to cover the risk of alternative fuels at the lowest price. If the investment community could see a clear portfolio strategy being used by either the government or the commercial airlines, there result may be a natural nexus to share the risk and help industry move from technology development to technology deployment.

7.7 Chapter Summary

Alternative energy projects could be evaluated with balanced scorecards to compare the financial, environmental, social, and global impacts of the continued use of petroleum. If the balanced scorecard was compared to a risk profile, a portfolio of investment similar to a stock market portfolio could be established. The relationship between the price of a risk free investment (oil or coal) could be compared to the performance of the overall alternative energy portfolio and used to guide future investments in alternative energy. The application of natural hedging (producing products for different markets with different dynamics) combined with other novel long- and short-term hedging strategies might be effective to balance the short-

term interests of the financial community with the longer term interests of the government and commercial airlines. In addition, the combination of using scale benefits related to fossil fuel and the environmental benefits of biomass may offer portfolio options that provide long-term returns for both the government and the industry. In Chapter 8, I will show how the tools described in this Chapter can be combined with other frameworks to form a series of recommendations to help establish an alternative fuels industry for aviation.

8.0 Conclusions and Recommendations

8.1 Chapter Overview

In this chapter, I provide some final analysis of the key issues that are critical to helping technology developers cross the “Valley of Death” and provide some scenarios and recommendations to facilitate the crossing. I also will show how the military and civil airlines can work collaboratively to help start the dynamics of an alternative fuel industry and how with federal and state government support, to help build an industry. I will describe how this collaboration bridges the “Chasm,” thereby increasing demand and spurring on the new entrants to the industry.

8.2 Chapter Introduction

In the United States we live in a world where the energy markets work. We can walk to the wall, flip on a switch and lights come on; we drive to the corner gas station and there is enough gas to fill our cars. So why worry about alternative energy? When dramatic events cause crises and shortages, the interest in alternatives rises to become a national priority, but as the crisis subsides and markets correct themselves complacency returns. Oil and other forms of energy have experienced boom and bust cycles over the last 100 years. Concerns regarding supply raise debate and industry steps forward to find and develop new reserves and fill the voids. Oil is a worldwide fungible product that is increasingly controlled by nations that use the resource as a tool for political agendas rather than as a true free market commodity. Demand for oil is inelastic which allows the price to continue to rise until economic conditions change such as a recession. World populations are growing at explosive rates as are world

economies. This growth spurs demand, fueling economic growth, which in turn spurs more demand. The use of fossil based fuels has changed the environment of the earth over the last 100 years and scientists project significant events if global warming continues to grow unchecked. Global climate change will affect some societies more than others as drought, changes in growing seasons, severe weather and other changes create social distress. Social distress may require the U. S. military to take on additional roles and missions both in humanitarian missions and potentially in peace keeping or direct combat situations. Global competition for resources is currently changing the energy markets and global warming will increasingly change them in the future. As a result, free market access to resources may diminish over time. National security, economic security, environmental security are now intertwined and the military will face new missions as a result. This scenario becomes a compelling reason to support the development of alternatives.

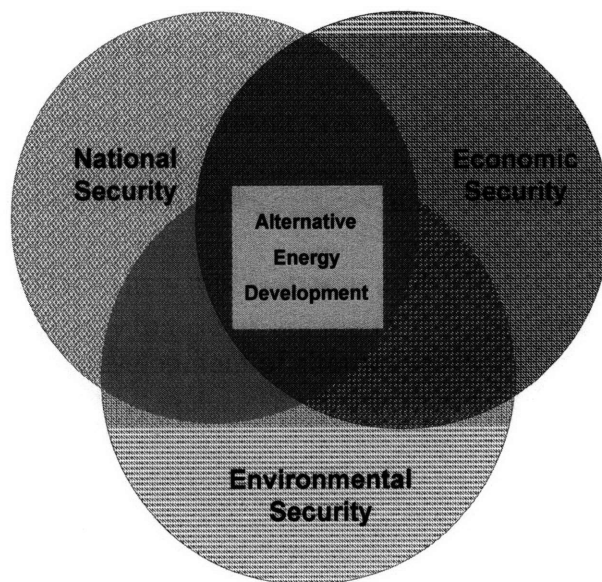


Figure 8.1. Drivers for alternative energy development

Alternative energy development must be guided by careful consideration of the alternatives: not just by short-term and sometimes self-serving views of politicians, environmentalists, and business developers but with a longer time horizon. The oil and energy industry is well known for boom and bust cycles. Add to this the lack of legal frameworks for greenhouse gas emissions and clear regulations. When this situation is tempered by the investment community's short-term horizons and perceived risks and required rewards for unproven innovative technology, we have an environment that will be slow to react. The investors will wait for someone else to prove the technology, and, in general, forward movement will become paralyzed. Innovators are developing technologies, but they struggle to deploy them. Customer markets are growing for new innovative alternative energy products. Aviation is a sector that is often overlooked. The market is small compared to gasoline and diesel and there are complex requirements to qualify a product to ensure safety of flight. With all this uncertainty, is there a way forward for alternative aviation fuels? Is there a process that can be carefully crafted to help industry cross the "Valley of Death" and secure early adopters? Is there a way to create an early majority to sustain the industry? Can it be done in an environmentally sound way? In this chapter, I will provide some conclusions based on my research, some suggestions for the military and commercial sector to consider helping foster an alternative energy industry for aviation and some tools that take into account life-cycle and sustainability issues.

8.3 Creating Demand for Alternative Aviation Fuels

The first step in the process of developing choices is leadership, first to overcome the perception that there will always be plenty of oil and that there is no need for alternatives. Aviation does not have to be the last transportation sector to use oil. This is a mental model that has significant limitations for the future. This mental model will become increasingly deficient as the concerns about corporate social responsibility, the need for a balanced energy portfolio for sustainability, and the social dynamics of global warming drive future trends for aviation. Corporate cultures that offer resistance to change will face major hurdles. Crisis and disruption of supply will become motivators for these groups, but then, because of the long cycle time required to build infrastructure and production capabilities, these companies may suffer significant financial distress. What is needed is a sound step-wise learning approach and a balanced portfolio of alternatives. In a sense, what needs to happen is for the aviation industry to foster a "toe in the water" approach to work with industry on alternatives for aviation. By being an early adopter, trying new fuels and helping the industry move forward along the learning curve, the aviation industry will open the door to additional opportunities and the wisdom of markets will hone the future to the correct set of sustainable products. A simple model of the key steps needed to start the alternative fuel industry is shown in Figure 8.2

The fuel must be certified for use to attract an individual airline to become a first adopter. This airline must convince all the airlines at a single location to become a cluster of early adopters. They must be willing to contract with an alternative fuel developer to create a certainty of demand. These actions reduce the market risk for the developer and create a market pull situation. The alternative fuel developer faces financial risks and uncertainty

related to the cost of the plant, the technological risk of a new process, and the uncertainty of feedstock costs and availability. If the fuel can be produced at a price competitive with oil or can offer a significant environmental advantage the airlines at the airport benefit and the first stage of learning for all parties begins.

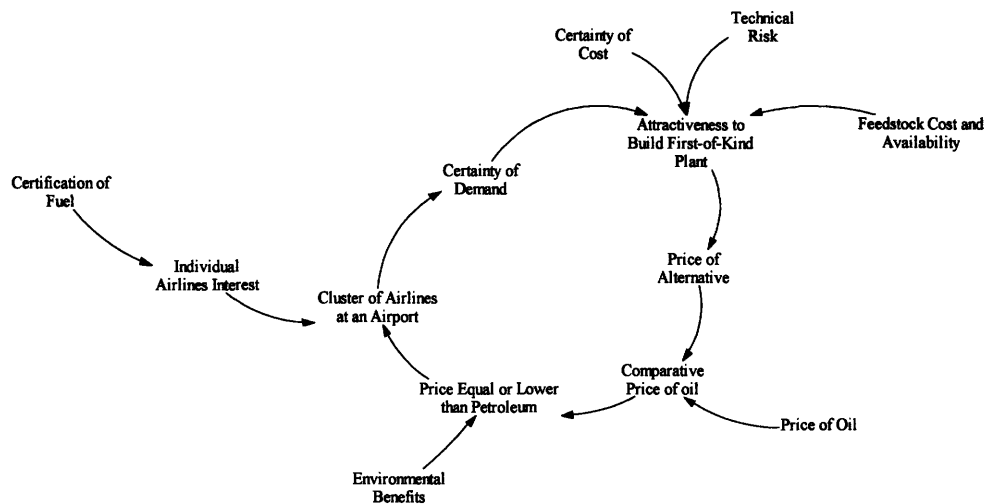


Figure 8.2 Simplified Model of Relationships Required to Start an Alternative Fuels Industry for Aviation Fuels

8.4 Waves of Innovation

The DoD in the 1970's and 1980's led the first wave of innovation for alternative fuels. With a single user, the model shown in Figure 8.2 is simplified even further as it only requires a single customer at a single location to create the market rather than a cluster of airline customers at a specific airport. However, the second wave of innovation started with SASOL and the need to increase the supply of jet fuels at Johannesburg International Airport, thus

requiring a cluster of airlines to act at this location. (see Figure 8.3) The demand for aviation fuel at Johannesburg was growing beyond the level that could be supported with petroleum. To solve this supply imbalance, SASOL worked with the commercial aviation sector to approve blends of coal derived Fisher-Tropsch (FT) fuels and conventional petroleum fuels. This development created a cluster of airlines using the fuel and generated the interest of other potential customers. The DoD took FT fuels further by evaluating FT fuel produced from natural gas as part of the Assured Fuels Initiative. This launched the Air Force initiative to demonstrate and certify FT fuel blended 50/50 with petroleum fuels for use in all its aircraft. Interest continued as recently Airbus, Shell, and Rolls Royce followed suit and demonstrated Gas-to-Liquid (GTL) blends in an Airbus 380 aircraft. Desiring to be proactive environmentally, Boeing and Virgin demonstrated the first biojet blends with commercial petroleum derived jet fuel in a test flight of a 747 aircraft. This wave of innovation continues to gain momentum with commercial organizations such as CAAFI providing the leadership for the commercial sector, and the AF continuing to lead the DoD as shown in Figure 8.3.

8.5 Environmental Concerns of Alternative Aviation Fuels

Flight demonstrations pave the way for early adoption of the technology, but my research has shown that many more factors must be considered to gain demand from early adopters. For example, added supplies of alternative fuels may reduce fuel price volatility and the selection of the right mix of fossil and bio-based fuels may reduce greenhouse gas footprints for the aviation industry. The challenge is how to measure environmental benefits both in the short-term and the long-term? The corn ethanol debate has evolved from a debate

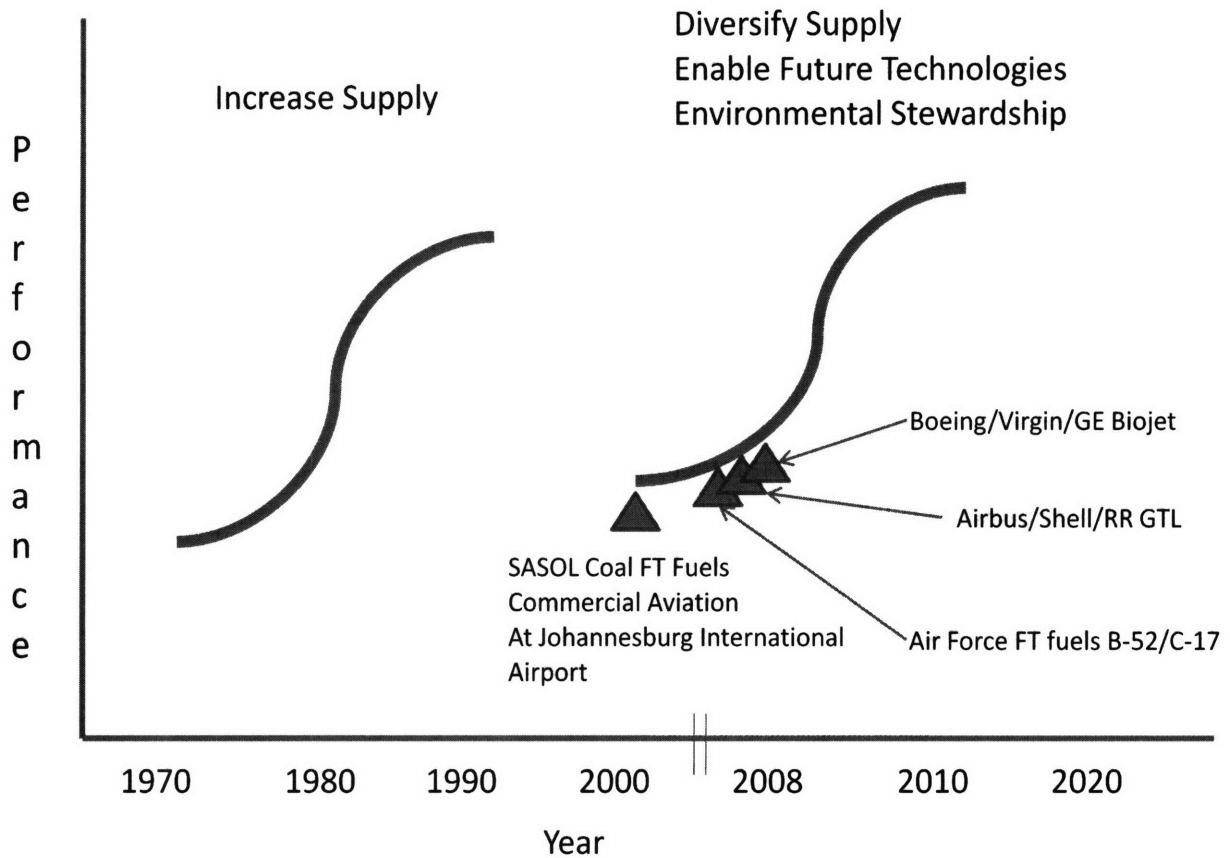


Figure 8.3 Waves of Technical Innovation

over the energy required to produce a gallon of ethanol compared to the amount of energy available to a debate of short-term benefits greenhouse gas mitigation versus long-term doubling of greenhouse gas emissions with continued growth.⁹⁷ Similar debates in the European Union relate to the use of palm oil produced by displacing rain forests in Malaysia, which created a long-term net increase in CO₂. Fossil projects that offer environmental benefits also face continuing uncertainty. For example, the cancellation of FutureGen which was touted to as the first zero emissions power plant has created uncertainty related to this form of

⁹⁷ Timothy Searchinger, Ralph Heimlich, R. A. Houghton, Fengxia Dong, Amani Elobeid, Jacinto Faiosa, Simla Tokgoz, Dermot Hayes and Tun-Hsiang Yu, "Use of US Croplands for Biofuels Increases Greenhouse Gases Through Emissions for Land Use Change," Scienceexpress, Feb 2008.

electricity production.⁹⁸ It is difficult to determine the actual environmental benefit of bio-derived or fossil-derived alternatives.

Congress can help foster the development of alternative and unconventional fuels for aviation. For example, the Energy Act of 2005 (EPAAct 2005) provided a specific direction to the DoD with respect to the procurement of clean unconventional fuels. Section 369 stated:

Procurement of fuel derived from coal, oil shale, and tar sands:

- (a) Use of Fuel to meet Department of Defense needs – the Secretary of Defense Shall develop a strategy to use fuel produced, in whole or part, from coal, oil shale, and tar sands that are extracted either by mining or in-situ methods and refined or otherwise processed in the United States in order to assist in meeting fuel requirement of the Department of Defense when the Secretary determines that it is in the national defense.*
- (b) Authority to Procure – the Secretary of Defense may enter into 1 or more contracts or other agreements (that meet the requirements of this section) to procure a covered fuel to meet 1 or more fuel requirements of the Department of Defense*
- (c) Clean Fuel Requirements – a covered fuel may be procured under subsection (b) if the covered fuel meets such standards for clean fuel produced from domestic sources as the Secretary of Defense shall establish for purposes of this section in consultation with the Department of Energy*

⁹⁸ The Demise of FutureGen, 'The Washington Post,' <http://www.washingtonpost.com/wp-dyn/content/article/2008/02/15/AR20080215031>

- (d) Multi-year Contract Authority – Subject to applicable provisions of the law, any contract or other agreement for the procurement of covered fuel under subsection (b) may be for 1 or more years at the election of the Secretary of Defense*
- (e) Fuel Source Analysis – in order to facilitate the procurement by the Department of Defense of covered fuel under subsection (b), the Secretary of Defense may carry out a comprehensive assessment of current and potential location in the United States for the supply of covered fuel to the Department⁹⁹*

This section of the law clears the way for the Department of Defense to be an early adopter of alternative fuels produced from domestic resources. Other provisions in EAct 2005 related to biomass derived fuels provide incentives for the DoD to develop a portfolio of alternatives fuels, procure the fuels and become an early adopter. Concerns about the environmental impact of alternative aviation fuels surfaced in 2007 when Congress amended EAct 2005 with the following language in the Energy Independence and Security Act of 2007 section 526:

No federal agency shall enter into a contract for procurement of an alternative or synthetic fuel, including a fuel produced from non-conventional petroleum sources, for any mobility-related use, other than for research and testing, unless the contract specifies that the lifecycle greenhouse gas emissions associated with the production and combustion of the fuel

⁹⁹ Energy Policy Act of 2005, Public Law 1009-58, Aug 8, 2005.

supplied under the contract must, on an ongoing basis, be less than or equal to such emissions from equivalent conventional fuels produced from conventional petroleum sources.¹⁰⁰

Reflecting back on the simplified model shown in Figure 8.2, for the industry to move forward the environmental benefits of the alternatives must be determined.

First Recommendation: The DoD should collaborate with other government agencies to develop the tools and procedures to compare life-cycle-analysis and sustainability criteria such that alternatives can be compared on an equal basis and re-evaluated periodically to allow the determination of long and short-term impacts as each alternative fuel emerges.

One of the main issues raised by Section 526 of EPCA 2007 is the determination of the baseline value for petroleum derived aviation fuels. Different crude oils have different CO₂ lifecycle impacts. To compare the impact of alternatives there must be an accepted baseline. The boundaries for a lifecycle calculation need to be defined to avoid the current debate in biomass based fuels. The boundaries and lifecycle CO₂ footprint model parameters have a direct influence on the outcome of the results. For example, that recent articles on corn based ethanol¹⁰¹ shows a CO₂ lifecycle similar to coal-to-liquids without sequestration. Clearly, defined model boundaries are needed.

Second Recommendation: The DoD should request that the EPA and DOE develop a clear definition of the CO₂ lifecycle footprint for petroleum and the boundaries for a well-to-wake calculation of alternative fuels and collaborate with them on alternative fuels analyses.

¹⁰⁰ Energy Independence and Security Act of 2007, Pub L. No. 110-140.

¹⁰¹ Timothy Searchinger, Ralph Heimlich, R. A. Houghton, Fengxia Dong, Amani Elobeid, Jacinto Faiosa, Simla Tokgoz, Dermot Hayes and Tun-Hsiang Yu, "Use of US Croplands for Biofuels Increases Greenhouse Gases Through Emissions for Land Use Change," Scienceexpress, Feb 2008.

8.6 Sustainability and Other Uncertainties

Sustainability and other uncertainties require a tool such as the balanced scorecard described in Chapter 7 and shown in Figures 8.4 and 8.5 to help make informed analyses of different alternatives. The balanced scorecard as shown in Figure 8.5 provides a methodology to rate technical maturity, cost, environmental impact, as well as externalities and barriers for each potential feedstock. The DoD, in consultation with other federal agencies, as well as the commercial sector, could develop this tool and use it to follow progress as new technologies are developed. Time horizons are very critical for long-term thinking and planning. For example, conservation is a method to reduce fuel consumption, fuel cost and environmental impact in the short-term. Alternative fuels can change environment impacts and potentially reduce fuel cost volatility in the medium term. Fuel efficiency improvements impact the amount of fuel purchased (and cost) and the environmental impact in a long time horizon controlled by the rate of aircraft replacement. A balanced scorecard for alternative fuels can be compared to the progress of conservation and efficiency improvements and adjusted over the long-term.

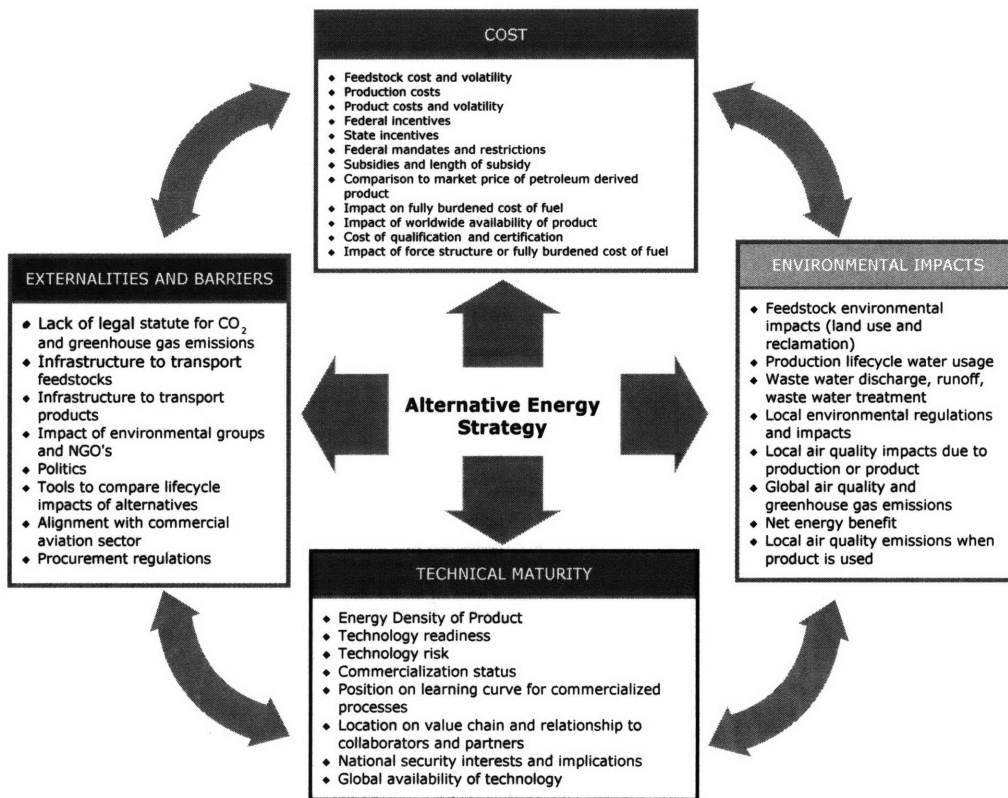


Figure 8.4 Considerations for a balanced scorecard toward sustainable alternative fuel

Balanced Scorecard Part 1

Technical Maturity	Importance (0 - 5)	Impact (0 - 3)
Technology Readiness Level		
Technology Risk		
Commercialization Readiness		
Position on the Learning Curve for Commercialized Process		
Correctly Positioned on Value Chain with Collaborators		
Technology Saleable Globally		
Feedstock Supply Infrastructure Readiness		
Product Distribution Infrastructure Readiness		
Score		

Cost	Importance (0 - 5)	Impact (0 - 3)
Feedstock Cost		
Feedstock Volatility		
Production Costs		
Product Cost		
Product Cost Volatility		
Cost of Production Facility \$/bbl basis		
Federal Incentives Required		
State Incentives Required		
Subsidies Required		
Subsidy Availability for first 5 - 10 Years of Plant Operation		
Estimated Price of Oil for Economic Viability		
Additional Infrastructure Required		
Cost Impact to Fully Burden Cost of Fuel		
Cost of Fuel Qualification and Certification		
Impact of Force Structure		
Contracting Mechanisms and Off-Take Agreements		
Score		

Figure 8.5 Balanced Scorecard

Balanced Scorecard Part 2

Environmental Impact	Importance (0 - 5)	Impact (0 - 3)
Feedstock Environmental Impact		
Land Use and Reclamation		
Water Use		
Soil Depletion and Erosion		
Life Cycle Run-Off and Treatment		
Local Environmental Impacts		
Local Air Quality (Clean Air Act)		
Local Water Quality (Clean Water Act)		
Socio Economic Considerations (e.g. NIMBY)		
Life Cycle Greenhouse Gas Footprint Compared to Petroleum		
Emissions Profile When Fuel is Burned (e.g. soot, HAP's)		
Net Energy Value		
Score		

Externalities and Barriers	Importance (0 - 5)	Impact (0 - 3)
Legal Statutes and Regulations		
Infrastructure Availability for Feedstock Transport		
Infrastructure Availability for Product Transport		
Compatibility with Existing Infrastructure for Transport and Storage		
National Security Impact		
Impact on Federal or State Mandates		
Environmentalists and NGO's Support		
Political Support		
Alignment with Commercial Aviation Sector		
Compliance with Executive Orders and other Mandates		
Perceived Risk By Financial Institutions		
Score		

Figure 8.5 Continued, Balanced Scorecard

The military is affected by world events and the risk evaluation analysis is another key tool as shown in Figure 8.6. This tool can be used with the balanced scorecard, conservation tools, and efficiency gains to help guide investments and actions. The risk analysis balances investor risk for project, national security issues, economic security issues, and environmental stewardship issues and can be used with scenario planning to look at snap shots of options over a long time horizon. The relative importance and impacts of risks derived from scenarios can be used with the balanced scorecard, conservation tools, and efficiency programs to optimize DoD programs.

Risk Analysis Worksheet Part 1

Project Risk (Financial Market)	Importance (0 - 5)	Impact (0 - 3)
Technology Risk		
Capital Cost of Project		
Cost Increases During Construction Cycle		
Engineering Capacity to Build Plants		
Operating Performance Guarantee/Start-up Time		
Crude Oil Price Slide		
Alternative Fuel Feedstock Price Increase		
Greenhouse Gas Legislation		
Score		

(40 max)

(24 max)

National Security Issues	Importance (0 - 5)	Impact (0 - 3)
Domestic Versus Global Supply		
Diversity of Supplier Base		
Improve Global Availability of Fuel		
Supply Interruption Buffer		
Improve Fuel Critical Infrastructure		
Score		

(25 Max)

(15 Max)

Figure 8.6 Risk Analysis Worksheet

Risk Analysis Worksheet Part 2

Economic Security Issues	Importance (0 - 5)	Impact (0 - 3)
Balance of Trade		
Domestic Tax Base		
Domestic Jobs		
Effect on GDP		
Score		
	(20 Max)	(12 Max)

Environmental Stewardship Issues	Importance (0 - 5)	Impact (0 - 3)
Local Air Quality		
Global Climate Change (Greenhouse Gases)		
International Operability		
Land Use Including Reclamation		
Water Pollution		
Water Demand		
Score		
	(30 max)	(18 Max)

Figure 8.6 Continued, Risk Analysis Worksheet

A strategy should be developed that looks at short-term (5 – 10 years), mid-term (10 – 25 years) and long-term (25 – 50 years) effects. The costs and benefits will change for each alternative over each of these time frames based on global markets and socio-economic policies. In addition, this analysis is important when the project development time line is evaluated. Some large projects may require up to a decade to design, permit, construct, and operate; whereas smaller projects may only require 2 – 3 years. For example, a large scale project such as coal-to-liquids has many steps and a long development time, which creates risk exposure for the development of the project. A project such as a biodiesel plant can be designed, permitted, and constructed in 2 – 3 years and has a different exposure to risks due to

the shorter time horizon as shown in Figure 8.7. However, these comparisons may not reflect a true comparison of scale. For example the coal-to-liquid plant may produce 30,000 – 80,000 barrels per day while a biodiesel plant may only produce 50 million to 100 million gallons per year (3260 – 6520 barrels per day). To match scale, five large biodiesel plants may equal the production of one small coal-to-liquids plant or approximately five to ten smaller plants may equal one large plant. A second generation biofuels plant producing biojet will likely take a longer time to build and construct due to the need for hydrotreating capability to produce a specification fuel.

In a comparison of the costs and environmental footprints, metrics must be developed to compare accurately the issue of scale. For example it may turn out when all the life cycle cost and environmental impacts are included an optimal plant size for any alternative may be determined. Variations of scale around the optimum may have significant cost and environmental implications. If one takes a staged approach to build capacity through many smaller plants over the same time frame as that of the construction of a large plant, the need for time phased analysis becomes much more important. If not, one may be misled by the thought that a small plant is desirable and a large plant is undesirable when, in aggregate, a large number of small plants may be less advantageous than one large plant. Also a plant is designed to operate for approximately 30 years. The length of plant operation should also be considered in a careful analysis of choices.

Industries will likely move slowly in constructing multiple plants as a way to reduce risk and take some time to learn how to reduce operating costs. In this type of scenario, one might

only see two or three small biojet plants constructed (by a single company) in the same time frame as one large plant. A time lag of a few years would be expected for the developer of a large project until a second one is constructed as a way to reduce risk and to move down the learning curve before the second plant is built. This learning phase is important as the first projects built will be watched closely by all competitors. They will look at the real risks that were encountered through the process as well as intangible risks that cannot be quantified until an actual plant is operating.

The analysis of the first plants will also help identify some early wins to stimulate the dynamics of the industry. Alternative fuel developers that can act as first movers will be the pioneers in the technology and will likely garner any government support that may be given. Later movers should focus on the long-term financial sustainability of the projects and may not receive significant levels of government support.

Third Recommendation: Develop tools such as balanced scorecards and risk analysis tools. Conducting time-phased analysis that considers the short-term (5 – 10 years), mid-term (10-25 years), and long-term (25 – 50 years) would provide a path that incrementally brings in new innovations and disengages from those that are no longer sustainable from an environmental or business standpoint.

Through use of a time-phased analysis, a portfolio could be developed that encourages interim solutions that are cost effective as well as longer term solutions. All alternative energy projects have a high level of uncertainty (financial, environmental, and operational) and therefore need to be demonstrated at commercial scale to help pave the way for additional

plants. If multiple government agencies collaborate in the support of few projects, learning can be accomplished in a cost effective manner.

8.7 Stimulating Alternative Energy Project Learning

One way to stimulate alternative energy project learning and for government to help a few projects across the “Valley of Death” is to conduct a commercial demonstration. In a sense, this is a way to start a project in the “Valley.” The proposed concept is a hybrid R&D, demonstration, and logistics program established to develop baselines for cost, performance, operation and environmental impacts of first generation coal-liquid-plants. This concept is shown in Figure 8.8. The critical issue here is to make this project a true learning experience for the industry. To do this, industry must be willing to shoulder significant risk to make the project efficient and representative of other commercial operations. The government should be a partner to backstop some of the risk, primarily in areas where the risk uncertainty is beyond the financeability of a commercial project. Although the proposed concept is for a coal-to-liquids plant producing Fisher-Tropsch fuels for the military, it could be adapted for biomass projects or for any combination of unconventional fossil fuels and biomass.

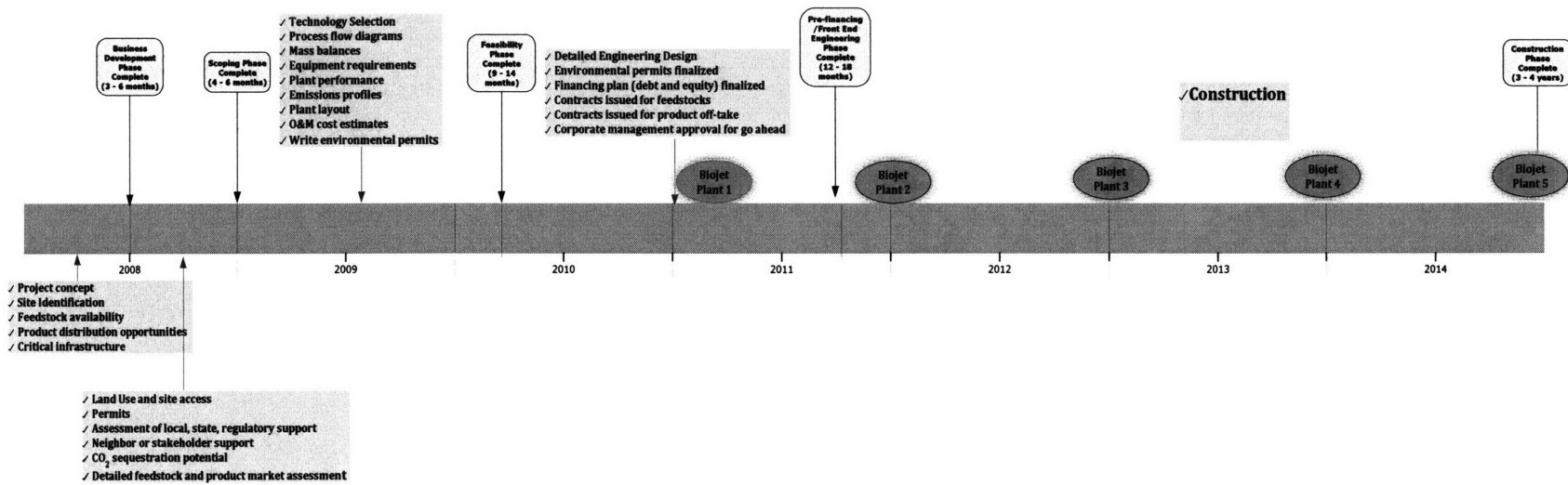


Figure 8.7 Comparative time lines between one large plant and multiple smaller plants.

The proposed concept is a joint program between the Air Force, Department of Energy, Department of Agriculture and the Environmental Protection Agency. Each agency will have a well defined set of goals and objectives, and provide the necessary funding for its role. The proposed approach is a competitive solicitation sponsored by all agencies; it will have an evaluation team composed of members of all parties involved. The contract will be a hybrid research and development contract awarded as a cost plus fixed fee contract. The program would open the developer's books for transparency and provide the DOE with solid cost figures for construction and operation. The project is to be a commercial operation with five years of protection by the government with the Air Force purchasing all the specification quality fuel from the project at market price. Any cost difference between market and the actual cost would be absorbed by the DOE and the EPA as part of the learning process related to cost and environmental performance. All CO₂ produced by the process will be captured and sequestered as part of a long-term research project on sequestration and will provide the EPA with information related to best practices for CO₂ control. The DOE with its active programs on clean coal and CO₂ sequestration, could use this information as one of its major technology demonstration platforms.

This concept will be difficult to manage, and coordination between all the agencies and will require planning to align budgets. A single agency must be chosen to lead the effort and all agencies should have embedded personnel in the program office. If successful, this project could be a model for other alternative energy projects.

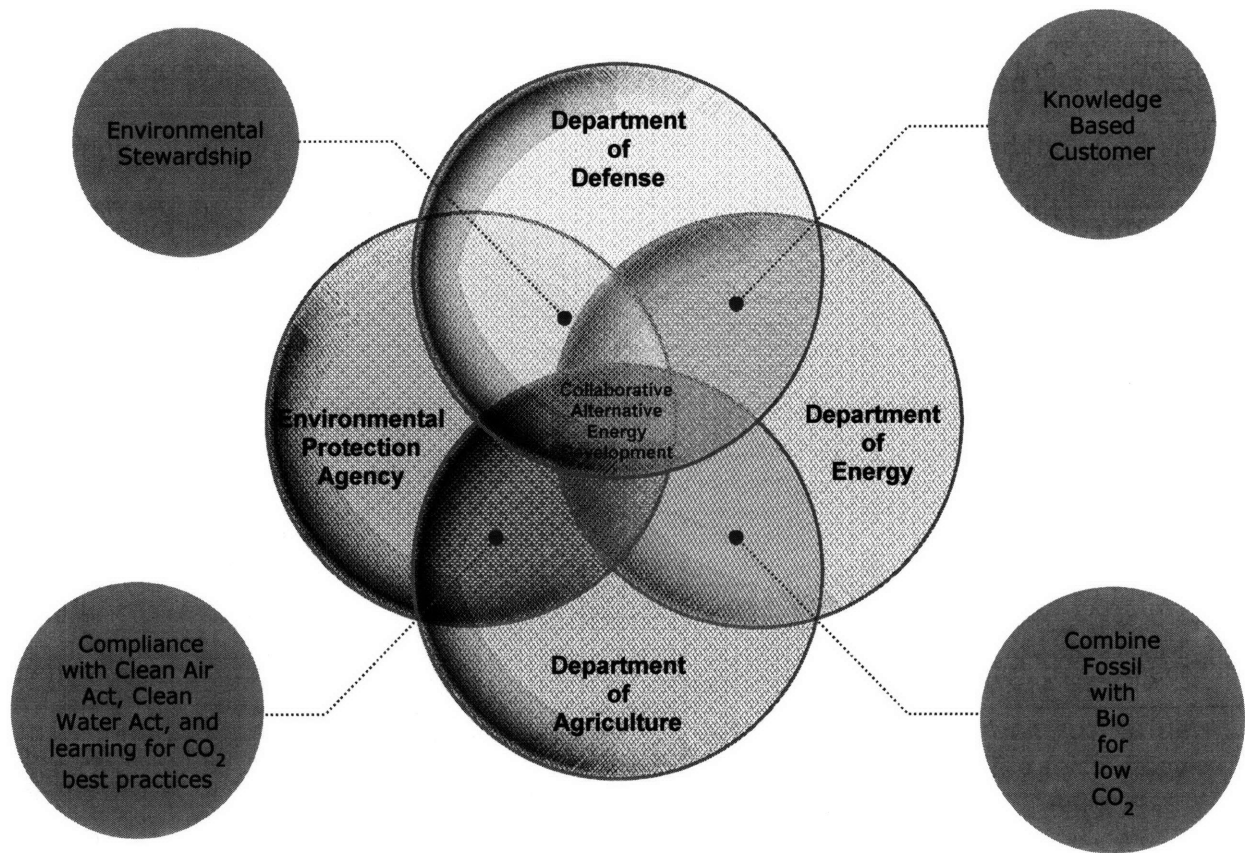


Figure 8.8. Joint Agency Alternative Fuel Learning Demonstration.

Roles:

- Air Force – purchase fuel for a 5-year field evaluation of FT fuels in an operational environment. The fuel produced from this project will be used for a period of 5 years (with additional yearly purchase options) in an operational field experiment to develop operational experience on the fuel, measure long-term durability and performance parameters, and ensure that any unknowns are found and resolved. For the logistics community it will offer an opportunity to develop a hands-on operational experience and training program. To purchase

the fuel, a cost plus fixed fee contract can be put in place prior to the production of the fuel and delivery and expense occur in the year fuel is actually purchased. Since the fuel is purchased at market price this should fit into our existing budgeting process. Other expenses for the field evaluation can be budgeted and added to the operational wing conducting the demonstration. In addition, the AF could purchase green electricity for use at the base.

- DOE – provide funding to pay for any cost differential between market price for fuel and the cost of the fuel. The DOE would benefit from the learning related to a first-of-a-kind commercial demonstration plant on cost, operation, and CO₂ sequestration. Results obtained from a 5-year experiment would be used to guide future R&D and other technology demonstrations.
- Department of Agriculture – provide technical assistance and funding to demonstrate viable biomass candidates to improve long-term sustainability and reduce CO₂ emissions. Feedstocks would be recommended based on sustainability criteria including competition with feed crops, impact on biodiversity, preservation of top soil, and soil quality, water requirements and runoff, and the impact on rural communities.
- EPA – currently no legal framework for CO₂ exists. Other pollutant emissions are regulated by industry best practice criteria. The demonstration would help the EPA develop best practice legal frameworks for CO₂. The EPA would cost share with DOE any cost differential between actual and market price. If CO₂ cap and

trade or taxes are in place prior to opening the plant, the DOE and the EPA can administrate the application of these mechanisms to the project.

At the end of five years, an assessment would be made by the commercial developer/operator and the government agencies. If the approach has been proven viable, the developer/operator could take title of the plant, secure necessary financing and sales markets, and operate the plant until its life is used up. This approach provides a safety net for the commercial developer to buy down as much debit as possible and work towards cost reductions learned during the operation of the plant. The AF could continue to purchase the fuel at market price if it chooses. The DOE could opt to disengage from the partnership or continue with the developer to use the facility as a commercial laboratory for new technologies to reduce cost, improve performance, or reduce emissions. The EPA could disengage from the project or continue a long-term evaluation of CO₂ sequestration for the life of the plant. The Department of Agriculture could chose to disengage or continue research using different biomass resources.

Benefits of this approach:

- Fits with current contracting rules for R&D cost plus fixed fee contracts and the logistical restriction on multiyear purchases of fuel. Also meets OMB guidance that the military cannot pay a premium for fuel.
- Provides alternative fuel to the Air Force to continue long-term durability evaluations and support of the goal of using 50% alternative fuels by 2016.

- Provides the DOE with a commercial laboratory to learn about CTL costs, operations, and CO₂ sequestration in a cost effective manner. Costs would be incurred only when the plant is operational and the market conditions prevent full cost recovery by the sale of fuel. Estimated costs could be budgeted in advance.
- Provides the EPA with a commercial laboratory to learn about best practices for CO₂ recovery and sequestration. Information would be helpful for defining legal best practices. Costs would be incurred only when the plant is operational and the market conditions prevent full cost recovery by the sale of fuel.
- Provides the developer a 5-year risk free learning experience for a first of a kind CTL project. Since the developer has the ability to continue commercial operations after 5 years, the incentive would be to retire as much debt as possible and develop processes improvements to reduce cost and improve efficiency. If the project were to prove uneconomical after 5 years, the developer would be saddled with all costs that were not recovered in the first 5 years. Careful consideration of a business plan where all costs are recoverable for the first 5 years of operation should make this an attractive prospect for a serious commercial firm.

Fourth Recommendation: To help the industry cross the “Valley of Death,” develop multiple-agency projects that create government and industry learning for first-of-a kind plants utilizing tools to minimize cost and maximize commercial potential. Use the

Department of Defense as the knowledgeable buyer and the other agencies as agents facilitate learning about new technologies and environmental effects. This risk mitigation approach should enable commercial financing of the project and minimal expenditures from the government and allow the industrial partner to focus on business practices and efficiencies needed for unsubsidized operation. The data from these projects can be used to update the balanced scorecard and risk analysis tools and to assist the government in future R&D investment and generate support for other alternative fuels projects.

8.8 Look for a quick win project

Multi-agency/industry learning utilizing a few first-of-a-kind facilities demonstrates that the “Valley of Death” can be crossed, and the military can be a first adopter of the technology. To spur the industry forward, not only should long-term high risk projects be undertaken, but some lower-risk, quick win projects should be fostered. Many business authors such as Utterback,¹⁰² Weil¹⁰³ and Christenson¹⁰⁴ have studied the rapid growth of industries during bubbles and shown that once the dominant standard is set, the industry commoditizes and the numerous technologies and firms are reduced as competition drives out the marginal performing companies. The oil industry has been going through this process for approximately 100 years and has become very efficient. It will therefore be very difficult for an alternative fuel to compete against the large established oil companies and the current efficient scale of the industry. Unconventional resources such as oil shale and oil sands fit very well in this industry

¹⁰² James Utterback, Mastering the Dynamics of Innovation, Harvard Business School Press, 1996

¹⁰³ Henry Weil, “Disrupting Mature Markets with Innovative Technology”, 2004.

¹⁰⁴ Clayton Christenson, “Strategies of Survival in Fast-Changing Industries,” *Management Science* 44(12): 207-220, 1998.

and benefit from the installed base and economies of scale. If the production of the alternative oil is cost competitive with the development of new oil resources, the industry will develop and supply will increase and keep up with demand. Oil shale, for example, will require limited governmental intervention, primarily related to commercial leasing and access to federal lands. The socio-economic and environmental aspects of oil shale need to be explored and pathways established to assure environmental stewardship. Oil shale provides the government with an opportunity to employ options-based reasoning and use the revenues for social good. Opportunities in oil shale development are options that are rights but not obligations to take action in the future. The EPOA of 2005 set into motion the first government option by establishing a R&D leasing program. This development created a first wave of investment to explore the recovery of oil shale. Although this option is a good start, it does not provide the revenue opportunities that the federal government can use for other programs. By establishing a commercial leasing program, the government creates the option for industry to move forward and recover the resource. The revenues generated by the lease and royalties of production could be used by BLM or other government agencies to develop complementary programs in land reclamation, greenhouse gas, and water use abatement programs. Since the government controls the pace of the awarding of leases, social and regional economic programs can be developed from the cash flows. If the first commercial operations are successful (through use of the balanced scorecard and risk analysis tools) more commercial operations can be started and the revenues of the leases and the royalties used for other social welfare programs such as reducing the national debt, improving social security, or developing low cost health care insurance programs. Oil shale could be the first fossil based fuel program in the U.S. that is

focused on a significant social benefit outcome while providing a valuable resource for national security and driving the economic growth of the country.

Fifth Recommendation: Look for a quick win project in addition to longer term complex programs that require significant amounts of learning. The low cost domestic resource that fits into the current dominant exchange and commercial industrial base is oil shale. The government needs to establish a commercial leasing program and provide access to federal lands for this to succeed. Legislation related to environmental stewardship related to greenhouse gases needs to be enacted. Environmental stewardship needs to be demonstrated. Carefully enacted federal and state policies can ensure that socio-economic interests are balanced, infrastructure is developed in lock step with commercial development, and national security and domestic supply are increased. The military and commercial sector can adopt these fuels very quickly as the specifications are in place for this type of fuel.

8.9 Using the Position of Dominant Exchange to Stimulate Alternatives

Other alternative fuels such as coal-to-liquids and biomass require interaction among those that control the dominant exchange, the FAA and the military to open the market for the use of these resources for aviation. In Chapter 3, I used the Hax Delta Model to show how the military and FAA control the dominant exchange: this application of the model is shown in Figure 8.9. To further the development of coal based and biomass based fuels, the dominant exchange should be expanded in a manner that promotes the growth of these industries. The tool that enables the expansion of the dominant exchange is the careful development of the specifications and standards. Since the safety of flight is a critical controlling parameter, the

expansion of the specification should be coupled with strong R&D by the military and NASA and the modification should take place in a controlled and careful manner. In general, the chemistry of coal and biomass derived fuels is different than that of typical petroleum based fuels. The differences are either they contain chemical compounds not found in petroleum derived fuels, or, in the case of Fischer-Tropsch fuels, certain chemical compounds are missing. Biomass derived fuels may have a different carbon number range distribution of molecules that require combustion and emissions studies and all alternative fuels will require some studies related to material compatibility. One approach to opening the specifications controlled by the dominant exchange is to develop an R&D program sponsored the military, NASA, and the private sector to carefully study the behavior of alternative fuels in regards to combustion, emissions, material compatibility, and the interactions with fuel wetted engine, aircraft and ground equipment components. Investment in this arena would help shape the final scope that the specifications can change and with increased scope open more options for the industry to provide alternative fuels at a lower cost.

If a strong R&D program is established and the military and CAAFI work closely together, the dominant exchanges can guide the process of opening the fuel domain architecture in a harmonized fashion. The Delta Model suggests that each station along the model should be explored. The low cost station would include analysis of the process to qualify and certify fuels such that it is clearly defined and well documented. Buying power of the industry could be explored and buying consortia established to reduce risk exposure. CAAFI could collaborate with federal and state agencies both to foster the development of the alternative fuels industry and to explore the leverage that these agencies can bring to the problem. Since aviation is a

conduit for other businesses, and every state has multiple airports and military bases, the development of a coordinated leveraged approach could yield low cost solutions.

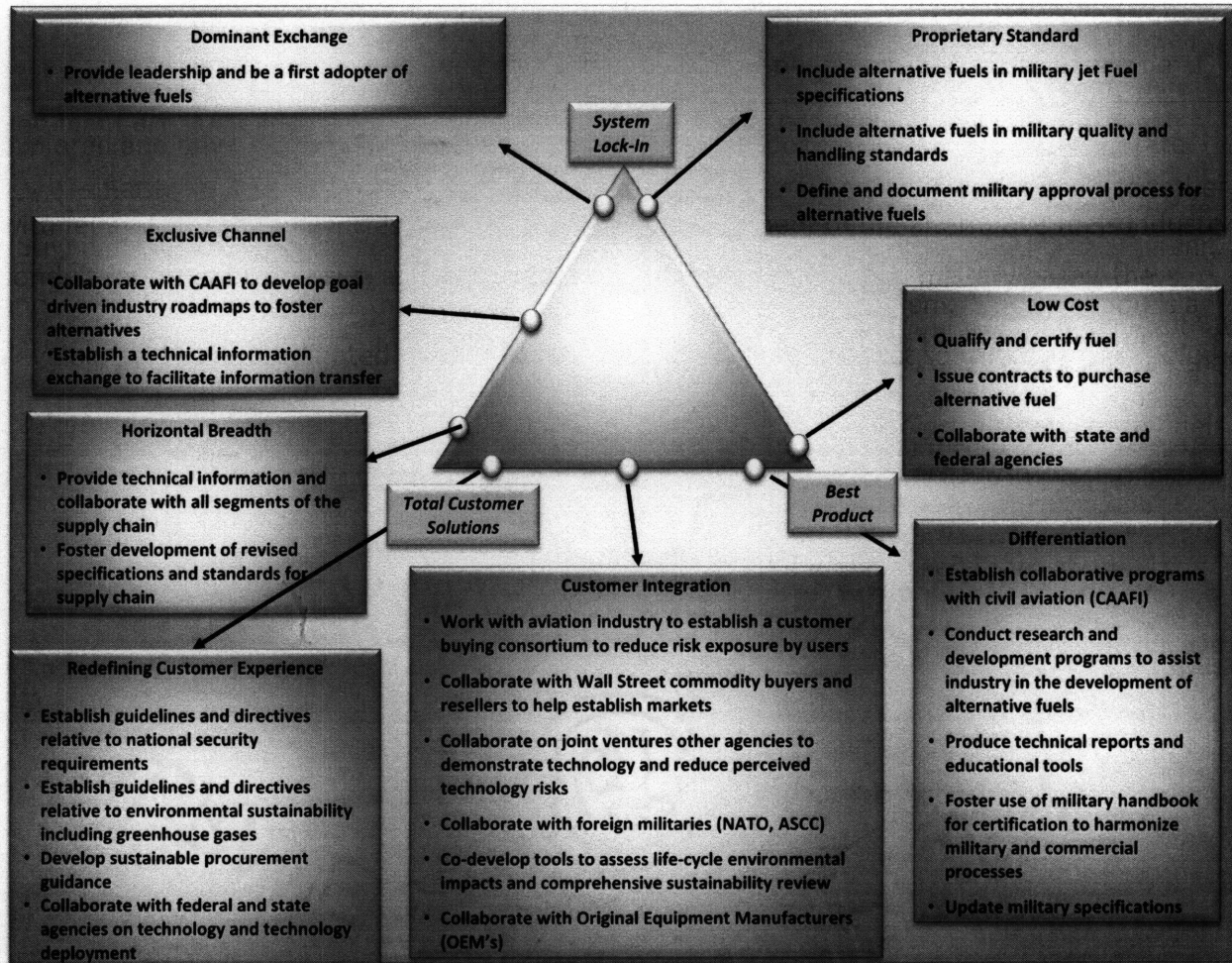


Figure 8.9 Applying the Hax Delta Model to Broaden Fuel Specifications

The differentiation that CAAFI brings to this strategy is to work as a central exchange to coordinate R&D, produce technical reports and technical exchange meetings, and to maintain documentation so that best practices can be shared. CAAFI, along with the military, should work to establish strong customer integration, primarily with all the stakeholders in aviation. By establishing a strong interface between the OEM's, the fuel producers, the aviation

regulators, and the financial community, all members of the value chain have the opportunity to participate, learn, and develop best practices. The overall flying customer experience and social welfare can be improved with the CAAFI process and military processes. National security impacts can be quantified and guidance and direction for greenhouse gas mitigation for aviation can be defined and documented. Collaboratively developed standards for life-cycle emissions analysis, sustainability analysis, and long-term financial stability for both the producers and the airlines can be developed and implemented. With CAAFI and the military both controlling their dominant exchanges and will cross flow of information between the groups, the next highest value would be for CAAFI to establish a central data base and forum for information exchange. For example, a user friendly information portal could be established to share non-proprietary information and a company networking program established to control the sharing of restricted proprietary information.

Sixth Recommendation: Open the military and commercial standard architecture to allow the entrance of alternative fuel technologies and build enthusiasm for business to compete against oil. Expand the role of CAAFI to include guiding a robust R&D program to solve technical challenges, become a data exchange platform for the industry, expand stakeholder networking, and focus on the key elements of fuel cost reduction, environmental stewardship, and safety of flight.

8.10 Develop Industry Wide Roadmaps

Since CAAFI and the military are exclusive channels and control the dominant exchange, a set of comprehensive roadmaps needs to be developed. CAAFI has developed a first

generation set of roadmaps, but they lack true interlocked goals and objectives as well as a set of metrics such that broad level goals, such as a biomass fuel spec by 2012 can be realized. CAAFI could use the general structure of the process used by the semiconductor industry to develop its integrated roadmaps. The U.S. semiconductor industry realized that it was losing competitive advantage due to a lack of alignment of all segments of the industry. To gain competitive advantage, a well respected industry leader was chosen to lead a new effort to align the industry. The task for this leader was to develop a clear set of roadmaps to align the industry and to support the necessary R&D required to keep the industry aligned. The leader of the consortia used a staff composed of employees supported by the consortia and supplemented by each stakeholder, providing additional employees when needed to assure alignment and support for the effort. CAAFI could consider a modified version of this approach. It could build upon its existing roadmap organization and appoint a well respected industry leader for each segment of the roadmap with a government official as the co-lead. The leads and co-leads would then pull together sessions to identify the technical challenges and barriers and develop a strategy to overcome them. Once the barriers and challenges were outlined, they would be mapped against a series of high level development goals, such as biofuel certification by 2016. From this exercise, a roadmap for each sector would be documented, and a meeting could then be held to align the roadmaps from each sector. At the alignment meeting, a joint set of interlocked roadmaps would be developed. The roadmaps would be published and a process established to meet the objectives of the roadmaps and to track the progress with metrics. A virtual network of employees would be made available by the stakeholders to solve the technical challenges, and the coordination of the roadmap activities

would be controlled by the co-leads of each roadmap segment. With the industry aligned roadmap and metrics established a mechanism for funding could be established. The funding could come from the government but should include cost shares from all the industry stake holders. With a roadmap and a funding pool, the domain architecture is opened and the alternatives fuel industry and airline industries can be aligned.

Seventh Recommendation: Develop goal- and objective-based roadmaps patterned after other industry consortia to align the stakeholders. Use CAAFI as the lead for the effort and use industry and government leaders to guide a virtual network of stakeholders to meet the objectives and goals. Align the roadmaps with funding pools and track progress with documented metrics.

With a clear set of goals and roadmaps, CAAFI could unite with similar bodies globally to develop an international set of goals and roadmaps. By leveraging global activities, overall industry alignment and harmonization can be fostered.

8.11 Risk and the “Valley of Death”

The recommendations so far have focused on the development of overarching tools and methodologies to help the government evaluate new innovations in alternative energy and to provide a pathway to a market for aviation fuels based on collaboration between the military and the commercial sector. These recommendations relate primarily to environmental and market issues, but they are not sufficient to secure the development of alternative aviation fuels. The risks and uncertainties must be evaluated at the entire project level, which includes project risk, industry, and competitive industry risks, as well as political, financial, and

regulatory risks. For a project to be financially sustainable, it must have a comparative advantage. To evaluate the comparative advantage, one must consider all the risks and uncertainties associated with the project. When looking at the alternative aviation fuel needs of the military and commercial airlines, one should take a broader view of competitive advantage that goes beyond the single firm financial sustainability advantage. This top level view should include the risk identified in the risk analysis worksheet described earlier in this thesis, which includes the project risk, national security issues, economic security issues, and environmental stewardship issues. Since these projects are first-of-a-kind and will not likely be built by a very large energy company, such as an integrated oil company who could assume all the risks, they will likely need some level of governmental support. Financially sustainability of such project requires a minimal level of government support and financial backstops to motivate the investment community to assume the risk, but also to keep enough project risk in the investors' hands to assure project efficiency and smart financial decisions. This critical balancing is a key element in helping industry cross the "Valley of Death."

Project financing is a key barrier to constructing first-of-kind plants. The financial community will evaluate whether the technology has a comparative advantage in cost, best value, and/or consumer differentiation and preferences. Airline and military customers are looking for advantages in price or price stability, security of supply, or sound environmental benefits. Plants that rely on government subsidies to be profitable are very risky, as the length of the subsidy can be changed by the government on an annual fiscal basis. Commercially viable projects without government subsidy are the most sound, but first-of-a-kind examples of

these plants may need some government sharing of the risk to allow an industry to start if there is a strong public benefit.

The commercialization of an alternative energy project has many risks that must be reduced or controlled and innovators may look towards government collaborations to share risk. For example, if an innovator develops a concept in the laboratory he will likely need funds to mature the concept. Funds may come from personal sources, government R&D funding, Small Business Innovative Research (SBIR) programs, National Science Foundation (NSF) grants and/or a variety of other sources. If the concept looks promising for commercialization, the innovator may secure funding from an angel investor or through venture capital firms providing equity to mature the technology. These investors in general are looking for a quick return on the investment and have limits on the number of rounds and the amount of financing that can be secured to mature the technology. This disconnect can be a limiting step as one of the challenges with alternative energy projects is the need to demonstrate the scalability of the concept at the process development unit level and produce gallons of fuel for evaluation. It becomes even more challenging to secure financing for a pre-commercial scale demonstration that proves the final scalability of a commercial plant. These challenges are all part of the technology maturation cycle, as shown in Figure 8.10 and they position the developer at the edge of the “Valley of Death.”

The cost of each of these steps increases significantly and is a barrier to the innovator. Government funding is sometimes available through the DOE through competitive programs to help reduce the demonstration risk at the process development phase and for very costly

projects at the pre-commercial demonstration phase. Venture capital and other equity funding can also be used to help demonstrate the technology and reduce pre-commercialization risk. Equity financing tends to favor projects that can reach the market quickly and require relatively small amounts of capital (tens of millions of dollars). For example, this approach tends to favor small biomass conversion processes that can be commercialized for a few hundred million dollars and constructed in about 2 years over large projects such as oil shale, or coal, which may require over \$1 billion and 4 – 6 years to construct. Biomass plants may produce fuel at a scale of 100 million gallons per year, where as a small coal-to-liquid or shale plant may produce 450 million gallons per year. The scale up to the commercial size plant will require new sources of equity and debt. Both types of projects pose risk for first-of-a-kind plants and investors may need backstops to reduce the risk. In general, project developers would like to have as much debt as possible for a project (for example, 80%). However, for high risk projects such as alternative energy they may need to provide more equity (for example, 40%) and pay a premium for the cost of capital. Many projects languish in this part of the “Valley” as the developers do not have the equity to create the leverage for debt and the cost of debt is higher than the expected return on the project.

8.12 Government Support Scenarios for First-of-a-kind Alternative Energy Plants

The financial barriers could be reduced with support from the government for first-of-a-kind plants. State and federal government support to help reduce project risk occurs in the four different time segments related to the development of a first-of-a-kind plant. These time segments are the siting and permitting phase, the construction phase, the initial operational

and shakedown phase, and the technology deployment phase as shown in Figure 8.11. Each of these time segments has different types and levels of risk. Some of the risk is imposed by government policies, regulations (or lack of them), or procedures (or lack of them). Other risks stem from the technical, financial, or market uncertainty. Government risk sharing should be a careful balancing act where the industry shoulders enough of the risk to keep the project efficient and profitable and the government provides the incentives and backstops for the project to move forward. In the past, the government has been too generous with support and has not let the project be managed in an efficient manner. Most of these projects have failed in the end, even if they clearly demonstrated the viability of the technology. The following scenario analysis and recommendations are based on a methodology that tries to strike this balance and provides the proper incentives to help develop the attractiveness to build first-of-a-kind plants, as was shown in Figure 8.2.

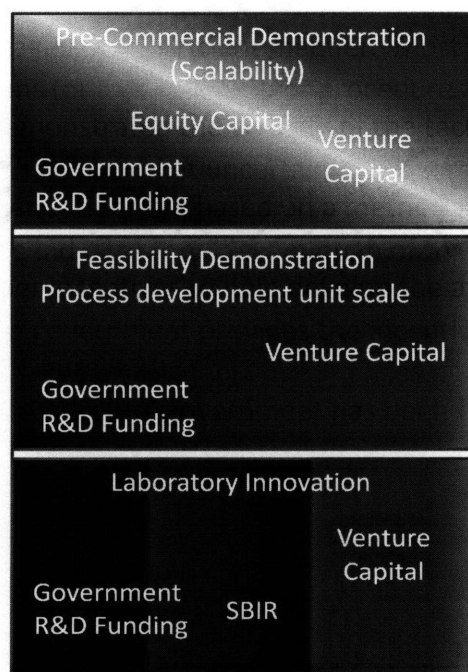


Figure 8.10 Technology Development Maturation

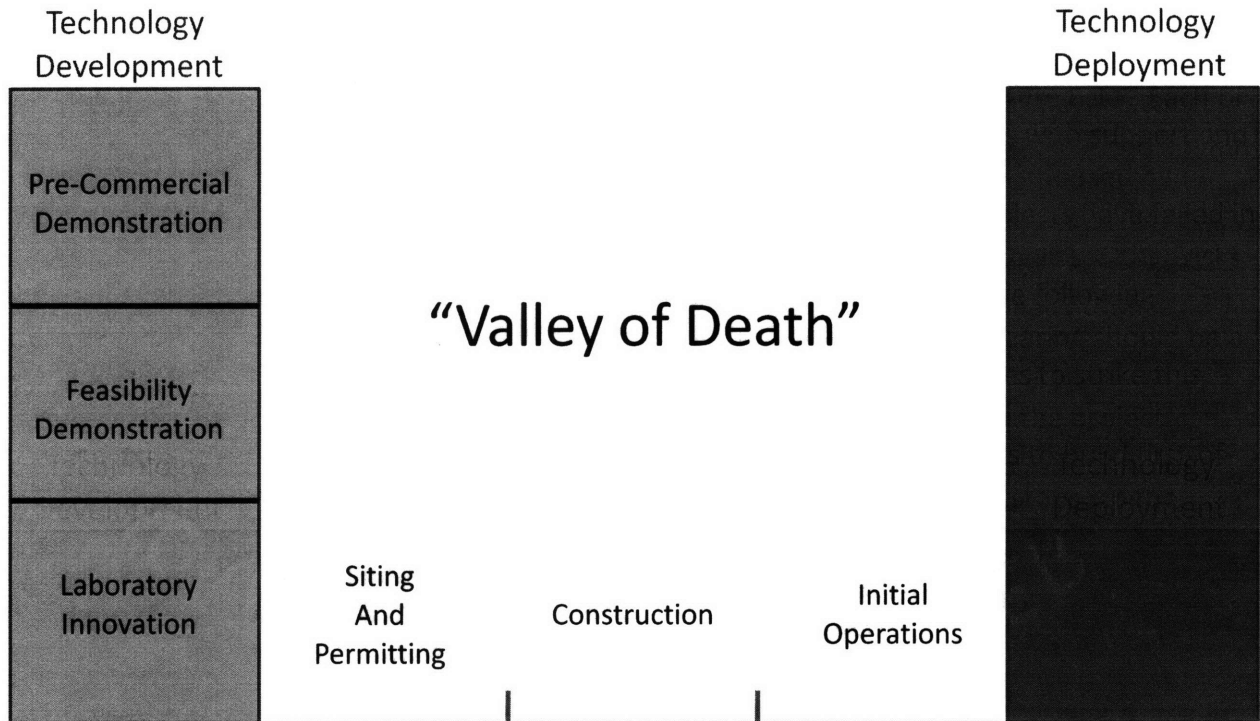


Figure 8.11 Crossing the Segments of the “Valley of Death”

Government support must be provided competitively and transparently but it can come from different state and federal agencies depending on the time segment of the project. One of the key phases in which state and federal government can reduce risk is in the siting and permitting phase. In my discussions with financial institutions and project developers, many expressed concerns about the difficulty in siting and permitting alternative energy facilities. Since these facilities will be first-of-a-kind plants, state and federal processes may need to be adapted. Developers and financial institutions face significant financial risk if they length of the process cannot be defined upon filing or if there is a process in place to deal with the facility. In many cases, developers are driven to look only at locations with favorable siting and permitting regimes: states that do not have efficient processes will be avoided by the developers. Since aviation impacts every state in the U.S., a streamlined siting and permitting process with known

approval timelines would help reduce development and financial risk. Along with the siting and permitting, some resources require a new land use policy. This is critical for the development of oil shale on federal lands but may also be important for land changes required to raise energy crops. Federal and state attention to land use policy in regards to energy would also reduce risk and increase the potential for multiple alternative energy projects. All sectors interviewed expressed concern about the lack of greenhouse gas legislation and carbon sequestration legislation. Since CO₂ is not currently regulated, and uncertainty exists at all levels that carbon regulations are not imminent, almost all projects are on hold until legislation is passed. In many ways, the lack of legislative frameworks for greenhouse gases is holding up the deployment of new technologies that would reduce carbon footprints and bolsters the use of imported oil. Clear legislation related to greenhouse gas emissions and carbon sequestration would unbridle all industries and allow them to move to more aggressive carbon mitigation strategies. The National Environmental Policy Act (NEPA)¹⁰⁵ may require the evaluation of the environmental effects of an alternative energy project involving the government. The development of environmental assessments (EA) and environmental impact statements (EIS) for each alternative energy resource, fossil or biological, would help reduce the risk of new projects and first-of-a-kind plants. Government support of EIS would help the decision making process to determine the overall hazards or benefits of each alternative energy technology. To support the development of an alternative energy industry for aviation, the federal government should develop greenhouse gas legislation and carbon sequestration legislation. Where federal lands are involved, federal land use policy must be in place for the development to occur.

¹⁰⁵ National Environmental Policy Act, <http://www.epa.gov/compliance/basics/nepa.html>.

These policies should address national security, economic security, and environmental security. Federal support of EIS would help expedite the NEPA process and help decisions makers determine the best levels of program support.

The final step that the military and the commercial airline sector can facilitate is the qualification and certification of the fuel. Current processes require approximately 250,000 gallons of fuel for full qualification and certification. If the fuel is produced from pre-commercial demonstration facilities and represents commercial production quality, the qualification and certification step would ensure that the fuel can be purchased by the early adopters. Figure 8.12 illustrates the potential government interventions that would enable the initiation of an alternative energy plant.

Eighth Recommendation: State and federal governments play an important role in helping first-of-a-kind plants to be built. Government should provide support for siting and permitting processes, have land use policy in place, and develop comprehensive greenhouse gas and carbon sequestration legislation. This legislation, combined with programs to analyze alternative energy projects under NEPA guidelines and with proper land use policy, can lead to the deployment of next generation fuel technologies that have low environmental impact. The military and commercial airlines should qualify and certify the fuels such that they are willing to buy them once the plant is completed.

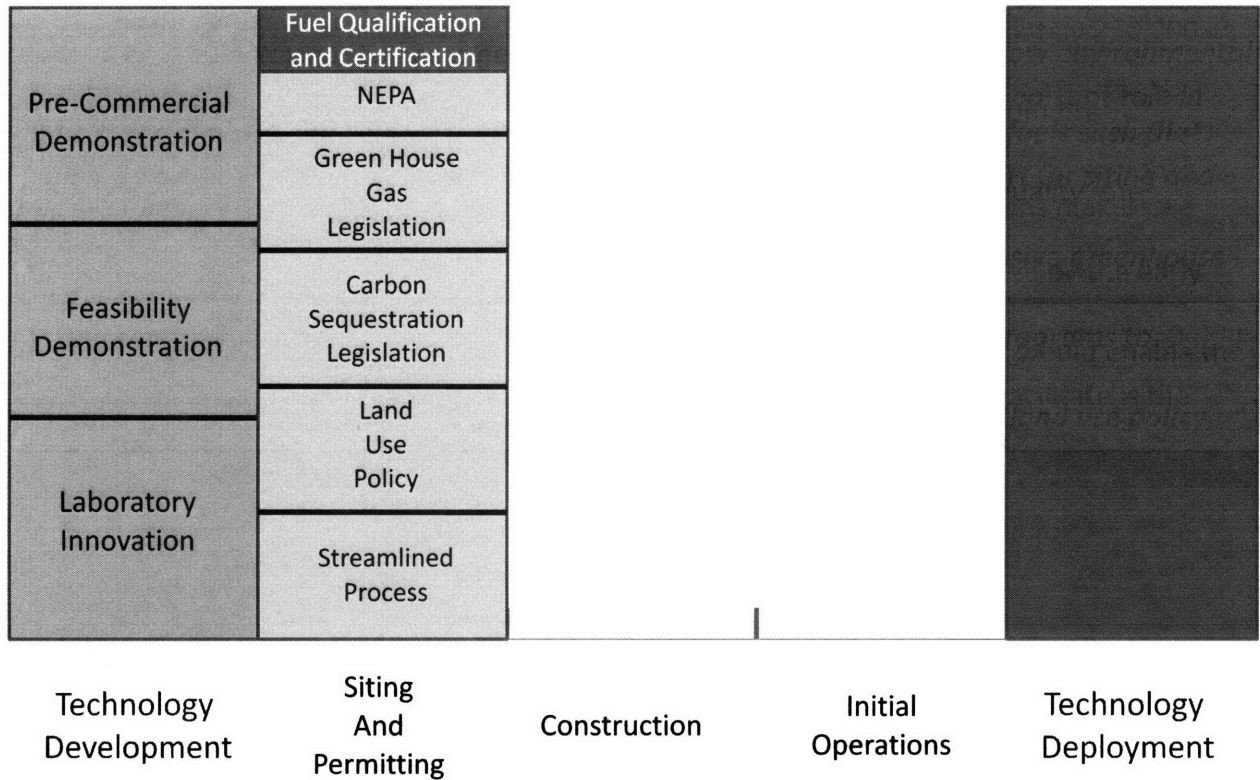


Figure 8.12. Federal and State Support Required to Cross the “Valley of Death”

8.13 State Government Involvement

State governments are key collaborators in the development of an alternative energy industry to support the military or the airline industry. Porter (2005)¹⁰⁶ describes an approach to compare sources of locational competitive analysis for a company. I have used this basic framework to compare how states can provide competitive advantage to alternative energy developers and help them cross the “Valley of Death,” as shown in Figure 8.13

¹⁰⁶ Michael Porter, “Competing Across Locations”, Harvard Business School Press, 1995.

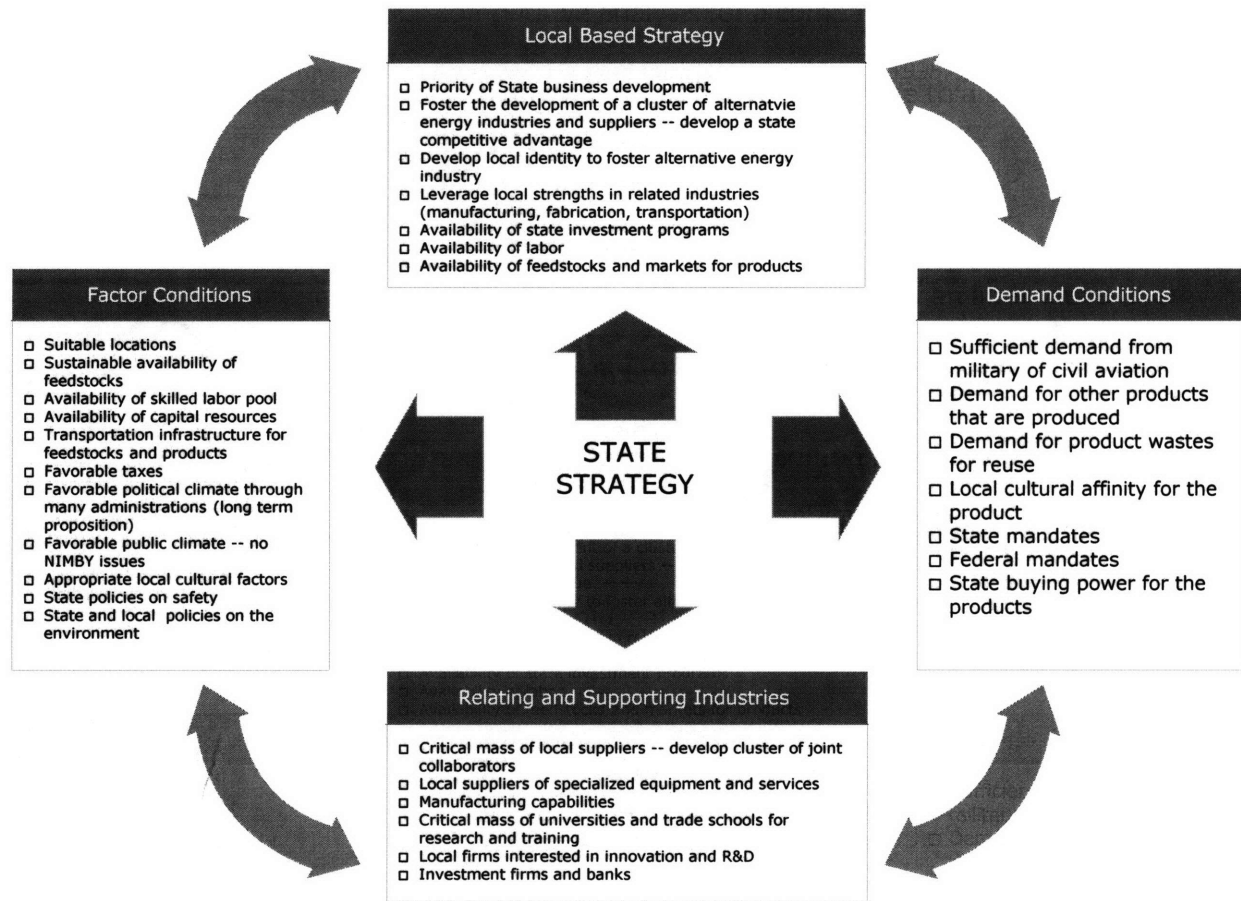


Figure 8.13 Analysis of States role in alternative energy developer's competitive advantage

A state government can be the source of an alternative energy developer's competitive advantage or can create insurmountable hurdles and impediments. Improving the culture and political environment within a state is the first step to helping cross the "Valley of Death." States that value alternative energy projects can increase growth opportunities by developing a cluster of alternative energy projects and related suppliers. The state can leverage local strengths in related industries such as manufacturing, fabrication and transport with the development of natural and agricultural resources in the state. If the state provides proper economic development incentives multiple projects can be developed and provide the state

with economic wealth in terms of jobs and taxes. The best locations would have a ready market for the alternative jet fuel, either large airports or a military base. The plants would be located in communities that welcome the industry. Plants should be located within economical transport distances for the feedstocks and have a strong infrastructure to mine or harvest and transport it to the production facility. Production can be stimulated by state or federal mandates, and the state may even become a customer for the products by using them in state transportation assets. The construction of a plant can be a magnet for a cluster of supporting industries and services and thus become an economic multiplier for the region. The state can also encourage future growth by supporting its universities and vocational schools in the development of skilled workers and long-term research and development needed for continuous innovation in the sector.

One of the key barriers identified in the literature and interviews was the legal frameworks and time constraints of the permitting processes. A developer places resources at risk when he buys land for a project and conducts sufficient design and engineering to fulfill the requirements of the permits needed to start construction. States that have structured processes with defined time lines for permits are more likely to garner alternative energy developer than those that have poor processes. Since any alternative energy project is capital intensive, the developers can not afford to spend significant amounts of resources only for the state to hold them in an indefinite state of limbo waiting for permits. One area that needs state attention is the development of permits and oversight of CO₂ sequestration. States that develop well defined processes in this arena will be very attractive to alternative fuel developers. States that provide financial incentives related to taxes, depreciation, investment

bonds, and direct investment in projects will achieve yield significant leverage over states that do not. States that have sufficient rural infrastructure and resources to develop that infrastructure as needed offer significant competitive advantage.

Ninth Recommendation: The military and commercial airlines should collaborate with state governments that are favorable to the development of alternative energy projects and provide support for project developers. Alternative aviation fuel projects would provide rural economic development and increase local wealth. Partnerships with the military and the commercial airlines bolster national security and enable strong business commerce.

8.14 Project Construction Risk Sharing

One major financial risk is the construction of first-of-a-kind plants. The risk currently is heightened due to the large worldwide demand for engineering, procurement, and construction (EPC) contractors and the demand for construction materials. Many EPC contractors have a waiting list of projects and are most inclined to work on those that require the least amount of project insurance or “wrap” or those for which they may receive premium. In the interviews, many project developers commented that only a few EPC contractors worldwide have the skills to manage a large alternative energy construction project and most are not willing to provide full performance wraps due to the uniqueness of first-of-a-kind integration. If they provide a wrap it would likely be based on an inflated project cost to provide a wedge of “insurance.” At the present time, EPC contractors are concerned about the technical maturity of the design of alternative energy projects. In addition, most are unable to give solid cost estimates due to the upward spiral of material and labor costs resulting from

worldwide demand. With oil over \$100 per barrel at the time of this writing, the incentives for worldwide energy projects are very high and contractors will be drawn to the most lucrative projects first. With cost uncertainty and concerns over EPC wraps, the investment community faces high risk. One way to potentially reduce this risk is to bundle a package of incentives with the government as a partner or a backstop. In the interviews, the financial community stated that all projects would have to be a mixture of equity and debt and the instruments to reduce risk needed to account for both the equity and the debt risk. The two main instruments that have been suggested were loan guarantees to help reduce the debt risk especially in the area of potential cost growth, and long-term off take agreements for the product to help reduce the equity risk. Both tools help reduce risk of the entire financing package. Off-take agreements with a price floor reduce risk even more. Both of these tools could be costly to the government if not properly structured. Loan guarantees could be costly if the project is poorly managed and is not focused on long-term profitable sustainability. Off-take agreements should be structured such that the purchaser and the producer benefit. There are some potential models that could be explored to develop these agreements. For example, the military supports the Civil Reserve Air Fleet (CRAF) to enable increased airlift capability in the time of a crisis. This program is managed by long-term contracts where a certain amount of airlift is purchased and a fee paid for the use of more capacity. Utilities use a somewhat similar model for “peaker” plants to provide electricity during high demand periods. These models may provide a structured off-take agreement that balances the needs of the producer and the consumer and provides security for the financial community.

Reducing the risk related to EPC wraps is a challenging task. It might be possible to build a hedging strategy with a basket hedge of construction or some type of new risk cost sharing agreement be developed by the government and the developer where price consideration is scaled and rewarded based on operating capacity and efficiency. Other options may include some sort of government backed construction bonds, government backed insurance, or effective tax incentive. Figure 8.14 illustrates this risk feature.

The challenge of these state and federal incentives to reduce risk is to making sure the financial community maintains enough of the risk to assure commercial viability and cost competitiveness, while the incentives provide a solid enough backstop for the risk such that a project can succeed. It is my belief that these types of incentives may only be needed only for the first two or three plants to assist the industry with the learning curve. After the initial commercial deployment of a few plants, the risk structure will be better understood and normal market mechanisms should provide the capital for expanded production.

Tenth Recommendation: The government should develop an effective set of tools such as an expanded loan guarantee program for alternative energy projects and frameworks for long-term market based off-take agreements to help reduce the financial risk of first-of-a-kind plants. These incentives should help provide risk reduction backstops and provide benefits to the government, the developer, and the public.

Pre-Commercial Demonstration	Fuel Qualification and Certification	Debt Risk	Loan Guarantee	Technology Deployment
	NEPA			
Feasibility Demonstration	Green House Gas Legislation	Equity Risk	Off-Take Agreement Price Floor	
	Carbon Sequestration Legislation			
Laboratory Innovation	Land Use Policy	Construction Risk	EPC Incentive	
	Streamlined Process			
Technology Development	Siting And Permitting	Construction	Initial Operations	

Figure 8.14 Federal and State Incentives to Reduce Construction and Initial Operational Risk

8.15 Sustainment of the First Plants through the Learning Process

The key benefit of government support for first-of-a-kind plants is that it fosters the learning process the industry needs to grow and become more efficient and cost effective. This process requires that the first plants run for several years to help develop the knowledge base related to operations, de-bottlenecking, efficiency gains, cost reductions, maintenance and overall durability. This is critical to increase the attractiveness of the technology such that other facilities are built. At this point, the developer has crossed the “Valley of Death” but is in a vulnerable position as there needs to be a bridging strategy of the “Chasm” of both the early majority consumers and new market entrants to meet the increasing demand. The federal and state governments should provide sustaining support for the first few alternative energy plants

in this technology deployment phase as shown in Figure 8.15. For example, long-term off-take agreements provide a continuing market for the product and if the fuel were purchased at a fixed price (with a programmed escalator) or at market with a price floor, the purchaser would have a measure of price stability. The market price of the product could be capped with a collar to provide upside cost growth for the off-taker as a benefit for providing risk reduction for the project. State and federal incentives related to tax reductions; accelerated depreciation, job creation or other means would also help the sustainment of the initial deployment of first-of-a-kind projects and ensure that the projects can help the industry gain knowledge on the learning curve.

Pre-Commercial Demonstration	Fuel Qualification and Certification	Debt Risk Loan Guarantee	Purchase Agreements	
	NEPA			
Feasibility Demonstration	Green House Gas Legislation	Equity Risk Off-Take Agreement Price Floor	State Incentives	
	Carbon Sequestration Legislation			
Laboratory Innovation	Land Use Policy	Construction Risk EPC Incentive	Federal Incentives	
	Streamlined Process			
Technology Development	Siting And Permitting	Construction	Initial Operations	Technology Deployment

Figure 8.15 Crossing the “Valley of Death”

8.16 Building a Growing Industry

Once the challenge is to get the first company to cross the “Valley of Death” is met the next challenge is to spur other competitors on to build plants based on demand. For the first plant is built a company needs to have a secured set of early adopters; in this case, a cluster of airlines at a single airport or the military. Early adopters are best positioned to take advantage of long-term off-take agreements, but must balance any additional risk exposure that might occur with a strong drop in the price of oil. If the airlines form a buying consortium for the fuel at specific locations, any potential risk exposure would be spread equally across all the airlines at that location equally. The buying consortium could gain cost stability with long-term off-take agreements and pave the way to help establish an industry that could provide price arbitrage situations in the future.

In Chapter 6, I presented a model that showed the dynamics of how the industry can progress if the fuels were approved, and first-of-a-kind plants were built that produced fuel competitive to petroleum derived fuels and potentially offered an environmental benefit. The model shown again as Figure 8.16 demonstrated that if the first plants can be built, and the airlines are willing to buy the product, the dynamics of the system will likely create an industry. Clusters of airlines at a single airport will drive the use of the fuel at multiple airports which increases the attractiveness of building additional alternative energy plants. If the fuel is attractive from both a price and an environmental standpoint, more demand will be created and more users will buy the fuel. Assuming the plants are profitable, then more interest will be.

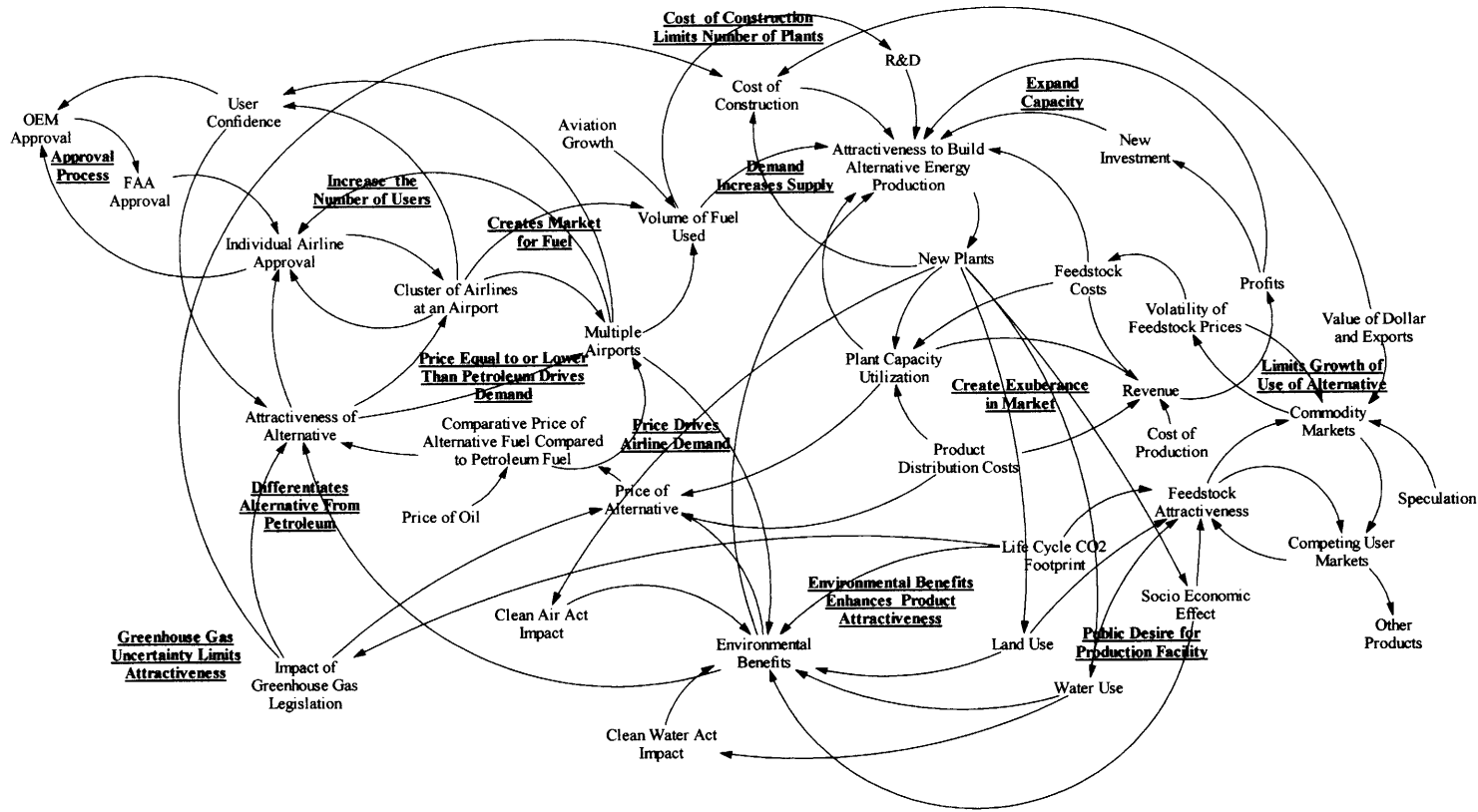


Figure 8.16 Alternative Aviation Fuel Systems Dynamics Model

generated on the production side, thereby increasing the number of plants that will be built. If the plants maintain a high capacity utilization rate they may be able to compete more favorably over time in terms of price and continue the dynamics of the process. If the feedstock commodity markets react favorably and keep the price in a range where the industry can remain profitable, the market will remain sustainable. If the fuel is produced in an environmentally acceptable manner, the benefit of the shift to alternatives will be enhanced

8.17 Bridging the “Chasm”

Using the tools described in this thesis, early adopters can become acquainted with technologies and conduct comparative analysis. The more options that can be used by groups of early adopters, the more choices will become available and more competition generated to help reduce costs. Since cost of the product and the volatility of the cost are key drivers in the financial sustainability of the airlines industry, approaches that lead to multiple alternatives and producer competition should be encouraged.

Once groups of airlines become early adopters, the process can be opened up to achieve the right balance of alternative and petroleum derived fuels for the early majority. The early majority requires that all aircraft and engines are qualified and certified, and that all airlines have chosen to be able to use alternative fuel. Bridging the “Chasm” between early adopters and the early majority is more likely to occur if the alternative fuels are cost competitive, readily available, fully fungible, and qualified and certified for all aircraft and engines. The best approach is to be able to certify fully synthetic fuels such that any blend ratio of the fuel can be used fungibly in the system.

Eleventh Recommendation: The military and the civil community must certify alternative fuels for use in all aircraft, engines and ground infrastructure and become early adopters. The collaborative actions would provide a market for the alternatives and create an early majority of airports and airbases such that it will drive the dynamics of adoption at other locations until demand is satisfied. Increasing demand will help the industry grow and be viable and is likely to provide a global leadership for the industry.

8.18 One Final Thought

In this chapter and in this thesis as a whole I identified the challenges of the innovation technology development cycle for alternative aviation fuels and provided tools, scenarios and recommendation to help start an alternative aviation fuel industry. My final thought is “Nullis in Verba” (take nobody’s word): debate what is in this document, implement what makes sense, and help the aerospace industry move toward a sustainable future with multiple fuel choices.

9.0 Thesis Summary

In this thesis I explored the risks and uncertainties related to the development of an industry to produce alternative aviation fuels for the military and commercial airlines in the United States. The approach I used was to explore the technology adoption lifecycle (as shown in Figure 9.1), from the innovator of the technology to the establishment of an early majority of users, through the lenses of the alternative fuel innovators, potential early adopters, the early majority, and the financial community. The technology adoption lifecycle has two main regions of risk and uncertainty: the “Valley of Death,” the region between the technology development and the early adoption by users and the “Chasm,” the region between the early adopters and the early majority of users. I then described the risks and uncertainties associated with the “Valley of Death” and the “Chasm” using business frameworks, scenarios, systems dynamics models, and research from the literature and interviews with industrial representatives to offer tools, suggestions, and recommendations on how the “Valley” can be crossed and the “Chasm” can be bridged.

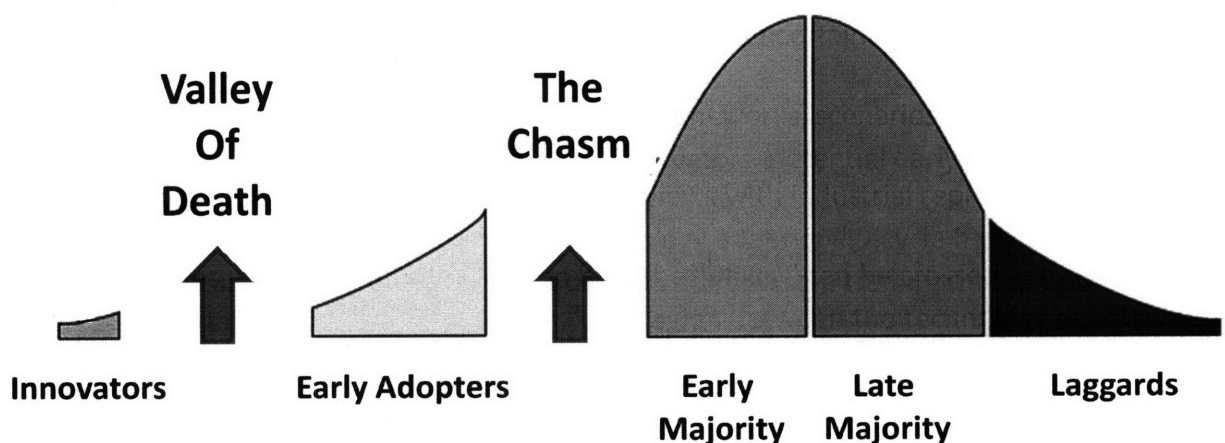


Figure 9.1 Technology Adoption Lifecycle

We are in a second wave of innovation for aviation fuels produced from alternative resources as shown in Figure 9.2. With oil price above \$100 per barrel, and growing concerns about the impact of oil on national security, economic security and global warming, we should develop an aggressive strategy to foster an alternative energy industry for aviation. With alternatives, the industry will have choices that could impact supply, cost, and/or environmental footprint. This thesis shows that by looking at the relationships among national security, economic security and environmental stewardship as shown in Figure 9.3, and developing strategic frameworks, evaluation tools, and system dynamics models, the military and the civilian airlines can help initiate a sustainable alternative fuel industry.

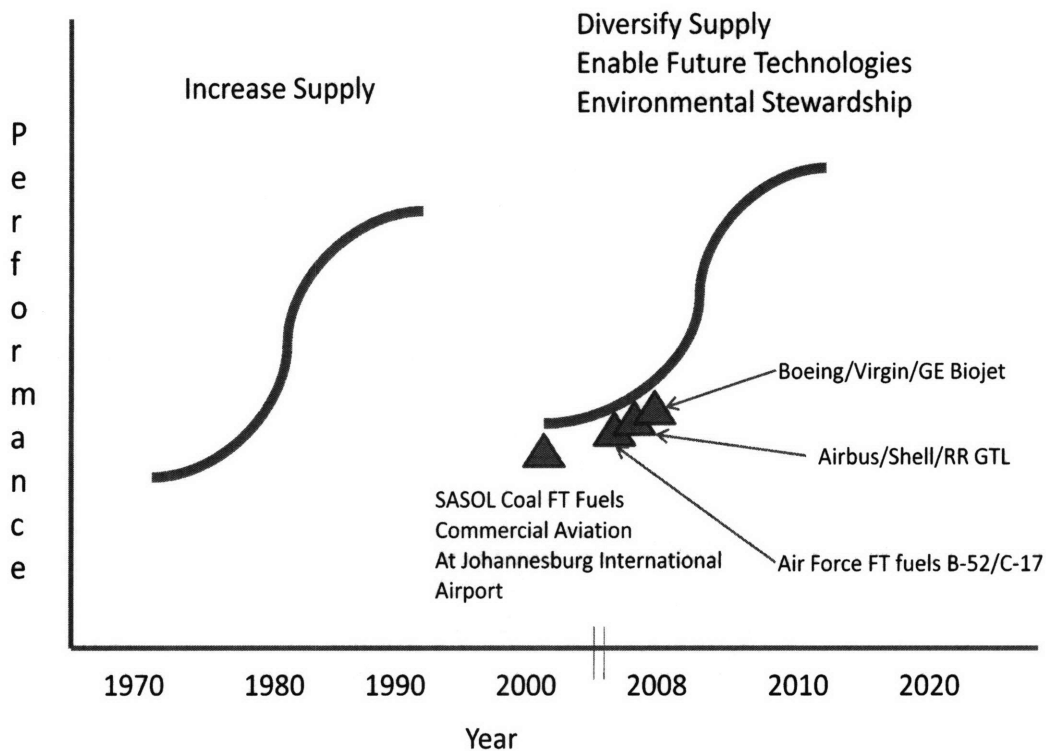


Figure 9.2. Waves of Innovation for Alternative Aviation Fuels

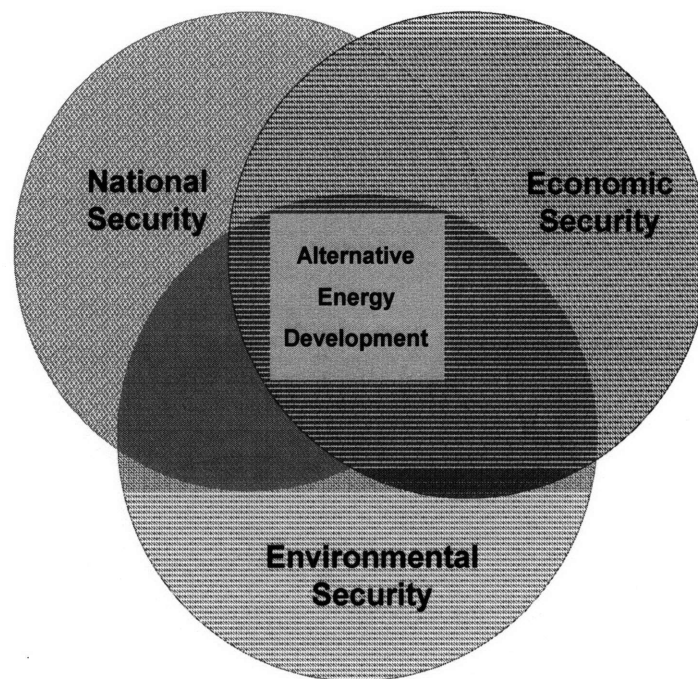


Figure 9.3 The Alternative Aviation Fuel Nexus.

In this thesis I conducted research using the literature in the field and by interviewing representatives from companies developing oil shale, coal-to-liquids, and biofuels, airlines, and the financial community to explore the challenges and barriers associated with crossing the “Valley of Death” and bridging the “Chasm.” This research led me to develop an alternative fuels portfolio approach that uses a balanced scorecard to assess the benefits of the technology and a risk assessment worksheet to assess the risks of the project. This process takes into account the issues of sustainability, including financial, market, technology, and environmental uncertainties. By using these tools and models, I developed the following recommendations that will assist the alternative aviation fuel industry start and become a sustainable part of the fuel supply in the United States. My recommendations:

- ***First Recommendation: The DoD should collaborate with other government agencies to develop the tools and procedures to compare life-cycle-analysis and sustainability criteria such that alternatives can be compared on an equal basis and re-evaluated periodically to allow the determination of long and short-term impacts as each alternative fuel emerges.***
- ***Second Recommendation: The DoD should request that the EPA and DOE develop a clear definition of the CO₂ lifecycle footprint for petroleum and the boundaries for a well-to-wake calculation of alternative fuels and collaborate with them on alternative fuels analyses.***
- ***Third Recommendation: Develop tools such as balanced scorecards and risk analysis tools. Conducting time-phased analysis that considers the short-term (5 – 10 years), mid-term (10-25 years), and long-term (25 – 50 years) would provide a path that incrementally brings in new innovations and disengages from those that are no longer sustainable from an environmental or business standpoint. An example of these tools is shown in Figures 9.4 and 9.5.***
- ***Fourth Recommendation: To help the industry cross the “Valley of Death,” develop multiple-agency projects that create government and industry learning for first-of-a-kind plants utilizing tools to minimize cost and maximize commercial potential. Use the Department of Defense as the knowledgeable buyer and the other agencies as agents facilitate learning about new technologies and environmental effects. This risk mitigation approach should enable commercial financing of the project and minimal expenditures from the government and allow the industrial partner to focus on***

business practices and efficiencies needed for unsubsidized operation. The data from these projects can be used to update the balanced scorecard and risk analysis tools and to assist the government in future R&D investment and generate support for other alternative fuels projects.

- ***Fifth Recommendation: Look for a quick win project in addition to longer term complex programs that require significant amounts of learning. The low cost domestic resource that fits into the current dominant exchange and commercial industrial base is oil shale. The government needs to establish a commercial leasing program and provide access to federal lands for this to succeed. Legislation related to environmental stewardship related to greenhouse gases needs to be enacted. Environmental stewardship needs to be demonstrated. Carefully enacted federal and state policies can ensure that socio-economic interests are balanced; infrastructure is developed in lock step with commercial development, and national security and domestic supply are increased. The military and commercial sector can adopt these fuels very quickly as the specifications are in place for this type of fuel.***
- ***Sixth Recommendation: Open the military and commercial standard architecture to allow the entrance of alternative fuel technologies and build enthusiasm for business to compete against oil. Expand the role of CAAFI to include guiding a robust R&D program to solve technical challenges, become a data exchange platform for the industry, expand stakeholder networking, and focus on the key elements of fuel cost reduction, environmental stewardship, and safety of flight.***

- ***Seventh Recommendation: Develop goal- and objective-based roadmaps patterned after other industry consortia to align the stakeholders. Use CAAFI as the lead for the effort and use industry and government leaders to guide a virtual network of stakeholders to meet the objectives and goals. Align the roadmaps with funding pools and track progress with documented metrics.***
- ***Eighth Recommendation: State and federal governments play an important role in helping first-of-a-kind plants to be built. Government should provide support for siting and permitting processes, have land use policy in place, and develop comprehensive greenhouse gas and carbon sequestration legislation. This legislation, combined with programs to analyze alternative energy projects under NEPA guidelines and with proper land use policy, can lead to the deployment of next generation fuel technologies that have low environmental impact. The military and commercial airlines should qualify and certify the fuels such that they are willing to buy them once the plant is completed.***
- ***Ninth Recommendation: The military and commercial airlines should collaborate with state governments that are favorable to the development of alternative energy projects and provide support for project developers. Alternative aviation fuel projects would provide rural economic development and increase local wealth. Partnerships with the military and the commercial airlines bolster national security and enable strong business commerce.***
- ***Tenth Recommendation: The government should develop an effective set of tools such as an expanded loan guarantee program for alternative energy projects and***

frameworks for long-term market based off-take agreements to help reduce the financial risk of first-of-a-kind plants. These incentives should help provide risk reduction backstops and provide benefits to the government, the developer, and the public.

- ***Eleventh Recommendation: The military and the civil community must certify alternative fuels for use in all aircraft, engines and ground infrastructure and become early adopters. The collaborative actions would provide a market for the alternatives and create an early majority of airports and airbases such that it will drive the dynamics of adoption at other locations until demand is satisfied. Increasing demand will help the industry grow and be viable and is likely to provide a global leadership for the industry.***

These eleven recommendations provide a series of tools to assess the viability of projects, provide pathways to successful first-of-a-kind demonstrations, and provide actions that could reduce project risk. For example, Figure 9.6 shows how a series of actions by industry and the government can bridge the “Valley of Death.” With proper government incentives for a few plants that carefully balance risk between the developer and the government to ensure efficient profit oriented operation, an industry can take root. With a few plants and a growing demand from clusters of airlines at airports, and/or increasing use by the military, the growth will sustain as shown in Figure 9.7 until demand is satisfied. This growth bridges the “Chasm” between the early adopters and the early majority.

In many areas I have just touched the surface and additional work is required to clearly define the details of the proposed strategy. In addition, additional effort is required to search for ways to make the industry grow in a sustainable manner without government support or intervention. It is my hope that this thesis will stimulate the discussions and debate that is needed for the military and the airlines to move into a new age of aviation fueled with alternative fuels.

Balanced Scorecard Part 1

Technical Maturity	Importance (0 - 5)	Impact (0 - 3)
Technology Readiness Level		
Technology Risk		
Commercialization Readiness		
Position on the Learning Curve for Commercialized Process		
Correctly Positioned on Value Chain with Collaborators		
Technology Saleable Globally		
Feedstock Supply Infrastructure Readiness		
Product Distribution Infrastructure Readiness		
Score		

Cost	Importance (0 - 5)	Impact (0 - 3)
Feedstock Cost		
Feedstock Volatility		
Production Costs		
Product Cost		
Product Cost Volatility		
Cost of Production Facility \$/bbl basis		
Federal Incentives Required		
State Incentives Required		
Subsidies Required		
Subsidy Availability for first 5 - 10 Years of Plant Operation		
Estimated Price of Oil for Economic Viability		
Additional Infrastructure Required		
Cost Impact to Fully Burden Cost of Fuel		
Cost of Fuel Qualification and Certification		
Impact of Force Structure		
Contracting Mechanisms and Off-Take Agreements		
Score		

Figure 9.4 Balanced Scorecard

Balanced Scorecard Part 2

Environmental Impact	Importance (0 - 5)	Impact (0 - 3)
Feedstock Environmental Impact		
Land Use and Reclamation		
Water Use		
Soil Depletion and Erosion		
Life Cycle Run-Off and Treatment		
Local Environmental Impacts		
Local Air Quality (Clean Air Act)		
Local Water Quality (Clean Water Act)		
Socio Economic Considerations (e.g. NIMBY)		
Life Cycle Greenhouse Gas Footprint Compared to Petroleum		
Emissions Profile When Fuel is Burned (e.g. soot, HAP's)		
Net Energy Value		
Score		

Externalities and Barriers	Importance (0 - 5)	Impact (0 - 3)
Legal Statutes and Regulations		
Infrastructure Availability for Feedstock Transport		
Infrastructure Availability for Product Transport		
Compatibility with Existing Infrastructure for Transport and Storage		
National Security Impact		
Impact on Federal or State Mandates		
Environmentalists and NGO's Support		
Political Support		
Alignment with Commercial Aviation Sector		
Compliance with Executive Orders and other Mandates		
Perceived Risk By Financial Institutions		
Score		

Figure 9.4 Continued, Balanced Scorecard

Risk Analysis Worksheet Part 1

Project Risk (Financial Market)	Importance (0 - 5)	Impact (0 - 3)
Technology Risk		
Capital Cost of Project		
Cost Increases During Construction Cycle		
Engineering Capacity to Build Plants		
Operating Performance Guarantee/Start-up Time		
Crude Oil Price Slide		
Alternative Fuel Feedstock Price Increase		
Greenhouse Gas Legislation		
Score		
	(40 max)	(24 max)

National Security Issues	Importance (0 - 5)	Impact (0 - 3)
Domestic Versus Global Supply		
Diversity of Supplier Base		
Improve Global Availability of Fuel		
Supply Interruption Buffer		
Improve Fuel Critical Infrastructure		
Score		
	(25 Max)	(15 Max)

Figure 9.5 Risk Analysis Worksheet

Risk Analysis Worksheet Part 2

Economic Security Issues	Importance (0 - 5)	Impact (0 - 3)
Balance of Trade		
Domestic Tax Base		
Domestic Jobs		
Effect on GDP		
Score		
	(20 Max)	(12 Max)

Environmental Stewardship Issues	Importance (0 - 5)	Impact (0 - 3)
Local Air Quality		
Global Climate Change (Greenhouse Gases)		
International Operability		
Land Use Including Reclamation		
Water Pollution		
Water Demand		
Score		
	(30 max)	(18 Max)

Figure 9.5 Continued, Risk Analysis Worksheet

Pre-Commercial Demonstration	Fuel Qualification and Certification	Debt Risk Loan Guarantee	Purchase Agreements	
	NEPA			
	Green House Gas Legislation			
Feasibility Demonstration	Carbon Sequestration Legislation	Equity Risk Off-Take Agreement Price Floor	State Incentives	
	Land Use Policy	Construction Risk EPC Incentive	Federal Incentives	
Laboratory Innovation	Streamlined Process			
Technology Development	Siting And Permitting	Construction	Initial Operations	Technology Deployment

Figure 9.6. Actions to help the first alternative aviation fuel developers cross the “Valley of Death”

Appendix A

Questionnaires

Alternative Energy Developers

The working title for my thesis is: Alternative Fuels: How can Government Cross the “Valley of Death.” The Department of Defense (DoD) would like to diversify fuel supplies and become feedstock neutral. I began working on this project when I was assigned to an Assistant Deputy Under Secretary of Defense (ADUSD) in the Advanced Systems and Concepts Office in the Office of the Secretary of Defense. The Assured Fuels Initiative was to catalyze the industry to provide alternative fuels for the Department of Defense in an environmentally sound manner. As a member of the staff working on this initiative, it became clear to me that there was a gap between technology development and technology deployment. Many technologies are available to provide alternative energy resources to the US and the technology readiness ranges from small lab experiments to commercially available technologies that have been deployed in other countries. The Department of Energy (DOE) has provided support to a number of technologies that have never been commercialized. In discussions with colleagues in the International Policy Office in DOE they dubbed this problem as “The Valley of Death.” The more I looked at the needs of the DoD, it became apparent that we needed to help foster a strategy to cross “The Valley of Death” as we are a customer of products that would rely on the deployment of the alternative fuel technology. In our opinion the problem requires the actions of many government agencies and each could contribute a plank to help bridge the “Valley of Death.” Figure 1.

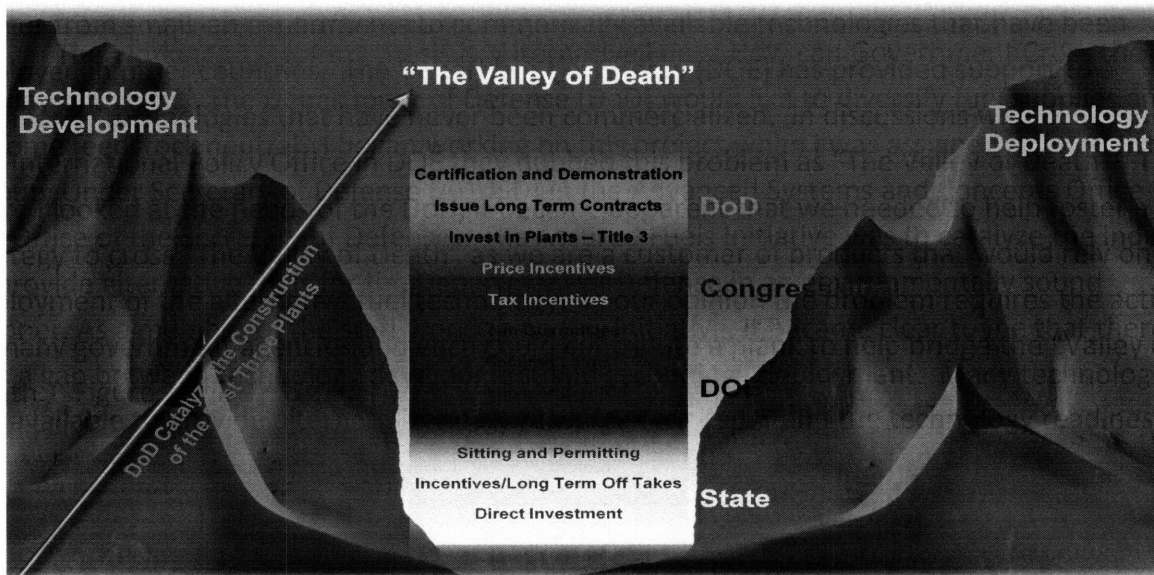


Figure 1. Bridging the “Valley of Death.”

The Honorable Michael Wynn, Secretary of the Air Force, believes that the Air Force should take a leadership role and has issued strong guidance to the Air Force. This guidance includes: “make energy a consideration in all you do” and that the Air Force should use 50% alternative fuels by 2016 if economical. To facilitate that effort he authorized and was a strong sponsor the demonstration of Fischer Tropsch (FT) fuels in a B-52 aircraft which occurred in late 2006. He also sponsored the development of a new military handbook to stream line and clearly delineate a process to certify jet fuel in all Air Force systems and across all enterprises. I had the privilege to be one of the co-leaders of the B-52 flight demonstration and the team that developed the new handbook. The systems engineering process that frames the handbook is currently being employed by a new Alternative Fuels Certification Office set up at the Aeronautical Systems Center at Wright Patterson AFB Ohio to certify all Air Force systems. This office was responsible for the recently certification of the C-17 aircraft and a supersonic engine from a B-1B aircraft tested at the Arnold Engineering Center. The Air Force has a plan to certify the entire fleet by 2010 .

I was selected to attend the MIT Sloan Fellows Program in Innovation and Global Leadership in early 2007 and I started classes in June. As part of the MBA program, I have elected to write a thesis and explore the “Valley of Death” problem from a commercial business standpoint to better develop some possible recommendations to the Air Force to help foster alternative energy technology deployment. My plan is to look at a series of business strategy frameworks from to help analyze the technology adoption life cycle (Figure 2) that Geoffrey Moore describes in his book “Crossing the Chasm” and look at the two key gaps, the “Valley of Death” faced by technology innovators trying to attract early adopters and the “chasm” between early adopters and the early majority. Figure 3.

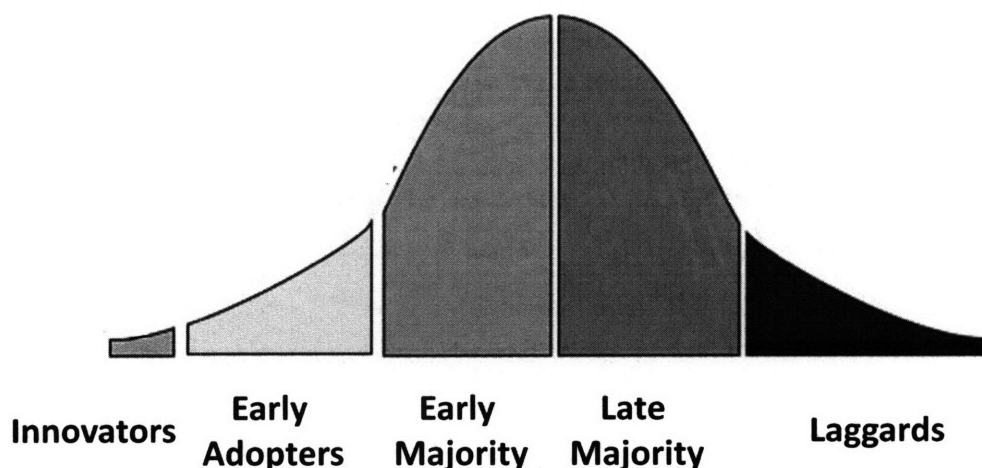


Figure 2. Technology Adoption Life Cycle (Moore 1999).

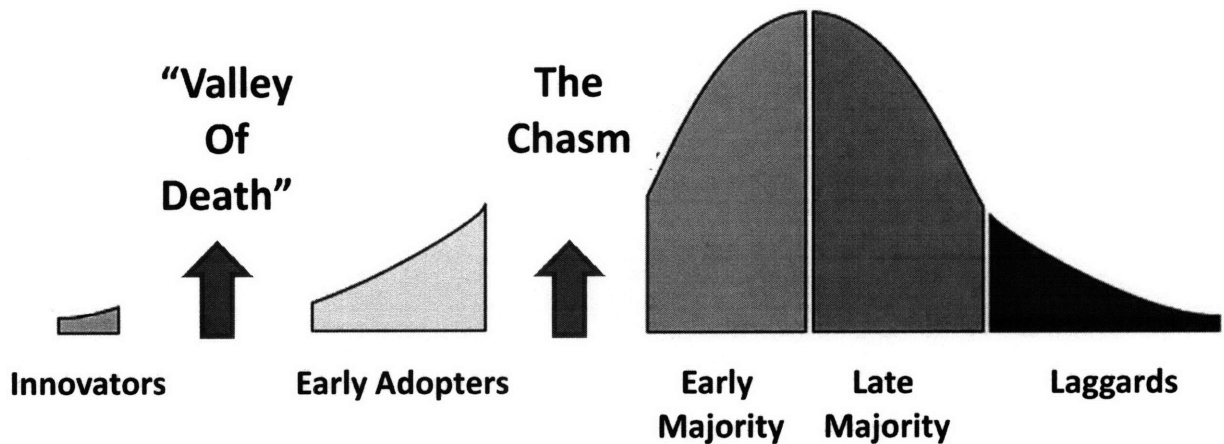


Figure 3. Technology Adoption Cycle for Energy Technologies.

The more that I study the problem; it has become apparent that both the “Valley of Death” and the “Chasm” must be considered as part of the strategy for the Air Force and the commercial sector. There are a number of considerations related to interactions and barriers across value chains. The initial interviews I have conducted suggest that I also must look more closely at the early adopters and the “Chasm” as some of the early adopters are really facilitators for demonstrations and may not actually adopt the technology. In some cases they are looking for a group of adopters to move together in the adoption. One of the reasons relates to infrastructure issues. My initial conclusion for aviation is that I may need to look at groups of adopters at specific locations as the first adopters rather than specific airlines.

The Air Force is looking for partnerships with industry to increase availability of alternative fuel sources and refueling locations. I would like to probe deeper into the issues driving the developers of alternative fuels to understand what barriers they face in producing alternative jet fuels and distributing them to the commercial airlines and the military. I would like to gain some insight on how environmental concerns of CO₂ and other greenhouse gases influence alternative fuel development in terms of selection of feedstocks and the production of finished products. I am also interested in how the product will be qualified, certified and distributed. If you are willing to share any information on the early adopters that have expressed interest in your product, it would help me characterize the early adopters and early majority of users.

I also would like some suggestions that the Air Force and the DoD might use to improve the transition to alternative fuels. What types of actions do you need from the Air Force and DoD to make things happen? In addition, any additional suggestions for this thesis would be greatly appreciated.

One of my biggest challenges will be the short time that I have to write the thesis (~3 months part time) so I will not be able to delve deeply into any one topic. I do hope to continue this type of work when I return back to the Air Force in June.

To help me think through these topics I am interested in the following areas:

1. Sustainable energy is critical to sustainable business in the US. What scenarios for alternative energy are you exploring and what do you think are the key barriers that they are facing?

2. Who are the key players that are necessary for early adoption of the new energy products?

3. What techniques should be used to establish an early majority of adopters?

4. Is aviation a target market for your products? What do you see as the barriers for entry into this market both from the commercial airline as well as military?

5. I am interested in developing balanced scorecards to characterize alternative fuels. What issues should be included in a balanced scorecard? Do you use these parameters in your decision making process?
 - a. Feedstock cost and market trends?
 - b. Feedstock availability?
 - c. Feedstock transportation and distribution range?
 - d. CAPEX of plant construction?
 - e. OPEX of plant?
 - f. Importance of federal and state incentives?
 - g. Water use?
 - h. Land use and environmental concerns?
 - i. Water pollution?
 - j. CO₂ production?
 - k. Other greenhouse gas impacts?
 - l. Local air quality impact?
 - m. Employment?
 - n. Cost of products?

- o. Production of other products, i.e. fertilizer, electricity, construction materials?**

- 6. What scenarios would you recommend that I analyze with the frameworks and the models? Is the type of model a direct to customer model or a business to business model?**

- 7. What should the commercial airline industry do to help develop an alternative fuels industry that produces aviation fuels?**

- 8. What should the Air Force and the Department of Defense do to help foster the development of an alternative aviation fuels industry?**

- 9. Can you provide some information on construction cycle times? What are typical timelines for the development of an alternative fuel production facility?**

- 10. Any other suggestions for the thesis and recommendation for other interviews?**

Financial Institution Questions

The working title for my thesis is: Alternative Fuels: How can Government Cross the “Valley of Death.” The Department of Defense (DoD) would like to diversify fuel supplies and become feedstock neutral. I began working on this project when I was assigned to an Assistant Deputy Under Secretary of Defense (ADUSD) in the Advanced Systems and Concepts Office in the Office of the Secretary of Defense. The Assured Fuels Initiative was to catalyze the industry to provide alternative fuels for the Department of Defense in an environmentally sound manner. As a member of the staff working on this initiative, it became clear to me that there was a gap between technology development and technology deployment. Many technologies are available to provide alternative energy resources to the US and the technology readiness ranges from small lab experiments to commercially available technologies that have been deployed in other countries. The Department of Energy (DOE) has provided support to a number of technologies that have never been commercialized. In discussions with colleagues in the International Policy Office in DOE they dubbed this problem as “The Valley of Death.” The more I looked at the needs of the DoD, it became apparent that we needed to help foster a strategy to cross “The Valley of Death” as we are a customer of products that would rely on the deployment of the alternative fuel technology. In our opinion the problem requires the actions of many government agencies and each could contribute a plank to help bridge the “Valley of Death.” Figure 1.

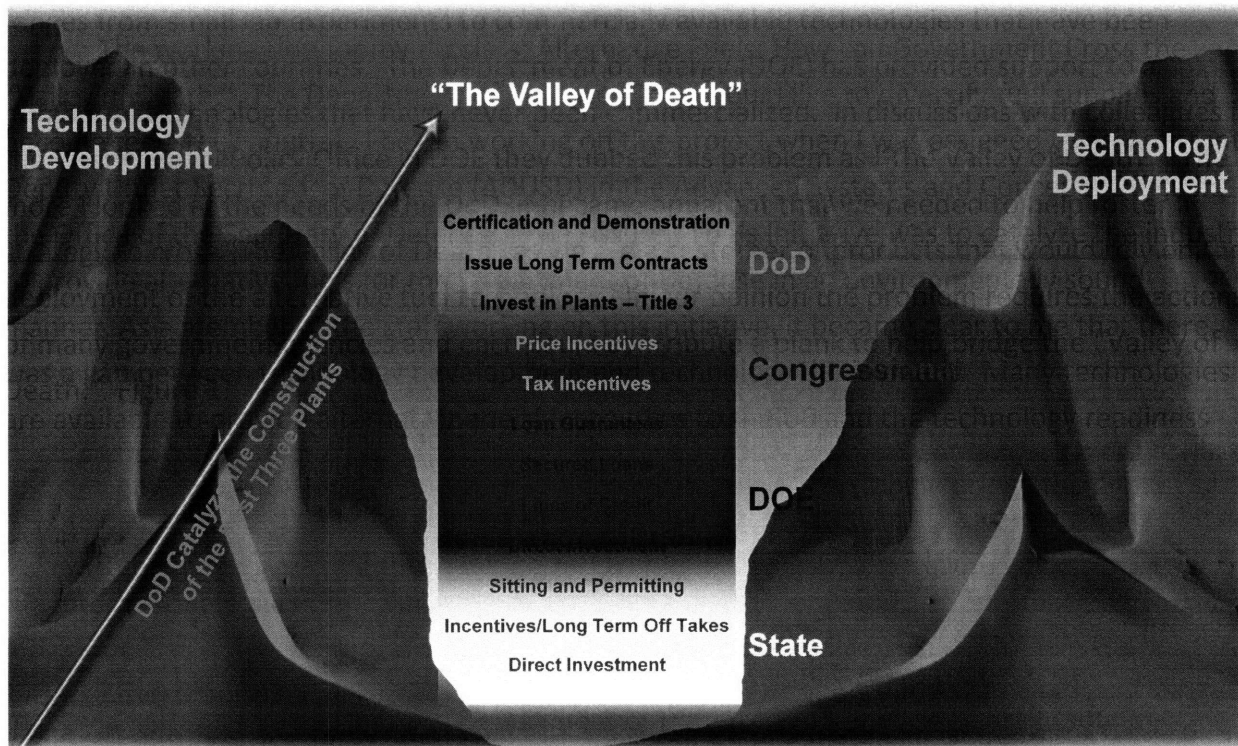


Figure 1. Bridging the “Valley of Death.”

The Honorable Michael Wynn, Secretary of the Air Force, believes that the Air Force should take a leadership role and has issued strong guidance to the Air Force. This guidance includes: “make energy a consideration in all you do” and that the Air Force should use 50% alternative fuels by 2016 if economical. To facilitate that effort he authorized and was a strong sponsor the demonstration of Fischer Tropsch (FT) fuels in a B-52 aircraft which occurred in late 2006. He also sponsored the development of a new military handbook to stream line and clearly delineate a process to certify jet fuel in all Air Force systems and across all enterprises. I had the privilege to be one of the co-leaders of the B-52 flight demonstration and the team that developed the new handbook. The systems engineering process that frames the handbook is currently being employed by a new Alternative Fuels Certification Office set up at the Aeronautical Systems Center at Wright Patterson AFB Ohio to certify all Air Force systems. This office was responsible for the recently certification of the C-17 aircraft and a supersonic engine from a B-1B aircraft tested at the Arnold Engineering Center. The Air Force has a plan to certify the entire fleet by 2010 .

I was selected to attend the MIT Sloan Fellows Program in Innovation and Global Leadership in early 2007 and I started classes in June. As part of the MBA program, I have elected to write a thesis and explore the “Valley of Death” problem from a commercial business standpoint to better develop some possible recommendations to the Air Force to help foster alternative energy technology deployment. My plan is to look at a series of business strategy frameworks from to help analyze the technology adoption life cycle (Figure 2) that Geoffrey Moore describes in his book “Crossing the Chasm” and look at the two key gaps, the “Valley of Death” faced by technology innovators trying to attract early adopters and the “chasm” between early adopters and the early majority. Figure 3.

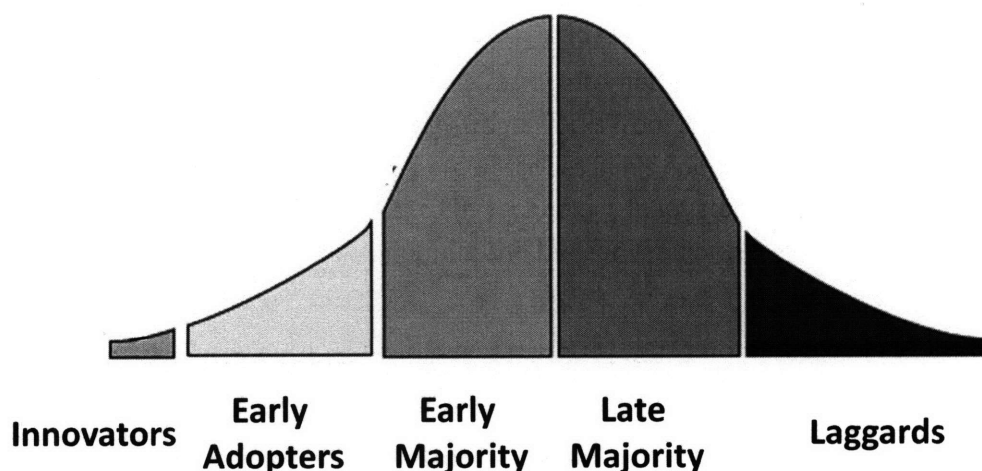


Figure 2. Technology Adoption Life Cycle (Moore 1999).

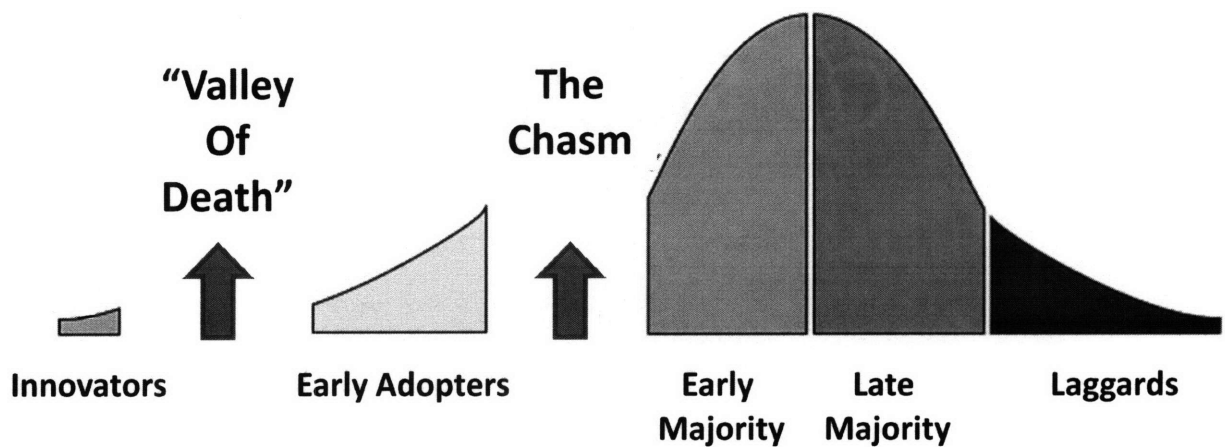


Figure 3. Technology Adoption Cycle for Energy Technologies.

The more that I study the problem; it has become apparent that both the “Valley of Death” and the “Chasm” must be considered as part of the strategy for the Air Force and the commercial sector. There are a number of considerations related to interactions and barriers across value chains that have large effects on the final outcome. I am conducting research on this subject in two ways. The first has been a review of the literature and the second has been a series of interviews. I have focused the first part of the interview cycle on alternative energy project developers and the commercial airlines. I am now starting a series of interviews with the financial sector.

One of my biggest challenges will be the short time that I have to write the thesis (~2 months part time) so I will not be able to delve deeply into any one topic. I do hope to continue this type of work when I return back to the Air Force in June.

- To help me think through these topics I am interested in the following areas:

1. Sustainable energy is critical to sustainable business in the US. What alternative energy investments do you believe are sustainable? What is your time horizon for the investments?
2. How do you define sustainability and what is your view toward alternative energy investment and climate change? How do you evaluate environmental risk?
3. Are airlines financially stable enough to act as partners for alternative energy developers? Is aviation a risky niche market?

4. What are the most troubling issues related to financing alternative energy projects?
 - a. Lack of greenhouse gas legislation?
 - b. Lack of technical maturity in CO₂ capture and sequestration?
 - c. Uncertainty in plant costs?
 - d. Lack of construction and engineering infrastructure?
 - e. Lack of EPC wraps?
 - f. Lack of federal incentives (loan guarantees, off take agreements, tax incentives)?
 - g. Do you think an investment tax credit for greenhouse gases would be helpful?
 - h. Aggressiveness of environmental groups?
 - i. Commodity market volatility for feedstocks?
 - j. Others?
5. I am exploring how hedge strategy might help the industry develop. Do you see natural hedges when the project provides products to multiple markets such as electricity and liquid fuels?
6. Is there a way to hedge construction cost uncertainty?
7. What should the commercial airlines do to help foster the development of an alternative aviation fuels industry?
8. What should the Air Force and the Department of Defense do to help foster the development of an alternative aviation fuels industry?
9. Any other suggestions for the thesis and recommendation for other interviews?

Early Adopter Questions

The working title for my thesis is: Alternative Fuels: How can Government Cross the “Valley of Death.” The Department of Defense (DoD) would like to diversify fuel supplies and become feedstock neutral. I began working on this project when I was assigned to an Assistant Deputy Under Secretary of Defense (ADUSD) in the Advanced Systems and Concepts Office in the Office of the Secretary of Defense. The Assured Fuels Initiative was to catalyze the industry to provide alternative fuels for the Department of Defense in an environmentally sound manner. As a member of the staff working on this initiative, it became clear to me that there was a gap between technology development and technology deployment. Many technologies are available to provide alternative energy resources to the US and the technology readiness ranges from small lab experiments to commercially available technologies that have been deployed in other countries. The Department of Energy (DOE) has provided support to a number of technologies that have never been commercialized. In discussions with colleagues in the International Policy Office in DOE they dubbed this problem as “The Valley of Death.” The more I looked at the needs of the DoD, it became apparent that we needed to help foster a strategy to cross “The Valley of Death” as we are a customer of products that would rely on the deployment of the alternative fuel technology. In our opinion the problem requires the actions of many government agencies and each could contribute a plank to help bridge the “Valley of Death.” Figure 1.

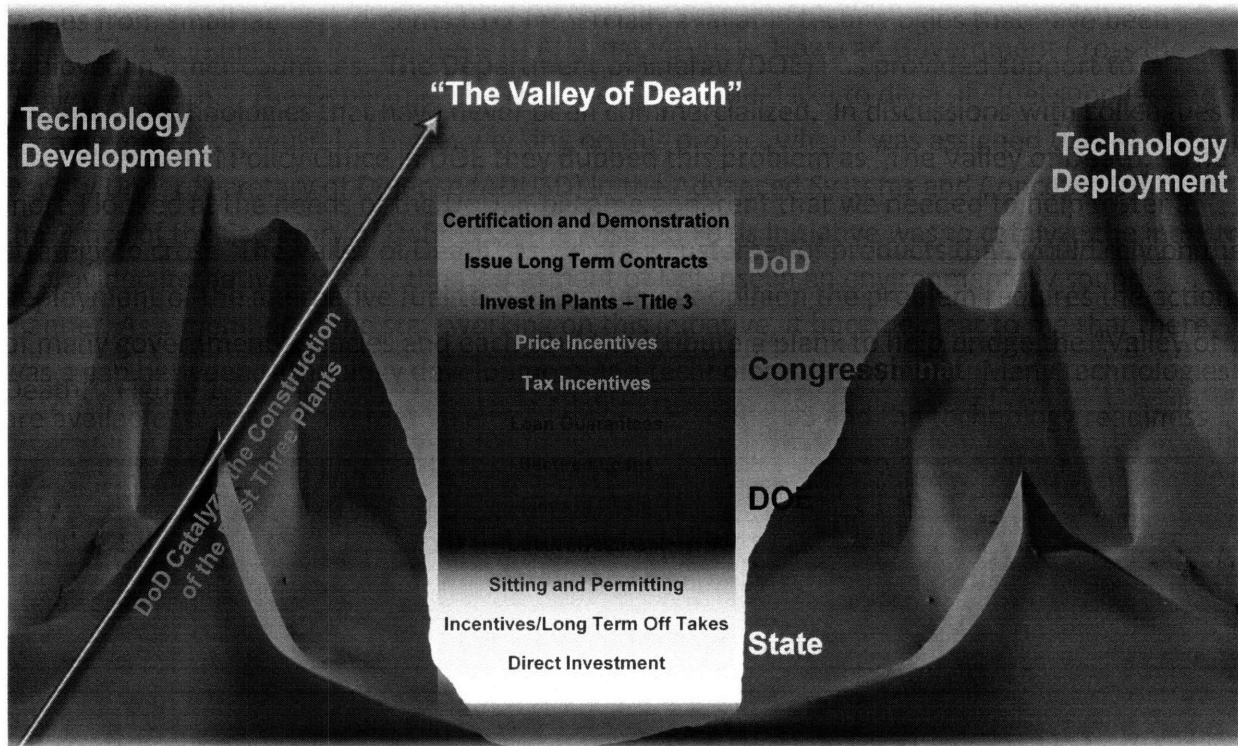


Figure 1. Bridging the “Valley of Death.”

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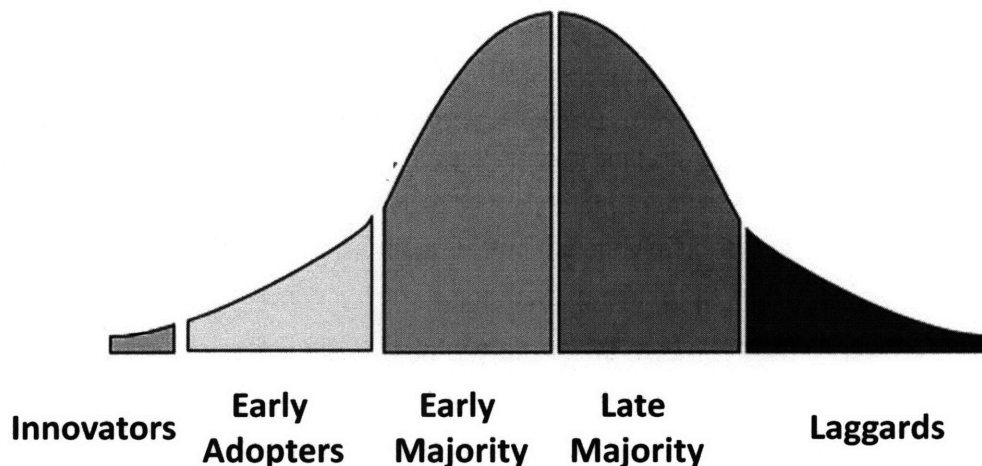


Figure 2. Technology Adoption Life Cycle (Moore 1999).

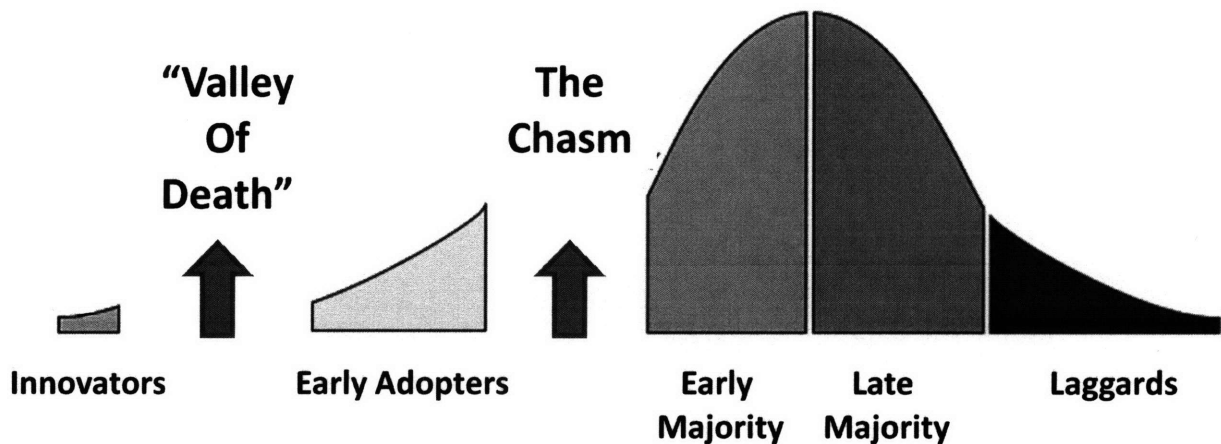


Figure 3. Technology Adoption Cycle for Energy Technologies.

The more that I study the problem; it has become apparent that both the “Valley of Death” and the “Chasm” must be considered as part of the strategy for the Air Force and the commercial sector. There are a number of considerations related to interactions and barriers across value chains. The initial interviews I have conducted suggest that I also must look more closely at the early adopters and the “Chasm” as some of the early adopters are really facilitators for demonstrations and may not actually adopt the technology. In some cases they are looking for a group of adopters to move together in the adoption. One of the reasons relates to infrastructure issues. My initial conclusion for aviation is that I may need to look at groups of adopters at specific locations as the first adopters rather than specific airlines.

The Air Force is looking for partnerships with industry to increase availability of alternative fuel sources and refueling locations. I would like to probe deeper into the issues driving the developers of alternative fuels to understand what barriers they face in producing alternative jet fuels and distributing them to the commercial airlines and the military. I would like to gain some insight on how environmental concerns of CO₂ and other greenhouse gases influence alternative fuel development in terms of selection of feedstocks and the production of finished products. I am also interested in how the product will be qualified, certified and distributed. If you are willing to share any information on the early adopters that have expressed interest in your product, it would help me characterize the early adopters and early majority of users.

I also would like some suggestions that the Air Force and the DoD might use to improve the transition to alternative fuels. What types of actions do you need from the Air Force and DoD to make things happen? In addition, any additional suggestions for this thesis would be greatly appreciated.

One of my biggest challenges will be the short time that I have to write the thesis (~2 months part time) so I will not be able to delve deeply into any one topic. I do hope to continue this type of work when I return back to the Air Force in June.

To help me think through these topics I am interested in the following areas:

1. What scenarios for alternative aviation fuels are you exploring and what do you think are the key barriers?
2. Who are the potential early adopters of alternative fuels for aviation?
3. What challenges and barriers need to be removed to establish an early majority of adopters?
4. What should the commercial airline industry do to help develop an alternative fuels industry that produces aviation fuels?
5. Are there different approaches that should be used in the other parts of the world to develop a global market for alternative aviation fuels?
6. What should the US Air Force and the Department of Defense do to help foster the development of an alternative aviation fuels industry?
7. Any other suggestions for the thesis and recommendation for other interviews?

Appendix B

Companies Interviewed

The Boeing Company	IATA
CAFFI	Delta Airlines
Virgin Airlines	US Airways
Council for Competitiveness	Air BP
WMPI	Southwest Airlines
Ted Sheridan and Associates	Integrity Biofuels
Tucker Associates	EERC
Baard Energy	AIG
Headwaters	Credit Suisse
GE	Scully Capital
Ohio PUCO	LS9
RenTech	Queensland Energy Resources Pty Limited
Baere Aerospace	ATA
UPS	Syntroleum
Energy, Environment and Security	Flagship Ventures
Peabody Energy	Matrix Venture Capital
Headquarters DOE	Devon Kincaid
U S Air Force A5/7	Exxon-Mobil
US Air Force IE	JP Morgan Chase
Jim Bunger and Associates	
Redleaf	

