Integrated Method to Create Optimal Dynamic Strategic Plans for Corporate Technology Start-ups

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"The only constant is change, continuing change, inevitable change; that is the dominant factor in society today. No sensible decision can be made any longer without taking into account not only the world as it is, but the world as it will be."

— Isaac Asimov

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Abstract

This thesis presents an innovative method for evaluating and dynamically planning the development of uncertain technology investments. Its crux centers on a paradigm shift in the way managers assess investments, toward an approach that incorporates uncertainty in the beginning phases of planning – instead of first choosing a plan and then considering the effect of risk. By proactively identifying critical uncertainties and "purchasing" flexibility to handle them, management can increase the value of the start-up technology.

The method builds on extensive literature in corporate venture capital (CVC), opportunity identification, and opportunity development, to present a new *integrated* approach that:

1. Explicitly identifies the synergies between an investing company and an opportunity, and articulates the new value network created through a Technology-Implement-Commercialization (TIC) linkage framework.
2. Develops the opportunities articulated in the TIC networks using a tool that identifies current and goal positions for a set of critical issues, and states the critical uncertainties.
3. Combines the outcomes of the TIC and opportunity development steps in a decision analysis of the possible development paths. The result is a recommended dynamic strategy that invests initially in some form of flexibility to enable program directors to avoid paths that eventually appear unproductive, while seizing opportunities that develop along the course of the project.

The thesis demonstrates the approach by applying it to a start-up project in solar concentrators, done from the perspective of a corporate sponsor. The purpose of this case study is to provide a comprehensive guide to the process used in the new method. While extensive effort was dedicated to creating a representative and reasonably accurate assessment, the analysis and numbers are neither authoritative nor exhaustive. The goal, indeed a major contribution of the thesis, is to provide a teaching tool to aid future use of the innovative planning and valuation method.

Thesis Supervisor: Richard de Neufville
Title: Professor of Engineering Systems

Thoughts and Acknowledgements

Every so often one embarks on a life-changing experience that provides a steep learning curve for so many facets of his or her character. From the outset, and through every word read, graph interpreted, or model created, I realized that this thesis was as much about learning and creating something relatively new and of value as it was about learning more about and challenging myself. I have gained two important skills from this experience—the first is a solid understanding of systems analysis, with an emphasis on dynamic and flexible project planning and valuation.

The second is the expansion of my comfort zone that has resulted from the hundreds of hours of focused work that went into this project. Working on a Masters thesis has given me the opportunity to think creatively and synthesize so many concepts learned in the lab or in courses into one central topic. The emotions and effort that are part of the process of writing a thesis have taught me much about myself—what my weaknesses are (and what needs to be done to improve them), and what my strengths are (and how I can more fully use them). Overall, I believe I have emerged as a more capable and confident thinker, and do not think such a steep learning process could have occurred in a relatively painless way without the support of my thesis advisor, Professor Richard de Neufville, and my peers in the Engineering Systems Division and elsewhere. I am grateful to have embarked on my greatest academic journey here at MIT.

This thesis, and indeed the steps that were taken to get to this position, could not have been done without the unrelenting, tireless, and stupefyingly dedicated effort of my parents, Omar and Nada Mikati. What is amazing is how effortless they made it seem— my brother and I always felt that raising us was their great joy in life. I now understand why: it was all done out of their complete love for us.

How does one express gratitude for such utter and selfless love and support? I choose to do it by taking full advantage of their efforts and dedicating myself as tirelessly and passionately in my work and life as they have in raising me. My brother (another person who has greatly affected my life) and I have gladly chosen a path that has led us to great though difficult experiences, and looking to the future my gift back to my parents is in always having them be a central part of my decisions and life in general.

To Professor Richard de Neufville, who gave me the keys to enter the microcosm of thought and challenge that is MIT, I am forever grateful. Rarely does one meet such an accomplished man who is so passionate, so energetic, so caring, so professional, and so motivating to work for. Most students speak of their nervousness before and frustration after meetings with their advisors. But my meetings were the highlights of my experience—I felt my work and effort was truly appreciated, and I learned much from the seemingly effortless yet invaluable knowledge/advice given. Professor, it has been an honor to work for you and to get to know you and your family, and I look forwards to a lifelong friendship.

In meeting Professor Claro, I met a man whose dedication to his work and family was striking. Indeed, his limitless time with me in the fall of 2008 was astounding— this type of collaboration on a student-to-student level would be exceptional, but on a professor-to-student level, I think it is unheard of. His contributions to our published work, patient teaching of so many subjects, and personal commitment to our team is truly noteworthy. From the bottom of my heart, thank you Professor Claro, and I look forwards to meeting you and your family some day in Portugal and to continuing our friendship.

To our friends from Eni—Nicola De Blasio, Raffaella Turatto, Stefano Saviano, and Giuliano Russo— you have been fantastic "bosses" and collaborators to work for. From the more serious meetings and research briefings in Boston, to workshops in Milan followed by authentic Italian cuisine, this experience has been an enriching one on both a professional and personal level. I hope that our research will provide a meaningful new approach that Eni will further develop and use in its ambitious future plans.

This thesis is dedicated to my two recently deceased grandparents,

"teta" Souad, and "jiddo" Raja.

Leaving home at the age of 17 and bound for a wonderful academic and personal journey in the US, I did not expect to have to return 6 years later with them gone. Those we love most give us inspiration and a reason to passionately live out our lives, and teta Souad and jiddo Raja did just that. I thus dedicate this experience which I am most proud of to those that cannot share it with me today, but are remembered just as much, teta Souad and jiddo Raja.

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List of Abbreviations

CAB – Commercialization Advisory Board

CLFR – Compound Linear Fresnel Reflector

CSP GMI – Concentrated Solar Power Global Market Initiative

CSPond – Concentrated Solar Power on demand

CSP – Concentrated Solar Power

CST – Concentrating Solar Technologies

CVC – Corporate Venture Capital

DA – Decision Analysis

DCF - Discounted Cash Flow

DDP – Discovery Driven Planning

DNI – Direct Normal Irradiance

DoE – Department of Energy (US)

DSP – Dynamic Strategic Planning

DT – Decision Tree

DTA – Decision Tree Analysis

ENEA – National Agency for New Technologies, Energy and Environment (Italy)

EU – European Union

FEE – Fuzzy Front End

GT – Gas Turbine

GEF – Global Environmental Facility

GCC – Gulf Cooperation Council

HRSG – Heat recovery steam generator

IEA – International Energy Agency

IPP – Investment Protection Plan *or* Independent Power Producer

IRR - Internal Rate of Return

ISCC – Integrated Solar Combined Cycle

LEC – Levelized Electricity Cost

MEW – Ministry of Electricity and Water (Kuwait)

MITei – MIT energy initiative

NCD – New Concept Development

NEAL – New Energy Algeria

NGCC – Natural Gas Combined Cycle

NPV - Net Present Value

ONE – Office Nationale d'Electricité (Morocco)

OPT – Option Pricing Theory

PPA – Purchase Price Allocation

R&D - Research and Development

ROT – Real Options Thinking

ROV – Real Options Valuation

RSPCL – Rajasthan State Power Corporation

RPS – Renewable Portfolio Standards

SEGS – Solar Electric Generating Systems

SolarPACES – Solar Power And Chemical Engineering Systems (part of IEA)

ST – Steam Turbine

TDW – Technology Description Worksheet

TIC – Technology Implement Commercialization

TPM – Technology Product Market

USPTO – United States Patent and Trademark Office

VAR – Value At Risk

VARG – Value At Risk and Gain

VC – Venture Capital

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Organization of Thesis and General Approach

The main point of this thesis is to use a new approach recently developed by a team (which the author was a part of) that assesses and creates a dynamic development plan for uncertain technology investments. As such, it presents a rather detailed undertaking of the *process* one takes in order to successfully apply the method. Thus, while the method itself is addressed at length, the main point of the thesis is to provide an example of how this approach is used to plan and assess uncertain technology investments.

The *introduction section* motivates the need for a new and more appropriate method for analyzing and planning opportunities (dynamic strategic planning), and provides context for the case study that is developed. A fundamental message of this thesis is that a new approach must be taken to plan and evaluate projects. Such an approach is appropriate because it shifts away from the existing valuation methodologies- which necessarily bind the development of a project to a static "most likely profitable scenario", towards a flexible approach that recognizes and incorporates flexibility as a means to optimize the development of the project. Such an approach is not only more representative of reality (because it recognizes the certainty of uncertainty), but it also raises the value of the system by purchasing flexibility "in" and/or "on" the project, providing insurance against downside risks and the ability to take advantage of the upside potential.

Important contextual information for the case is provided through an extensive discussion of the situation within the energy (oil and gas) industry, and the necessity for embracing innovation in order to remain competitive. Eni, a large Italian oil and gas firm, is introduced, with specific focus on its situation within the energy industry and vision for the future. Access to innovative ideas, in the form of pursuing hi-tech start-ups, is a necessary investment strategy to maintain leadership in the energy industry. The applicability of a dynamic planning and valuation approach is reinforced through the intrinsic high uncertainty that is characteristic of innovative hi-tech startups. Thus, while a dynamic strategic planning (DSP) method is universally applicable, it is particularly crucial in the case where high uncertainty erases any reasonably accurate prediction of future development scenarios.

The *background and related works section* provides a rather comprehensive review of the current best practices in project evaluation. It introduces and discusses why the traditionally used discounted cash flow model is not applicable to highly uncertain projects.

Also, it introduces the concept of option pricing theory (projects as financial options), and gives some of the shortcomings/incompatibilities of this approach to valuing "real" projects. The lack of a suitable valuation methodology using existing best practices is used as a springboard to introduce a new integrated planning and assessment method for uncertain technology investments. A detailed summary of the related works reviewed (in the areas of corporate venture capital, opportunity identification and development, and uncertainty identification) is given to acquaint the reader with relevant contributions in this field. Finally, the contributions from our new method are given, thus relating where our additions map on the existing knowledge base.

The new method that is used to plan and assess uncertain technology investments is described in the *method section*. A discussion of the main components of this assessment and planning technique, in the following areas, is given:

1. Identification of technology based business opportunities.
2. Development of the components of the opportunities.
3. Dynamic planning and valuation of the opportunities.
4. Dynamic business plan preparation.

Several tools are introduced, the templates of which are provided in the Appendices, which create convenient and systematic ways to complete each of the aforementioned tasks.

The central component and contribution of this thesis is in the *case study section*. A detailed step-by-step recount of the required analysis is given. While the case study is itself not an exhaustive application of the method proposed (such an analysis would require dedicated teams many months to create a reasonably complete report), it provides a detailed and representative "tutorial" of the method.

Finally, conclusions about the findings, strengths and weaknesses of the method are given in the *conclusions/further suggestions section*. Furthermore, the findings of and lessons learned from this thesis are used to propose further areas of development and improvement. Appendix 1: Complete Description of new integrated method provides a detailed description of the new integrated method, while Appendix 2: Technology Description Worksheet – Appendix 5: Opportunity Development Tool provide the four tools that were developed/modified to carry out the analysis.

1. Introduction

1.1 Motivation for a new approach: Dynamic Strategic Planning (DSP)

The issue at hand is how to plan and assess business opportunities: the current approaches for preparing business plans can be greatly improved. This is because they choose a fixed plan that focuses on the "most likely profitable" outcome, effectively ignoring the value of new information learned and its effect on the most profitable commercialization path(s). This invokes unnecessary exposure to risk by placing "all the eggs in one basket" (due to the singular reliance on the 'most likely profitable" scenario). Furthermore, this approach incurs lost opportunities as a result of its pursuit of a single "optimal" development path.

In contrast, a dynamic, strategic plan (DSP) provides a flexible approach that eliminates these problems. The DSP approach recognizes uncertainty, and purchases some form of flexibility so that development can later be modified in a way that reflects the outcome of new information learnt. Thus, instead of committing early on to a fixed investment strategy, the team may pursue several opportunities ("purchasing flexibility"), recovering the marginal or nonexistent cost of doing so through the hedging of risk (limit downside potential) and exposure to a set of development paths (maximize upside potential). The use of a multi-stage learning and decision process thus enhances the quality of decisions made and the overall performance (value) of the system (hi-tech startup) being analyzed.

1.2 Context: Innovation as an Imperative

1.2.1 Context

Reference to general market forces and a discussion of the relevant characteristics of the oil and gas industry reinforces the need for a flexible and dynamic planning and valuation method. We thus discuss some of the prevailing theories on market dynamics and value creation, which place innovation as an integral component of capitalistic markets. We then analyze the energy industry, recognizing innovation's historical and future importance in it. Finally, we relate Eni's position as an industry leader, and the necessity of applying an appropriate planning and valuation method that takes advantage of the uncertainty inherent hi-tech startups that provide new innovative ideas.

1.2.2 Innovation as an Imperative

The process of innovation is as ubiquitous through time as it is through different industries. A hallmark of the human spirit is our ability to combine imagination with ingenuity to constantly improve upon existing processes, products, technologies, etc. From the early days of the cavemen who first thought of using tools and weapons to improve their lives, to current improvements in the biomedical, aerospace and energy fields, we have come very far in our technological abilities.

Great strides have been made in advancing our capabilities from the now ancient "bow and arrow" technology to some of our greatest feats: landing a man on the moon or decoding the human genome. The *dynamic* behind this path of constant and ubiquitous change has been documented extensively by philosophers, engineers and economists.

Creative destruction is a theory that was first seen in the works of Bakunin, Nietzsche, and Sombart, and was later popularized by the eminent economist, Joseph Schumpeter. In his book, (Schumpeter 1942) describes the process of long term economic growth consisting of a continuous cycle of entry by entrepreneurs with new and superior products/processes that would destroy the value of existing established firms. While the value of firms (with obsolete processes/products) was destroyed, the vitality and long term sustainability of a capitalistic market is ultimately ensured through this destructive yet value-creating process.

A key aspect of the creative destruction theory is that the process of advancement is highly non-linear, more like a "step function": major, disruptive technologies are introduced that cause discrete "jumps" in performance. For example, the bow-and-arrow is an example of such a discrete performance leap: there was high utility derived from being able to kill animals too fast to chase, or those too dangerous to approach.

More recent literatures, such as (Utterback and Abernathy 1975), (Utterback 1996), and (Christensen and Raynor 2003), build on Schumpeter's early works on modeling the innovative process. Both (Utterback and Abernathy 1975) and (Utterback 1996) specifically address the dynamics behind innovation, with a deductive approach that allows them to make conclusions about innovation dynamics based on extensive empirical findings. Christensen further contributes to the area of innovation dynamics by proposing a framework through which companies can remain competitive, as value migrates through multiple disruptive innovation leaps.

Figure 1, taken from (Utterback 1996) validates Schumpeter's claim of discrete jumps in product performance through new innovations and gives a good summary of the overall process. While "disruptive" technological changes account for the bulk of increased performance (and where most of the "destruction" occurs), industry is of course not static in between these events. Thus, instead of being strictly a step function, there is a positive slope in each of the "steps" associated with *incremental* improvements in the existing product/process.

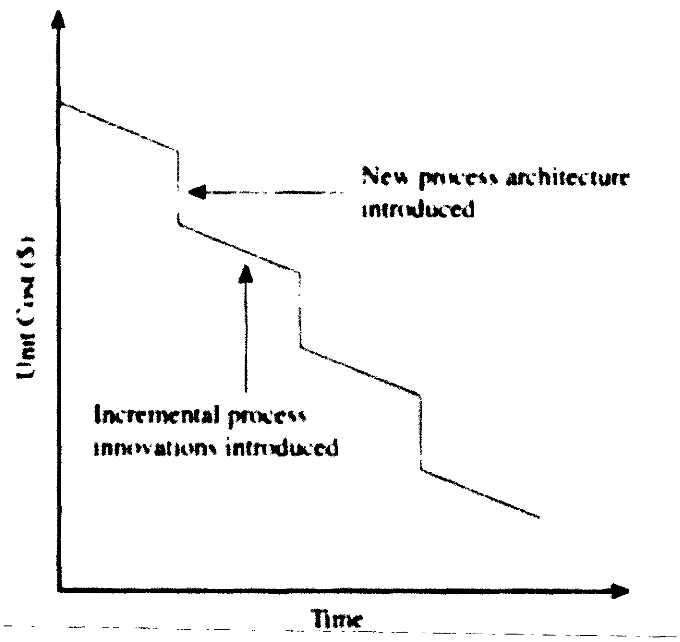


Figure 1: Utterback's model for improvements in product/process innovation through 2 fundamentally different innovation types (incremental v. disruptive) (Utterback 1996)

Figure 2 from (Christensen and Raynor 2003) shows the "performance threshold model" proposed. In this model, Christensen argues that a customer can only use a certain level of a product/process's capability- the performance threshold. This limit is gradually increasing as our ability/expectations are generally increasing. A similar graph, Figure 3, shows that when the performance of a product/service is below this threshold, one should integrate company processes; while when it is above, processes should be modularized and focus centered on customer needs. Quantum, unpredictable leaps in customer expectations and product performance play a duet in the constant quest for the appropriate product/process architecture a company employs.

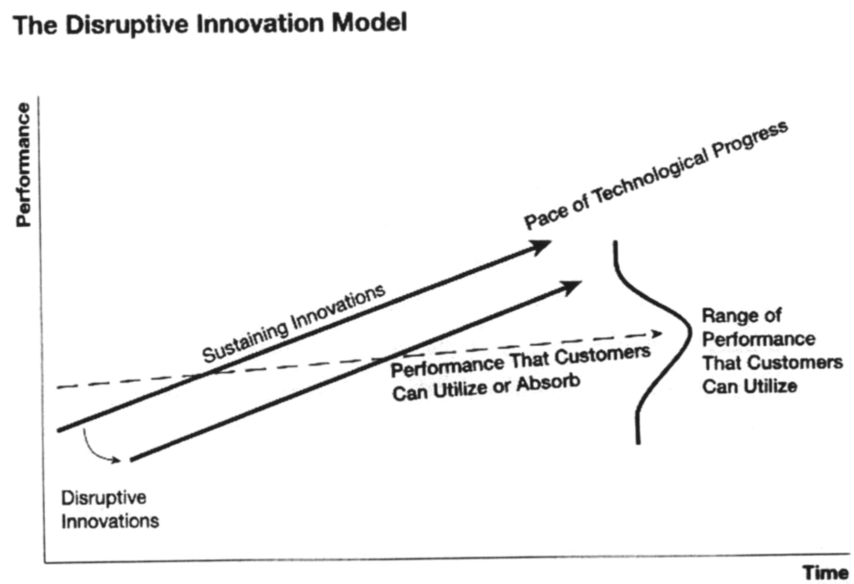


Figure 2: Christensen's "Disruptive Innovation Model" showing the customer's performance threshold, and how the pace of technological innovations tend to outpace this increasing requirement

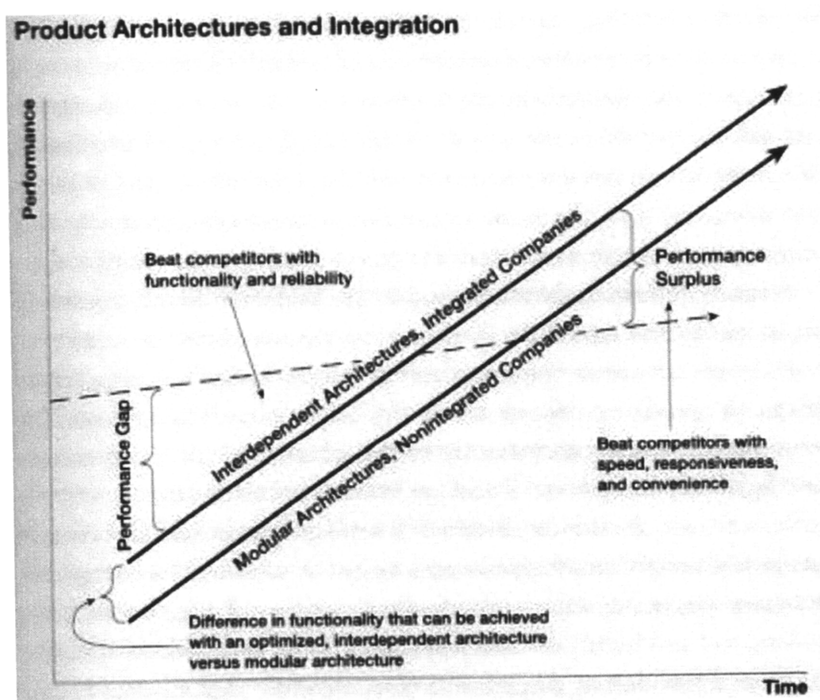


Figure 3: Christensen's "Product Architectures and Integration Model" showing that a firm should structure its activities depending on the performance of the product/service compared to the customer's needs

1.2.3. A Brief History of Innovation within the Energy Sector

It is of particular interest to study the technological development of the way we have powered our processes. Energy, itself a ubiquitous requirement in any economy, has gone through a long path of innovation-driven development. With its obvious importance as the literal fuel driving the world economy, the energy sector provides an interesting and crucially important area to study. Not surprisingly, the evolution of our "energy technologies" is primarily driven by *disruptive* innovations that lead to quantum improvements in performance:

<u>Initial state:</u> The sun

At the dawn of the human age, the first and only source of energy was the sun. It provided light and heat for the first humans; when it was gone in the night, humans' activities essentially stopped (Elementary Energy Infobook 2008). Humans relied on their own bodies to carry out such primitive tasks as searching for food and seeking shelter. Later, with the advent of the domestication of animals, we had more powerful creatures to aid such tasks as pumping water from wells, tilling fields, and moving heavy materials.

<u>Quantum leap #1:</u> The age of fire

While at first humans, like other animals, were afraid of fire, perhaps its utility finally convinced early humans to master it. Man's ability to create and control fire was of immeasurable value: it provided heat, illumination, a means to build improved weapons/tools (heating metals made them malleable and "mixable"), and even security (for example against animals).

<u>Quantum leap #2:</u> The age of wind and water

It would take many centuries before humans would experience a new disruptive technology that would fundamentally change civilization. Starting about 5,000 years ago, humans started using wind (sailing) to move from one place to another. Other applications of wind energy that occurred later (starting 2,500 years ago) were the use of windmills to grind grain, power sawmills, and pump water (Elementary Energy Infobook 2008).

Water power also proved to be a disruptive technology that first took hold in the Roman Empire a several centuries BC (Williams 2006). Vertical waterwheels, with similar applications to windmills, first took hold in Europe a couple of centuries BC, and quickly spread due to their superior cost performance (no longer needed costly livestock to power equipment/processes). Incremental improvements in hydraulic technologies occurred steadily for several centuries (i.e. mills placed on boats and bridges, first hydropower dams, and water-powered cotton mills in 1770's) (Williams 2006).

Quantum leap #3: The age of steam

A central problem with water power was its geographic inflexibility, and inherent unpredictability (i.e. drought, flooding, ice, etc.) (Williams 2006). This, in conjunction with developments in the coal mining industry, led to the establishment of steam energy as a dominant source of power in the western world. In the 18th century, the introduction of steam power by Savery and Newcomen in coal mines provided the first "quantum leap" in steam-based technologies (Williams 2006). During the 19th century, incremental improvements in steam technology led to its proliferation in the industrial (mining, textiles, and milling) and transportation (locomotives and boats).

Quantum leap #4: The age of electricity

The impetus for the birth of the electricity age is actually very similar to the steam age's creation. While steam provided dependable, controllable, and non-geographically dependent energy, its "direct connection" requirement (to the machines it was operating) gave way to a technology that solved this problem. As (Williams 2006) notes, " [t]he production of electricity with primary batteries and eventually with electromagnetic induction, the transmission of electricity through copper wires, and the development of electric motors ultimately revolutionized the transmission of power [thus being a *disruptive* technology]".

While electricity is what directly powers the machines it is connected to, it is important to distinguish between an "energy carrier" and an "energy source". While steam and electricity both transmit energy (electricity in the form of an electric potential), they themselves are not a *source* of energy (one cannot mine electricity or steam power). Thus, steam and electricity represent increasingly sophisticated methods of transferring the *chemical potential energy* stored in the *energy source*- petrochemicals buried beneath the earth's surface.

While, at least in the foreseeable future, we will continue to use the movement of electrons (electricity) to transmit power (the rate at which we use energy) to our industries, it seems to be a matter of time before the fuel used to provide the energy is *disrupted*. Perhaps fundamental to this notion is the fact that our current largest sources of energy (petrochemical-derived fuels such as coal, natural gas, and oil) are *non-renewable*: given out technological capabilities, there is a finite amount that can be economically extracted and used. It is true that incremental improvements will no doubt raise the amount of oil that can be economically reached. However, our accelerating demand, in addition to social pressures, environmental concerns, and economic incentives will ultimately require new, disruptive technologies that can meet our growing energy needs in a more sustainable fashion.

1.2.4 Innovation Dynamics: The Dominant Design

While an energy disruption is likely to occur (and is arguably already occurring, most notably through the wind energy sector), the dynamic of shifting from the current *dominant design* (petrochemical-based energy production) to a more renewables-based energy portfolio is a complicated process. It exists within a highly uncertain environment that requires time to evolve, good vision to understand where the most value lays, a fundamental understanding of how disruptions affect established markets, and significant exposure to a diverse set of risk.

(Utterback 1996) states that after a certain period of time, firms/industries competing for control of a market, a *dominant design* emerges as the "industry standard". Subsequent to this, all innovations tend to be process innovations that improve the efficiency of this design (incremental though non-disruptive improvements). Furthermore, new waves of innovation are all heavily influenced by the dominant design (Utterback 1996). This is because of the extensive ties between suppliers and distributors, competitors who nonetheless require this design in order to exist, loyal customers used to the technology, and a set of related industries who feed off the existing dominant design.

As Figure 4 shows, the process of changing dominant designs requires navigating through a complex design hierarchy of dominant architectures (Clark et al. 1990). Thus, moving from a natural gas/oil based industry to, for example, a solar based energy industry is not a simple one-step process. To embark on a solar dominant design path, the industry must "go up the design hierarchy" start again from the beginning, and building a new solar-based design path, with related industries, partner suppliers and distributors, customers, and competitors. Thus the point is that even if solar, or any another renewable technology, is indeed a disruptive technology that will unseat the traditional oil and gas energy industry, it requires significant adaption from the industry before it can be established as a dominant design.

The integrated method presented in this thesis aims to provide a planning and valuation tool that will help corporate investors address the appropriate risks present for risky technology start ups. Given the high uncertainty in an industry being disrupted (many "dominant design" paths can be taken) as well as in the technology itself (since it is a hi-tech start-up), a method that places uncertainty and risk identification at the core of its analysis is deemed to be highly relevant to the situation.

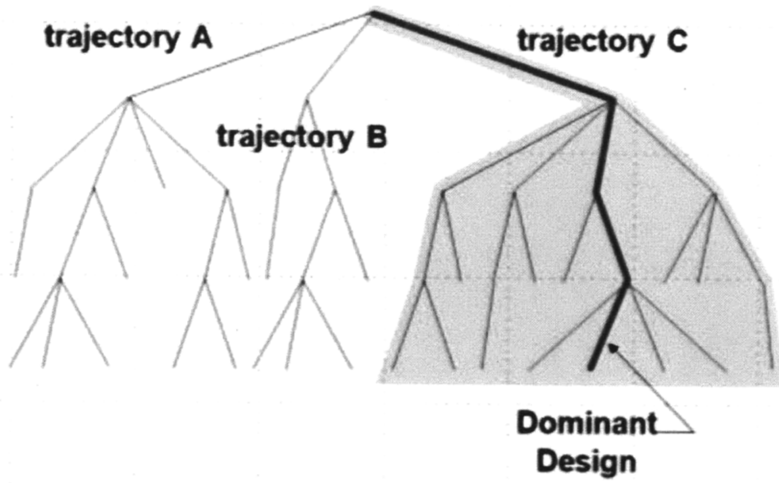


Figure 4: Dominant design architecture, from Spring 2009 ESD.58 lecture, adapted from (Clark et al. 1990)

1.2.5 Innovation within Eni

Eni, a large Italian oil and gas company, has played a leading role in the petrochemical service industry for over 55 years. As such, it has prospered largely though continual efforts to position its services in highly value-added sections of the overall value chain. These improvements, such as operating in increasingly harsh and remote environments, expanding oil & gas-related capabilities/services, and enhancing the efficiency of processes, have all been essential in maintaining the company's current leadership position. A crucial point is that no *disruptive* changes have occurred in the energy industry over the lifetime of Eni. Thus, it has continued to prosper through mobilization of its resources and capabilities to produce cutting-edge incremental improvements within our current energy dominant design: petrochemical-based energy.

Eni is of course aware of the finite nature of the petrochemical "stock". While currently available supplies are projected to last for several decades if not more, there is a realization that the development of alternative energy technologies could in the very least be used to leverage the oil & gas capabilities of Eni, appealing to a broader customer base.

In the long term, sustained improvements in the alternative energy sectors could even make obsolete current petrochemical-derived energy. While (Utterback 1996), (Clark et al. 1990), and a host of other academic and industry sources will give different reasons for why this process will take time (i.e. "inertia" required to replace incredibly capital intensive and entrenched energy infrastructure, creating a new dominant design, etc.), the current state of the energy industry does seem to fit the classical description of an industry being gradually penetrated by a (set) of disruptive technologies.

Thus, the question from Eni's (or any other leading petrochemical company) point of view is: what strategy should be incorporated to ensure their presence as a leading energy provider? The answer is that they should incorporate a "flexible" decision making process that does not lock the company's future development into a rigid path, but rather constantly evolves to reflect information learned to make the best possible decisions.

Within this general framework, the forces guiding Eni's evolution should be two tiered: a shorter term focus on incremental improvements in Eni's existing vast pool of resources and capabilities, as well as a medium/longer term vision for planning and assessing the incorporation of potentially disruptive technologies. The aim of this thesis is to address the latter portion of Eni's strategy: presenting an integrated method for the planning and valuation of uncertain technology investments.

(De Blasio 2009) presents Eni's vision within this context, consisting of plans to both enhance existing oil & gas capabilities to reach ever more difficult wells and meet stricter environmental requirements, and also to invest in renewable technologies. It is interesting to note that one of the ways Eni plans to gain access to new oil & gas reserves is through the transfer of knowledge in new high-potential technologies (such as solar or other renewable technologies). Thus, we see a bridge linking the short term incremental improvements of the oil & gas sector to the new disruptive renewables technology sector. The very incremental improvements that create new access to oil & gas wells are themselves the potential seeds of implementing a disruptive technology. This vision thus contains a self-reinforcing loop that organically links an existing industry with a new disruptive technological improvement.

Lastly, it is important to note that a good strategy still needs operational soundness in order to succeed. How does Eni realize its vision of ultimately gaining an expertise and market share in renewable technologies? The answer, as (De Blasio 2009) indicates, is that "in-house R&D must be complemented by collaborations with the most prestigious and advanced universities and R&D centers worldwide. Partnerships with cutting edge technological start-ups are also part of Eni's strategy".

Indeed, as (Nambisan 2007) suggests, "the perennial quest for growth has become more challenging in the era of global competition and shrinking product life cycles". Thus, while Eni's internal research departments are themselves conducting cutting-edge research, the dynamic of today's world, characterized by an increasingly rapid sharing of information, has made it close to impossible to "go at it alone" in terms of technological development. In fact, "the forces of rapidly decreasing product lifecycles, decreasing internal innovation productivity, and global competition together are creating a Red Queen effect ... that drives companies to invest more and more just to maintain their market position" (Nambisan 2007, referring to Van Valen 1973's "Red Queen" theory). Globalization has decreased product cycles and necessitated the use of collaboration to sustainably create innovative ideas.

Recent academic works thus support Eni's quest for technological innovation through external research programs. Although more elaboration on the justifications for and motivations behind corporate venture capital (CVC) will be given in the *related works* section, it suffices to say that Eni has created an operational plan for realizing its strategic goal of creating a renewables capability. This operational plan involves a mix of internal R&D efforts, external collaborations with leading universities and R&D centers, and obtaining stakes in promising high-technology start ups in the renewables sector. The focus of this thesis aims to apply a new integrated planning and valuation method to assess and create a development plan for a potential high-technology start-up of interest to Eni.

2. Background: Related Work and Contributions

2.1 Project Evaluation Methods

Methods for evaluating investment opportunities are essential because they not only determine which opportunities a company will pursue, but also *how* such an opportunity will be exploited once obtained. It is thus crucially important to employ an evaluation method that accurately models the opportunity being considered, as well as the capabilities of the investing entity. This section briefly covers the paradigm shift away from a deterministic, "static" discounted cash flow method, to the more appropriate "options" approach to project valuation.

2.1.2 Traditional "Discounted Cash Flow" method

The traditional "discounted cash flow" (DCF) method calculates a discounted net present value based on the "most-likely" future cash flow scenario. This method gained widespread use because of its conceptually intuitive framework: the most likely future cashflows are discounted, by an appropriate rate, back to a net present value (NPV). If the NPV is positive, then the project is profitable and hence the opportunity should be pursued. So ubiquitous has this method of project valuation been (i.e. companies using DCF increased from 19% in 1959 to 94% in 1975, Hayes and Garvin 1980) that it has come to be known as the "traditional approach" (Faulkner 1996).

The simplicity of this analysis method is guised by the often incredibly complex excel or other spreadsheets that conduct sensitivity analyses to determine which parameters can be changed by which increments to yield an acceptable internal rate of return (IRR), NPV, or any other performance metric. The problem with this type of analysis is that while it does analyze the "robustness" of the revenue stream, it does so *only* for the scenario being considered (i.e. most likely development path). Hence these calculations' value is at best limited because they only enhance our understanding of the financial performance of the reference scenario.

We thus arrive at an important point: how enlightening are these detailed analyses when we know that the performance of potential projects is necessarily uncertain? The answer is that while the DCF method is a conceptually straightforward method, it is fundamentally flawed because it considers neither the inherent uncertainty nor the ability to respond to it (through the incorporation of flexibility). Furthermore, in situations where the investment is highly uncertain (i.e. hi-tech start-ups), the number of permutations through which the technology may be developed rapidly increases; hence the information provided by the DCF method diverges quickly from meaningful calculations.

2.1.2 Option Pricing Theory (OPT): Start-ups as "Options"

The incompatibility of the DCF evaluation method for Research and Development (R&D) projects was first pointed out over 20 years ago by MIT Sloan's Stewart Meyers and in a series of articles in the *Harvard Business Review* (Faulkner 1996). As Myers states, "DCF is no help at all for pure research and development. The value of R&D is almost all option value" (Myers, 1984). Since then, it has become generally accepted that the DCF method is an inappropriate valuation method that inhibits investment in promising though by definition risky technology developments. The DCF method is biased against highly uncertain technology investments because it incorporates a rigid valuation framework that does not incorporate the ability of managers to respond to changing circumstances (i.e. react to the outcome of an uncertain event by modifying a flexible parameter). Thus, uncertain is viewed as a "headache", another problem that must be addressed through a sensitivity analysis.

In contrast, an Options Pricing Theory (OPT) approach to R&D development projects views uncertainty as a source of *value creation*. In this light, investment decisions are made depending on the outcome of uncertain events. When the chance outcome is favorable, management should exploit this "upside potential", and when the chance outcome is not favorable, management minimizes the "downside risks" by ceasing (or somehow minimizing) operations. This process of using flexibility to respond to uncertain conditions raises the performance of the system, and hence its value. We thus realize that in order for the options-based valuation model to be valid, our system (i.e. the investing company) must incorporate flexibility into its operations in order to take advantage of the uncertainty. Without such a setup, the options-based analysis would not accurately model the system and hence would not be valid.

The paradigm shift away from the deterministic "most likely case" DCF based analysis to an "options thinking mentality" is illustrated in (Faulkner 1996)'s Figure 5. This greatly simplified decision tree represents a series of development paths (from R&D to market commercialization) for a new color printer technology. (Faulkner 1996)'s Table 1 is a summary of the results of 4 different valuation calculations.

Table 1: List of Different Valuation Methods and associated NPV's for color printer R&D project (Faulkner 1996)

Valuation Method	NPV	1993	1994	1995
DCF #1: Use most likely values.	− $11.4	− 6 −	$\left(\frac{15}{1.12}\right)$ +	$\left(\frac{10}{1.12^2}\right)$
DCF #2: Consider market uncertainty.	− $9.0	− 6 −	$\left(\frac{15}{1.12}\right)$ +	$\left(\frac{(0.3)(20) + (0.7)(10)}{1.12^2}\right)$
DCF #3: Plan to introduce, considering all uncertainties.	− $5.4	− 6 −	$\left(\frac{15}{1.12}\right)$ +	$\frac{(0.3)[(0.8)(60) + (0.2)(15)] + (0.6)[(0.3)(20) + (0.7)(10)] + (0.1)[(0.1)(-15) + (0.9)(-60)]}{1.12^2}$
Options Thinking Valuation	+ $2.2	− 6 − (0.3)	$\left(\frac{15}{1.12}\right)$ + (0.3)	$\left(\frac{(0.8)(60) + (0.2)(15)}{1.12^2}\right)$

In DCF 1, no uncertainty is considered, and the NPV is calculated strictly based on the reference, or most likely, development path. DCF's 2 and 3 go a step further by incorporating market return, and both market return and R&D uncertainty, respectively. Finally, the "options thinker" realizes that in addition to accounting for both market and R&D uncertainty, management does not necessarily have to commit itself to funding the costs of commercialization unless it is sufficiently promising. Hence, the option to abandon the project is incorporated.

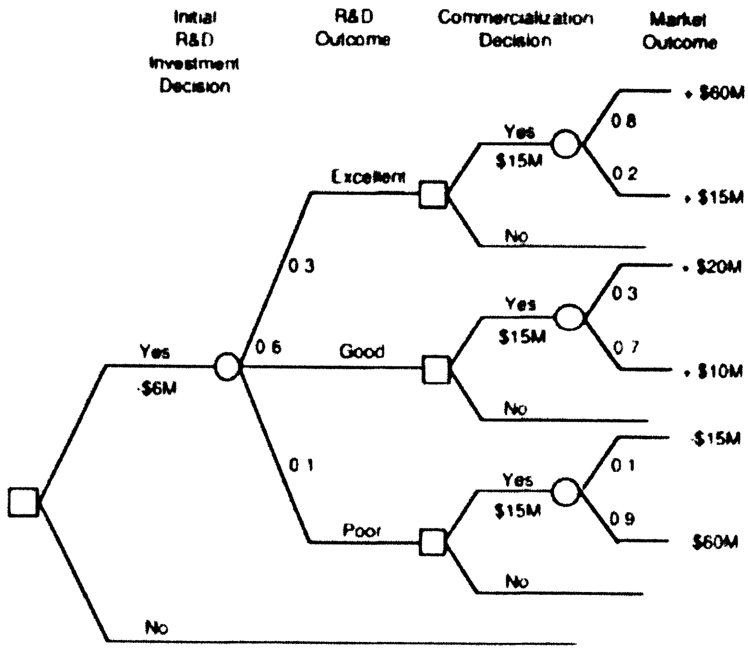


Figure 5: Simplified Decision Tree showing R&D to commercialization paths for a color printer R&D project (Faulkner 1996)

This is a basic example (i.e. flexibility need not be limited to an abandon, or "put option" on the project) whose aim is to illustrate the fundamental change in the way hi-technology investments are evaluated. The options valuation method usually yields a higher NPV value than the traditional DCF method because it takes advantage of the upside potential while limiting exposure to downside risks. According to (Faulkner 1996), relying on the use of DCF analysis "has been one of the factors blamed for placing US companies at a disadvantage relative to Japanese companies (Naj 1990)… the growing application of options valuation to R&D projects has been seen as an important step in removing a self-inflicted disadvantage that has impaired the competitive ability of U.S. companies". In short, US companies' short term "rigid equations and models" DCF approach has resulted in a conservative spending approach that has been biased away from the naturally uncertain yet potentially highly valuable technology start-ups. Employing an OPT based model employs a longer term approach that views the high uncertainty associated a large time span as a source of value creation.

2.1.3 Financial OPT: Incompatibility and need for a more suitable approach

Options pricing theory, has been extensively used in the financial industry. While the tools available for financial options pricing (such as Black Scholes) are well developed and accurately model the prices of financial asset such as calls, puts, and a whole myriad of more exotic options, they should not be used to value start ups and other "real" engineering systems (de Blasio et al. 2007). The reason is that the assumptions they require are not met when analyzing these systems. Specifically, traditional financial analyses require (de Blasio et al. 2007) that:

- Options are traded in a perfect market (access to information is equal and universal among all entities). This is not the case because each investing company is in a unique circumstance and may have different needs for or capabilities with the same technology. Hence each company has "insider information" and there is no universal information symmetry.

- An accurate prediction of the asset's volatility (usually estimated by the asset's past volatility), a necessary parameter for the Black Scholes equation, by definition does not exist for a *start-up* (no past record).

- The volatility input is a constant (in the Black Scholes equation), and not a variable. While this assumption may be valid for the shorter time scales in which financial options are traded (i.e. on the order of weeks or months), it is certainly not the case for R&D projects whose duration may last two or more decades.

- The volatility process is "path independent". Stated differently, the way in which a certain outcome is reached does not dependent on the sequence of events that led up to that outcome. For example, the present size of a parking structure should not depend on whether there was high demand first and then low demand, or low demand first and then high demand. In reality of course, there *is* path dependency as managers react to changing conditions and change the system accordingly.

Furthermore, according to (Faulkner 1996), it is difficult to use the Black Scholes equation to value real options on projects because:

- The complexity of the formula means it remains essentially a "black box" to most managers. They do not develop an intuitive feel for why the formula responds to changes in certain parameters the way it does.

- It requires an assumption that the future volatility has a lognormal distribution. While this may be a reasonable assumption for random, independently evolving assets, it is may not always apply to R&D and commercialization activities.

It thus becomes evident that while an options mentality is required to analyze and value the development path(s) of a hi-technology start-up, the traditional tools of financial option valuation cannot be used.

The proposed method is similar to (de Neufville and Neely 2001)'s "hybrid real options analysis" framework in that it accomplishes all of the steps in the hybrid approach:

It verifies the technical promise and gap of the technology, and then identifies major scenarios that create value from this technology. The associated probabilities and outcome values of these scenarios are calculated (using appropriate financial analyses), and a decision analysis is conducted to create the optimal investment path(s).

While (de Neufville and Neely 2001)'s approach successfully assesses uncertain technology opportunities, it was not created specifically with a corporate venture capital (CVC) context in mind. The method used in this thesis thus builds on (de Neufville and Neely 2001)'s conceptual framework by conducting the analysis using a series of new and adapted tools that are customized to the dynamics of a CVC context.

Key contributions of this method are: the focus on the synergies created from the knowledge asymmetries present in corporate venture capital (CVC) to qualitatively/quantitatively measure the unique value of a start-up to a CVC investor (opportunity identification), and the incorporation of a new tool that systemizes the process of uncovering and understanding the key risks associated with the opportunity development. Thus, while the general approach to project valuation is similar to (de Neufville and Neely 2001)'s hybrid real options framework, there are new contributions specifically in the areas of verifying the technical gap and promise of the technology, and in identifying the major scenarios that create value from this technology. A detailed overview of the specific method will be presented in Section 3. The Method**)**.

2.2 A New Method: Related Works and Contributions

The work of this thesis builds on extensive literature within the domains of CVC, technology valuation using real options, and technology-based innovative opportunities. Furthermore, it picks up on the work initiated one year ago between the MIT energy initiative (MITei) lab (under Professor de Neufville) and Eni (a founding contributor of MITei). A diverse team was assembled in the fall of 2008 (Professor

Richard de Neufville, MIT; Professor Joao Claro, University of Porto; Samir Mikati, MIT; and Nicola De Blasio and Raffaella Turatto, Eni) to develop a new method for planning and assessing the development of uncertain technology investments. This team successfully completed a journal article describing the new method.

Since the goal of this method is to aid CVC investors in planning and assessing uncertain technology investments, a review of the major works in this area was conducted to "identify the requirements of such a method, and the tools that have been previously proposed to address some of those requirements" (Claro et al. 2008). The distinctiveness of CVC investments and the high uncertainty associated with hi-technology start-ups were important attributes of this system being analyzed.

The literature review, as organized by (Claro et al. 2008), is grouped into four subjects: research on the specific objectives of CVC investments, work on previous concepts and models of opportunities, structured issues to consider for opportunity development, and concepts and tools to address uncertainty in the development, planning, and evaluation of opportunities. The sections in this thesis that address this literature review (Sections 2.2.1 through 2.2.5) were written by this team (which I was a part of), largely through Professor Claro's efforts.

2.2.1 Corporate Venture Capital (CVC)

A recent survey (MacMillan et al. 2008) defines CVC as "programs in established firms that make investments in entrepreneurial companies". The report differentiates between internal and external programs, depending on whether the technology sources are internal or external to the parent corporation.

(Chesbrough 2002) classifies CVC investments according to their objective and the strength of operational ties between the parent company and the entrepreneurial company. The objective can be strategic – the company tries to take advantage of synergies to grow the profits of its businesses – or financial – the company's resources may enable it to outperform VC firms and appropriate value that is not chiefly related to its businesses. The operational ties can be strong – resources are shared – or loose. Crossing these dimensions provides a framework with four types of investment: driving investments (strategic objective with tight links), appropriate to sustain the company's current strategy; enabling investments (strategic objective with loose links), aiming at growing a company's value system or improving the efficiency of its value chain; emergent investments (financial objective with tight links), to have access to options on new markets or products; passive investments (financial objective with loose links), where the company is just a regular investor.

According to (MacMillan et al. 2008), CVCs generally combine strategic and financial objectives and will analyze investments by first examining their strategic value, and then carry out financial evaluation only if the strategic assessment is positive. This requires from the CVC a thorough understanding of technology and business strategies in the parent company and a close communication and interaction with both R&D and business units. The financial evaluation requires a rigorous approach that will greatly benefit the investments. Additionally, a CVC operation that is not financially self-sustainable will find it difficult or impossible to secure support from management in the parent company.

The view of this work is similar to that of Henderson and Leleux (2005), who identify three strategic objectives for CVC:

- leverage or enhance competences through the combination or transfer of resources;
- secure options to explore new technologies or new opportunities for commercialization; and
- develop implementors and complementors in the company's value system.

2.2.2 Identifying Opportunities

(Holmén et al. 2007) review the literature on opportunities and identify a set of limitations that led them to introduce the concept of *innovative opportunities*, consisting of three elements – economic value, mobilization of resources and appropriability – that are to be present in order for actors to have the possibility of identifying, acting upon and realizing the potential inherent in an idea. Perception and uncertainty are two fundamental challenges in the conceptualization of opportunities emphasized in that work.

Opportunity identification belongs to the first part of the innovation process, called the Fuzzy Front End (FFE). Contrary to what happens in the following parts, best practices for the FFE are not well known, and as a result, it presents one of the biggest opportunities for improvement in the innovation process. With this motivation, (Koen et al. 2002) address the absence of a common terminology and vocabulary for the FFE through the development of a New Concept Development (NCD) model, which consists of three parts: uncontrollable influencing factors (organizational capabilities, outside world, internal and external enabling sciences), the controllable engine that drives the activities in the FFE (leadership, culture, and business strategy), and the five activity elements of the NCD (opportunity identification, opportunity analysis, idea generation and enrichment, idea selection, and concept definition).

(Markham and Kingon 2004) propose the use of the concept of TPM linkages as a systematic process for developing new technology product concepts and logic. Central to the logic and technique of turning technical advantages into product advantages is linking unique technical performance capabilities with enduring customer needs. This linkage requires specifying product features based on new technology capabilities and testing them for receptiveness with potential customers. A single technology can be used to create multiple product ideas for multiple markets. This articulation of the basics of the logic of an opportunity as providing a unique solution to a problem is shared by some of the most popular references in the field of technology entrepreneurship: Moore's *elevator test* (Moore 1991), Christensen and Raynor's *job-to-be-done* (Christensen and Raynor 2003), Dorf and Byers's *new venture concept summary* (Dorf and Byers 2005), or Kawasaki's *art of positioning* (Kawasaki 2004).

For the purposes of corporate venture capital – indeed, in general – a larger view of the situation is required. Accordingly, we propose a Technology-Implementation-Commercialization (TIC) process that distinctively focuses on Implementation, and Commercialization. This TIC process builds upon and is indeed structurally similar to the conventional TPM process. However, it recognizes the reality that the focus on "product" and "market" often is either inappropriate or too narrow. Indeed, a corporation may ultimately not want to market the results of a technological innovation, but may wish to use it in their business to enhance their competitive advantage. In short, the corporation may ultimately be interested in Commercialization and not "markets". Similarly, the company may want to apply the technology to its processes, and may be interested in Implementation and not "products" as commonly understood. For these reasons, our proposed method refers to and uses the TIC or Technology-Implementation-Commercialization perspective.

The TIC linkages framework fits perfectly with NCD activities in the context of technology ventures, and addresses the key issues in conceptualization of opportunities outlined previously. TIC linkages are informed by the team's knowledge and perceptions, and address the three elements of innovative opportunities: creation of economic value from the fit between features of the implementation of the technology and real opportunities for commercialization, mobilization of technological expertise as the core resource for a technology venture, and uniqueness as a determinant factor for appropriability.

Additionally, the TIC linkages framework also plays a role in addressing uncertainty. The framework satisfies the two requirements for predictable commercialization identified by (Christensen and Raynor 2003): a plausible statement of causality – that providing a unique solution to a problem will enable the creation of economic value and basic conditions for its appropriation – and circumstance-based categorization – identification of specific commercialization opportunities is based on the problem that needs to be addressed. Also, the generation of multiple concepts of implementation for multiple commercialization opportunities creates multiple options for the development of the opportunity. Finally, the TIC linkages can be assessed early in the innovation process, before a commitment to important investments in implementation of the technology.

2.2.3 Developing Opportunities

The most widely used tool to communicate business opportunities is the business plan. Although there is no standard for the structure of a business plan, there is a *de facto* theme for that structure, consisting of an outline of chapters, sections and subsections to be developed. A typical business plan structure therefore offers an organized set of issues to be addressed when developing an opportunity. For representative structures, we suggest (Ernst & Young 1997), (Sahlman 1997) and (Dorf and Byers 2005).

An alternative source of an organized set of issues to consider is the literature on investment criteria used by venture capitalists. (Franke et al. 2008) reviewed prior research in this area, but with a restricted focus on the evaluation of the venture team component. (Kakati 2003) reviewed this stream of research with a wider focus and compiled a set of 38 criteria, divided in six groups: four groups proposed by (MacMillan et al. 1987) – characteristics of entrepreneurs, product characteristics, characteristics of potential uses, and financial considerations – and two groups suggested in more recent studies – resource-based capabilities and competitive strategies.

(McGrath and MacMillan 2000) identify a detailed set of issues to address when examining each of a set of factors that influence the value of a technology project: the size and sustainability of potential revenue streams, speed or delay in market adoption, development costs, commercialization and market access costs, company strengths, likely competitive responses, dependence on standards, and the degree of uncertainty.

(McGrath and MacMillan 1995) propose a planning tool – Discovery Driven Planning (DDP) – for new ventures, where relevant past experience does not exist and management will have to make decisions with a high proportion of assumptions relative to knowledge. This requires an appropriate method of planning – planning to learn, in particular to learn how to achieve the venture's objectives, maximizing the conversion of assumptions to knowledge at the minimum possible cost. DDP involves:

a the specification of a goal position for the business – what it will have to look like to be successful and justify investment (financial performance, scope of the opportunities of commercialization, competitive benchmark standards, and operations);

b the identification of all assessments that are uncertain – best guesses used when data is not available, goals whose level of achievement is uncertain, etc. – and their characterization regarding how critical they are, how their uncertainty can be reduced and what the corresponding cost will be;

c the creation of a plan for the development of the business that includes checkpoints for the generation, as soon and with as low cost as possible, of information to reduce the uncertainty about the most critical assumptions.

2.2.4 Addressing Uncertainty

Investments in technology are characterized by considerable uncertainty, essentially concerning the degree of success in the development of the technology, the magnitude of commercialization costs, and the behavior of demand and competitors (McGrath 1997).

Traditional valuation methods, such as discounted cash-flows, have been shown to evaluate innovative developments inappropriately, as they are unable to account for the value of updated information and flexibility in future decisions (Dixit and Pindyck 1994). Real Options Thinking (ROT) is an approach to the valuation of uncertain investments that takes into consideration the value of flexibility in future decisions to enable an increase of the upside profits or a reduction in downside losses. ROT brings a different mindset, a different way of stating problems and a different way of thinking about the future (Faulkner 1996).

(Nichols 1994, McGrath 1996 and Faulkner 1996) are early works suggesting real options approaches for the evaluation of technology projects. (Dissel et al. 2005) provide an overview and a comparison of technology valuation approaches (discounted cash-flows, real options, decision trees, portfolio methods, value roadmapping and expert systems) and advocate for interdisciplinary approaches. (Steffens and Douglas 2007) also review and compare several valuation approaches (discounted cash-flows, decision trees and real options), and recommend the use of traditional decision analysis, with subjective adjustments for firm specific risk.

(Faulkner 1996, Steffens and Douglas 2007 and de Blasio et al. 2007) describe why the assumptions that underlie financial options models do not hold in uncertain technology investments, and propose using Decision Tree Analysis (DTA) as an alternative to Real Options Valuation. (Amram 2005) also favors DTA, due to its ability to provide the essential insights about the investment and improve the communication of results.

Technology investment projects are predominantly treated in the ROT literature as black boxes. This leads to a limited view of the flexibility that is available or can be deployed in the projects. (MacMillan et al. 2006) suggest combining DDP and ROV for planning and selecting among alternative investments. The combination partially addresses this issue by proposing an approach to plan the project for learning. However, at each checkpoint, only an option to continue is considered. (Schneider et al. 2008) have suggested modeling the flexibility in the project with five types of options – continue, expand, switch, abandon, and defer. However, the focus has not yet shifted significantly from opportunity *evaluation* to opportunity *design*. Technology ventures are complex socio-technical systems offering many sources of flexibility, in technology, product, operations or organization design. This more complete appraisal of the impact of uncertainty and flexibility in technology ventures requires broadening the options perspective to include options "in" projects (Wang and de Neufville 2005).

Business plans play a key role in communicating opportunities and also in providing a discipline for a venture team to be specific about what it intends to do and what it hopes to accomplish. As such, they should reflect the critical importance of addressing uncertainty for new technology ventures. (Sahlman 1997) argues that the best business plans address four interdependent factors that are critical to new ventures – people, opportunity, context, and risk and reward – and discuss the venture as a moving target, confronted with the critical risks ahead – both downside and upside. The logical implication is that business plans should be *dynamic*, proactively incorporating the key uncertainties and the associated decisions on how best to proceed given each outcome, dynamically adapting the venture's development path.

However, references in this area typically pay little attention to uncertainty ((Ernst & Young 1997) is an example) or focus mostly on downsides (as in (Dorf and Byers 2005)). Another common approach to dealing with uncertainty consists of performing a sensitivity analysis on the financial projections. With this approach, the effect of uncertainty is only considered after the business plan has been developed, and the plan itself does not consider alternative decision paths making use of updated information and managerial flexibility.

2.2.5 Contributions

The first main contribution is related to the identification of technology based opportunities to a CVC context. The framework that is used in this thesis (developed by our research team in Fall 2008) provides a more operational conceptualization of the synergies between the parent corporation and the technology venture. From the standpoint of opportunity modeling, it extends previous frameworks to allow an explicit modeling of those synergies.

A second contribution is the integrated nature of the method. Literature and practice suggests several methods to address partial issues in planning and assessing uncertain technology investments. We adapt, build on, and bring together several concepts and tools from those methods, in order to provide an integrated method that covers the whole process from technology to valuation, including opportunity identification, development, and planning.

A final main contribution is an improved treatment of uncertainty. We propose a widening of the scope of previously proposed assessment methods, from valuation of opportunities to design of opportunities. This supports an improved search for value, through a broader identification of uncertainties and sources of flexibility, and their earlier consideration, starting from the stage of opportunity development.

3. The Method

This section provides a brief overview of the integrated method that was created in the fall of 2008 (by a team I was a part of) to plan and assess the development of uncertain technology investments. While the central goal of that effort was to create a new integrated methodology, the goal of this thesis is to show how it can be successfully applied to a "real world" example.

As such, sections 3.1 through 3.4 present a summary of the key components of each of the 4 stages used in our method. These sections use and build extensively upon the literature Professor Claro and I created in the fall of 2008. A more complete explanation of the method is provided in Appendix 1.

3.0 Overall Description

The process of moving from a technology to the assessment of business opportunities presents a set of different challenges that require different approaches. We have identified four top-level challenges in this process, underlying its division in four phases (see Figure 6).

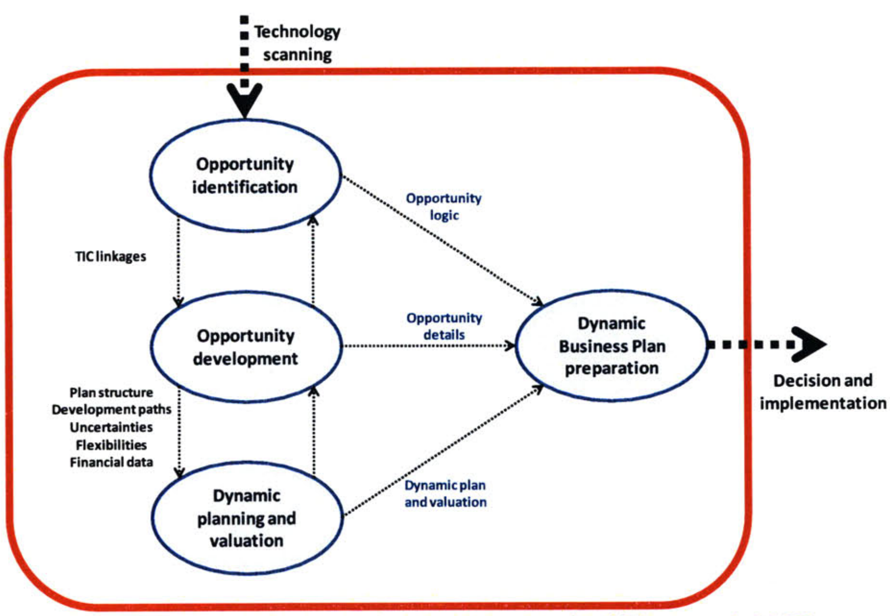


Figure 6: Map of integrated assessment method (Claro et al. 2008)

3.1 Identification of technology based business opportunities

This phase adopts the Technology-Implementation-Commercialization (TIC) linkage framework that builds upon the TPM concepts articulated by (Markham and Kingon 2004). This framework links technical capabilities with customer needs through concepts of implementation, articulating the basic logic for a particular implementation and hence an opportunity, and is usually applied to create multiple concepts of implementation targeted at multiple forms of commercialization, from a single technology. We propose an adaptation of the TIC linkage framework to identify synergies on which the parent corporation's business can build to grow its profits, since CVC investments usually have a combination of financial and strategic objectives (MacMillan et al. 2008, Chesbrough 2002).

1.1 The team performing the assessment will first specify current and potential, complete and partial, TIC linkages for each company on its own. Figure 7 illustrates the basic structure for these TIC linkage charts.

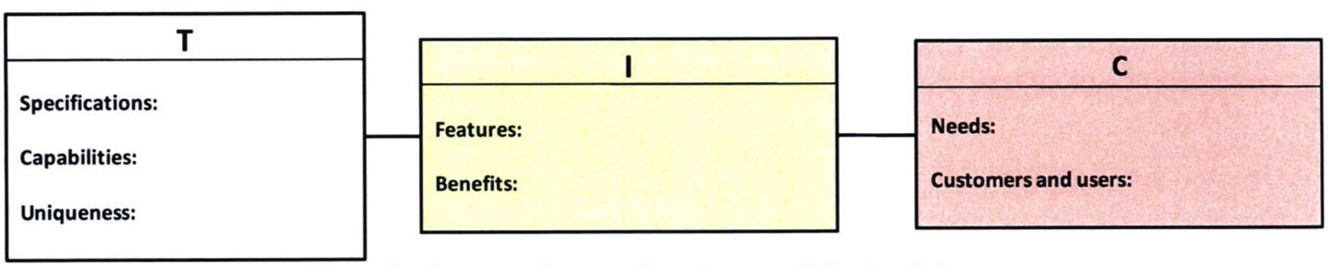


Figure 7: Technology - Implementation - Commercialization linkage

Basically, the specifications, capabilities, and uniqueness of the technology of interest are first articulated (blue box). A useful tool to conduct a comprehensive analysis of the relevant issues related to the technology is (Markham and Kingon 2004)'s "Technology Description Worksheet" (which groups the analysis into 3 areas- *technology description, technology advantage, and level of development*, see Appendix 2: Technology Description Worksheet). Teams then identify need(s) from potential customer groups that could be fulfilled by somehow applying this technology (the red box). Finally, the team bridges the gap between a technology and a need by creating the appropriate implement (and stating its features and benefits) that can use the technology to satisfy the need (the green box). This is an iterative process- while the first iteration may use this sequence to generate a TIC linkage, teams can build on ideas and new information to improve the linkages.

1.2 It will then look at combinations of these linkages to identify new or improved technologies or implementations, and develop the corresponding TIC linkages, as well as to identify opportunities for commercialization and interactions between them (for example, affecting demand or adoption rate). Thus, in this stage the "synergies" are articulated by combining TIC linkages of the parent company with the external source(s) (see Figure 8). Also, it is important to note that there are many ways to combine 2 or more TIC linkage charts (for example, T-T, T-I, T-C, see Figure 9) to create a new combined TIC framework.

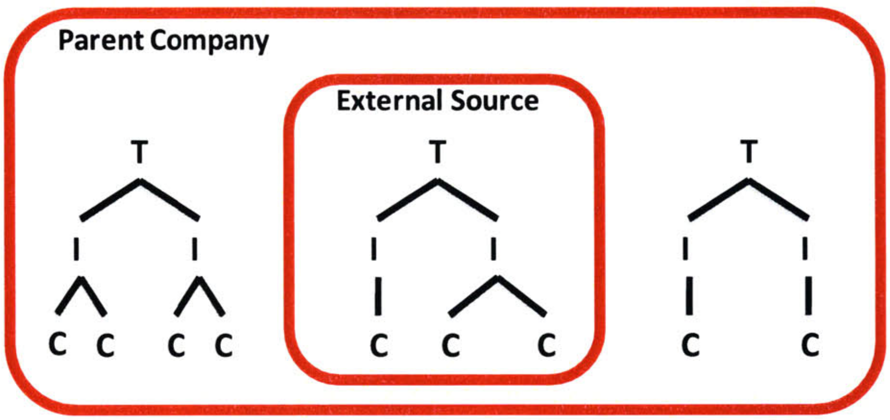


Figure 8: Individual Technology-Implementation-Commercialization Linkages

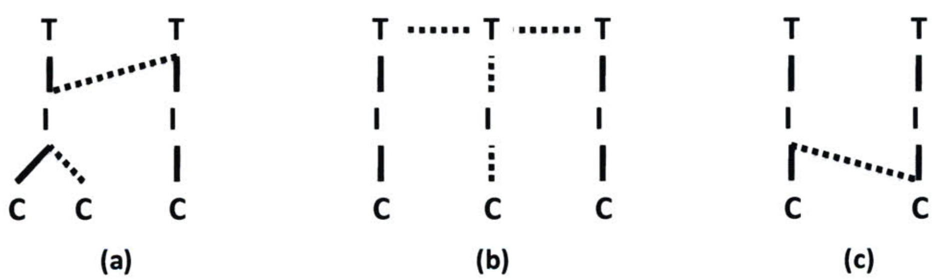


Figure 9: Combinations of Technology-Implementation-Commercialization Linkages

3.2 Development of the components of the opportunities

The TIC linkages of the evaluated company and the new TIC linkages articulate a set of business opportunities that must subsequently be developed with more detail. For this purpose we have created a tool that incorporates key ideas of Discovery Driven Planning (McGrath and MacMillan 1995) and the method for assessing uncertain projects through the scoring of a series of statements proposed by (McGrath and MacMillan 2000). This tool lists important issues identified in the literature, grouped according to the typical structure of a business plan (see Table 2 for list of categories), for which the evaluation team must:

2.1 Assess the current and goal positions, and development paths between them (similar to (McGrath and MacMillan 1995)'s DDP approach).

2.2 Recognize uncertainties, express them as assumptions, and identify alternatives to address them.

2.3 Point out dependencies between issues.

Table 2: Classes of Issues for Opportunity Development

Intellectual Property	Operations
Technology	Sales and Marketing
Implementation	Team and Management
Commercialization Opportunity	Funding and Financials
Regulation and Competition	

This tool has an immediate use as a guide for the assessment team to go through the effort of gathering information, within their time and resource constraints, to convert as many assumptions to knowledge as possible, thus improving the assessment. The basic structure of this tool is provided in Figure 10, while the complete structure (developed by Professor Claro and myself) is provided in Appendix 5: Opportunity Development Tool.

Issue	Assessment		Uncertainty	Addressing Uncertainty			
				How	Value	Cost	Dependencies
	Current						
	Goal						
	Develop						
	Current						
	Goal						
	Develop						

Figure 10: Structure of the Opportunity Development Tool

For each issue presented in this tool, the team must first conduct an initial analysis, specifying:

1. The current position of the project – How does the project currently look?
2. The goal position for the project – How does the project have to look to deserve funding?
3. The development path for the project – How can the project be developed from its current position to the goal position?

For each of the previous points, the team should then:

1. Identify uncertainties in the assessment, i.e. assumptions, and express them as probability distributions of outcomes.
2. Determine how critical the reduction of the identified uncertainties is.
3. Identify alternatives to reduce the uncertainties and the corresponding cost.
4. Verify whether the uncertainties depend on other issues in the project.

Each of these points are addressed in the tool provided (Figure 10)- this description is meant to provide guidance into how each element within this tool assists in the overall "opportunity development" phase.

Once the initial analysis is completed, the team must address both the uncertainties that can and cannot be reduced within the time and budget constraints of the project. Uncertainties will be reduced largely through information gathering from researchers, industry experts, etc. Uncertainties that are either too costly or impossible to reduce should be prioritized by importance and used as a basis for identifying the most crucial sources of managerial flexibility (hence creating a dynamic business plan).

3.3 Dynamic planning and valuation of the opportunities

3.3.1 Inputs: Opportunity Identification and Development stages

It is at this stage where significant synthesis of our past analysis steps manifests itself in a unified vision for the planning and valuation of the opportunity(s). Each of the two preceding steps is invaluable to the ultimate development of a DSP for the planning of an opportunity:

The *Opportunity Identification* stage articulates the commercial opportunities whose needs will be served through implements based on the original technology (through Christensen's job-to-be-done framework). This is done by developing a network of TIC linkages that communicates the set of different development paths that could be taken by the single technology.

In the *Opportunity Development* stage, the team will have identified a structure for the technology-to-commercialization plan, as well as development paths in specific issues, for the opportunities under scrutiny. The team will use this information to build a specific structure for the plan. The team will also have identified a set of critical uncertainties, and associated flexibilities, that should now be inserted in the structure of the plan, which as a result will take the shape of a decision tree (Faulkner 1996).

The opportunity identification and development stages thus provide information on two different levels, each of which is crucial to the development of a DSP. The opportunity identification phase broadly defines the "system boundary" of the decision trees- the commercialization paths that could be pursued using the technology. The opportunity development phase analyzes the critical uncertainties within this system that determine which sources of flexibility must be incorporated into the decision tree. These uncertainties are found in each of the development paths created in the opportunity development phase. Figure 11 illustrates a conceptualized two dimensional framework for the decision tree.

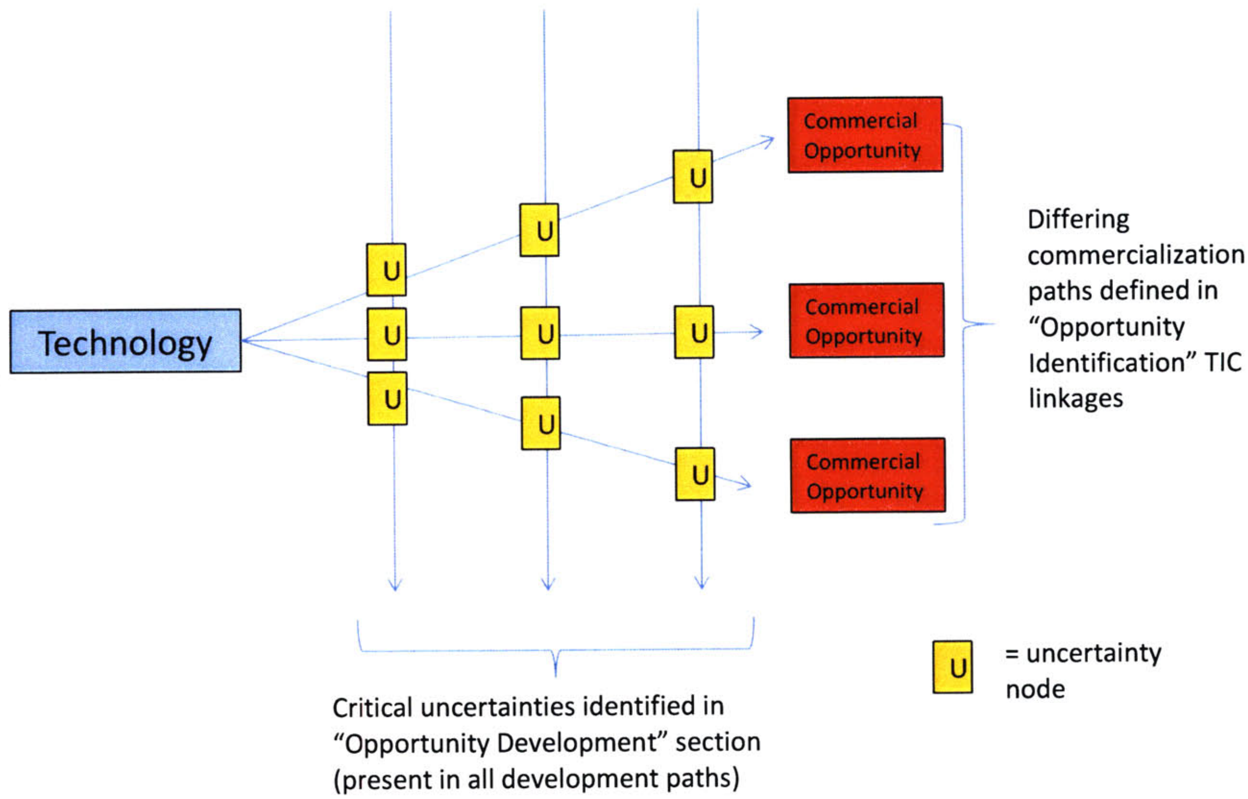


Figure 11: Conceptualization of decision tree (based on inputs from opportunity identification and development phases)

3.3.2 Creating a framework for conducting a DSP: Decision Analysis

While we have mentioned "decision trees" in passing, it is useful to explicitly define the method of analysis they represent (Decision Analysis) and justify their use as an appropriate model for communicating the ideas of DSP. Broadly speaking, Decision Analysis (DA) is an effective technique for evaluating alternatives in uncertain situations. The key strength of the decision analysis approach is that it is a standard model that provides a simple way of defining a wide range of choices (states) over several periods of time (stages).

Decision trees are a clear and powerful way of displaying the different paths an opportunity has to consider, and the accompanying analysis that must be conducted to determine the best development strategy. They are built by iterating a binary uncertainty-decision node system: for every identified uncertainty (i.e. oil price, or technological development success), there is an accompanying set of decisions (this is how flexibility is manifested) that management must choose from. Two types of data are needed to conduct an analysis of the DT: the probabilities associated with each outcome, and the values of the outcomes themselves.

A powerful feature of this approach is that the number and type of decisions for any uncertainty node is not restricted in any way. The main drawback of DT's is that they become large quite quickly (expanding as an exponential function of the number of stages [time periods] and outcomes [states]). Hence, for practical purposes, parsimony is advisable, especially in the case where decision trees are used to guide general management decisions.

As (Claro et al. 2008) note, to develop the decision tree, the assessment team should:

1. Build the sequence of stages for the venture. Architecting such a sequence requires careful and logical consideration: the limits of the stages should include the times when managers are expected to make decisions on how to continue activities. An example of such a sequence is: research and development, prototype development, implementation of the technology and beginning of commercialization.

2. Incorporate investments in flexibility. Considering each investment at a time, the alternatives (including no investment) should be introduced as decision nodes, at the relevant point in the sequence. This turns a linkage between two stages into a decision node with different activity paths.

3. Incorporate uncertainties. The critical uncertainties identified in opportunity development should be introduced one at a time. In this case, a linkage between two stages becomes an uncertainty node with several different outcomes (usually a discrete set, although a continuous set can be defined).

4. Incorporate managerial flexibility. In order to consider the use of flexibility, decision nodes are placed after the corresponding uncertainty node. The decision node should reflect a decision

management can make that will minimize the loss in performance associated with unfavorable outcomes, and improve performance by taking advantage of situations where the outcome is favorable.

Once the tree has been constructed, and the data (probabilities and values of associated outcomes) has been incorporated, one is ready to analyze the tree and create a dynamic plan. The way to conduct such an analysis is to use the "folding back" method, where one starts with the last stage of the DT, and multiplies each outcome value with the associated probability. One then picks the path that has the maximal expected value. This process will be clarified in the next section, where we introduce a simple motivating example for the use of such a planning and valuation method. The key point that arises from the use of this decision analysis approach is that we do not arrive at a simple, step-by-step plan (i.e. do X in Period 1, and Y in Period 2). Instead, the output is a *dynamic* plan whose later steps depend on the outcome of previous ones; i.e., do X in Period 1, and depending on the outcome of Uncertainty 1, do Y_1, Y_2, or Y_3 in Period 2.

3.3.3 Value of Flexibility: A motivating example

The shift in thinking from a fixed to a flexible, dynamic planning method is probably best illustrated through a simple, motivating example. Consider a simplistic example where a solar start-up has determined two potential commercialization paths for its technology:

1. Apply the solar technology to electricity production (power plants)
    a. Has a 70% chance of earning $ 100 million
2. Apply the solar technology to power desalination plants
    a. Has a 50% chance of earning $80 million

Assuming that the development cost for either commercialization path is $ 10 million, the standard business plan approach would be to assess both opportunities, and pick the "most likely profitable" application:

Electricity Production: (.7)*($100 million) - $10 million = **$60 million**

Desalination: (.5)*($80 million) - $10 million = **$ 30 million**

From this point of view, the electricity production application is clearly the best choice. Figure 12 illustrates the decision tree that models this decision structure.

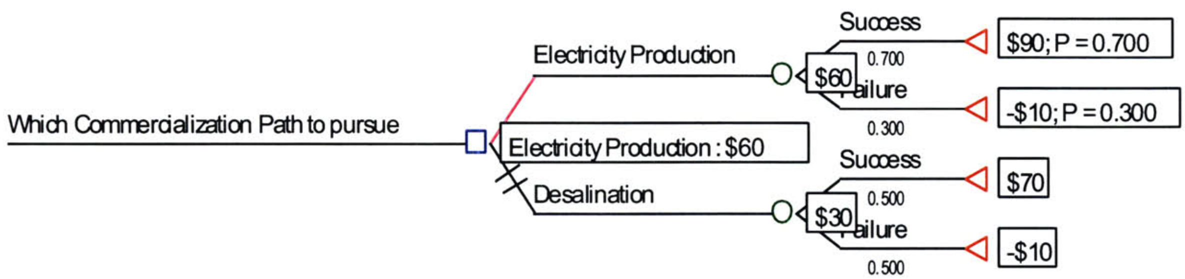


Figure 12: Decision Tree modeling traditional valuation approach (Electricity Production application is chosen with an NPV of $60 million)

In contrast, the dynamic strategic planning approach recognizes uncertainty, and uses it as a fundamental component of the analysis. As such, it recognizes that we can develop *both* efforts, with the aim of minimizing exposure to downside risks (i.e. desalination provides some insurance in case electricity production is not successful), and having greater opportunity (both desalination and electricity production could be successful).

Analyzing the concurrent development of both paths requires considering the joint distribution of possibilities for failure/success, Table 3 presents this distribution in table format. There are two key insights: by developing both commercialization paths, one purchases some "insurance", in this case correlating to the probability that desalination succeeds while electricity production fails (15%, or there is a 15% chance that the insurance will be useful). Also, if both commercialization paths are successful (in this case 35% chance), then we have the opportunity to reap benefit from both paths.

Table 3: Joint distribution of desalination and electricity production probability of success/failure

		Probability of Desalination:		
		Success	**Failure**	
Probability of Electricity Production:	**Success**	**0.35**	**0.35**	**0.7**
	Failure	**0.15**	**0.15**	**0.3**
		0.5	**0.5**	

In this case and in general, the cost of buying this insurance and/or opportunity to pursue both applications if successful is small. In this case, financing the initial R&D phase is "cheap" compared to later stages of concept development and commercial production. This phenomenon is not restricted to this case: *in general*, the cost of pursuing more than one development path until new information guides management to make decisions (building in flexibility) is small (and often nonexistent) compared to the increases in value of the outcomes (commercialization).

Finally, Table 4 illustrates the possible outcomes for the four possible combinations of success and failure for the electricity production and desalination commercialization paths. The calculations assume some savings in the cost of development because much of the engineering work may overlap. Thus, a 25% cost saving is assumed, bringing the development cost to $15 million instead of $20 million. The result is a rise in the value of the system:

Table 4: Outcomes of joint Desalination and Electricity Production development

		Outcome if Desalination is:		
		Success	**Failure**	
Outcome if Electricity Production is:	**Success**	**0.35*(100+80-15) = 58**	**0.35*(100-15) = 30**	**0.7**
	Failure	**0.15*(80-15) = 10**	**0.15*(-15) = -2**	**0.3**
		0.5	**0.5**	

=> 0.35*(100+80-15) + 0.35*(100-15) + 0.15*(80-15) + 0.15*(-15) = **$95 million**

=> Over 50% improvement!

As Figure 13 shows, the plan is dynamic because it does not give a fixed development path. Instead, the DSP proposes a dynamic approach whose later steps depend on what happens in the periods before hand.

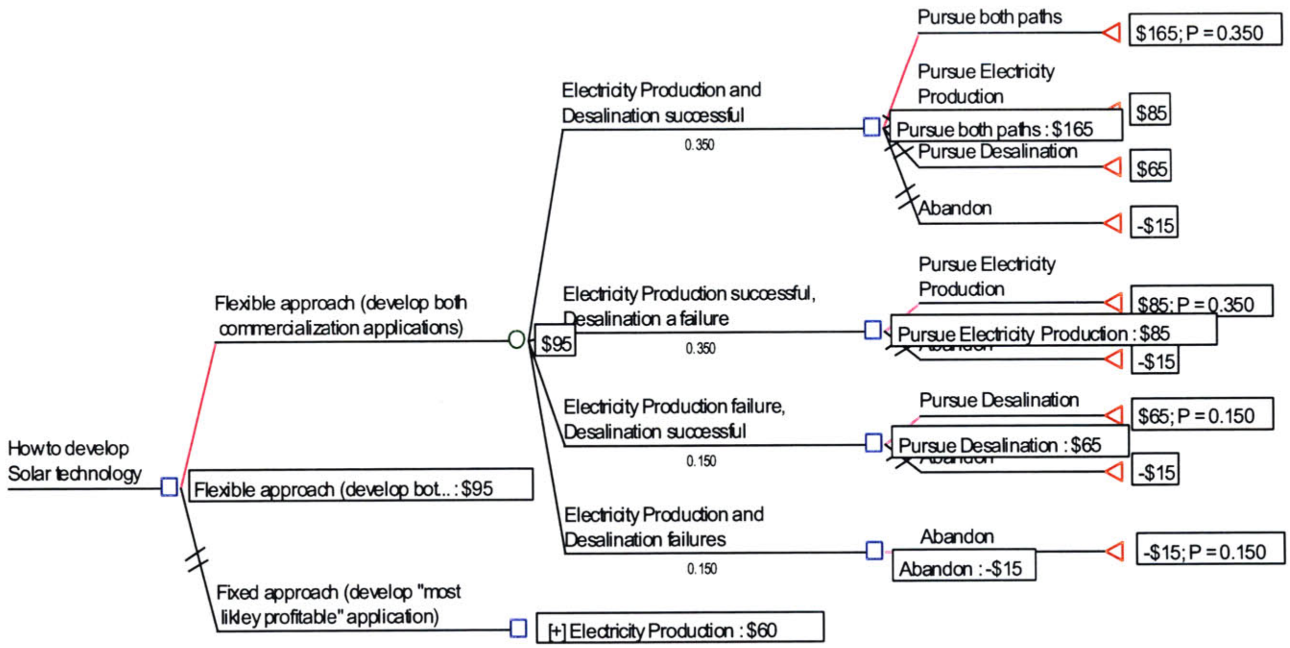


Figure 13: Decision Tree modeling DSP approach (higher project value of $95 million instead of $60 million)

As this simplistic example illustrates, using a flexible, dynamic business development approach minimizes exposure to risk and gives an opportunity to exploit many development paths. The difference in system performance is not negligible and justifies a shift in the way companies plan and assess the development of uncertain technology investments.

3.3.4 Interpreting the results: VARG plots

A convenient way of representing the information embedded within a decision tree is the "VARG" chart- Value At Risk and Gain. The VARG is based off of the "VAR" (Value At Risk) chart, which represents how much it might be possible to lose for a given probability. The VAR is thus most applicable to lenders who are mainly concerned with the likelihood of getting repaid.

In contrast, the VARG has a more balanced view on the cumulative distribution of outcomes, incorporating the "Gain", or upside potential, of a project. The VARG conveniently represents the cumulative distribution of outcomes, arranged from worst case (i.e. Outcome_{min} @ x% cumulative probability of occurring) to best case (i.e. Outcome_{max} @ y% cumulative probability of occurring). When the number of outcomes is small, the VARG plot has a "step function" shape; when the number of outcomes becomes sufficiently large, the step function gradually turns into a smoother curve like function.

In terms of interpreting the graph, the intuition is that the more the VARG plot is shifted to the right, the better the system performance (since for a given level of risk, the returns are higher). Figure 14 illustrates the VARG curves for both the flexible development method, and the fixed method. As is observed, for a given probability, the flexible approach tends to have a larger value than the fixed.

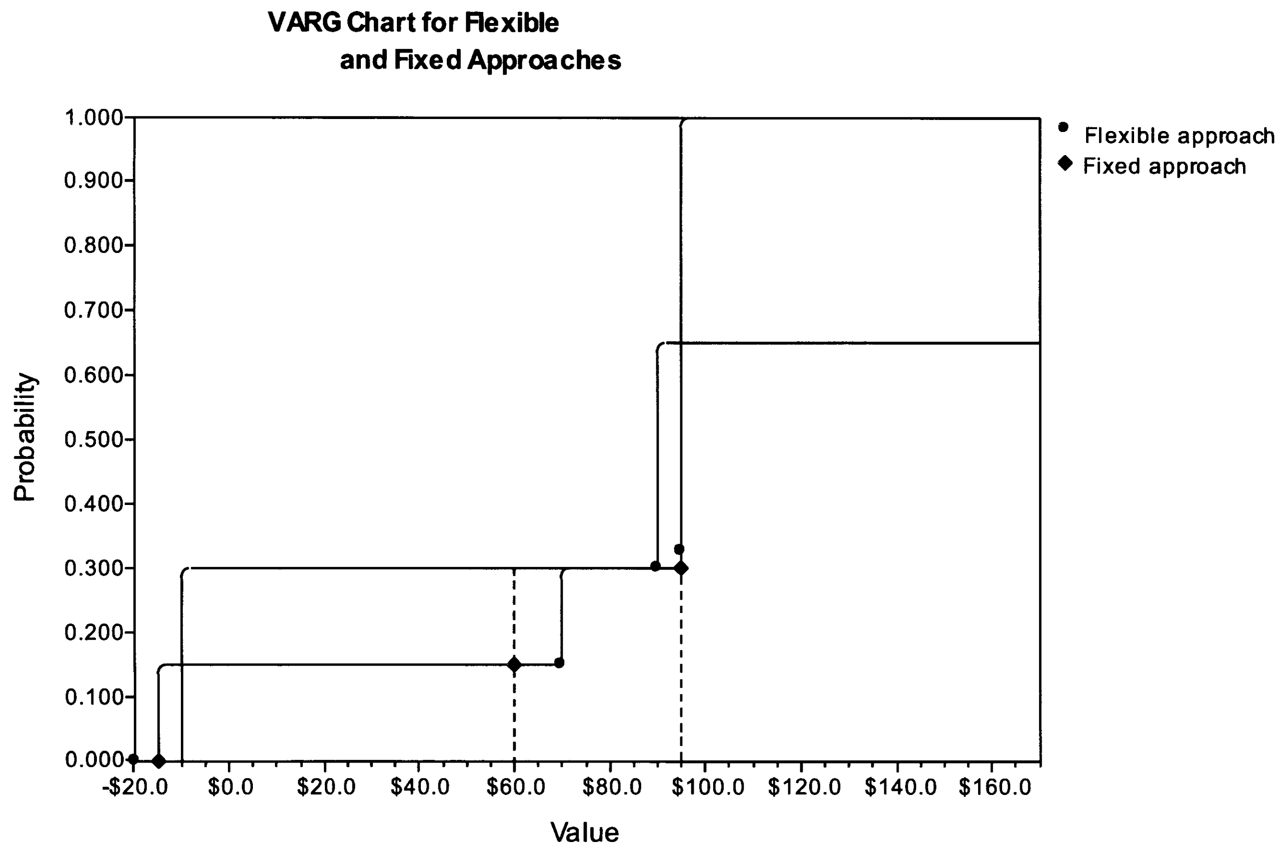


Figure 14: VARG chart for Flexible and Fixed development paths

3.4 Dynamic Business Plan Preparation

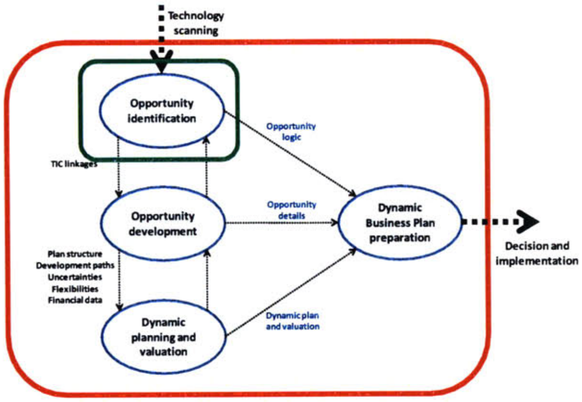
A business plan-like report should be the final deliverable of the evaluation process, since business plans are effective tools for the characterization and communication of business opportunities. Because there is no single optimal plan, but a set of multiple optimal paths dependent on the ways in which uncertainty is resolved, we suggest that this business plan be a *dynamic business plan*, in which the identification of critical uncertainties and relevant flexibilities, both *on* and *in* the project, is brought to the forefront of the analysis.

4. Case Study: A new "CSP" technology

This section of the thesis presents a significant portion of its main value. The application of our new integrated method to plan and assess the development of a "real-life" technology is meant more to serve as an example for how to apply it rather than being an exhaustive analysis of the technology itself. Our analysis is thus conducted according to the 4 components of the method: opportunity identification, opportunity development, dynamic planning and valuation, and dynamic business plan preparation.

It is important to note that while this thesis presents each component in a linear, sequential pattern, there is significant feedback and iteration between the steps. For example, analysis in the "opportunity development" component may lead to critical insights that can affect the structure of the TIC linkages. The overall framework for the approach and anticipated structure of these feedback loops is captured through the arrows that link each component to the other in Figure 10.

4.1 Opportunity Identification



Section 4.1, Opportunity Identification, is completed in accordance with the Method section's framework for identifying and articulating an opportunity. First, in section 4.1.1 a TIC network is created for the start-up in consideration. Next, section 4.1.2 an independent TIC network for the investing firm is created. Using information gathered from these networks, section 4.1.3

4.1.3 Creating a joint Eni-CSPond TIC creates a combined TIC network that articulates how the investing company will take advantage of its resources and capabilities to implement the new technology.

4.1.1 Creating the CSPond Technology-Implementation-Commercialization (TIC) network

4.1.1.1 CSPond: Technology

In accordance with the Method section, the first order of business when "technology scanning" (see Figure 10) is to analyze the new technology that a start-up (or other entity) is developing. An investing company should have a clear picture of exactly what it is the technology does. While this may seem a straightforward requirement, I have found that it is often more difficult than is expected to describe in a succinct and pertinent manner, what exactly a new technology performs.

Our example centers on a new technology being developed at the Massachusetts Institute of Technology (MIT), within the Mechanical Engineering department. The technology, Concentrated Solar Power on demand, or "CSPond", is meant to be a more efficient (and hence economical) way of receiving and storing thermal energy.

While there has obviously been much technical analysis that has led to this new innovation, for the purposes of our assessment and development method, we seek a very specific set of information that will be relevant to the rest of the process.

A useful tool developed by (Markham and Kingon 2004) to address the relevant attribute of a technology (in terms of future commercialization potential) is the "Technology Description Worksheet" (TDW). While a complete TDW for the CSPond technology is provided in Appendix 2: Technology Description Worksheet, a brief description of the CSPond technology is provided.

The CSPond technology is a new CSP (Concentrated Solar Power) system that "simultaneously directly receives and stores thermal energy in a volume of molten salt using a beam-down solar power tower" (Slocum et al. 2008). The setup of this system is most similar to "solar tower" technologies that use heliostats (collecting mirrors) to track and reflect the sun's energy onto a solar boiler. The problem with this conventional design is that the heat that is directed to the boiler relies on surface absorption (similar to light absorption by land) as the means for transfer to the coolant within the tubes (results in large radiation flux back out of the system).

In contrast, the CSPond technology uses *volumetric based* absorption (similar to light absorption by the ocean) where the light is passed through a narrow aperture into a volume of nanoparticle-filled salt basin. Absorption by a volume maximizes absorption, and thus allows for a very small aperture (opening) into the pond, to further minimize thermal inefficiencies. Figure 15 illustrates a schematic for one such molten salt pond.

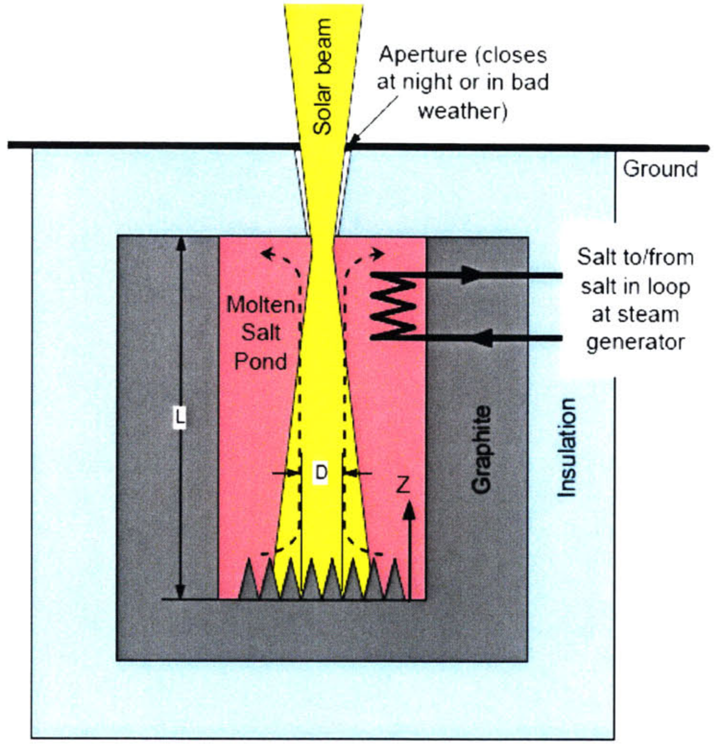


Figure 15: Schematic of Slocum et al.'s "CSPond" technology (Slocum 2008)

In addition to bulk absorption, the CSPond system is inherently more thermodynamically efficient for 2 reasons: a reduction in the number of thermodynamic cycles, and higher operating temperatures.

In a conventional solar tower design, the surface-heated liquid coolant is transferred through (un-insulated) tubes where it transfers heat to a nitrate salt. Then, when the heat is once again needed, the heat must once again be transferred between the storage medium (the salt) and the coolant. By having a design where the receiving liquid (the "coolant") is itself the storage medium, one eliminates 2 thermodynamic cycles (thus raising system efficiency).

Secondly, this system both inherently supports and has used novel innovations to function under higher operating temperatures. An inherent attribute of the system is that it does not have to use boiler tubes to move heat from one source to another. Incidentally, in conventional systems this portion of the system limited operating temperatures to ~600˚C; with its elimination the system can operate at higher temperatures (~1,000˚C) and hence higher efficiencies. To accommodate this higher operating temperature, it is critical that the heat flux is properly distributed in the ponds (creation of "hotspots" and generally differential temperatures in the pond leads to reduced system performance and can damage the physical structure). To do this, the ponds are filled with a special nanoparticle laden molten salt that better distributes the heat once it has entered the pond. While the molten salt stores part of the heat, the vast majority is stored in the graphite-lined basin wall.

Lastly, thermal stratification is addressed through two mechanisms. First, choosing an appropriate "truncated cone shape" geometry for the storage chamber (see schematic of CSPond, Figure 15) promotes convective flow of the salt. Second, the way heat is transported can be used to mitigate thermal stratification. Two modes can be applied for thermal transport. A liquid coolant can be directly circulated through pipes going through the upper section of the pond (hence cooling the higher temperature salt at the top, and buoyancy forces causing it to naturally sink down), or the salt itself can be circulated by having the "cooler" salt exit through the bottom portion of the pond, and re-enter (in an even cooler state) in the top portion of the pond.

A summary of the projected CSPond (referred to as "Diode/Volume Receiver) cost performance as compared with conventional setups (referred to as "Surface Receiver + storage tank") is provided in Table 5.

Table 5: Projected relative performance and cost comparisons between CSPond ("Diode/Volume Receiver") and conventional (Surface Receiver + storage tank) technologies (Slocum et al. 2008)

Proportional costs	Diode/Volume Reciever	Surface Reciever + storage tank
collector efficiency	85%	60%
steam plant efficiency	40%	30%
storage temperature (oC)	1000	600
Solar collector field	0.4	0.7
Tower	0.1	0.1
thermal storage	0.1	0.3
steam plant	0.4	0.5
Total	1	1.6

Of course, we must summarize all of this information into just a few bullet points that will be placed in the blue "T" (Technology) box (as part of the TIC network). See Figure 16 for the blue "Technology" box which lists the description, capabilities, and uniqueness of the CSPond technology.

T

CSPond Design

Specifications
- Improved energy capture
- Improved Energy storage
- (near) Zero emissions

Capabilities
- Lower capital costs
- 24/7 operation
- (near) Zero emissions

Uniqueness
- Sufficiently unique as compared with existing patents/technologies to get patent protection

Figure 16: "T" (Technology) component of the CSPond TIC network

4.1.1.2 CSPond: Commercialization

While this technology may rightfully seem very promising, an ingenious technology on its own does not lead to commercial success. For the technology to succeed in the market, it must satisfy a need from a (or many) particular market segment, or as (Christensen and Raynor 2003) describe it, a "job-to-be-done". The majority of the research conducted in the area of commercialization potential is presented in the *combined* CSPond-Eni TIC diagram; however, a simple schematic of how an independent CSPond commercialization initiative might unfurl is presented.

A preliminary investigation of the electricity market reveals two main commercialization opportunities for a CSPond-based implement. The first is through the growing mandate for renewables-based electricity in developed nations, i.e. in the European Union (EU), or the US. The second is the creation of new electricity demand in industrializing nations located in "sun rich" regions (see Figure 17) such as North Africa, the Middle East, and India (CSP GMI report 2004). Figure 18 illustrates the red "Commercialization" box which lists the needs, and customers & users of the CSPond-based implementation.

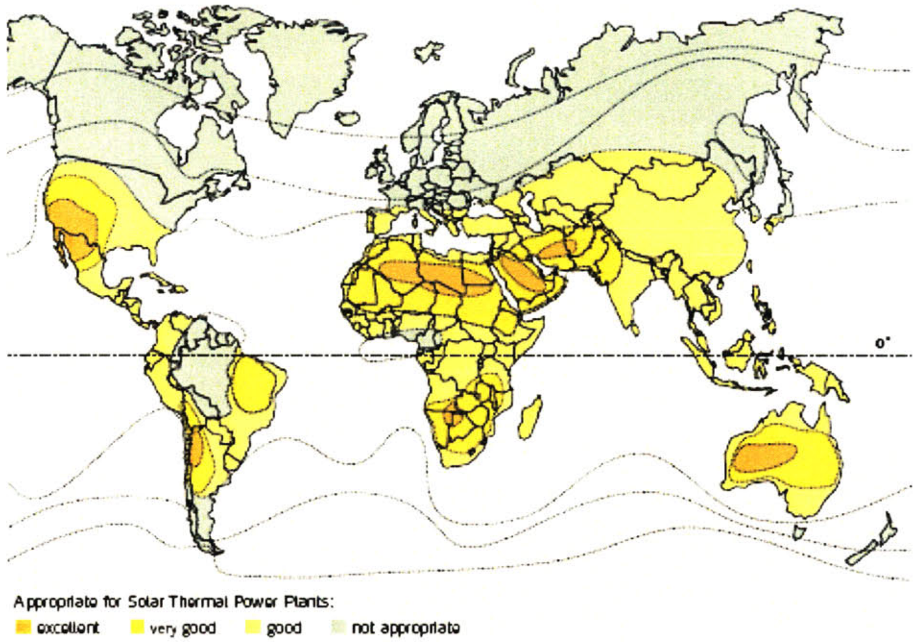


Figure 17: "Sunbelt" regions suitable for solar thermal power plants (CSP GMI report 2005)

C

Power Generation Companies
(Capacity Expansion)

Needs

• Increasing "green" energy requirements in developed nations (i.e. US, EU) through tariff incentives, minimum "renewables" component of electricity produced, etc..

• Need for more energy in developing, "sun rich" nations. Associated needs: technology transfer from new technologies, greener and more sustainable energy source, cheap local energy source (in order to save petrochemicals for exports)

Customers and users:

• Power generation companies

Figure 18: "C" (Commercialization) component of CSPond TIC network

4.1.1.3 CSPond: Implementation

For the start-up developing the CSPond technology, the implement associated with this commercialization opportunity is limited to creating CSPond-based SEGS power plants (solar-based power plants are known as "Solar Electric Generating Systems", SEGS). Since the start-up would have no other expertises (i.e. in fossil-based power plants), these plants would operate as "stand alone" facilities, generating power solely from solar energy. See Figure 19 for the green "Implementation" box which lists the features and benefits of the CSPond-based implementation.

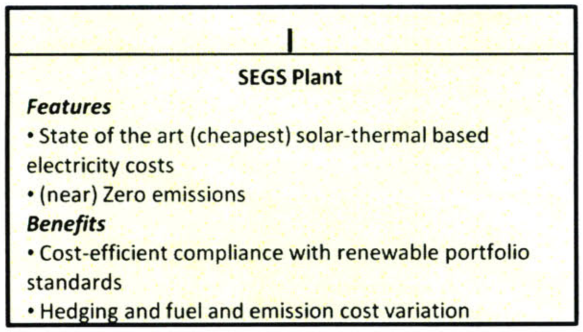


Figure 19: "I" (Implementation) component of CSPond TIC network

4.1.1.4 Producing a sample CSPond TIC Network

With preliminary T, I, and C "boxes" completed, we are now ready to assemble a first-estimate of how the CSPond-based TIC network should look like. It must be emphasized that at this stage we are still viewing this technology in isolation- its development is not aided by any external capabilities/ competences (that might arise through combination with a CVC). A simple combined TIC linkage for the CSPond is displayed in Figure 20.

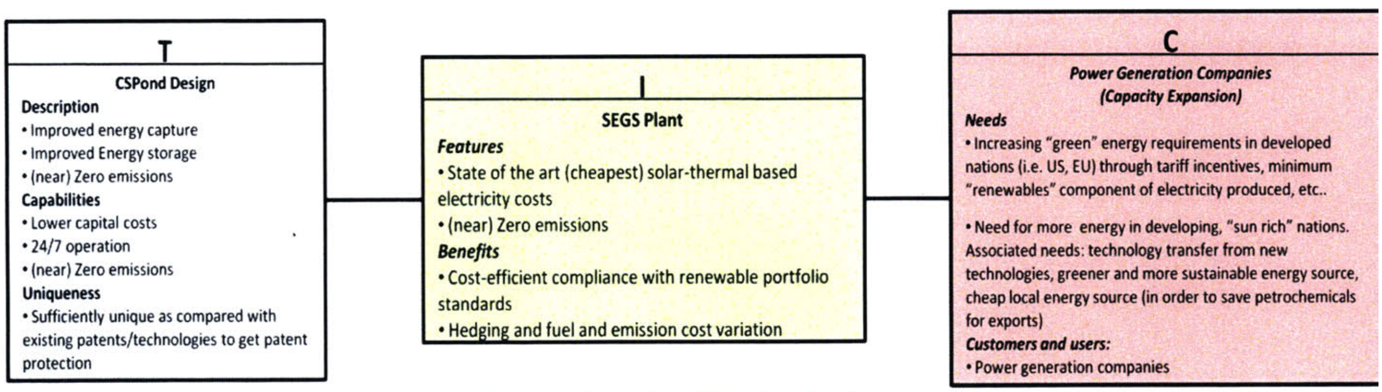


Figure 20: TIC network for the CSPond technology

A further analysis would involve iterating the TIC generation process by gathering more information and enhancing the network. For example, after this preliminary TIC linkage has been created, the team would gather further information about the points in the commercialization box, and refine the definition of the "job-to-be-done". This would in turn lead to a more refined definition of what the appropriate implement should be.

4.1.2 Mapping Eni, Creating Eni TIC

Of course, combining the superior performance of a new technology with a highly relevant organization's resources and capabilities can result in the increased commercialization success of the technology. The first step in creating this highly favorable partnership is to assess the capabilities, resources, and goals of a potential investing company. In this case, we will analyze Eni, a large Italian oil & gas services provider, observing what its goals are, and how its existing resources can aid in a successful combination with the CSPond technology.

We begin with Section 4.1.2.1, which acquaints the reader with the investing company used in this example (Eni). Section 4.2.2.2 then creates a TIC chart that seems to be relevant to the start-up's technology. Finally, Sections 4.1.2.3 (Eni challenges) and 4.1.2.4 (Eni vision) provide contextual background regarding the impetus and general plan for investing in renewable energy (and specifically CSP technologies).

4.1.2.1 Eni: an overview

Eni is a largely state-owned (30% of total shares) Italian energy company. Founded in 1953 by the Italian government, ENI's purpose was to "promote and develop a national energy strategy based on the concentration of all the activities in the energy sector into one group" (Wikipedia 2008). Since at the time energy strategy was almost exclusively equivalent to oil and gas strategy, this became ENI's core competency.

During the 1970s' and 80's, as a result of the dramatic repercussions of the oil embargo, ENI set out to strengthen it natural gas operations. Although there were several significant developments in the former USSR, the Congo, Holland, and Angola, Eni's main accomplishment in the natural gas field came through completion of the Transmediterranean Pipeline. This pipeline begins in the Algerian desert, goes under the Mediterranean Sea, and serves as a vital "natural gas-artery" that spans the entire Italian peninsula.

The 1990's and early 21st century can be characterized as a period of aggressive international expansion in the field of oil and natural gas. Eni launches or expands efforts all over the world: North Africa (Algeria, Egypt, Libya), the North Sea, West Africa (Nigeria, Angola), Central Asia (Kazakhstan, India, Azerbaijan), the Gulf of Mexico, the Middle East, Far East (Indonesia and China), Alaska and Brazil.

Currently, Eni is active in 70 countries, and employs about 76,000 employees (ENI 2008). It has also bought several subsidiary companies in its strategic expansions efforts (Saipem, Italgas, Snam Rete Gas, Polimeri Europa, and AGI). Its latest annual revenues (92 billion Euros, or ~ $135 billion, 2007) place it as the 3rd largest European refiner, after Royal Dutch Shell and Total (Wikipedia 2008).

Currently, Eni operates in several parts of the oil and gas services value stream: exploration, production, transport, distribution, engineering, and construction (engineering and construction through Saipem subsidiary). According to Eni, "We are a major integrated energy company, committed to growth in the activities of finding, producing, transporting, transforming and marketing oil and gas" (Eni 2008). Eni's operations are split into 3 divisions: Gas and Power, Exploration and Production, and Refining and Marketing. Other activities, such as engineering and construction, and corporate/financial services are organized outside the 3 divisions, serving as support services for each main division. Figure 21 illustrates Eni's basic organizational setup.

Figure 21: Organizational setup of Eni

4.1.2.2 Eni TIC Chart

Generally, TIC linkages for investing companies will be larger and more complicated than for the start-ups being considered. This is expected as most firms engaging in CVC will be of a relatively substantial size. Thus, while it may be useful to map the entire organization's TIC network, it is not necessary for this method. Teams should instead focus on creating TIC networks of the relevant portions of the investing company (where they see the new technology "fitting in" within the greater company). This ensures that the team's time is spent in the most efficient way and the focus is maintained within the scope of researching the start-up's usefulness to the investing company.

Of the three divisions within Eni (see Figure 21), the "Gas and Power" division is the most relevant to the CSPond technology. This is because the process of making power can be accomplished through *gas* and also through renewable sources, such as CSP (the "exploration and production", and "refining and marketing" divisions are not as directly relevant). Further, referring back to Figure 21, we find that the "Engineering and Construction" support companies (i.e. through SAIPEM) could provide the necessary services for building and operating power plants. Figure 22 thus creates a focused TIC linkage that represents what seems to be the most relevant portion of Eni's overall operations and services. Of course, further investigation by experts within the company could provide more detailed information about exactly which departments/divisions are applicable to the CSPond technology, and hence create refined TIC networks for the investing company (Eni).

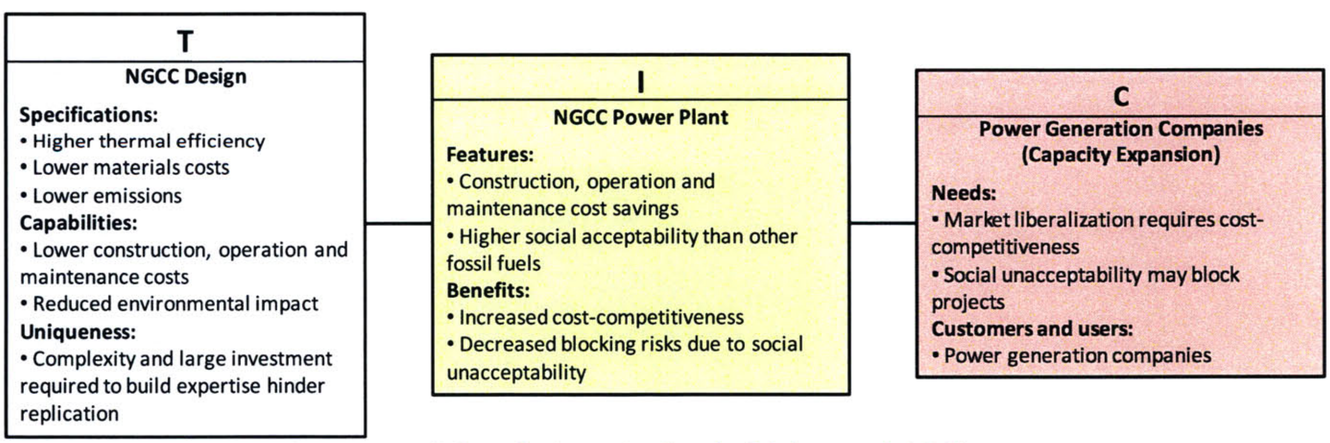


Figure 22: TIC linkage for investing firm (Eni) (Claro et al. 2008)

4.1.2.3 Eni challenges

(De Blasio 2009) summarizes the challenges Eni and most oil and gas firms face in the 21st century. A summary of his work presents the following four concerns:

- Limited access to new mineral resources often *located in extreme conditions* and subject to *strict environmental constraints*, although the industry is "capable of and *prepared to address them"*.
- Production declines of big reservoirs and the *need for advanced technologies* for reservoir management.
- *Rising concerns* in producing nations about *social issues* and the *environmental foot print* of engineering and procurement activities in host nations.
- Increasingly tighter fuel specifications to *meet air quality standards* also in developing countries. Limited options for addressing climate change on a local and global basis raise issues *about long term sustainability of the Oil & Gas industry*.

Two themes become evident from this list of concerns. Firstly, the process of finding and extracting oil & gas reservoirs is becoming more technologically demanding (assumed mainly because the "low hanging fruit" has already been picked). Second, there is increasing social as well as client-based demand for more environmentally friendly energy extraction and use. While these two observations by themselves do not constitute a formal market potential for solar-based technologies, they do point to an internally-driven acknowledgement by the oil and gas firms of the changing requirements and needs of the energy sector.

4.1.2.4 Eni vision

Faced with these top level challenges, top management at Eni has had to create a vision for how they will respond to the changing environment in which they operate. This vision is critical in our analysis because it gives us valuable information regarding how Eni will plan to potentially mobilize and hence leverage its resources with a start-up's technology.

The following is a summary from (De Blasio 2009) outlining Eni's vision for its future operations.

Assumptions:

- Access to new resources in producing nations will be driven by *unique technological capabilities*, experience in complex projects management and *know-how sharing* in dedicated partnerships with producing countries.

- Global as well as local environmental concerns will be important issues in the relationship with stakeholders.

Goals:

- In the medium term, optimization of large solar thermal plants, using Concentrating Solar Power (CSP), integrated with conventional gas fired plants and desalination units will help the sustainability of the business.

- *Technology Innovation is a key strategy for supporting Eni's medium to long term goals.* Accordingly, since 2006, Eni has invested in an extraordinary R&D effort to strengthen its technological portfolio and address market discontinuities associated with declining access to quality fossil fuel resources.

- In the *long term*, it will be important to identify energy sources that could be *alternative or complementary to fossil fuels*. The "extended core business view" will help the long term sustainability of the Oil & Gas business.

Method:

- To address the energy and technology challenges identified above, *in-house R&D* must be *complemented* by collaborations with the most prestigious and advanced *Universities and R&D Centers* worldwide. Partnerships with *cutting edge technological start-ups* are also part of Eni's strategy.

This account gives us key insights into Eni's strategic reasons for its CVC investments. Within (Henderson and Leleux 2005)'s framework, we see that Eni's vision neatly fit into two strategic goals for CVC investments: leverage or enhance competences through the combination or transfer of resources (medium term goal), and secure options to explore new technologies or new opportunities for commercialization (long term goal).

4.1.3 Creating a joint Eni-CSPond TIC

This step of the process is *essential* because it captures how the investing firm intends to use its resources, process, and/or capabilities to maximize the usefulness of the new technology. It is precisely this step that differentiates the evaluation process of a start-up from a CVC as opposed to a normal VC valuation. It is thus imperative that teams have conducted thorough analyses of the start-up's new technology, and equally if not more importantly, the investing company's relevant technologies, implements, commercial applications, or any other leverageable resource.

It may be immediately obvious to the astute reader that the process of combining two or more TIC charts is done through three basic linkage mechanisms: T-T, T-I, and I-I (it is assumed that "T-C" and "I-C" linkages are nonsensical because technologies and implementations are not directly combined with commercial opportunities). While Appendix 3: 3 Common TIC combinations (from Claro et al. 2008) provides a more thorough description of the three linkage types, the following is a brief outline:

> T-T (where two technologies are used to create a new technology with superior performance and/or increased commercialization opportunities);
>
> T-I (where a new technology is added to an existing implement to increase its performance or give it a unique competitive advantage); and
>
> I-I (where the combined use of two implementations results in the improved use of one of them).

For our specific case study, we will be using the T-T linkage because it seems the most appropriate. However, subsequent and more detailed analysis by experts may lead to additional ideas that combine the TIC linkages using T-I or I-I combinations (although I-I might be less probable for this case because the CSPond technology does not yet have an implementation).

The following sections 4.1.3.1 through 4.1.3.3 thus go through the *combined* TIC linkage process. Section 4.1.3.1 begins by describing the research and analyses conducted to arrive at a new possible *technology* application. Section 4.1.3.2 illustrates the research methodology required to explore possible *commercial applications* of our new technology(s). Finally, Section 4.1.3.3 proposes several *implementations* that use our new technology to satisfy the needs of different customer group (commercial opportunity). Although this process is presented in a linear fashion, it need not and probably should not be conducted in this way in a more detailed analysis. Ideally, this process would be iterated several times, (i.e. after the first TIC linkage is created, new information based on the model is used to revise the initial T-T linkage, which creates new commercial opportunities, leading to new implementations, etc.).

4.1.3.1 Creating a new TECHNOLOGY (T)

At this stage in the method, it is assumed that the team has developed a firm fundamental understanding of the new technology associated with the start-up. The next step is thus to examine the existing technologies within this field (CSP) and in application areas (i.e. petrochemical based power and/or desalinization plants) to better understand how the improved technology maps on a global perspective.

4.1.3.1.1 Industry Research: Patents & Projections

As part of this thesis, extensive research was conducted to understand what the current level of development in the solar thermal technology area is. By conducting a survey of existing and past state-of-the-art technologies, one is in a better position to articulate the competitive advantage of the new technology. One of the most useful methods of aggregating a comprehensive pool of recent technological developments is by searching a patent database. Table 6 highlights the results of a comprehensive search into CSP and ISCC technologies.

Table 6: Compilation of relevant patents (United States Patent and Trademark Office)

Date of Patent	Author(s)/ Submitters	Patent Number	Brief Description
1995, May	Bharathan et al.	5,417,052	A "hybrid central receiver for combined cycle power plant". This patent focuses on the heat transfer media and system setup in an Integrated Solar Combined Cycle (ISCC) plant. <u>Quoted from the patent:</u> "The power plant includes a molten salt heat transfer medium for transferring the thermal energy to an air heater... The tubes conduct the molten salt to the air heater where the thermal energy is used to heat the air therein. This preheating of the air results in fuel efficiencies..."
1995, August	Moore	5,444,972	A "Solar-gas combined cycle electrical generating system". It patent shows that the concept of an ISCC plant has been present for many years. In fact, the patent cites such a design as having existed since 1981. <u>Quoted from the patent:</u> "A design of a power plant which uses hydrocarbon fuels in conjunction with solar power to produce electricity. The power plant consists of an array of heliostats for concentrating sunlight on a central solar receiver..."
1998, March	Cohn	5,727,379	A "Hybrid solar and fuel fired electrical generating system". This patent deals mostly with the optimization of the overall hybrid system through solar-derived modified heating. <u>Quoted from the patent:</u> "... In order to balance the disparity between the specific heats of water and steam to thus optimize the system, the steam is superheated by an upstream portion of the turbine exhaust to first drive a high pressure steam turbine..."
1998, July	Sparkman	5,775,107	A "Solar powered electrical generating system". This patent addresses smaller, "daily use" systems (not industrial). <u>Quoted from the patent:</u> "The most common is a flat-plate collector... A primary object of the present invention is to provide a solar powered electrical generating system that will overcome the shortcomings of the prior art devices.
1999, January	Cohn	5,857,322	A "Hybrid Solar and fuel fired electrical generating system". This patent is basically an improvement on the one Cohn submitted in 1998.
1999, December	Bellac et al.	6,000,211	"Solar power enhanced combustion turbine power plant and methods". This patent is particularly relevant to the ISCC model, and it described a way to increase the capacity and efficiency of a plant using solar thermal technologies. This is done by injecting augmenting steam (solar derived) into the turbines. <u>Quoted from the patent:</u> "The present invention relates to combustion turbine power plants utilizing solar energy to increase their capacity and efficiency... Various schemes have been proposed... for making use of solar energy in a combustion turbine power plant for improving its heat rate (fuel usage per unit electric energy output) and/or its power capacity, to reduce the cost of supplying electric power to satisfy peak demand...
2001	Foppe	6,272,856	A "Method for storing energy in the form of thermal energy mass by means of high temperature accumulators". This patent addresses the materials and processes that can be used to increase the performance of thermal storage of ISCC/solar thermal based plants.

			Quoted from the patent: "The invention relates to a method in which thermal energy is stored in rapidly chargeable high temperature accumulators which can be converted directly via a thermionic generator into electrical drive energy or via a Sterling engine directly into pressure energy for the driving of hydraulic motors... "
2002	Bellac et al.	6,484,506	"Solar power enhanced combustion turbine power plant and methods". This patent is basically an improvement to the one Bellac submitted in 1999.
2003	Mehos et al.	US2003/0136398	A "Combustion system for hybrid solar fossil fuel receiver". This invention is slightly off topic as it does not relate to solar tower-based ISCC plants. However, it also describes using solar thermal derived steam (although through a solar dish) for improved efficiency in the Stirling cycle. Quoted from the patent: "A hybrid solar receiver comprises a pre-mixer which combines air and fuel to form an air-fuel mixture... The air-fuel mixture flows through the cooling jacket cooling the burner plenum to reduce pre-ignition of the air-fuel mixture in the burner plenum... Their primary benefit is higher system efficiency, enabled by... allow separate solar and fired heat transfer surfaces and therefore independent optimizations.
2005	Bellac et al.	6,941,759	"Solar power enhanced combustion turbine power plant and methods". This patent is basically an improvement to the one Bellac submitted in 1999.
2007	Goldman	US 2007/0084208	"Hybrid generation with alternative fuel sources". This technology basically uses a combined solar + fossil plant to create electricity, and also store energy through such forms as heated liquids, and even though the creation of biomass. Quoted from the patent: "A generating facility is provided for generating electricity from both solar and non-solar energy sources ... and to grow biomass to generate a solar fuel... solar energy is used both to grow a secondary, solar, fuel, such as biomass, including algae and derivatives thereof, and also to directly heat water for use in a traditional steam turbine cycle... ...
2008, Feb	Goldman	7,331,178	"Hybrid generation with alternative fuel sources". This patent is basically an improvement to the one Goldman submitted in 2007.
2008, June	Leitner	US 2008/0127647	"Solar-generated steam retrofit for supplementing natural –gas combustion at combined cycle power plants". Perhaps the most relevant patent compared to the CSPond technology when applied to use with natural gas power plants. Quoted from the patent: "A method is provided for retrofitting an existing combined cycle power plant...decrease the power plant heat rate using solar energy. The method is applied to combined cycle power plants that are equipped with an oversized heat recovery steam generator (HRSG) and steam turbine system... retrofitting a plant with a solar energy collection system to produce solar steam for use in the steam cycle portion of the combined cycle power plant... designed to deliver thermal energy to the existing, oversized and/or underutilized HRSG and steam system capacity in the combined cycle power plant... removes none of the functionality of the existing combined cycle power plant...

The results of this research process indicate that both CSP and ISCC technologies have existed at least since the early 1980's. This is important because we now have a better understanding of the *type* of innovation we are dealing with- it is not a *disruptive innovation*, but rather a *sustaining innovation* (Christensen and Raynor 2003). The CSPond technology is not a disruptive one because it is not using a completely new technology and aiming it at a non-user or low end market group. Rather, CSPonds are an enhancement to an already proven technological field (CSP). This distinction is important: (Christensen and Raynor 2003) discuss the very different commercialization strategies for each innovation type.

We have thus identified (Slocum et al.)'s CSPond technology as a sustaining innovation. We thus expect that CSPond's have a superior performance compared to existing CSP technologies. A useful exercise is to compare this technology's anticipated efficiency improvements with industry and other independent reports' projections of technological improvement. Knowing that the efficiencies predicted by the new technology conform to the overall industry's expectations on performance advancement is reassuring and can lend an additional form of validation. The following three figures outline industry's expectations for CSP-based electricity cost improvements in the coming 5 years. They confirm that (Slocum et al.)'s prediction of a ~40% improvement is in line with industry's expectation of an overall ~60% improvement by 2015.

Figure 23 from (Trieb 2005)'s MED-CSP report (a German Ministerial report on CSP potential in the Mediterranean) shows anticipated CSP component cost reductions. It shows that between now and 2015, the expected component cost (for a given electricity output) is projected to decrease by ~ 60%.

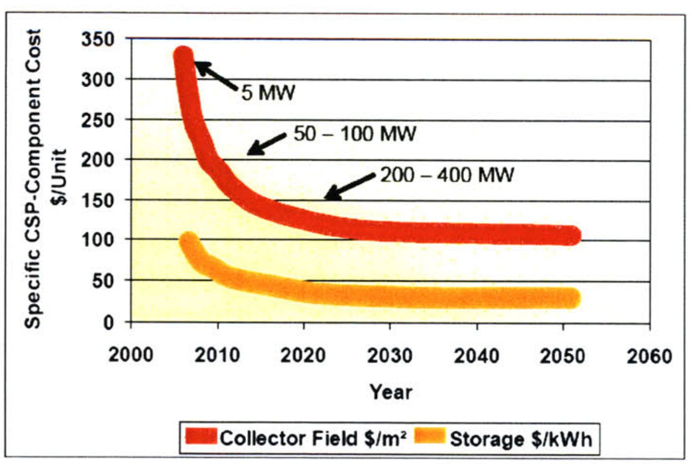


Figure 23: Expected learning curve of CSP and storage technologies (Trieb 2005)

Figure 24 from the (CSP GMI report 2004) (the GMI, or Global Market Initiative, is a solar thermal promoting initiative, and is part of the IEA) is a highly beneficial graph that shows the Levelized electricity cost (LEC) v. MW of electricity installed around the world. Graphing electricity cost versus installed power is an alternative and perhaps more accurate way of forecasting the LEC of CSP-based technologies because it models the price based on the learning curve associated with designing and operating new CSP-based facilities. Figure 24 thus shows a similar shape to Figure 23, with an expectation that increasing levels of installed capacity will lead to lower LEC's. Our current LEC (@ ~350 MW installed) of ~16-18 c/kWh is predicted to decrease to ~9 c/kWh (@5,000 MW installed, predicted around 2015). This yields a rough efficiency improvement expectation of ~ 50-60%.

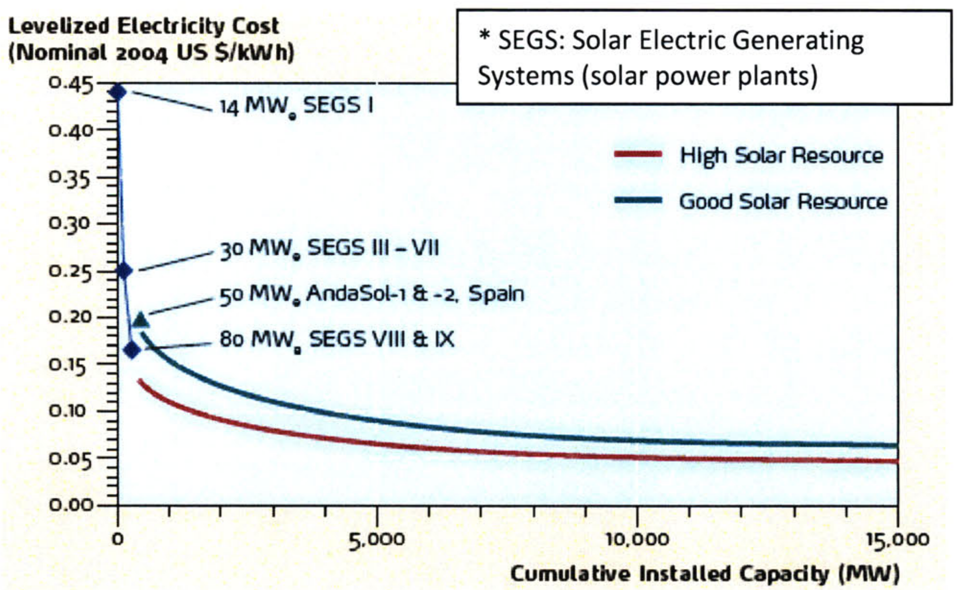


Figure 24: CSP electricity cost as a function of cumulative installed capacity (CSP GMI report 2004)

Finally, Tables 7 and 8 from (Eichhammer et al. 2006)'s World Bank CSP Market Development report list the cost reduction potentials due to predicted technical improvements in CSP technologies. The hallmarks of (Slocum et al.)'s new CSPond technology- improved "receiver design" and "heat transfer fluid and storage", are both featured in this list of improvements. Further, (Eichhammer et al. 2006) provides a 4-part framework delineating the type and source of cost reductions in CSP technologies:

> *Part 1:* Creation of technical and institutional experience (small number of new units, only a few hundred MW's, first "pilot tests" in developing countries, and operational plants in Spain, US, and GEF projects such as in Algeria)

Part 2: Generation of a market (total installation of 500 – 2,000 MW, diversification in technologies)

Part 3: Early phase of a growing mass market (total installations of 2,000 – 7,000 MW, decrease in costs due to scale and volume effects)

Part 4: Development of a mass market (near competitive and competitive market, further decrease in costs due to scale and volume effects)

Table 7: Cost reduction potentials from different technical improvements (Eichhammer 2006)

TABLE 2: ECOSTAR STUDY – COST REDUCTION POTENTIALS DUE TO TECHNICAL IMPROVEMENTS

Parabolic Trough [1]	Tower	Linear Fresnel [2]	Dish [3]
Innovative structures (up to 28 percent)	Larger heliostats above 200 m^2 (up to 12 percent)	Linear Fresnel collector field (up to 3 percent)	Mass production for 50 MW (38 percent)
Front surface mirrors (up to 19 percent)	Larger module size (up to 15 percent)	Thermal storage (up to 15 percent)	Brayton instead of Stirling cycle (up to 12 percent)
Advanced storage (up to 18 percent)	Ganged heliostats (up to 8 percent)	Reduced pressure losses (up to 7 percent)	Improved availability and O&M (up to 11 percent)
Reduced pressure losses (up to 16 percent)	Advanced storage (up to 10 percent)	Dust repellent mirrors (up to 7 percent)	Increased unit size (up to 9 percent)
Dust repellent mirrors (up to 16 percent)		Increased fluid temperature (up to 6 percent)	Reduced engine costs (up to 6 percent)
Increased solar field outlet temperature (up to 15 percent)			Increased engine efficiency (up to 6 percent)

[1] with thermal oil as heat transfer fluid and direct steam generation (DSG)
[2] reference: Trough with DSG
[3] parabolic dish concentrators in combination with a Stirling engine today realize the highest LEC compared to the other collector concepts.

Source: Authors based on DLR and others (2005).

Table 8: Cost reduction potentials from different technical improvements (Eichhammer 2006)

TABLE 3: SARGENT AND LUNDY—TECHNICAL IMPROVEMENTS FOR THE TROUGH AND THE TOWER TECHNOLOGY

Parabolic Trough[1]	Tower[2]
Receiver coating (solar absorptance, infrared/heat irradiance)	Increasing heliostat size (up to 148 m^2)
Receiver glass envelope transmittance	New primary mirror technology with thin glass or thin films
New front surface reflectors	Cost-effective support structure
Receiver reliability	Self-cleaning glass
Reduced parasitics (SF pumping etc.)	Drives for mirror tracking
Heat storage (up to 12 hrs)	Solar flux monitoring in the receiver
Solar field support structure (main solar field cost driver)	Improved receiver design
Higher operating temperature (up to 500°C)	Reduced start-up time and improved operation strategies
Self-cleaning glass	Improved heat transfer fluid and storage
Larger plant sizes	Larger plant sizes
Reduced operation and maintenance costs	Reduced operation and maintenance costs

[1] with thermal oil as heat transfer fluid. No direct steam generation (DSG) considered
[2] only molten salt technology considered.

Source: Authors based on Sargent and Lundy (2003).

(Slocum et al.)'s technology fits neatly into this framework- as a part of the first phase- because it is indeed a new unit that relies on new "technical and institutional experience". It thus builds a foundation for the future industry's cost improvements due to operational experience (Parts 2-4).

4.1.3.1.2 The ISCC technology: NGCC + CSP

With Eni's expertise in natural gas and power (and hence technologies such as NGCC plants), and (Slocum et al.)'s new CSP technology, the obvious question is: how can these technologies be combined? As became evident through an extensive literature search in the electricity production area, Integrated Solar Combined Cycle (ISCC) power plants use both technologies to create a technically (not necessarily economically) more efficient power generation system. While the specific plant designs that are based on this technology and their applications in different markets will be discussed in Sections 4.1.3.3 and 4.1.3.2, this section provides a technical summary of the integration of natural gas combined cycle (NGCC) and CSP plant technologies to yield ISCC plants.

NGCC description:

In his patent proposal, (Leitner 2008) provides an excellent technical description of how CSP technologies can be integrated into conventional NGCC power plants. Gas fired power plants were originally chosen to replace coal or oil-based power plants because of their higher burning temperatures (and hence efficiency). To further increase efficiency, a "combined cycle" system, meaning more than one thermodynamic cycle, is used (the second cycle using the waste heat from the first cycle as an input into another, albeit less efficient, cycle).

NGCC plants use gas turbines, (GT)'s, in the first cycle. The GT engines operate on a Brayton thermodynamic principle and "typically have high exhaust flows and high exhaust temperatures" (Leitner 2008). These rather valuable exhausts (since they are already quite hot) are then recovered and turned into steam in the heat recovery steam generator (HRSG) unit. This steam is then passed through another turbine, a steam turbine (ST) operating under a Rankine thermodynamic principle, to produce work. The combined use of two turbine systems operating under differing thermodynamic principles is why this mode of operation is referred to as "combined cycle".

CSP incorporation:

Present technologies allow for the solar-generated steam to be integrated into the Rankine cycle. The integration point is thus either in somewhere in the HRSG unit, or directly into the ST engine (Leitner 2008). Most commonly, the solar-generated steam will be incorporated "into the high pressure (HP) portion of the HRSG. The HP portion of the steam cycle is best suited for integration because it results in the highest efficiency utilization of the solar energy and generally has the highest capacity for additional steam…" (Leitner 2008). Figure 25 from (Aringhoff et al. 2005) provides a simple technical schematic of an ISCC plant.

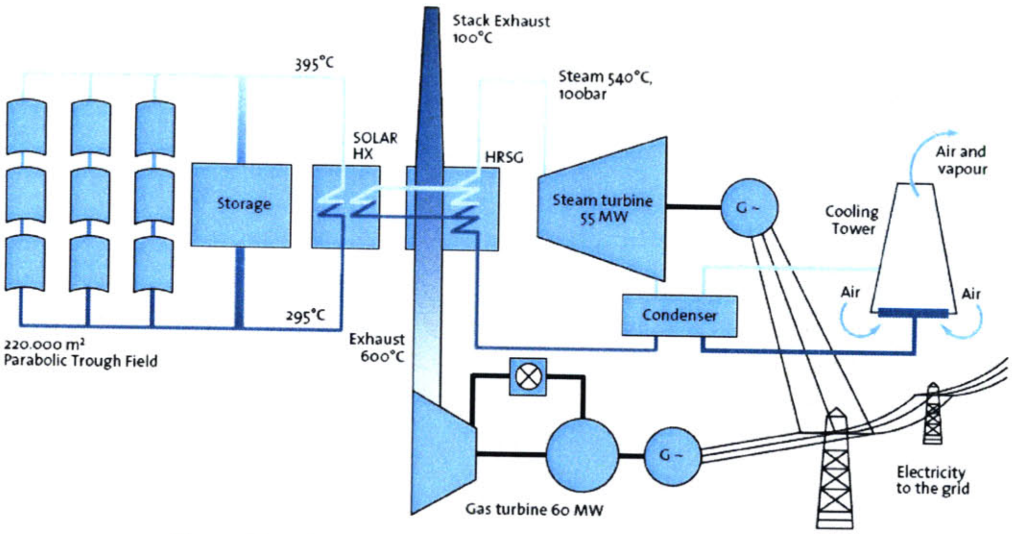


Figure 25: Schematic of an ISCC plant (Aringhoff et al. 2005)

4.1.3.1.3 Creating a new TECHNOLOGY (T)

At this stage, the team should have a fundamental understanding of the start-up's technology and have thought through potential ways this technology can be applied to the investing firm's existing technologies or implements. In this thesis, this process was limited to one T-T combination (CSPond technology + NGCC technology = ISCC technology). However, this need not be the case in a more extensive study. More detailed analyses could examine potential multiple T-T linkages (i.e. add CSP-desalinization), or other T-I linkages.

With the analysis complete, we are now ready to create the new ISCC technology box. As Figure 26 illustrates, we include the specifications, capabilities, and uniqueness of the technology.

T
ISCC Design **Specifications** • Higher thermal efficiencies than NGCC plants • Reduced fuel needs • Shared plant components, integration of CSPond-derived steam in HRSG unit or ST **Capabilities** • 24/7 operation (as opposed to SEGS plants) • CAPEX lower than for separate plants • Fuel costs lower than NGCC design • Reduced emissions (environmental impact) **Uniqueness** • Patent protection of sophisticated instrumentation and methods used to create optimized plant design

Figure 26: Combined TECHNOLOGY component of CSPond-Eni network

4.1.3.2 Finding COMMERCIAL APPLICATIONS (C)

At this stage in the analysis, we must ask: which needs does our new technology satisfy? While dramatically performing new technologies may be truly breathtaking from a scientific/engineering point of view, they will not translate to a commercial success unless they are fulfilling a need that has not been adequately satiated by implements stemming from other technologies.

Thus, in this section we analyze which need our new ISCC/CSP-based technology can serve. We begin by first developing a "big picture" understanding of the regions around the world with the largest solar potential, and then further develop this aggregate view by grouping the high-solar countries into appropriate "region" classifications. We then identify, through extensive research, the core of this section: the needs that will be satisfied through an implement based on this technology. We then gain insights on the mechanisms that increase the commercial feasibility of each of these needs- thus arriving at a more precise understanding of which needs can be addressed commercially. Finally, we relate the potentially commercially feasible needs to the unique capabilities and strategic vision of the investing firm, and introduce a general commercialization strategy. The result is a unique set of needs that are most likely to be commercially attractive to the investing firm.

4.1.3.2.1 The Big Picture: Country Groups

Before delving into the details of the relevant legislation, international collaboration, and needs being fulfilled by the new technology's implements, it is useful to gain a "big picture" view of which regions/ countries have the largest solar resources. While Figure 17 was used to show a general picture of the "sunbelt region" of the world, (Trieb 2005)'s Table 9 gives quantitative estimates of technically and economically feasible CSP-generated electricity in the Mediterranean region (the cut-off for economic feasibility is defined @ 2,000 kWh/m2/year since this is a generally accepted level of solar radiance required for profitable plant performance). Additionally, the list of countries provided in (Aringhoff et al. 2005)'s Table 10 that are currently developing solar thermal projects also gives a "general orientation" of which governments have acted upon their solar resources.

Table 9: Technical and Economically feasible "CSP potential" of various Mediterranean countries (Twh/yr) (Trieb 2005)

	CSP	
	Tech.	Econ.
Bahrain	36	33
Cyprus	23	20
Iran	>	20000
Iraq	30806	28647
Israel	318	318
Jordan	6434	6429
Kuwait	1525	1525
Lebanon	19	14
Oman	20611	19404
Qatar	823	792
Saudi Arabia	125260	124560
Syria	10777	10210
UAE	2078	1988
Yemen	5143	5100
Algeria	169440	168972
Egypt	73656	73656
Libya	139600	139477
Morocco	20151	20146
Tunisia	9815	9244
Greece	44	4
Italy	88	7
Malta	2	2
Portugal	436	142
Spain	1646	1278
Turkey	405	131
Total		**632099**
Remarks:	from DNI and CSP site mapping taking sites with DNI > 2000 kWh/m²/y as economic	

Table 10: List of location, CSP-design, and company funding various CSP projects around the world (Aringhoff et al. 2005)

Name/Location	Total Capacity (MWe)	Solar Capacity (MWe)	Cycle	Companies/Funding
Parabolic Troughs				
Algeria	140	35	ISCC	New Energy Algeria
Liddell Power Station, NSW, Australia	2,000	50	Compact Linear Fresnel Reflector	Macquarie Generation and Solar Heat and Power
Kuraymat, Egypt	150	30	ISCC	NREA / GEF grant, JBIC loan
THESEUS – Crete, Greece	50	50	Steam cycle	Solar Millennium, Flabeg Solar Int., Fichtner Solar, OADYK
Mathania, India	140	30	ISCC	RREC (Rajasthan Renewable Energy Authority) / GEF grant, KfW loan
Yazd / Iran	467	17	ISCC	Mapna / Iranian Ministry of Energy
Israel	100	100	Steam Cycle with hybrid fossil firing	Israeli Ministry of National Infrastructure with Solel
Italy	40	40	Steam Cycle	ENEA
Baja California Norte, Mexico	291	30	ISCC	Open for IPP bids GEF grant
Ain Beni Mathar, Morocco	220	30	ISCC	ONE / GEF grant, African Development Fund
Spain	12x50	12x50	Steam Cycles with 0.5 to 12 hours storage for solar-only operation with 12-15% hybrid firing	Abengoa, ACS-Cobra, EHN-Solargenix, Iberdrola, HC-Genesa, Solar Millennium
Nevada, USA	50	50	SG -1 SEGS	Green pricing, consortium for renewable energy park Sierra Pacific Resources with SolarGenix
Central Receivers				
Spain Solar Towers with Steam Receivers PS10 and PS20	10 + 2x20	10 + 2x20	Steam Cycle with saturated steam receiver and steam drum storage	Abengoa (Spain) group
Spain Solar Towers with molten-salt receivers	15	15	Molten-salt/direct-steam	SENER (Spain)
Parabolic Dishes				
SunCal 2000, Huntington Beach California, USA	0.4	0.4	8-dish/Stirling system	Stirling Energy Systems
EuroDish Demonstrations	0.1	0.1	6-dish/Stirling system	SBP and Partners

While such "top level" analysis is useful for orienting the team about which regions have the most potential, and have acted upon their reserves, it is also useful to categorize the multitude of countries into meaningful groups or regions. (Philibert 2006) provides an excellent classification (based on GMI reports) of the various "solar-endowed" regions. All countries are grouped into three regions:

- *Region I* countries and states have already partially implemented the policy measures recommended by the CSP GMI or will do so in the near term (e.g. southern Europe, southwestern United States and Israel).
- *Region II* countries are or will soon be connected to Region I countries for trans-national power exchange (e.g. Algeria, Morocco and Mexico). Solar power from CSP plants in these countries could be exported to Region I countries and supported essentially by ratepayers as in region I countries.
- *Region III* countries are developing countries not interconnected to the grid of Region I countries (e.g. Brazil, Egypt, India, Iran, Jordan, and South Africa). Subsidies from industrial countries are required to help these countries develop CSP plants.

The purpose of such a classification system is to not only create more manageable country groups but also to create regions that contain similar physical attributes and *commercial needs*. This creates a more focused vision of how each country fits in the "overall picture". The next three sections further refine our understanding of the CSP commercialization opportunities by looking at the specific needs of different regions, and the support mechanisms (both international collaborative and local legislation) that aid the commercialization potential of CSP-based implements.

4.1.3.2.2 The NEEDS of different countries/regions

In conducting research to understand which fundamental needs CSP-derived power would be addressing, I turned to articles and publications relating to CSP/ISCC-based power plant project proposals. These sources provided valuable insights because they are generally appealing to support agencies (such as IMF, World Bank, GEF, etc.) to help finance the projects. Hence, the technical and strategic justifications for building these new systems were an integral part of the reports.

An in-depth study of six projects in different countries (Algeria, Egypt, Iran, Jordan, Kuwait, and Morocco) was conducted to determine what the common needs and justifications for CSP-based power plants were. It is not a coincidence that these largely Arab countries were identified- their almost unique combination of high Direct Normal Insolation (DNI) and petrochemical reserves makes ISCC technologies especially applicable to this region.

Of course, this is not a complete analysis (as there are other CSP project proposals in developing and non-developing nations, etc.), but the structure of the analysis remains to conduct a study of the existing project proposals to understand why this technology has specifically been chosen.

Table 11 provides a summary of the projects and associated needs. Several recurrent needs appear in many of the project reports, summarized as follows:

- Provide stable electricity production (i.e. satisfy peak loads in the summer)
- Save fossil fuels for export
- Cover growing demand of electricity (i.e. provide more rural coverage)
- Diversify energy portfolio
- Enhance energy security
- Enhance local industry capabilities through technology transfer
- Create more jobs

Table 11: Summary of 6 projects and associated needs fulfilled using CSP technologies

Project & Details	Need	Source
Kuwait: CSP: solar troughs + IGCC plant Capacity: 60 MWe (solar), 220 MWe CC, 280 MW total Higher efficiency (through Rankine cycle) Will implement for both new installations and replacing/revamping old ones Solar thermal best for Kuwait because: 1. Geographic location (high DNI) 2. Once built, no/low operating cost 3. No political, social, and environmental restrictions	- To satisfy peak load in summer season when sun is most intense (cooling) - Serious power demand and supply situation; expect shorter construction period - "Matches with energy strategy of MEW" - Save fossil fuels: export them - Reduce GHG (Kuwaiti government policy to promote measures against global warming) - Create a new power market based on a renewable energy in the region	Japan External Trade Organization (JETRO) report commissioned by Kuwait's Agency for Natural Resources and Energy; and Ministry of Economy, Trade, and Industry (METI), 2008
Jordan: Solar Energy Research Center (SERC) performed solar technology studies for Jordan Past projects supported by Water Authority of Jordan (WAJ) Solar energy made reasonable progress in the traditional application of solar energy (space heating, desalinization)	- Development of ISE (industrial solar energy) will "have the most important impact in helping Jordan and some Arab countries (non-oil producing) meet their energy requirements)" - PV systems used to power remote areas to supply Bedouins with daily water - Important role to play in meeting needs of thousands of small communities across Jordan where electricity is scarce	Badran 2001

(Table 11 cont.)

Iran: ISCC-67 design concept is best choice 430 MWe total capacity: 2*115 MWe (gas) 200 MWe (steam, of which 67 MWe solar component)	Stable energy production especially in summer (power production in summer generally decreases in summer due to harsh conditions) There is a strong will in political and industrial institutions in Iran to implement ISCC plants.	Hosseini et al 2005
Morocco: Location: Ain Beni Mathar 470 MWe total capacity 20 MWe solar 450 MWe natural gas	- Cheaper energy - More reliable power production -Greener electricity production - More rural coverage, and general extension of generation facilities - Diversification of energy portfolio - Satisfy growing demand - Mastery of solar thermal technology with long-term aim of cutting unit cost to market levels	Idrissa et al. 2007
Egypt: Location: Kuraymat (90 km south of Cairo) 140 MWe total 120 MWe CC, 20 MWe solar	- Cover growing demand rate for electric energy (7% annually) - Save fossil fuels for export - Export clean energy from CSP to Europe and Africa - Trade CO2 offset - Enhance local industry capabilities through technology transfer - Create national/regional RE equipment market - Create new job opportunities	El-Zalabany 2007

(Table 11 cont.)

Algeria: Loaction: Hassi R'Mel Algeria's high solar potential fields lie in regions endowed with hydrocarbons ISCC plant in South: 130 MWe total: 25 MWe solar, 105 MWe gas 180,000 m2 of parabolic mirrors	Promoting renewable energies is one of major pillars of Algerian energy policy Policy: objective of increasing share of renewables in its total supply to 5% by 2010 (mostly through solar) Plan to use solar energy for rural electrification for covering eventually 95% of country with an electricity grid Algeria has one of the largest solar power potential in world (2,000,000 km2 receives DNI over 2,500 kWh/m2), aim to use to use for water pumping to develop steppe areas irrigation for remote southern populations Enhancing energy security (while maintaining adequate supply to population) Reinforcing local economy by creating small and medium sized companies Through use of solar tech, want to: contribute to innovation in this area of research (report says that innovation comes through number of hours online, basically learn through doing), "equitable commercial prospects", job creation, few emissions (little incidence on limited water resources) Aims: give electricity to non-users in rural south, contribute to existing national grid Aim to: experience sustainable development (inexhaustible) and meet domestic energy needs, delay depletion of hydrocarbon reserves, and provide large quantities of gas for European customers (use solar for national production)	Ainouche 2006

Of course, the results of this project search do not represent a comprehensive picture of the total needs of this technology. Thus, when time and resources are in short supply, a useful way to gather a list of needs (and hence commercialization opportunities) is to look for reports that conduct this analyses on their own. Even if the team has sufficient time to create their own list, comparing such a list with a published work can give confidence and validation to one's result. (Eichhammer et al. 2006)'s Table 12 provides such a table of needs for CSP-based power technologies. As the red rectangle shows, to a great extent, these needs conform with our independently researched needs.

Table 12: Possible role of CSP in different countries/regions (Eichhammer et al. 2006)

Function	Country/Region	Technology selection criteria	Technology implications
Local industry promotion	Spain, Italy, Greece, Egypt	Share of local manufacturing (foundations, steel, glass industry)	CSP in general, espe-cially Fresnel collectors because of high local value creation (due to larger share of simple collector components)
Environmental protection	Spain, Italy, U.S.	Environmental impact	Solar only or SEGS
Noon peaker	Israel, Egypt, Jordan	Local daily power load characteristics	Solar only or SEGS
Evening peaker	North Africa, South Africa	Local daily power load characteristics	Storage technology or ISCC
Summer noon peaker	Spain, U.S.	Local yearly power load characteristics; power mix (wind; hydro)	Solar-only options (including storage) or SEGS
Diversification of power mix	Morocco, China, Mexico	Fit to power generation mix	Solar only or SEGS; ISCCS technology (if own gas resources or large amount of MW needed)
Fuel Saver	Mexico (to prolong national gas resources or to reduce inefficient coal use), South Africa	Combination with natural gas or coal	Feed-water preheating but also ISCC
Exporter of Gas/Green Electricity	Algeria, Iran	Combination with natural gas	ISCCS technology
Remote Power Producer	Remote regions with larger electricity demand that cannot be satisfied by PV	Quality of energy service	Small-scale CSP
Transmission Stabilizer	Crete	Quality of energy service	Storage technology

4.1.3.2.3 Support Mechanism: International/Non-governmental initiatives

We have thus established that there is a pool of needs that a CSP-based electricity/power market can serve. While needs are a requisite for commercial opportunity to exist, they do not guarantee it. Further research must be conducted to understand the environment and mechanisms through which this technology may proliferate. These mechanisms serve to reinforce the commercialization potential of the "needs".

(Philibert 2004)'s OECD-IEA sponsored report delves into the issue of commercializing CSP technologies, focusing specifically on the collaborations, initiatives, and methods for promoting the adoption of CSP-based projects. In his report, he summarizes the major international CSP-based technology collaborations into three groups:

- The International Energy Agency (IEA)'s SolarPACES "implementing agreement", whose mandate is to "focus on the development and marketing of concentrating solar power systems [through technical and market development efforts]" (www.solarpaces.org 2009).
- The Global Environment Facility (GEF), setup in 1991; it is "the single largest funder of projects to improve the global environment" (www.gefweb.org 2009). "CSP is one of the technologies selected by the GEF for its "Operating Programme no 7" which aims at bringing new promising climate-friendly technologies to competitiveness".
- The IEA's "Global Market Initiative" (GMI), endorsed by various environment ministers at the Bonn renewable energy conference in June 2004, has a central mandate of reaching 5,000 MW of CSP worldwide by 2015.

As (Philibert 2004) states, this combination of international initiatives contains great potential for, although thus far little realization of, CSP projects. The existence of these global, ministerial level initiatives provides further backing for the existence of plausible CSP-based commercialization opportunities.

4.1.3.2.4 Support Mechanism: Governmental policies (legislation)

Although international collaboration and initiatives may provide some financial and technical support for CSP technology development and implementation (plant) construction, (Philibert 2004) states that "... domestic policy decisions remain decisive". While international collaboration may serve as an important support mechanism, real commercialization opportunities result from the "concrete" policies, laws, and/or regulations mandated by governments.

Thus, it is crucial that teams invest significant time researching governmentally enforceable laws/policies directed at CSP technology use. While this may seem like an overwhelming task, certain strategies can lead to the most fruitful usage of time (I have learnt this the hard way). For example, two good strategies are to: search non-governmental organization (NGO) databases, and those countries which lie in high solar-potential geographic areas (i.e. Algeria and not the UK). Table 13 provides a summary of an extensive research effort (analyzed in 4 different languages) to uncover the major legislations promoting the use of solar technology-based electricity.

As observed, there seems to be increasing legislative encouragement for renewable and solar-based power. More aggressive legislation (with Spain being the leader in “developed” nations, and Algeria the frontrunner among the “developing” nations) seems to directly correlate with the corresponding nation’s solar resources. Since most forms of renewable energy (and indeed solar) are not yet strictly price competitive with petrochemical-based energy, the information deduced from these legislations is essential for a company assessing which commercialization opportunities hold the most potential for successful (profitable) entry.

Table 13: Summary of major legislations promoting CSP development

Country/Region & Year	Legislation name	Summary of most relevant legislation details
Algeria; 2004 Algerian Ministry for Energy and Mines	Décret executive (Decree) **n° 04-92, 25 mars 2004** relatif aux coûts de diversification de la production d'électricité	The Government of Algeria has committed itself to develop solar energy as its largest renewable energy source, to cover 5% of the national electricity needs by 2010 with renewables. The Government of Algeria sees ideal opportunities of combining Algeria's richest fossil energy source – the natural gas – with Algeria's most abundant renewable energy source – the sun – by integrating concentrating solar power into natural gas combined cycles. Incentive premiums for CSP projects are granted within the framework of Algeria's Decree 04-92 of March 25th, 2004 relating to the costs of diversification of the electricity production. From Page 13 of official Decree: Art. 12. — Pour l'électricité produite à partir d'installations utilisant de l'énergie solaire thermique par des systèmes hybrides solaire-gaz, la prime s'élève à 200% du prix par KWh de l'électricité élaboré par l'opérateur du marché défini par la loi n° 02-01 5 février 2002 susvisée, et ceci quand la contribution minimale d'énergie solaire représente 25% de l'ensemble des energies primaires. Pour les contributions de l'énergie solaire inférieure à 25%, la dite prime est servie dans les conditions ci-après : — pour une contribution solaire 25% et plus : la prime est de 200%, — pour une contribution solaire 20 à 25% : la prime est de 180%, — pour une contribution solaire 15 à 20% : la prime est de 160% , — pour une contribution solaire 10 à 15% : la prime est de 140% , — pour une contribution solaire 5 à 10% : la prime est de 100% , — pour une contribution solaire 0 à 5% : la prime est nulle.
European Union; 2001	**Directive 2001/77/EC** of the European Parliament and of the Council on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market	Purpose: to promote an increase in the contribution of renewable energy sources to electricity production in the internal market for electricity and to create a basis for a future Community framework. Not later than 27 October 2002 and every five years thereafter, Member States shall adopt and publish a report setting national indicative targets for future consumption of electricity produced from renewable energy sources in terms of a percentage of electricity consumption for the next 10 years. The report shall also outline the measures taken or planned, at national level, to achieve these national indicative targets. To set these targets until the year 2010, the Member

European Union; 2001 (cont.)		States shall: — take account of the reference values in the Annex, — ensure that the targets are compatible with any national commitments accepted in the context of the climate change commitments accepted by the Community pursuant to the Kyoto Protocol to the United Nations Framework Convention on Climate Change. The report shall assess the success, including cost-effectiveness, of the support systems referred to in paragraph 1 in promoting the consumption of electricity produced from renewable energy sources in conformity with the national indicative targets.
Greece; 2006	**Law 3468/2006** Generation Of Electricity Using Renewable Energy Sources And High-Efficiency Cogeneration Of Electricity And Heat And Miscellaneous Provisions (Official Gazette A' 129)	Law 3468/2006 grants solar energy exploited in units employing a technology other than that of photovoltaics with an installed capacity up to five (5) MWe 0.23 €/kWh on the main land and 0.25 €/kWh on non-interconnected islands.
Germany, 2000 Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	**Renewable Energy Sources Act**; Act on Granting Priority to Renewable Energy Sources	Deals with the purchase of, and the compensation to be paid for, electricity generated exclusively from (renewables including CSP)... by utility companies which operate grids for public power supply (grid operators). The compensation to be paid for electricity generated from solar radiation energy shall be at least 99 pfennigs per kilowatt-hour. As of 1 January 2002, the minimum compensation paid shall be reduced by 5 per cent annually for new electricity generation installations commissioned as of this date. By guaranteeing compensatory payments down to the last pfennig per kWh, the act restores a secure climate for investment. This remunerative arrangement is made available for a period of up to twenty years per plant.
Israel, 2006 Israel Ministry of National Infrastructures	Israeli Feed-in-Tariff for CSP	The Israel Ministry of National Infrastructures, which is responsible for the energy sector, decided in 2002 to introduce to the Israel electricity market CSP as a strategic ingredient, with a minimal power unit of 100 MWe. There is an option to increase the CSP contribution up to 500 MWe at a later stage, after the successful operation of the first unit. In 2006, Israeli PUA's New Feed-in Incentives For Solar-Driven IPPs were published, being valid as from September 3rd, 2006 for a 20 years period. For plants with installed capacity larger than 20 MWe the tariff for the solar part only is app. 16.3 UScents/kWh (Nov.2006). Maximum allowed fossil back-up is 30% of the energy produced in the plant.

		For smaller plants below 20MW in the range of 100 kW to 20 MW for the first 20 years period the tariff is app. 20.4 UScents /kWhe.
Portugal 2007	Portuguese Feed-in-Tariff for CSP	A new feed-in tariff for solar electricity was published in Portugal in 2007, granting 0.27 €/kWh for CSP plants up to 10MW and 0.16-0.20 €/kWh for CSP plants beyond 10MW.
Spain 1997, 1998, 2002, 2004, 2007	Law 54/1197, of November 27th 1997 Royal Decree 2818 of 1998 38th additional provision to Law 14/2000 Royal Decree 841/2002 Royal Decree 436/2004 Royal Decree 661 from 2007	1998: For facilities based on renewable or waste energies, this incentive has no time limit, since their environmental benefits must be internalized and, due to their special characteristics and level of technology, their considerable cost does not allow them to compete on the free market. The incentives which are established for renewable energies are such that they are going to enable their contribution to the Spanish energy demand to be a minimum of 12 per cent in the year 2010 2000: Extends the allowance that incentive premiums may exceed the top of 90% of the medium electricity price to solar thermal installations. 2004: Royal Decree 436/2004 improves the incentives for the first 200MW of solar thermal electricity production in Spain considerably. Solar thermal electricity generators who cede their production to the distributor may receive as fixed tariff 300% of the reference price during the first 25 years after their startup and 240% afterwards. Solar thermal electricity generators who sell their electricity on the free market may receive as premium 250% of the reference price during the first 25 years after their startup and 200% afterwards plus an incentive of 10%. The average electric tariff or reference for the year 2004, has a value of 7.2072 EuroCent/kWh. 2007: Main change is the decoupling from the market reference price, which increased with oil price increases and automatically increased renewable tariffs with the oil price. A fixed tariff of 0.269375Euro/kWh is granted for CSP plants up to 50MW for 25years, increasing yearly with inflation minus 1 percent point. The CSP target was increased to 500MW by 2010.

United States, by State	State-mandated Renewable Portfolio Standards (RPS)	The US federal government has given its States the right to mandate their respective RPD standards. Results vary: about half of the US States have instituted punitive RPS standards, some states have opted for non-punitive RPS standards, and some have altogether not ratified any such legislation (about half have not). Each State's goals reflect its government's ambition to use renewables sources (i.e. California more aggressive than Maryland), and its access to resources (i.e. Sunbelt States- CA, AZ, NV, and NM- more focused on solar RSP) prioritize solar power more than the New England States). The Department of Energy (DoE) has created "Solar Enterprise Zones" in the Sunbelt States. These zones are aimed at assisting private companies to develop large scale solar electric projects of 1,000 MW over a 7 year period. CA has created a Solar Task Force aiming to define the rules to implement 3,000 MW of new solar power by 2015.

4.1.3.2.5 Creating unique Commercialization Opportunities

At this stage, we have developed a somewhat complete picture of the needs and support available for CSP-based commercial potential. However, we have yet to consider how the unique capabilities of the investing firm (Eni) may bias certain commercialization opportunities over others (i.e. due to location in strategically important markets, geographic proximity to existing operation centers, etc.).

While by no means comprehensive, for the purposes of this thesis, we can assume that the geographic proximity of, extremely high insolation and natural gas content of, and legislation promoting investment in CSP technologies, places North African countries in Region II (i.e. Algeria, Morocco, and Egypt) has attractive commercialization opportunities from the unique perspective of Eni. Figure 27 shows the strategically important electricity connections between North Africa and the EU (specifically southern Italy). While more detailed analysis may prove otherwise, the point of this section is to show that it is important to analyze how the unique qualities of the investing firm may favor certain commercialization opportunities over others.

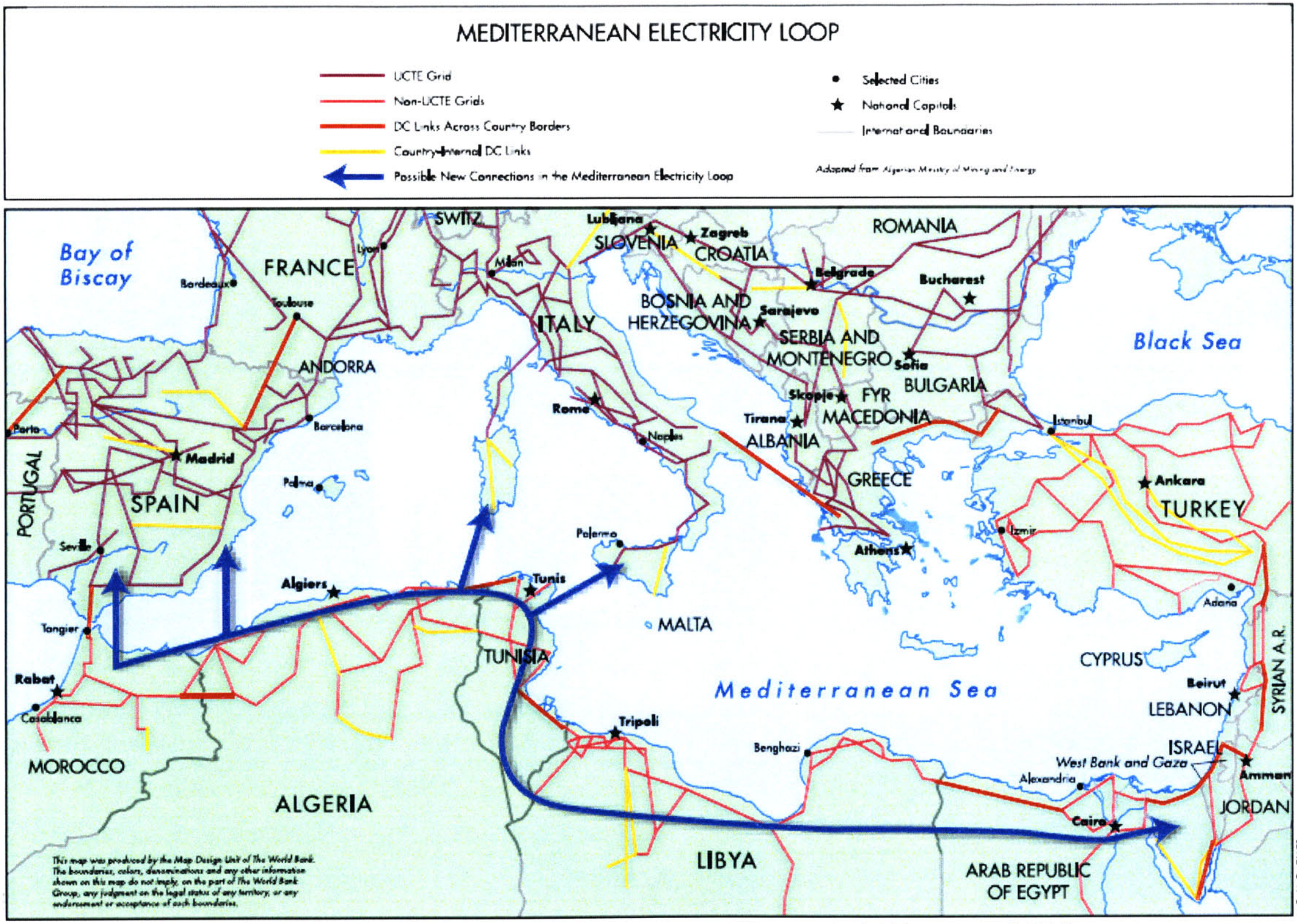


Figure 27: Interconnections of "Region II" electricity sector to EU countries (Eichhammer et al. 2006)

Additionally, although dated, a useful history of the current and projected commercialization pathways of CSP technologies (Dracker et al. 1996) may provide insight into how the industry has, as a whole, developed, and what its anticipated future paths may be.

4.1.3.2.5 Creating the new COMMERCIALIZATION linkages

At this stage the team should have a fundamental understanding of the needs that can be satisfied through the use of an ISCC-based implement. While there are many methods to research what the needs are, I have found that starting from a "global" perspective (based on physical potential), and then proceeding through several levels of detail (information gathered from ISCC project proposals, support mechanisms such as international collaboration and local legislations, and the unique capabilities of the investing firm), "zero in" on what the best commercialization opportunities are. The 5 "C" boxes constructed as a result of the research conducted in this thesis are presented in Figure 28.

C

Remote Power Production

Needs

- Power supply to increasingly populous areas in remote regions (demand larger than can be satisfied by PV systems)

Customers and users:

- Countries with inadequate power reach to remote local communities:
- i.e. Morocco, Jordan, Algeria, Egypt

C

Local Industry Promotion

Needs

- Transfer of new technology/industry knowledge and expertise
- Creation of new job opportunities

Customers and users:

- Countries especially depending on foreign energy expertise:
- i.e. Egypt, Algeria, Morocco, Libya

C

Export Gas/Green Electricity

Needs

- Maximize national revenues from gas/petrochemical exports by locally consuming renewables-based power

Customers and users:

- Nations whose revenues are significantly composed of petro-based exports:
- i.e. Algeria, Iran, Libya, GCC nations

C

Summer Peak Load Power Generation

Needs

- Reliable power production during summer peak power demand (i.e. midday)

Customers and users:

- Countries with especially arid climates:
- i.e. Israel, Egypt, Iran, Jordan, Spain, (Southwest) US, GCC nations

C

Diversification of power mix

Needs

- *A stable source of power* (achieved through diversification of energy portfolio)
- A secure source of power (achieved through reduced dependence on foreign petrochemical imports)

Customers and users:

- Countries whose economies are especially sensitive to and reliant upon foreign imports:
- i.e. US, EU nations

Figure 28: New Commercialization (C) opportunities (as a result of combined Eni-CSPond technologies)

4.1.3.3 Using an appropriate IMPLEMENT (I)

The stage has now been set for realizing how one can use the new CSPond-NGGC combined technology to satisfy the needs of the commercialization opportunities expressed in Section 4.1.3.2.5. The precise nature of each implement will change depending on the unique requirements of each commercialization opportunity. We begin with Sections 4.1.3.3.1 and 4.1.3.3.2 which provide a survey of the existing and planned CSP-based power plants, and end with Section 4.1.3.3.3, which provides a technical literature-based recommendation of CSP-based implements.

4.1.3.3.1 Implements: Past and present

The vast majority of currently installed implements were built between 1984 and 1990 in the Californian Mojave desert. Built by Luz International Ltd., these parabolic trough SEGS plants ranged from14 to 80 MWe capacities, and amounted to a total of 354 MWe electric grid output (Philibert 2004). While Luz's SEGS systems were the only commercially operating systems, (Aringhoff et al. 2005)'s Table 14 provides a list of the early solar-thermal pilot implements built in the 1980's and 1990's.

Table 14: Early solar thermal power implements (Aringhoff et al. 2005)

Name	Location	Size (MWe)	Type, Heat Transfer Fluid & Storage Medium	Start-up Date	Funding
Aurelios	Adrano, Sicily	1	Tower, Water-Steam	1981	European Community
SSPS/CRS	Almeria, Spain	0.5	Tower, Sodium	1981	8 European countries & USA
SSPS/DCS	Almeria, Spain	0.5	Trough, Oil	1981	8 European countries & USA
Sunshine	Nio, Japan	1	Tower, Water-Steam	1981	Japan
Solar One	California, USA	10	Tower, Water-Steam	1982	US Dept. of Energy & utilities
Themis	Targasonne, France	2.5	Tower, Molten Salt	1982	France
CESA-1	Almeria, Spain	1	Tower, Water-Steam	1983	Spain
MSEE	Albuquerque, USA	0.75	Tower, Molten Salt	1984	US Dept. of Energy & Utilities
SEGS-1	California, USA	14	Trough, Oil	1984	Private Project Financing – Luz
Vanguard 1	USA	0.025	Dish, Hydrogen	1984	Advanco Corp.
MDA	USA	0.025	Dish, Hydrogen	1984	McDonnell-Douglas
C3C-5	Crimea, Russia	5	Tower, Water-Steam	1985	Russia

(Trieb 2005)'s Table 15 provides a summary of the existing CSP-based plants in the US and EU. By comparing Table 14 and Table 15, one observes the general development path of CSP implements, and specifically which implements and technologies have been favored by industry.

Table 15: Existing CSP technologies and associated implements (Trieb 2005)

Technology	Experience	Next Step	Current Providers/Developers of the Solar Components
Parabolic trough reflector with oil-cooled vacuum-isolated absorber tube in hybrid steam cycle power plant	SEGS I – IX, 354 MW installed between 1985 and 1991 in California, since then operating, steam generated in oil/steam heat exchangers at 370°C, 100 bar	50⁺ MW projects under development in Israel and USA	Solel, Israel (design, absorber), Flagsol (Germany (reflectors)
Re-designed and up-scaled structure of oil-cooled parabolic trough for steam cycle operation	100 & 150 m units of SKAL-ET (up-scaled EuroTrough) collector integrated to SEGS VI in California since April 2003	2 x 50 MW project under development in Southern Spain	EuroTrough Consortium, Solarmillennium AG, Flagsol, Schlaich, Bergermann & Partner, Schott, Germany (reflectors, structure, absorber tube)
Direct steam generating parabolic trough	700 m DISS test-loop in Plataforma Solar de Almeria, Spain, direct steam generation demonstrated at 400 °C, 100 bar	Concept for a 5 MW demo plant under development (INDITEP project)	Iberinco, Initec, Ciemat, (Spain) Flagsol, DLR, ZSW (Germany)
Solar tower system with pressurised hot-air central receiver for solar gas turbine and combined cycle operation	240 kW gas turbine operated first time December 2002 at Plataforma Solar de Almeria, gas turbine operated at 800 °C, 8 bar, (SOLGATE project)	2 x 80 kW gas turbine co-generation system for electricity and cooling under construction in Italy	DLR (Germany), Esco Solar (Italy)
Solar tower system with un-pressurised volumetric hot-air receiver	3 $MW_{thermal}$ TSA project in 1996-1998, steam generated at 550 °C, 100 bar; new modular ceramic hot-air-receiver presently tested in the European. Solair Project	Receiver endurance test and concept development for a 2 MW prototype plant within the German Cosmosol project	Solucar, Ciemat (Spain), Heliotech (Denmark), DLR, Kraftanlagen München, (Germany)
Linear Fresnel collector with secondary concentrator and direct steam generating absorber tube	100 m prototype tested in Liege, Belgium, direct saturated steam generated at 275 °C Compact Linear Fresnel Reflector 1 MWth prototype installed in a steam cycle plant in Liddell in New South Wales, Australia	200 m test loop for superheated steam generation at Plataforma Solar, Spain Design and construction of a first 1 MWe pilot plant	FhG-ISE, PSE, DLR (Germany) Solar Heat & Power (Germany)

4.1.3.3.2 Implements: In development

Examining the projects that are currently in development provides two important lessons: by observing where each of these implements is located, we can gain insights about which implement is most suited for which commercialization opportunity, and secondly we gain a general understanding of the scope of existing implements. (Eichhammer et al. 2006)'s Table 16 provides an excellent summary of the current status of CSP projects (implements) worldwide. We see that the majority of new implements are being developed in Spain, and that these implements tend to be solar-only plants (probably feasible due to the high subsidization).

Table 16: Summary of CSP-based implements in developmental phase (Eichhammer et al. 2006)

Country and plant details (not including GEF projects)	Concept formally floated and preliminary assessment conducted	Consortia formed—ready to bid or RfP ready to release	Financial dosure	Construction commenced	Fully commissioned and operating
Algeria 25 MW trough, ISCCS	⇨	⇨	⇨	2006/7 (Original expectation Sep 2005)	Possibly 2009
Arizona 1 MW trough ORC	⇨	⇨	⇨	⇨	⇨ (since April 2006)
Australia/Solar Heat and Power Pty Ltd, 38 MW Fresnel into coal-fired power station	⇨	⇨	⇨	⇨ (of first stage)	First stage under commissioning
Australia/Solar Heat and Power Pty Ltd, 250 MW Fresnel, stand-alone with thermal storage	⇨				
Australia 120 kW tower providing solar-reformed natural gas to a heat engine	⇨	⇨	⇨	⇨	2006
China/Ordos 50 MW trough	⇨				
India/Solar Heat and Power Pty Ltd, 5 MW, Fresnel	⇨	⇨			
Iran 67 MW trough, ISCCS	⇨				
Israel 100 MW trough	⇨	⇨			
Italy/Empoli (2x 80 kW solar gas turbine with waste-heat usage for air-conditioning)	⇨	⇨	⇨	⇨	
Jordan 135 MW trough	⇨	⇨ (RfP 2001)			
Nevada 64 MW trough	⇨	⇨	⇨	⇨ (February 2006)	Estimate March 2007
Portugal/Solar Heat and Power Pty Ltd, 5 MW with potential to upgrade to 50 MW, linear Fresnel	⇨	⇨			
Spain/ACS + SMAG, Andasol-1 50 MW trough	⇨	⇨	⇨ (June 2006)	Expected July 2006	Around late 2007
Spain/ACS + SMAG, Andasol-2 50 MW trough	⇨	⇨	2006	Expected 2006	Around early 2008
Spain/Abengoa, PS10 11 MW tower (saturated steam)	⇨	⇨	⇨	⇨	Estimate July 2006
Spain/SENER, Solar Tres 15 MW tower (molten salt)	⇨	⇨			
Spain/EHN+SolarGenix, 15 MW trough (HTF)	⇨	⇨			
Spain/Iberdrola, 7x50 MW Trough (HTF)	⇨	⇨			
Spain/HC, 2x50 MW Trough (HTF)	⇨	⇨			
Spain/Abengoa, 2x 20 MW Tower, 1x 50 MW Trough	⇨	⇨			
Spain/SMAG,50 MW ExtremaSol 1	⇨	⇨			
Spain/5 MW trough with direct steam generation (INDITEP)	⇨	⇨			
Spain/Solar Heat and Power Pty Ltd, 5 MW, Fresnel	⇨	⇨			
South Africa/100 MW Molten salt tower	⇨				

4.1.3.3.3 CSPond-Eni: Implement Ideas

Generating creative and feasible implement ideas in this stage will be aided largely with the help of experts simply because they have the technical background necessary to think of multiple ways to create implement configurations based on the new technology.

While by no means comprehensive, Figure 29, based on ideas by (Eichhammer et al. 2006), displays several implementation ideas that arise from the new CSPond-Eni technology link, and can be used to enter the commercialization opportunities displayed in Figure 28. At this stage technical experts should be consulted to come up with a series of feasible implementations.

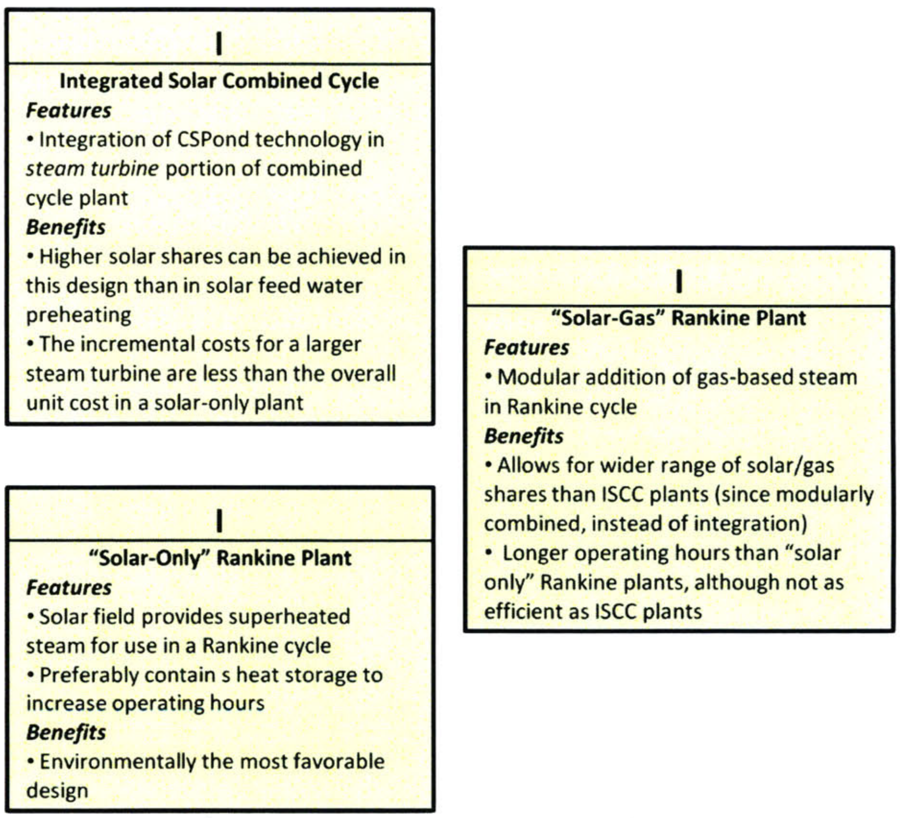


Figure 29: New implementations (systems using new CSPond-Eni technology to address commercialization new opportunities)

It is important to note that at this ideation stage, all feasible technologies, implements, and commercial opportunities, should be included in the TIC linkages. If time permits, analysis of the TIC linkages can be iterated to arrive at a more precise linkage. The subsequent steps of our method- opportunity development and dynamic planning and valuation, will build on the TIC linkages developed here, assessing which issues present the most significant material impact on commercialization potential, and are thus included as a flexible, dynamic plan.

4.1.3.4 Choosing an appropriate TIC linkage

At this stage, the team should have undergone a complete commercialization opportunity and technology literature review (and depending on availability of resources, conducted consultations with industry experts, etc.) to develop a set of new T, I, and C "boxes". The final step is to link these boxes and create a unified TIC linkage for the combined CSPond-Eni technology (see Figure 30).

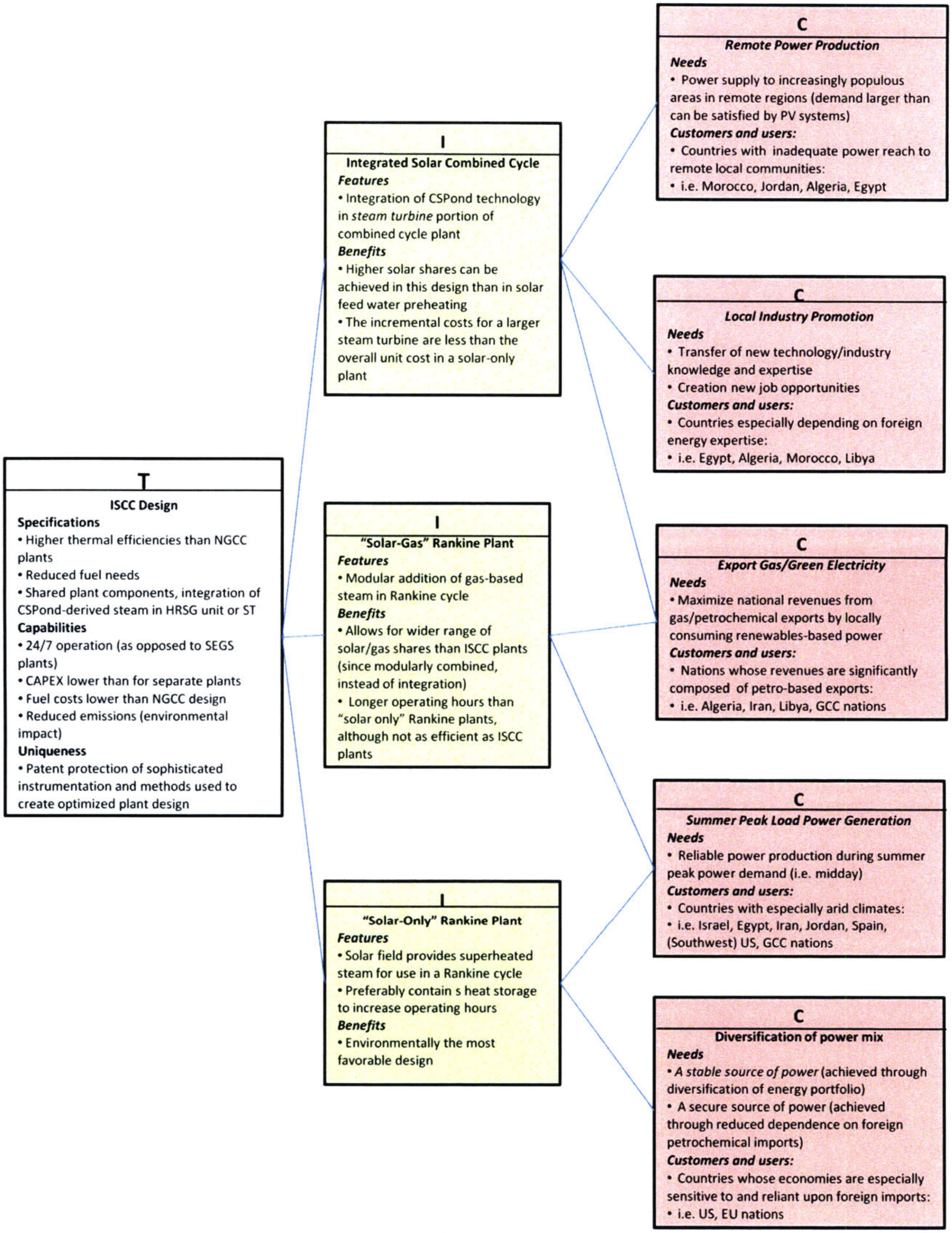


Figure 30: New combined CSPond-Eni TIC chart

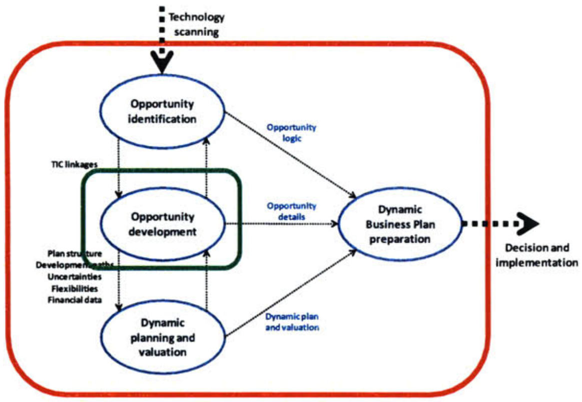
What becomes obvious in Figure 30 is that there are several linkages that a company can choose to pursue. Which ones should be chosen, and based on which assumptions? A useful tool that was developed by (Claro et al. 2008) and based on theory developed by (Kakati 2003) is the "TIC Scorecard" (See Appendix 4: TIC Scorecard). This tool scores the performance of each linkage based on team characteristics, resource capabilities, strategy, implementation and commercialization opportunity characteristics, and financial considerations of each linkage. Based on this tool, the TIC linkages should be prioritized based on their "TIC score".

4.1.3.5 Articulating the Opportunity: The Elevator Pitch

Finally, it is important to be able to succinctly and accurately articulate the opportunities that have been modeled using the TIC linkage framework. One tool that accomplishes this task is (Moore 1991)'s *elevator pitch*. The following framework is an adapted elevator pitch which addresses several key characteristics and functions of the new technology/start-up:

- **For** (who are the customers)
- **Who are dissatisfied** (what is the current implement and why is it inadequate)
- **Our technology/implement** (what does the new technology/implement accomplish)
- **That provides** (what needs is the implement satisfying)
- **Unlike** (contrast the capabilities of the new implement with existing insufficient implements)
- **We have assembled** (include a brief description of what the new implement does)

4.2 Opportunity Development



At this stage in our analysis of how to evaluate a technology based startup, the objective is to enhance our understanding of the critical issues that will contribute to the commercialization success of the opportunity(s). The opportunity development tool uses a list of over one hundred (102) issues identified through extensive literature reviews as critical to the commercialization success of a technology based opportunity. These issues are analyzed based on (McGrath and MacMillan 1995)'s Discovery Driven Planning (DDP) approach of identifying goal positions, and assessing how to reach them from the current position.

Based on an initial completion of this table, the team will know which issues require further development (through research and other knowledge enhancing activities), and consequently use available resources to reduce as much uncertainty about relevant issues as possible. A final completion of the issues will provide a new understanding of the current and goal positions, as well as the key uncertainties associated with the development path. The crucial information gained from the analysis of all the issues in this step is an understanding of which uncertainties are the most crucial to successfully commercializing the opportunity.

Tables 17-22 show how we have used the Opportunity Development tool to analyze five issues in different categories. Sections 4.2.1.1- 4.2.1.5 will then address how each of the tables was constructed.

Table 17: Initial analysis of a "Technology" issue

Issue	Assessment		Uncertainty	Addressing Uncertainty			
				How	Value	Cost	Dependencies
Stage of technology development	Current	A research project for the creation of a new design has been proposed. Preliminary computational models have been developed to confirm the possibility of achieving the levels of performance of the proposed design.	None				
	Goal	The research phase of the project will be completed with a proof of concept unit. This proof of concept unit will have to prove that the design is able to provide electricity with a cost at least 40% lower than current designs.	None				
	Develop	In the first phase of research, each of the design's components will be developed separately. The second phase will address the integration of these components. In the third phase, a proof of concept system will be created and tested.	The total duration of R&D can take between 2 and 6 years.	The estimates of total duration can be improved by gathering data from industry analysts and looking at previous R&D projects.	High	Low	None

Table 18: Final analysis (modified development path) of a "Technology" issue

Issue	Assessment		Uncertainty	Addressing Uncertainty			
				How	Value	Cost	Dependencies
Stage of technology development	Develop	In the first phase of research, each of the design's components will be developed separately. The second phase will address the integration of these components. In the third phase, a proof of concept system will be created and tested.	The total duration of R&D can take between 3 and 5 years: - 0.4 3 years; - 0.2 4 years; - 0.2 5 years; - 0.2 failure.	Project review point at year 3: - If unlikely to succeed, cancel. - If complete, continue. - If extra funding required - continue or abandon, depending on effort to completion.	High	Low	None

Table 19: Final analysis of an "Implement" issue

Issue	Assessment		Uncertainty	Addressing Uncertainty			
				How	Value	Cost	Dependencies
Implementation requires changes in infrastructure	Current	- For solar-gas Rankine (modular) implements, the only new infrastructure additions are equipment related to solar generation. ISCC plants may require retrofitting of existing infrastructure (i.e. increase operating temperature limit to accommodate new solar heat). - Solar power plants have similar transmission line requirements (to transmit power generated), but have higher water requirements (for cooling)	- Capacity expansion limit for ISCC retrofits, ~10-15%. - Size limits for modular Rankine systems.	- Consult with industry experts who have operational knowledge of plants. - Consult with leading designers who have understanding of thermodynamic/material limits of systems.	High	Medium	None
	Goal	- Demonstrated evidence of the equipment and labor requirements to retrofit existing plants for CSPond incorporation. - For retrofit model: demonstrated potential for significant add-on capability of solar-based power. - For integrated design: demonstrated ease of design integration (without need for many new parts) - Water requirements are proven to be feasible in locations where most of the implements are planned to be located.	None				
	Develop	- Communication with existing plant operators will define the system limits and constructability limitations. - Ideally, a proof of concept (small test plant) will demonstrate the extent of infrastructure additions required (such as new equipment, and upgrade in water transport infrastructure)	- Varying integration limitations and water constraints for differing plant setups and locations	- Consult with companies operating in different locations and with different production facility designs to understand infrastructure change requirements	High	Medium	None

Table 20: Final analysis of a "Commercialization Opportunity" issue

Issue	Assessment		Uncertainty	Addressing Uncertainty			
				How	Value	Cost	Dependencies
Commercialization Opportunity Growth	Current	- Current growth projections predict a rapid increase in installed CSP-based electricity production. - IEA's "GMI" initiative predicts total CSP market size of 5,000 MWe by ~2015 (current installed on order of 3-400 MWe) - Various other support agencies (i.e. GEF) offer incentives to launch CSP projects, although growth has been slow	None				
	Goal	- Information about commercialization opportunity growth and overall size will be large enough to create good predictions in the "funding and financials" section issues.	Size of market required to create lucrative investment environment.	In addition to gathering more data on market size, address barriers to entry and exit, and competitor/customer dynamics to determine what market share is anticipated.	High	Low/ Medium	- Influences of commercialization opportunity growth and size critical to issues in "funding and financials" section
	Develop	- Estimates of region specific commercialization opportunity sizes can be improved through more detailed literature review, interviews with experts, and conducting in-house/outsourcing consultancies for industry reports.	Which commercialization opportunities present the greatest potential for success?	- The team should adapt its commercialization strategy based on the outcome of more detailed reviews and analysis.	Very high	Low/ Medium	- Influences of commercialization opportunity growth and size critical to issues in "funding and financials" section

Table 21: Final analysis of a "Regulation and Competition" issue

Issue	Assessment		Uncertainty	Addressing Uncertainty			
				How	Value	Cost	Dependencies
Regulatory environment	Current	- Teams have conducted an extensive though preliminary study of the international, national, and regional policies and regulations that support CSP-based implements. - Detailed information about relevant CSP support mechanisms (primarily subsidies or portfolio standards) has been compiled.	Completeness and temporal relevance (how up to date) of legislation database	Contact local government agencies to get more up-to-date information on current and projected regulation/ legislation.	High	Low	
	Goal	- Subsidies have proven to be an effective promoter of CSP-based industry expansion. - Existing government support is stable, and provides necessary financial backing to make CSP implements financially attractive. - There is an increasing trend of countries/regions adopting CSP-promoting regulation.	Do not know stability of regulations: will they disappear with declining public support, or drops in oil prices?	- Only enter projects whose reliance on subsidies is minimal.	Extremely High	Medium/ High	- Limiting commercial opportunities to those with minimal regulation requirements adversely affects "commercialization opportunities" issues such as growth and total size
	Develop	- Use teams to further develop understanding of regulations. - Engage with local government agencies & industry to understand goals of drivers for regulation, long term vision, longevity and scope of CSP-based industry	None				

Table 22: Final analysis of an "Operations" issue

Issue	Assessment		Uncertainty	Addressing Uncertainty			
				How	Value	Cost	Dependencies
Access to Skilled Labor	Current	- It is assumed that there is a sufficient skilled labor force in Region I (i.e. USA, Australia, Spain, and Israel) countries. - Skilled labor in Regions II and III must be imported (from Region I), and developed (train local technicians and engineers). This is one of the main needs identified in the TIC linkage step.	- Amount of skilled technicians/ engineers in this new field	- Contact head hunting agencies and companies operating in this industry to get an estimate of the availability of qualified engineers/operators in this field.	Medium/ High	Low	None
	Goal	- Have a proven estimate of the size of qualified technical labor force in the industry. This number should be much smaller than that required to operate implements. - Have strong organizational support from local governments whose goal it is to train their engineers. I.e. they should provide technically trained personnel, time for training seminars and the like, and apprenticeship programs that facilitate learning, etc.	None				
	Develop	- This issue will likely not be addressed until the implements are ready to be commercialized. - Explicit agreement (i.e. through contracts) will state exactly how knowledge will be imported (through qualified labor) and transferred to local workers.	- Level of commitment and/or ability of local governments/ institutions to facilitate knowledge transfer	- Create own training programs/mentorship programs to help train local human resources.	Medium	Mediu m/ High	None

4.2.1 Assessments of Representative Issues

For the purpose of this thesis, analysis of a representative set of the complete set of issues will satisfy our pedagogical goal of illustrating how to apply this method. As such, a total of five issues (each from a different category) will be analyzed in the following sections. The first, related to a "technology" issue, is the most detailed, providing initial and final state analyses. The four subsequent issues are presented directly as "final" analyses. It is up to the team carrying out this analysis to identify, based on availability of resources, the scope (depth of analysis of each issue and total number of issues analyzed) of their analysis.

4.2.1.1 Technology

The "stage of technology development" issue is chosen in the "Technology" section. This issue raises the question of how far into the R&D phase the startup is. This issue is important for the investor (who is gauging how risky the investment is) and the startup (understanding what the effects of this stage are on subsequent commercialization steps).

- For the current position:
    - A research project for the creation of a new design has been proposed. Preliminary computational models have been developed to confirm the possibility of achieving the levels of performance of the proposed design.
    - The assessment team has complete knowledge about the current stage of development of the technology.
- For the goal position:
    - The research phase of the project will be completed with a proof of concept unit. This proof of concept unit will have to prove that the design is able to provide electricity with a cost at least 40% lower than current designs.
    - The assessment team has complete knowledge about the goal position on this issue of the technology development.
- For the development path:
    - In the first phase of research, each of the design's components will be developed separately. The second phase will address the integration of these components. In the third phase, a proof of concept system will be created and tested.

    - With current information on the project, the team's assumption is that the total duration of R&D can take between 2 and 6 years. The best research team available to work on this project has already been assembled and it is not likely that its expansion will result in an ability to shorten the duration of the project.
    - The team will try to improve its assessment of this issue by gathering data from industry analysts and looking at previous R&D projects. This is an important issue to get more data on, requiring an effort well within the capacity of the assessment team, and without dependencies on other issues.

Table 17 illustrates the initial analysis phase of the Technology Development issue.

The opportunity development analysis has identified the need to gather information on the duration of the project. The team accordingly engaged in contacts with industry analysts and gathered historic data from comparable R&D projects and reviewed their analysis of the development path (Table 18):

- The team's assumption is now that the complete duration of this phase can take between 3 to 5 years.
- To deal with this uncertainty, only the first 3 years of the project will be initially funded, and a review point will be created at the end of year 3:
    - If the project is found to be unlikely to succeed, it will be canceled.
    - If it is complete, it will proceed.
    - If it is found likely to succeed but requires more funding, the investors have the option to continue or abandon, according to the reviewed effort to completion and the impact of a delayed entry into commercialization.

4.2.1.2 Implementation

The "implementation infrastructure changes" issue is chosen in the "Implementation" section. This issue asks what level of infrastructure (i.e. existing buildings and access to power transmission/water) change is required to adopt this implementation.

- For the current position:

  - Current knowledge of the additional infrastructure requirements for CSPond module addition/integration is based on extensive theoretical design and limited construction and operations information.
  - The infrastructure components, namely housing of the plants, power systems, and coolant (i.e. water) remain essentially the same. Since solar systems have to be located outdoors, there is not a large impact on size of built up area. Water delivery infrastructure may need to be upgraded to account for increased solar requirement.
  - For ISCC retrofit implements, systems limits (such as temperature within boilers) may necessitate retrofit of entire plant to accommodate retrofit.
- For the goal position:
  - New equipment and labor requirements for expansion of existing plants, or for new requirements of integrated design are not only physically possible, but cost little in comparison to existing plant infrastructure.
  - New water supply requirements are feasible in regions where implements would be built.
- For the development path:
  - This issue will likely be further developed once research on the individual components of the CSPond technology has been completed, and system integration becomes a central focus of the team.
  - The team will rely on communication with existing plant operators to gain an empirical insight into infrastructure system requirements and constraints. Leveraging this information with an in-depth knowledge of the CSPond implements will develop the current theoretically based level of understanding to the goal position of demonstrated feasibility.

The central uncertainties for this issue are the "thresholds" of solar power additions to existing plants before significant infrastructure retrofitting is required, and also the variation in water requirements for different implement locations. The team would refine their knowledge of these uncertainties, and create a final analysis of this issue.
Table 19 illustrates an example analysis of the "Infrastructure Change" issue.

4.2.1.3 Commercialization Opportunity

The "Commercialization Opportunity Growth" issue is chosen as the representative point to address from the "Commercialization Opportunity" category. Its influence on the Funding & Financials issues, in addition to its general importance to overall project success made it a good example issue to use.

- For the current position:
  - The current best estimates of the size and growth of commercialization opportunities for CSP-based implements come primarily from international research consortiums and NGO's who promote the use of solar thermal technologies for power/desalination applications.
  - The most often cited benchmark is to achieve a 5,000MWe CSP-based global power output by ~2015. Given that current world installed capacity is ~ 500 MWe, this implies an average yearly growth rate of ~40%.
  - There are a few support agencies that provide financial assistance to CSP-based implements. Prominent among these institutions are the World Bank and the GEF, which have provided $50 million support packages to at least 4 projects (in India, Mexico, Egypt, and Morocco).
- For the goal position:
  - The goal is to have a market size large enough to provide an attractive investment environment for our CSPond-based technology startup.
  - While we know that the market for CSP-based implements is growing, we do not know what level it must reach in order to turn this commercialization opportunity into a commercially lucrative one.
    - This uncertainty will be addressed by conducting a more detailed analysis of both the market size/growth rate and various market forces (such as barriers to entry and exit, and competitor/customer power) to determine what market share can be expected.
- For the development path:
  - To get to the goal position of having an accurate prediction of a large enough commercialization opportunity, the best path seems to be to subdivide the overall commercialization potential into the constituent commercialization opportunities identified in the TIC section.

Table 20 illustrates an example analysis of the "Commercialization Opportunity Growth" issue.

4.2.1.4 Regulation and Competition

The most general issue within the "Regulation and Competition" category- the "Regulatory Environment" was chosen due to its representativeness of this general category.

- For the current position:

- The team has conducted an extensive literature review to determine the relevant support mechanisms (regulation and legislations) for CSP-based commercialization opportunities. The information has been gathered in two principle formats:
  - Conducting a comprehensive, country-by-country, region-by-region, search on environmental laws and regulations promoting solar thermal and CSP-based implements.
  - Using organization-generated (i.e. GEF, SolarPACES, etc.) databases to corroborate/supplement individual research. This format served as a check for completeness and timeliness of regulations uncovered.

- For the goal position:
  - The subsidies currently enacted by law provide a sufficient stimulus for industry to pursue this commercialization opportunity. For example, in Spain, the initial CSP price premium was not sufficient for industry to pursue CSP-based power production. As a result, the Spanish government had to revise the incentive structure, raising it to its current level of 300% (right to charge 300% of market price).
  - Perhaps even more important, a critical goal is a *stable* regulatory environment where laws passed "today" are not rescinded "tomorrow". It is desirable that the laws will remain stable in the face of changing economic (i.e. oil prices, recessions, etc.), and social (i.e. changing public opinion and support) situations.
    - It seems that there are two ways to address this uncertainty:
      - On the basis of encouraging healthy economic growth in the power sector, lobby governments to keep regulation standards relatively constant.
      - A more realistic mitigation would be to only pursue those projects that are determined to e financially attractive regardless of the regulatory support mechanisms.
  - Another goal position is to have an increasing trend of local/national/international regulations supporting CSP project development.
- For the development path:
  - To gain more confidence in the completeness of the regulation database compiled, teams should further engage with governments that have expressed interest in CSP development to get a better, more up-to-date understanding of existing laws, and the direction governments might be taking for future legislation.

Table 21 illustrates an example analysis of the "Regulatory Environment" issue.

4.2.1.5 Operations

In the "Operations" category, the "Access to Skilled Labor" issue was chosen because of its importance in many Region I countries where the goal is to educate local human resources on the design and operation of this new technology/industry.

- For the current position:
    - We currently assume that there is a sufficient supply of skilled labor for design and operation of CSP facilities within Region I countries. The critical uncertainty is however in how to build and operate these facilities in Region II and III countries. Since a "need" of many of these countries is the transfer of knowledge and training of their local technicians/ engineers, the issue of how to ensure adequate supply of constructors/operators of these plants in Region II and III locations must be addressed.
        - This uncertainty can be mitigated by contact head hunting agencies, and possibly interview existing experts/operators to get a feel for the size and willingness of qualified personnel to operate in rather remote locations.

- For the goal position:
    - The first goal position is to have a proven number of trained engineers and technicians that can satisfy the global requirements needed to build and operate CSP facilities. The number of trained individuals will most likely be highly correlated to the industry size: if it starts to increase, we can expect a rise in the number of trained individuals in this area.
    - Also, a goal is to have strong organizational support from local government whose goal it is to train their engineers.
        - For example, they should provide technically trained personnel, time for training seminars and the like, and apprenticeship programs that facilitate learning, etc.
- For the development path:
    - The team feels that issues pertaining to manpower training and allocation will not be addressed until later stages in development, probably when the implements are ready to be commercialized and operator questions arise.

- To reach our goal of having strong support from local clients and governments, explicit agreements (in the form of written contracts) will provide a good platform for addressing this issue. Resource requirements (mainly time) will be specified in such contracts and a mechanism for transferring knowledge (i.e. through apprenticeship programs, teaching seminars, demonstration units, etc.) will be specified.
  - The principle uncertainty in the development path is the level of commitment and/or ability of local clients/institutions to facilitate this knowledge transfer.
    - To mitigate this uncertainty, we propose that the developers should assume full responsibility (leadership) of this issue, creating their own training programs, etc. The price of such programs, associated with value of knowledge transfer, should be expressed in the contractual agreements.

Table 22 illustrates an example analysis of the "Access to Skilled Labor" issue.

4.2.2 Picking the most Critical Issue Uncertainties

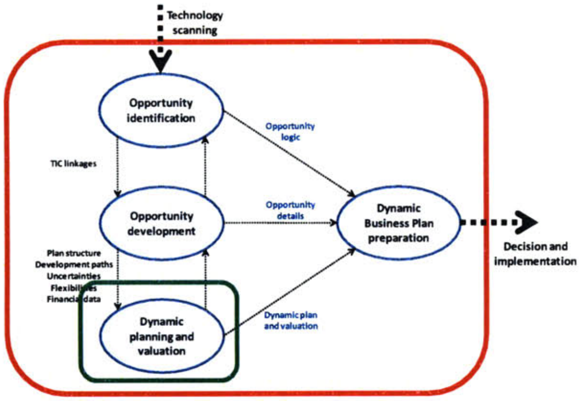
In completing the "Opportunity Development" section, the team will have analyzed the key issues influencing the successful commercialization of the implement(s) based on a new technology. Defining the scope of this step depends on the resources of the team: if there is sufficient time, a complete analysis of all 102 issues will result in a comprehensive analysis of initial and final states (final states are revised initial analyses that have incorporated the additional research needed) of the critical issues for technology commercialization. Given the large amount of work this entails, a strong research team would have to be given sufficient time and resources to complete the assessments. It is up to the company to decide the scope of this assessment phase.

The next critical step is to use the results of the opportunity development section as inputs into the final, and capstone portion of the method: the creation of a decision tree that represents a dynamic project planning and valuation approach. The team must pick, out of the pool of issues analyzed, the 3-5 critical uncertainties which the Opportunity Development section has shown to be central to project success. These uncertainties' range (distribution of likely outcomes) and effect (changing value of project) remain high even after development research to reduce the uncertainty has been undertaken. Generally, the critical uncertainties are those whose range cannot be narrowed through additional research ("unknowable unknowns", such as market performance or oil price) and/or those whose narrow range may have a large effect on the success of the project (highly sensitive uncertainties).

For this case study, three critical uncertainties are chosen for incorporation into the decision tree. They were chosen based on extensive research related to the technology, implements, and commercialization opportunities, in addition to the insights gained in the opportunity development section about the criticality of each uncertainty. They are:

1. Stage of Technology Development.
2. Commercialization Opportunity Growth
3. Regulatory Environment

4.3 Dynamic Planning and Valuation



We thus arrive at the very backbone of our new integrated process. The previous steps, Opportunity Identification and Opportunity Development, served complimentary roles in defining the materially relevant properties of the opportunity being analyzed. The Opportunity Identification and Development steps thus define the opportunity and critical uncertainties that an appropriate method, modeled using the decision tree, will plan and evaluate. The Dynamic Planning and Valuation step is thus the capstone of this approach because it introduces the single analysis phase which integrates the results of both previous phases to create the centrally important output: a method to develop and assess the opportunity at hand.

Beyond being a unifying step that creates the principal output of this method, the dynamic planning and valuation phase presents a new way for assessing the development of uncertain opportunities. As stated in the Introduction, the DSP approach presents a fundamentally different way to plan the development of opportunities. Instead of following a predetermined and rigid "most likely profitable" commercialization path, the team defers decisions on the commercialization effort until more information is made available (through the unfolding of future events). In this approach, the ability to dynamically choose the development path based on the outcome of critical uncertainties is the form of flexibility that is purchased. Most often, the price of this flexibility is more than offset by the increased exposure to unanticipated attractive opportunities and the hedging of risk from the failure of critical commercialization path(s).

4.3.1 Planning and evaluating the opportunity: Classical method

Planning and assessing the CSPond-based opportunity first using the classical method will provide good context and a means of comparing the differing performances (values) of the same opportunity. That is, we will analyze the same opportunity (the CSPond technology), according to the same set of market/ other constraints (uncertainties) using the traditional and flexible (DSP) methods. The difference in performance of the two approaches demonstrates the expected added value of a flexible, dynamic approach to opportunity development.

As (Faulkner 1996) illustrated, there are several levels of uncertainty incorporation. The prevailing traditional method of making informed investment decisions is to first map out all crucial uncertainties and the corresponding development paths that can be taken. The team then decides, usually based on predictions of the most likely outcomes of each uncertainty, what the "most likely profitable" development path is. The team then pursues this opportunity based on the initial analysis of the most likely profitable scenario, with little/no modifications based on the unfolding uncertainties. Figure 31 illustrates a representative portion of the decision tree that models the CSPond-based opportunity according to this framework.

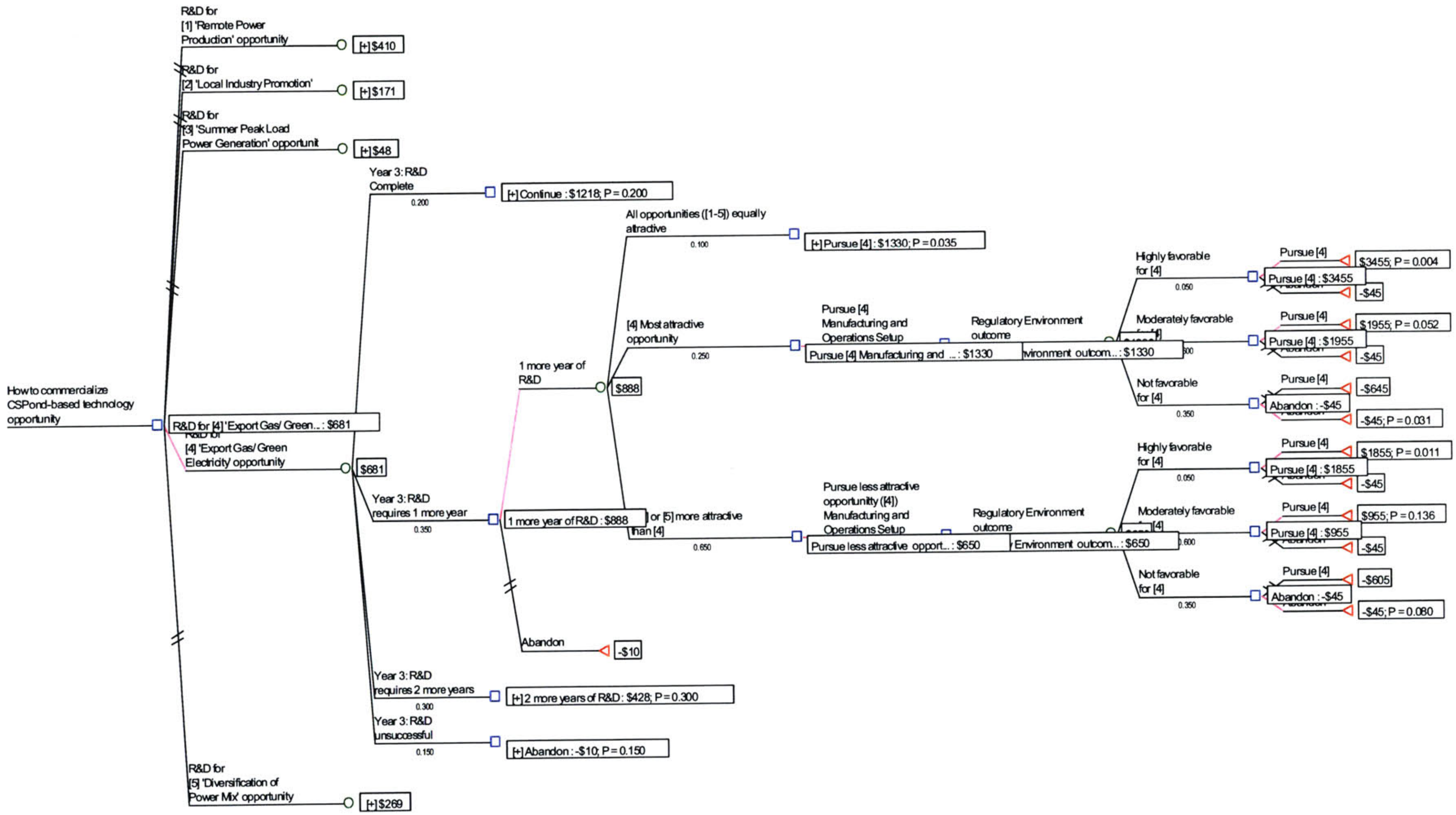


Figure 31: Representative section of "traditional approach" decision tree

The decision tree models the development of the system (the start-up) based on a chronological ordering of the key uncertainties and associated decisions that management must make to maximize the value of the project. For example, the first major uncertainty, R&D success, is the first uncertainty node, and the associated decision node is the decision on how to proceed with the commercialization effort based on the different R&D outcomes. The structure of the tree is thus an accurate representation of the development path for the technology opportunity. The values (probabilities and payoffs) used in this model are not based on an extensive financial analysis; they are inserted, based on logical assumptions, to show how one would carry out the analysis using the traditional valuation approach.

Based on the uncertainty, cost, and revenue values input into this model, the "Export Gas/Green Electricity" is the "most likely profitable" commercialization opportunity (the other commercialization paths are not shown in the decision tree to make it readable on one page). As such, the team decides to fix all research efforts and mobilizes all its resources to exploit this opportunity. Under this fixed plan, the subsequent development proceeds based on the identified critical uncertainties, i.e. market demands, regulatory environment, etc. The value of the project is finally calculated based on the standard rollback method.

4.3.2 Planning and evaluating the opportunity: Dynamic Strategic Planning

The Dynamic Strategic Planning approach solves two major problems that the traditional method for planning and evaluating opportunities possesses. The first is the unnecessary exposure to risk inherent in a rigid development plan. While the "most likely profitable" scenario may indeed have the highest chance of commercialization success, it will still contain a non-negligible chance of failure. The remedy for this problem is to insert the flexibility (at a marginal cost) to pursue a number of commercialization opportunities and use their (albeit smaller) chance(s) of success as a hedge against the probability of failure of the "most likely profitable" commercialization opportunity. As the VARG curve will show, such an approach increases system performance by reducing the exposure to downside risk.

The second major problem is the limit on maximal profit realization that is created when confining development to a single most likely profitable commercialization opportunity. While the opportunity with the largest potential payoff has been selected, one has cut off access to the potentially much larger payoff pool from the rest of the opportunities. Similar to the solution of the first problem, the DSP approach relaxes this constraint by inserting the flexibility to pursue a range of commercialization opportunities. Thus, one takes advantage of whatever chance there is of commercialization success for a whole range of opportunities. The expected payoff from these opportunities will most likely greatly exceed the cost of inserting this flexibility.

The incorporation of flexibility into the system can come in two forms-- flexibility "on" the system, and flexibility "in" the system. Flexibility "on" the system refers to the investment changes that can be made on the system at any point in time. Borrowing from Real Options terminology, a "put" option to abandon project development (after an unfavorable uncertainty outcome) would be an example of flexibility "on" the system. Conversely, a "call" option to increase spending on the project after very favorable uncertainty outcomes is another example of using flexibility "on" a system to raise its performance. Flexibility "on" the system is present in both the traditional and DSP approaches (in the form of a "put" option to abandon project development).

In addition to flexibility "on" the system, the DSP approach incorporates flexibility "in" the system, in the form of platform applicability of the initial R&D stage to several commercialization opportunities. By spending an additional amount on the R&D stage we have directly inserted flexibility into the system by giving it the capability to pursue multiple commercialization paths. The structure of the new, DSP based, tree is fundamentally different from the traditional approach in that management *does not* pick "the "optimal" commercialization path and rigidly follow it. Instead, R&D efforts allow the team to pursue several commercialization opportunities. The decision of which opportunity(s) to pursue is delayed until further information is learned. A more informed decision, which may include any number of the commercialization opportunities, is made, and this raises the value (worth) of the project. Figure 32 illustrates the structure of the flexible DSP approach decision tree. This figure illustrates a representative part of the greater tree (which is much too large to display on a single page). The next section outlines how one models this opportunity (investment in a hi-tech startup) using the decision tree framework.

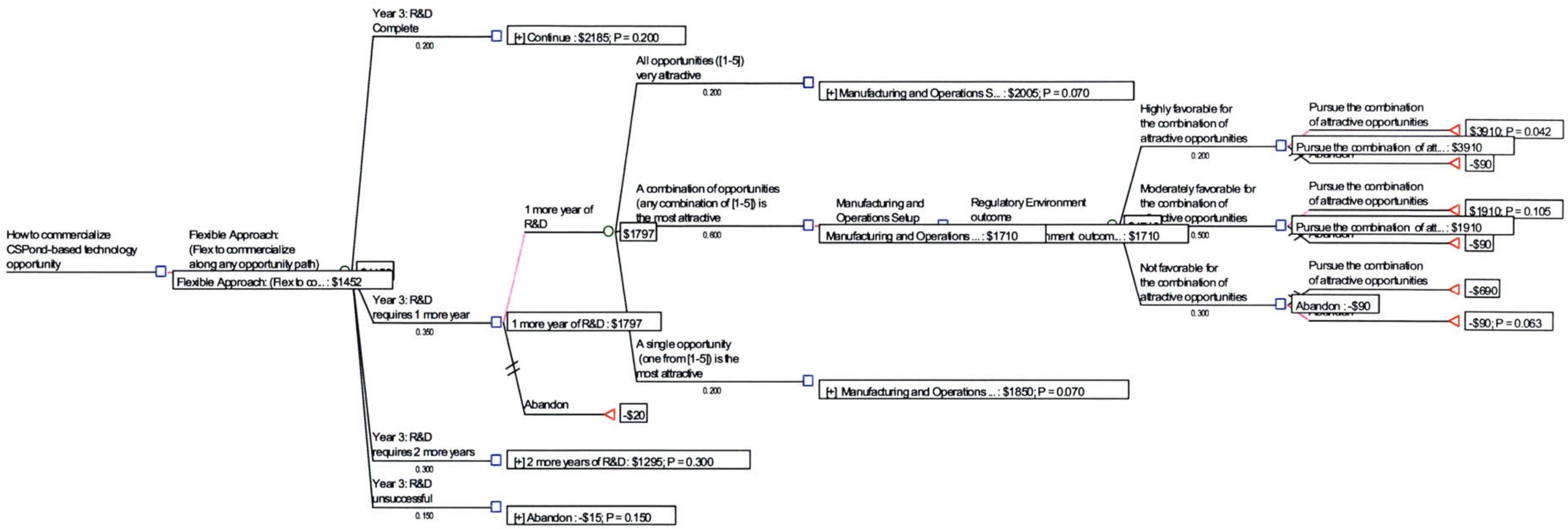


Figure 32: Representative section of flexible "DSP approach" decision tree

As a result of this flexible approach, the project can be attractive in many scenarios because we have not relied on the fixed "most likely profitable" approach. Rather, we can pursue several commercialization development paths the choice of which depends on the outcomes of critical uncertainties. Thus, instead of placing all our eggs in one basket, we take advantage of the high uncertainty by buying the right to pursue a range of attractive commercialization opportunities.

4.3.3 A Step-by-Step Guide to Constructing a Decision Tree

The construction of a decision tree is a disciplined process that involves adding successive "uncertainty-decision" node pairs. That is, for each uncertainty node incorporated into the tree, an accompanying decision node that provides some form of flexibility to deal with the uncertainty is inserted. One iterates this process *n* times (for n uncertainty-decision node couples), based on the desired level of detail and complexity.

4.3.3.1 Choosing the Uncertainties

Before constructing the decision tree, it is good practice to know the level of detail (number of uncertainty and decision node couples) will be used. As mentioned previously, we use the output of the Opportunity Development section (critical uncertainties) as inputs into our decision tree. In our case study, the three critical uncertainties that will be incorporated into the decision tree are:

1. Success of technology development
2. Market (commercialization opportunity) size/growth
3. Regulatory environment

One should also think about the order in which these uncertainties will be faced—i.e., we expect to face the technology development uncertainty before market size and regulatory environment uncertainties. Since decision trees model the development of a system (i.e. startup planning and development) in chronological order, it is useful to have an idea of which uncertainties precede which.

4.3.3.2 Incorporating Flexibility (Decision nodes)

This step is critical because it defines how management will react to the critical uncertainties. The options available to management in the decision nodes are the manifestation of flexibility in/on the system—it is thus crucial to think carefully about what the best forms of flexibility are to respond to the uncertainties.

In our case study, the types of flexibility incorporated were:

Flexibility *on* system:

- Continue/Abandon option
  - Based on outcome of uncertainties, management decides whether to continue or abandon development.
  - More options (i.e. Continue with higher investment, continue as planned, reduce effort, etc.) could have been used instead of this "continue/abandon" binary system. For our example, we used a binary system because it illustrates the concept without adding unnecessary clutter/complexity.
  - In our case study, this option was available after any of the 3 uncertainties (see section 4.3.3.1

Flexibility *in* system:

- Modifying the research and development effort to yield a platform technology that can be applied to any of the identified commercialization opportunities.
  - This is an example of flexibility "in" the system because we have modified a component of the system to increase its performance (in the face of several uncertain outcomes).
  - This option is obviously inserted after the first uncertainty (success of technology development).
  - Other forms of flexibility in the system could be inserted (such as modifying the implementation design to make it compatible with multiple commercialization opportunities, i.e. different power/desalinization plants, etc.).

4.3.3.3 Building the Decision Tree

With the uncertainties and decision nodes defined, constructing the decision tree now requires a disciplined and relatively straightforward connection process. Since our case example considers three critical uncertainties and their associated decision nodes, we explain the construction of the decision tree as a three step process:

Step 1: R&D uncertainty and decision nodes

R&D uncertainty is defined as the first critical uncertainty faced when developing the CSPond-base startup. Hence, our first step is to construct a decision tree with the R&D uncertainty node, its potential outcomes, and the decisions management can take to respond to this uncertainty. Figure 33: 1st step of decision tree construction (R&D) illustrates what the decision tree looks like after this first step (decision tree only partially built).

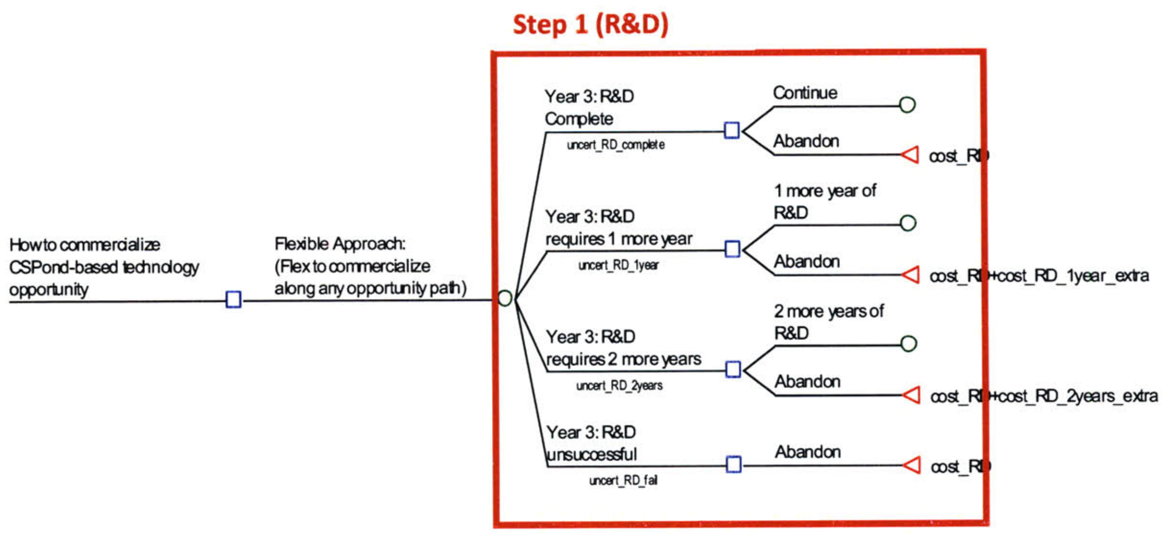


Figure 33: 1st step of decision tree construction (R&D)

Step 2: Commercialization opportunity size/growth uncertainty and decision nodes

We must now incorporate the uncertainty management is most likely to face once R&D is complete: commercialization opportunity size/growth. The way this is done is by inserting the same uncertainty nodes to *each* branch from the first step (one can see that the tree grows exponentially). Figure 34: 2nd step of decision tree construction (R&D and Market) illustrates the new tree, with the second uncertainty-decision node pair added to only one of the branches from step 1 (for simplicity, since it is duplicated for the other branches).

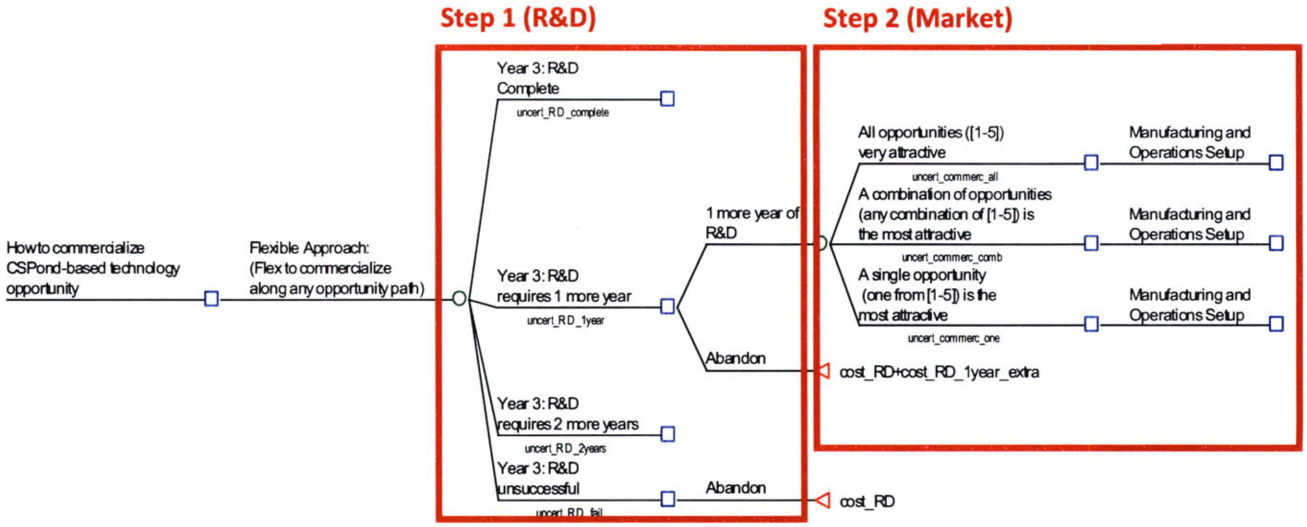


Figure 34: 2nd step of decision tree construction (R&D and Market)

Step 3: Regulatory environment uncertainty and decision nodes

The last uncertainty that we expect management to face and make a decision on is the regulatory environment that can affect the attractiveness of certain commercialization opportunities. The incorporation of step 3 to the decision tree follows a similar process as in the previous step: we add the uncertainty node corresponding to the regulatory environment (step 3) to the ends of each decision branch from step 2. Figure 35: 3rd step of decision tree construction (R&D, Market, Regulatory) illustrates this final addition.

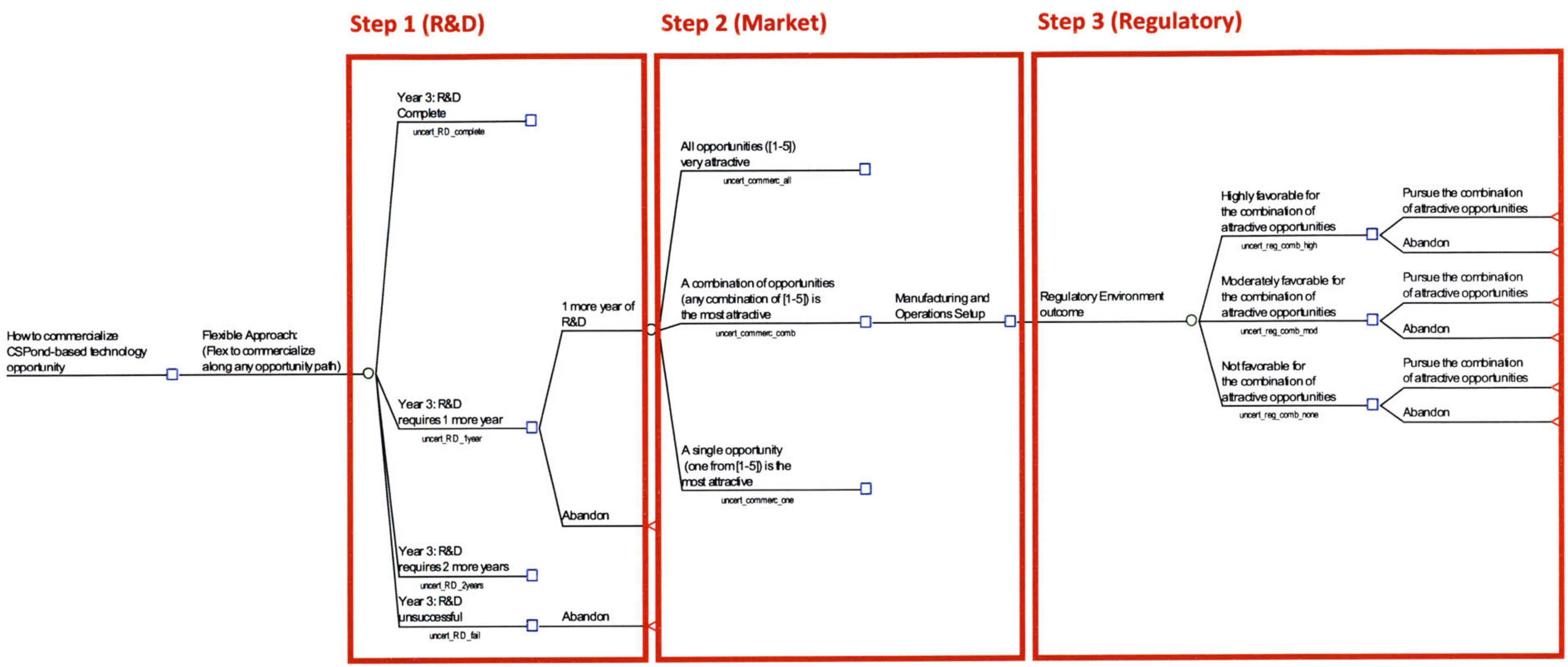


Figure 35: 3rd step of decision tree construction (R&D, Market, Regulatory)

Finally, once the decision tree has been fully assembled, the outcomes (revenues-costs) for each terminal node must be inserted. Additionally, probability values for each branch emanating from an uncertainty outcome must be inserted. It is advisable to create variables for the payoff and probability parameters (to run sensitivity analyses, etc.).

4.3.4 Analysis of the Decision Trees: VARG chart

A VARG (value at risk and gain) chart is a plot of the cumulative likelihood of project values; thus, it displays the cumulative sum of likelihood of our system having an NPV at or below a given level. It is useful in its concise representation of the entire range (and associated likelihood) of possible project values.

What Figure 36: VARG plots for traditional and DSP project planning and valuation method (the VARG plot) shows is that not only does the flexible development plan have a higher expected value ($1,452 M v. $681 M), but for the most part its NPV given any cumulative likelihood is greater than the inflexible development plan. The only exception is at the lowest cumulative probability, where the additional R&D cost that allows a flexible commercialization strategy results in a slightly lower performance. The performance of the flexible approach is generally better than the fixed "most likely profitable" one because of the exposure to potentially attractive commercialization opportunities. The performance of the flexible DSP approach becomes significantly higher in the upper 5% of project values because this represents the case where all of the commercialization opportunities are pursued (they are all commercially attractive).

As mentioned, the values used in this model are not based off of a detailed financial analysis. It is thus useful to have a list of all variables used in the model. One can test the robustness of this system by changing the values of any one/combination of the variables. Table 23 shows all 84 variables used (organized by 2 categories: Payoffs and Probabilities) in the decision trees.

Table 23: Compilation of variables used in decision trees

1. Payoff Variables	Value	2. Probability (Uncertainty) Variables	Value
1.a Cost variables		uncert_commerc_1most_attr	0.2
cost_delay_1year	-500	uncert_commerc_2most_attr	0.25
cost_delay_1yr	-500	uncert_commerc_3most_attr	0.15
cost_delay_2years	-1200	uncert_commerc_4most_attr	0.25
cost_delay_2yrs	-1200	uncert_commerc_5most_attr	0.15
cost_manuf_op_stp_all	-100	uncert_commerc_all	0.2
cost_manuf_op_stp_comb	-70	uncert_commerc_all_eq_attr	0.1
cost_manuf_op_stp_single	-30	uncert_commerc_comb	0.6
cost_op_stp_single	-30	uncert_commerc_one	0.2
cost_RD	-15	uncert_RD_1year	0.35
cost_RD_1year_extra	-5	uncert_RD_1_1year	0.3
cost_rd_1yrextra	-5	uncert_RD_1_2years	0.4

cost_RD_2years_extra	-10	uncert_RD_1_complete	0.1
cost_rd_2yrsextra	-10	uncert_RD_1_fail	0.2
cost_rd_complete	-10	uncert_RD_2years	0.3
		uncert_RD_2_1year	0.35
1.b. Revenue variables		uncert_RD_2_2years	0.3
rev_1_high	4000	uncert_RD_2_complete	0.15
rev_1_mod	2500	uncert_RD_2_fail	0.2
rev_1_none	-100	uncert_RD_3_1year	0.3
rev_2_high	3000	uncert_RD_3_2years	0.3
rev_2_mod	1000	uncert_RD_3_complete	0.25
rev_2_none	-50	uncert_RD_3_fail	0.15
rev_3_high	1500	uncert_RD_4_1year	0.35
rev_3_mod	500	uncert_RD_4_2years	0.3
rev_3_none	-50	uncert_RD_4_complete	0.2
rev_4_high	4000	uncert_RD_4_fail	0.15
rev_4_mod	2500	uncert_RD_5_1year	0.3
rev_4_none	-100	uncert_RD_5_2years	0.25
rev_5_high	3500	uncert_RD_5_complete	0.2
rev_5_mod	1500	uncert_RD_5_fail	0.25
rev_5_none	-100	uncert_RD_complete	0.2
rev_all_high	7000	uncert_RD_fail	0.15
rev_all_mod	3500	uncert_reg_all_high	0.05
rev_all_none	400	uncert_reg_all_mod	0.6
rev_comb_high	4500	uncert_reg_all_none	0.35
rev_comb_mod	2500	uncert_reg_comb_high	0.2
rev_comb_none	-100	uncert_reg_comb_mod	0.5
rev_scale_down_factor	0.6	uncert_reg_comb_none	0.3
rev_single_high	3500	uncert_reg_high	0.05
rev_single_mod	2500	uncert_reg_mod	0.6
rev_single_none	-100	uncert_reg_none	0.35
		uncert_reg_single_high	0.3
		uncert_reg_single_mod	0.5
		uncert_reg_single_none	0.2

It is useful to document the key attributes of the flexible/inflexible development plans when deciding which method to use. Table 24 shows the key performance metrics for our system: expected NPV (ENPV), minimum/ maximum NPV, initial CAPEX, and NPV/CAPEX ratio. Of course, the expected NPV is important because it gives an indication of, on average, what one expects the value of the venture will be. This metric is of particular importance to a risk neutral investor who is simply looking for the investment that is expected to return a larger NPV. For an investor that is risk-averse, the minimum NPV metric will be of greater importance because they are more sensitive to the expected worst-case scenario. Conversely, for an investor seeking to make as much money as possible and not as sensitive to the losses, the project's "ceiling" (maximum NPV) will be of greater importance.

Table 24: DSP (flexible) v. Traditional (fixed) system performance

($, millions)	Design		Which is better?
	Flexible	Inflexible	
ENPV	1,450	700	Flexible
Minimum NPV	-200	-100	Inflexible
Maximum NPV	7,000	4,000	Flexible
Initial CAPEX	-15	-10	Inflexible
NPV/CAPEX	500	400	Flexible

For the ENPV and maximum NPV, the flexible development plan is superior. However, due to the additional upfront R&D cost, the fixed approach has a slightly larger (less negative) CAPEX requirement. However, if one keeps in mind the scale of the later costs and revenues, such a metric may be less relevant. The fixed approach has a materially better performance in terms of minimum NPV because of the heavy manufacturing/operations setup costs associated with pursuing multiple commercialization paths that end up not being successful (in the flexible approach). The importance of this parameter will be dominated by the risk-aversion and general ability of the investing company to handle such losses, and also by the probability of its occurrence (which in this case is very small, ~ 5%).

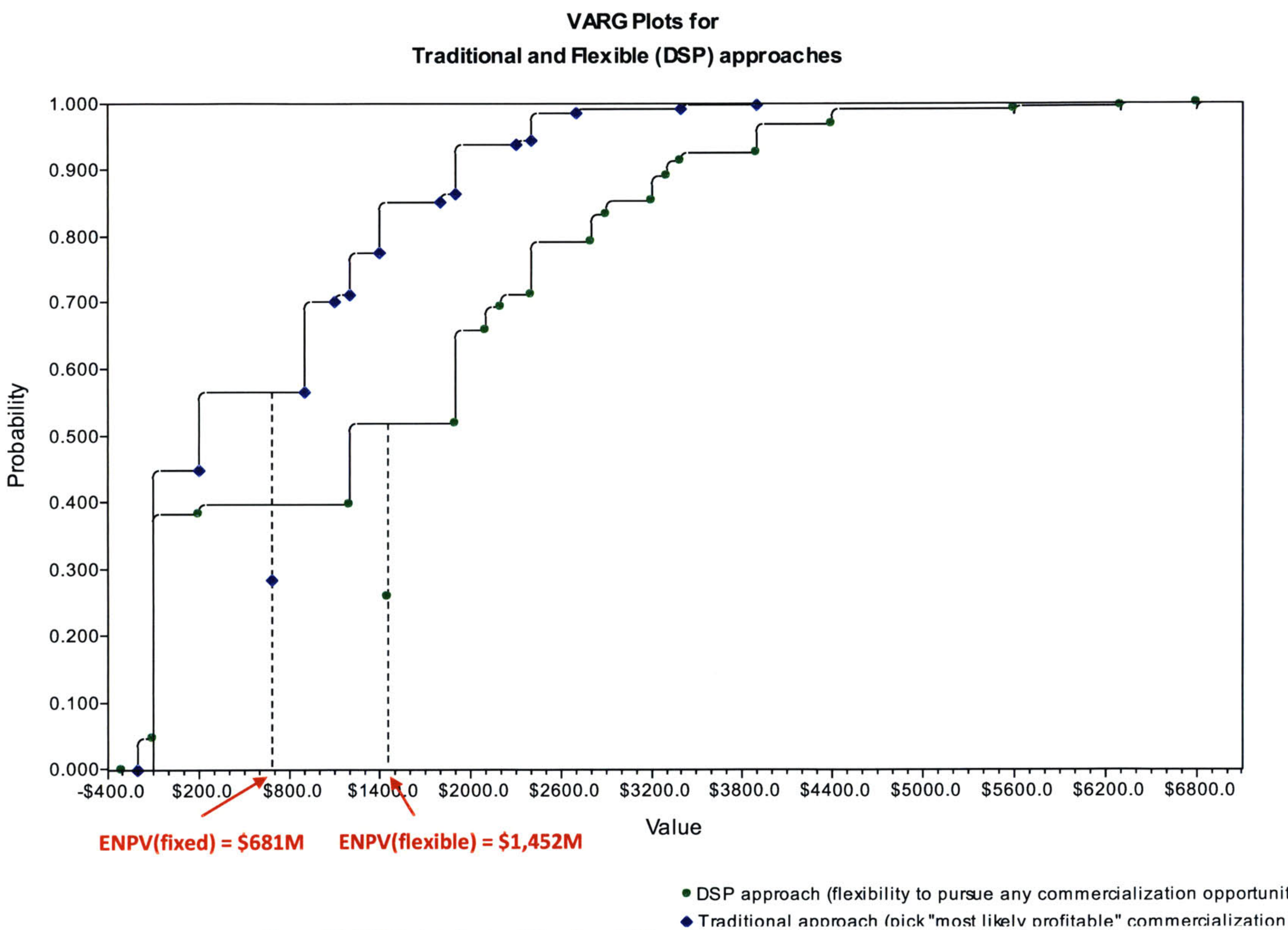
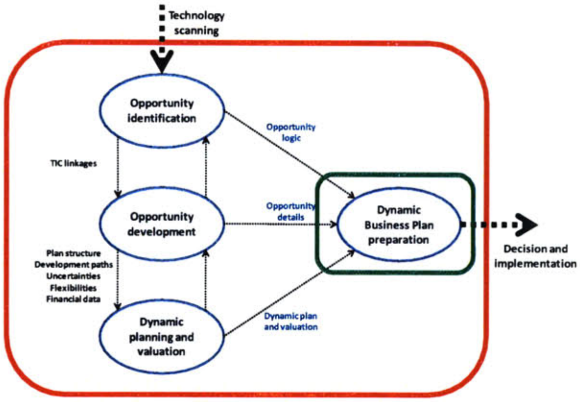


Figure 36: VARG plots for traditional and DSP project planning and valuation method

4.4 Dynamic Business Plan Preparation



A business plan-like report should be the final deliverable of the planning and evaluation process. Business plans play a key role in communicating opportunities and also in providing a discipline for a venture team to be specific about what it intends to do and what it hopes to accomplish. As such, they should reflect the critical importance of addressing uncertainty for new technology ventures. The inputs to this report are the three main stages of our process for identifying, planning, and evaluating technology-based opportunities. The goal of this report is to provide management with a summary of the most important factors affecting the success of a new venture.

(Sahlman 1997) argues that the best business plans address four interdependent factors that are critical to new ventures – people, opportunity, context, and risk and reward – and discuss the venture as a moving target, confronted with the critical risks ahead – both downside and upside. (Ernst & Young 1997), (Sahlman 1997) and (Dorf and Byers 2005) provide good business plan examples. The logical implication is that business plans should be *dynamic*, proactively incorporating the key uncertainties and the associated decisions on how best to proceed given each outcome, dynamically adapting the venture's development path. As such, the output from the dynamic planning and valuation step fits perfectly with this requirement as it provides a dynamic strategy for planning the development of a technology opportunity.

5. Conclusions and Future Research

5.1 Conclusions

Due to the inherent uncertainty in hi-tech start-ups, adopting a flexible development strategy is essential to successfully managing the development of such opportunities. The DSP approach recognizes and utilizes the high uncertainty present in hi-tech start-ups by using flexibility as a means to take advantage of changing uncertainty outcomes. There are several forms of flexibility that one can incorporate into a commercialization effort. In this thesis, both flexibility "on" (in the form of the option to abandon development) and flexibility "in" (in the form of a more comprehensive R&D effort that allows development of multiple commercialization opportunities) the system were used to improve the planning and assessment of the CSPond opportunity.

One is not restricted to these forms of flexibility on and in the system: there are many additional ways of incorporating flexibility into the development of the CSPond opportunity. Some additional examples of flexibility "on" and "in" the system include:

Flexibility "on" the system:

- "Increase in spending" option if the given development step (i.e. R&D or operations setup) is very successful. This would be analogous to a financial "call option". In the thesis's model, an "abandon", or "put option" was used.

Flexibility "in" the system:

- "Flexibility in the implement designs": flexible implement designs can be created that allow for easy capacity expansion, or even applicability to different commercialization opportunities.

The VARG plot provides a good comparison between the overall system performances of the flexible DSP approach and the traditional "most likely profitable" approach. It shows how in this case the flexible approach performs better in almost every scenario (except for the case when the team abandons opportunity development immediately after a failed R&D stage). In the vast majority of cases, the DSP approach performs better than the traditional approach because the costs of buying flexibility to pursue multiple commercialization paths based on new information is justified.

5.2 Future Research

While this thesis has successfully demonstrated the applicability of a flexible planning and assessment method for a solar hi-tech opportunity, it also brings up several important topics and questions for further research:

- Find a way to further embed "un-used" knowledge created in Opportunity Development phase
    - A transfer of knowledge, in the form of selecting the most critical uncertainties, occurs between the Opportunity Development step and the Dynamic Planning and Valuation step.
    - While all the information in the Opportunity Development section is indirectly used (as a pool of uncertainties from which the most critical are chosen), there may be a better way to more directly incorporate such an extensive and valuable pool of information.

- Use the approach in a comprehensive manner, to professionally plan and assess an opportunity; build on the thesis's case study demonstration by:
    - Developing all of the issues identified in the Opportunity Development" section.
    - Conducting extensive financial analyses and link it to the DT to create a "real" DSP based financial analysis of the opportunity.

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Opportunity Identification

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Appendix

Appendix 1: Complete Description of new integrated method

Appendix 1: Complete Description of new integrated method provides a more comprehensive description of the integrated method developed (Claro et al. 2008) to plan and assess the development of uncertain technology opportunities. Developing this new method was the goal of the research team assembled by Professor de Neufville in the summer of 2008. This method was written mostly by Professor Claro, with my assistance, and invaluable guidance from Professor de Neufville. Our partners at Eni also provided insights that the research team greatly benefited from.

A.1 Overall Description

The process of moving from a technology to the assessment of business opportunities presents a set of different challenges that require different approaches. We have identified four top-level challenges in this process, underlying its division in four phases (Figure 37):

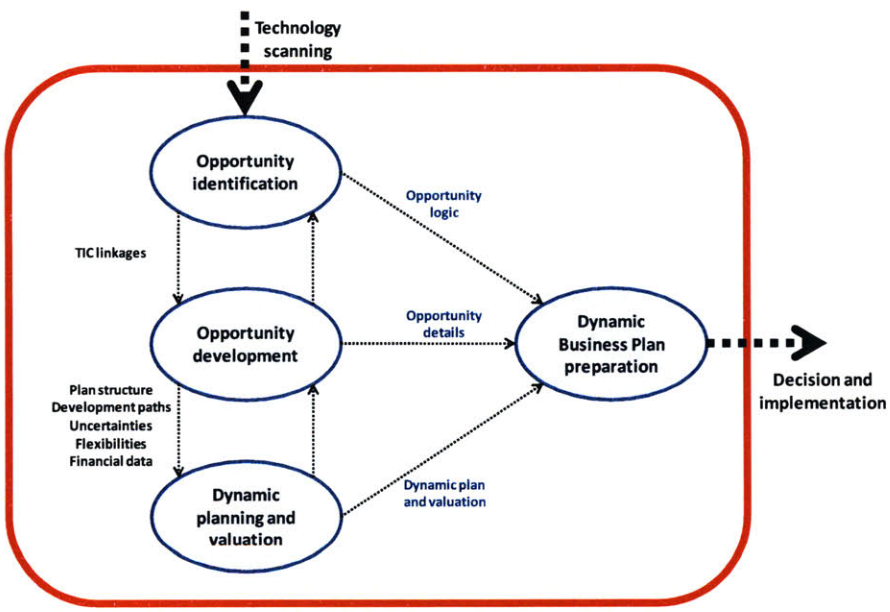


Figure 37: Assessment Method

1. Identification of technology based business opportunities.

   For this phase we have adopted the Technology-Implementation-Commercialization (TIC) linkage framework that builds upon the TPM concepts articulated by (Markham and Kingon 2004). This framework links technical capabilities with customer needs through concepts of implementation, articulating the basic logic for a particular implementation and hence an opportunity, and is usually applied to create multiple concepts of implementation targeted at multiple forms of commercialization, from a single technology. We propose an adaptation of the TIC linkage framework to identify synergies on which the parent corporation's business can build to grow its profits, since CVC investments usually have a combination of financial and strategic objectives (MacMillan et al. 2008, Chesbrough 2002).

1.1. The team performing the assessment will first specify current and potential, complete and partial, TIC linkages for each company on its own.

1.2. It will then look at combinations of these linkages to identify new or improved technologies or implementations, and develop the corresponding TIC linkages, as well as to identify opportunities for commercialization and interactions between them (for example, affecting demand or adoption rate).

2. Development of the components of the opportunities.

The TIC linkages of the evaluated company and the new TIC linkages articulate a set of business opportunities that must subsequently be developed with more detail. For this purpose we have created a tool that incorporates key ideas of Discovery Driven Planning (McGrath and MacMillan 1995) and the method for assessing uncertain projects through the scoring of a series of statements proposed by (McGrath and MacMillan 2000). This tool lists important issues identified in the literature, grouped according to the typical structure of a business plan, for which the evaluation team must:

2.1. Assess the current and goal positions, and development paths between them.

2.2. Recognize uncertainties, express them as assumptions, and identify alternatives to address them.

2.3. Point out dependencies between issues.

This tool has an immediate use as a guide for the assessment team to go through the effort of gathering information, within their time and resource constraints, to convert as many assumptions to knowledge as possible, thus improving the assessment.

3. Dynamic planning and valuation of the opportunities.

A plan for the exploitation of an opportunity specifies the work that will be carried out, the milestones and results that will be achieved, when they will be achieved, and the resources that will be required.

3.1. At the end of development, the team will have identified a structure for the technology-to-commercialization plan, as well as development paths in specific issues, for the opportunities under scrutiny. The team will use this information to build a specific structure for the plan. In the previous phase the team will also have identified a set of critical uncertainties, and associated flexibilities, that should now be inserted in the structure of the plan, which as a result will take the shape of a decision tree (Faulkner 1996).

3.2. The financial assessment should then be developed on top of this decision tree, and an analysis method can be used to determine the optimal decision paths in the tree, according to the critical uncertainties that will be resolved with the progress on the plan, thus generating a *dynamic plan*.

4. Dynamic business plan preparation.

   We propose a business plan-like report as the final deliverable of the evaluation process, since business plans are effective tools for the characterization and communication of business opportunities. Because there is no single optimal plan, but a set of multiple optimal paths dependent on the ways in which uncertainty is resolved, we suggest that this business plan be a *dynamic business plan*, in which the identification of critical uncertainties and relevant flexibilities, both *on* and *in* the project, is brought to the forefront of the analysis.

A.1.1 Opportunity Identification

The assessment of CVC investment proposals will usually address primarily criteria of strategic fit. This requires knowledge of the technology and business directions in the parent company and the technology venture (MacMillan et al. 2008). The possible combinations of technology and business components from both sources must therefore be examined for the identification of business opportunities that may be created from those combinations.

A.1.1.1 Describing Individual Technology-Implementation-Commercialization Linkages

We conceptualize the fundamental building block of high-tech business opportunities as Technology-Implementation-Commercialization (TIC) linkages (Figure 38) (Markham and Kingon 2004).

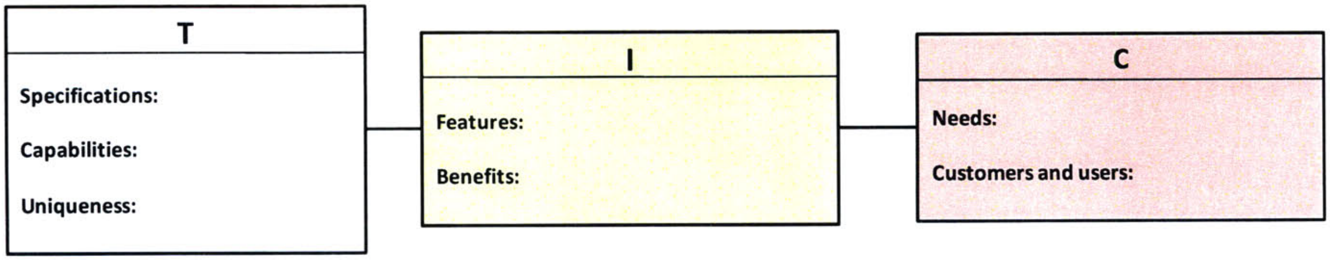


Figure 38: Technology-Implementation-Commercialization Linkage

The TIC linkages are created in a three step process:

1. Find technical advantages. The assessment team will start by identifying sources of technical advantage – higher performance, lower cost, or new, needed capabilities – that present significant improvements over alternative technologies, and uniqueness (difficulty to duplicate). The technical advantage is initially characterized in terms of *specifications* (measurable performance parameters) and then translated to *capabilities* (what the specifications enable a specific implementation of the technology to do).

2. Identify opportunities for commercialization. The team must then detect *needs* that the technical capabilities may address. This will provide the initial knowledge of the opportunities that is required to articulate an implementation and opportunity concept, in a way that offers plausible causality. Accordingly, these opportunities will not be the users, but the *circumstances* in which the users experience a *problem* (Christensen and Raynor 2003).

3. Create the concept of implementation. This should align the technical capabilities with the opportunities: the technical capabilities enable *features*, which in turn will enable *benefits* to the customers by providing *solutions* for their problems.

Because a single technology can be used to create many possible implementations for many forms of commercialization, TIC linkages will usually be presented in the form of a tree.
TIC linkages can be used to describe both the external source and the parent company's currently explored and potential opportunities (Figure 39: Individual Technology-Implementation-Commercialization Linkages) presents a situation with two technology sources in the parent company, and one external source).

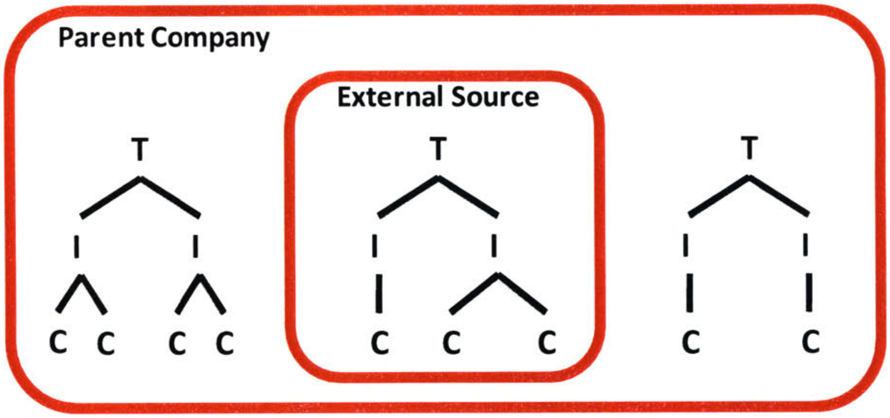


Figure 39: Individual Technology-Implementation-Commercialization Linkages

A.1.1.2 Combining Technologies, Implementation and Commercialization

Combining components of these linkages and subsequently developing new complete linkages provides a way to identify and articulate opportunities aligned with the previously outlined strategic objectives, by making use of the parent company's specific knowledge and capabilities,

The following is a list of examples of combinations, one for each of the three strategic objectives of CVC:

1. Leverage or upgrade existing competences through resource combinations and transfers – combining an external technology and a current use to provide an implementation with an enhanced customer value proposition that may enable addressing a new segment (Figure 40-a).
2. Reserve the right to operate in new technologies and forms of use – exploring new opportunities for commercialization from a new technical capability arising from the combination of technologies (Figure 40-b).
3. Develop a business value system of third-party implementers and complementors – providing a new use or service to a common needs (current or new), driving up the demand of an existing use (Figure 40-c).

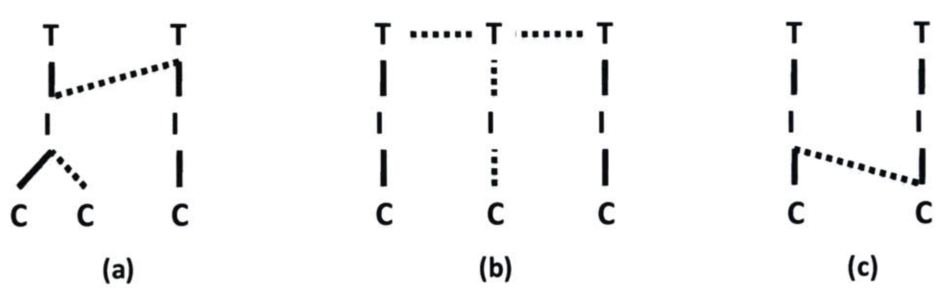


Figure 40: Combinations of Technology-Implementation-Commercialization Linkages

A.1.2 Opportunity Development

Each TIC linkage of the evaluated company or new TIC linkage is a building block for a form of commercialization and business concept that must now be developed in more detail.

The tool created to facilitate this work lists a number of strategic issues that must not be overlooked, identified in relevant literature (MacMillan et al. 1987, McGrath and MacMillan 2000, Kakati 2003, Van Mieghem 2008), and grouped according to areas that are usually considered in a business plan (Table 25).

Technology	Operations
Implementation	Sales and Marketing
Commercialization Opportunity	Team and Management
Regulation and Competition	Funding and Financials

Table 25: Classes of Issues for Opportunity Development

The design of the tool is also based on the key principles of the Discovery Driven Planning method (McGrath and MacMillan 1995): specification of business goals, characterization of uncertainties, and planning to reduce uncertainties.

A.1.2.1 Initial Analysis

For each issue, the team must specify:

4. The current position of the project – How does the project currently look?
5. The goal position for the project – How does the project have to look to deserve funding?
6. The development path for the project – How can the project be developed from its current position to the goal position?

For each of the previous points, the team should then:

5. Identify uncertainties in the assessment, i.e. assumptions, and express them as probability distributions of outcomes.
6. Determine how critical the reduction of the identified uncertainties is.
7. Identify alternatives to reduce the uncertainties and the corresponding cost.
8. Verify whether the uncertainties depend on other issues in the project.

Figure 41 shows the structure of the tables that support this analysis.

Issue	Assessment		Uncertainty	Addressing Uncertainty			
				How	Value	Cost	Dependencies
	Current						
	Goal						
	Develop						
	Current						
	Goal						
	Develop						

Figure 41: Structure of the Opportunity Development Tool

A. 1.2.2 Analysis Development

Once the initial analysis is complete, the team should:

1. Address the uncertainties that can be reduced within the time and resources available for the assessment. Most of this will be achieved with information gathering from researchers, industry experts, potential customers, suppliers, or partners, and other relevant information sources.

2. Address the remaining uncertainties. Some may be actively reduced with learning activities outside the time and resource constraints of the assessment, while others will be too costly or impossible to reduce, and will just naturally disappear with time and the evolution of the project. The team must identify inherent flexibility or appropriate flexibility investments to address these types of uncertainties.

The information regarding value, cost and dependencies of addressing uncertainties will be useful to prioritize these efforts.

As soon as information gathering is completed, the team will be faced with a set of certain and uncertain assessments about the current and the goal positions for the project, and the development path between both positions. The global assessment of the opportunity will be related to the ability of the project to successfully execute an overall dynamic plan to go from its current position to the desired position. If at any point, there is no such plan that is feasible or if the expected result of the best plan is a loss, the project should be canceled.

A.1.3 Dynamic Planning and Valuation

Addressing uncertainty requires considering alternative potential development routes and building the appropriate capabilities to enable managerial flexibility to pursue upside routes and limit losses in downside routes.

At the end of development, the team will have identified a structure for the technology-to-commercialization plan, as well as development paths in specific issues, for the opportunities under scrutiny. The opportunity plan is the tool that brings together the critical uncertainties, flexibility investment alternatives, and flexibility enabled responses to uncertainty. This *dynamic plan* should be the core of a business plan. It will be different from a *static plan* conceived to perform well in the "most likely" scenario (lower/higher initial costs, or lower/higher maximal/minimal performance), but it will be better suited to the certainty of uncertain conditions, by being able to perform well in more than one "most likely" scenario.

A.1.3.1 Decision Tree Construction

The decision tree construction process can be thought of as an iterative process that successively incorporates the most important uncertainty nodes and associated decisions. The tree rapidly expands with the number of uncertainties and decisions that are incorporated, and its analysis and interpretation become increasingly difficult. Hence, for practical purposes, parsimony is advisable, especially in the case where decision trees are used to guide general management decisions.

To develop the decision tree, the assessment team should:

5. Build the sequence of stages for the venture. Architecting such a sequence requires careful and logical consideration: the limits of the stages should include the times when managers are expected to make decisions on how to continue activities. An example of such a sequence is: research and development, prototype development, implementation of the technology and beginning of commercialization.

6. Incorporate investments in flexibility. Considering each investment at a time, the alternatives (including no investment) should be introduced as decision nodes, at the relevant point in the sequence. This turns a linkage between two stages into a decision node with different activity paths.

7. Incorporate uncertainties. The critical uncertainties identified in opportunity development should be introduced one at a time. In this case, a linkage between two stages becomes an uncertainty node with several different outcomes (usually a discrete set, although a continuous set can be defined).

8. Incorporate managerial flexibility. In order to consider the use of flexibility, decision nodes are placed after the corresponding uncertainty node. The decision node should reflect a decision management can make that will minimize the loss in performance associated with unfavorable outcomes, and improve performance by taking advantage of situations where the outcome is favorable.

A. 1.3.2 Planning and Valuation

Once the entire decision tree is completed, the assessment team will:

1. Develop standard financial analysis for each unique project path in the decision tree. This is a process that is greatly simplified and automated with the current level of integration between decision tree analysis and spreadsheet software, provided by packages such as TreeAge or Crystal Ball.

2. Use its favored financial performance criteria to guide choices at the decision nodes. Completing the set of choices in the decision tree creates a *dynamic plan* for the venture, which reflects management's ability to dynamically pursue alternative paths, reacting to new information as it becomes available.

   A dynamic plan is composed of a set of alternative sequences of conditional uncertainties and decisions, and is therefore characterized by a probability distribution of financial outcomes. In general, the team should at this stage choose the set of decisions that yield a preferred probability distribution.
   As an example, if the team is focusing on optimizing the expected NPV, DTA can be used to determine the optimal decisions at each decision node and, as a result, the optimal paths to pursue. For this situation, DTA will require analyzing the tree from leaves to root, computing expected NPVs at each uncertainty node, and choosing the option with the highest expected NPV at each decision node.
3. Perform *what-if* or sensitivity analysis, using the decision tree as a platform to investigate the impact of alternative decisions, or the robustness of the decisions to assumptions in the team's assessments.

A. 1.4 Dynamic Business Plan Preparation

The results of the previous phases should now be combined in an assessment report that will support a decision on the investment and an eventual move towards its implementation. We propose a business plan format for this report, with the content originating from the following inputs:

1. An opportunity section can be built from the core logic described by the TIC linkages.

2. For the sections on specific areas, the information gathered in the opportunity development phase, already grouped accordingly, will enable an appropriate characterization of where the venture currently stands, where it wants to be, the path to get there, and uncertainties and alternatives to address them.

3. A dynamic plan for the venture is available from the planning phase, with an overview of the most important investments in flexibility, the key uncertainties and the corresponding flexibility enabled decisions.

4. The financial performance indicators can be presented with the dynamic plan, and the underlying standard financial projections included as appendix.

Appendix 2: Technology Description Worksheet

Technology Description

Name technology	Concentrated Solar Power on demand (CSPond)
List technologists	Alexander Slocum, George Barbastathis, Jacopo Buongiorno, Charles Forsberg, Ahmed F. Ghoniem, T. Alan Hatton, Tom McKrell
Describe technology in scientific terms	A solar energy collector and storage system. Uses system of primary mirrors to focus sunlight to a single secondary mirror which then passes single concentrated beam to a graphite-insulated underground salt filled tank. The chloride/fluoride salt filled "pond" contains nano-particles that allow for controlled energy absorption and flux. Such a volume based ("bulk") storage method is superior to conventional (i.e. surface heating) methods because it allows for heat storage through a volume, increasing capacity and decreasing variability (in surface heating, top surface becomes superheated) of storage. Can operate at 1000 C (traditional solar collector systems @ 600 C), thus has higher operating efficiencies.
Describe what the technology does	Uses mostly existing technologies to come up with a better design for how to collect and store thermal energy. While old systems focused thermal energy onto an un-insulated boiler (through heat storage mechanism of surface heating), this design uses subterranean insulated ponds to store heat @ higher temperatures, more economically. CSPond systems thus use better materials (salts) and a better system design (light absorption through volume instead of surface) to deliver a more efficient and cost effective system.
Describe what the technology does not do	Does not deal with solar photovoltaic technologies. Does not create a fundamentally new technology; uses existing concepts to deliver superior design setup for thermal collection and storage.

Technology Advantage

In what way is the technology superior to other technologies?	Uses graphite-insulated molten salt ponds to capture and store thermal energy. This volume-based, insulated, storage mechanism allows for greater energy storage capacity, both in terms of higher peak temperature, and larger total quantity (volume based instead of surface based). It uses a new salt-base (chloride/fluoride base, which has superior operating qualities) for the molten salt. The nanoparticle-ladden salt is used to optimally capture and distribute thermal energy to the graphite-lined walls, where most of the heat storage takes place.
Describe the advantages of the technology	Does not require development of new technologies to implement. Only new tech, nanoparticles, can be built/designed currently. Can provide electricity continuously and at required levels (due to better storage capabilities and higher operating temperatures/efficiency). Has potential to be cost-competitive with existing coal-based plants with CO_2 sequestration. System parts can be optimized for differing environments. Have flexibility to change design parameters (i.e. size of ponds, number of mirrors, choice of materials) in order to have optimal design for given output requirements (i.e. power/energy requirements) and input constraints (solar intensity and intermittency)
List and describe possible applications	Energy capture and storage, applications in electricity sector, as well as industrial/residential. This is a new source of electricity that can be plugged into the grid. Can also be integrated into existing petrochemical based plants to increase environmental efficiency.
List and describe possible users	Progressive governments looking for alternative energy sources. Energy companies looking to gain a foothold in the alternative energy industry.

	If the technology is demonstrated to be economically comparable to coal/oil/gas facilities, users may include any private/public entity. It could be a "game-changing" technology.
Explain how a user would actually use the new technology	Would have to build a CSPond facility, much as one would have to build a coal plant in order to harvest energy. Thus, users (mostly private corporations/governments) would have to pick suitable sites that would have a suitable energy need (end users), and build the facility.
Discuss advantages to potential users of the new technology	Cost competitive with petrochemical source energy, while having a much smaller CO_2 footprint (still exists due to construction of optics/storage facilities). Have a sustainable (non-depletable energy source). Have energy security (not significantly affected by global events). Is not a radical new technology. While the system design is new (hence requiring research in optimal design of each of 4 main subsystems and analysis of integration), technologies are available for such a process.
Discuss platform implications for the technology. (Can the technology be a platform for multiple implementations?)	It is a platform in that the basic facility design can and should be modified for each case used (differing input constraints and output requirements). Since it uses a modular design for power creation, it can be added to (modified) power generating facilities (i.e. power plants) or even to industrial facilities that require large amounts of energy (i.e. desalinization plants).
Discuss patent efforts. (Is the technology patentable? Can the patent be policed? Can it be kept secret?).	This new design seems to be patentable as it offers a completely new design for a facility using solar thermal technologies. Based on a preliminary (though extensive) patent search conducted through the US Patent and Trademark Office (USPTO), it becomes clear that such a technology should

	definitiely be patentable (other innovations of similar scale were successfully patented in the 1990's and 2000's). Policing is subject to many factors. Where this technology is implemented (i.e. developing nations) should be taken into account. The complexity is assumed to be a natural deterrent for theft of information (difficult to understand complex system design). The basic idea does not seem to be a secret (already public information about the basic conceptual design). The secret lies in the analysis required to choose right materials, variables, sizes, etc., of all the components to make the system economically functional/superior. Such information will be the principle source of value, and proprietary to the companies investing in the venture.

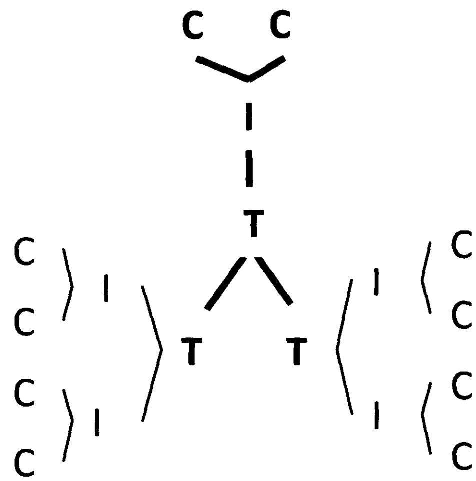
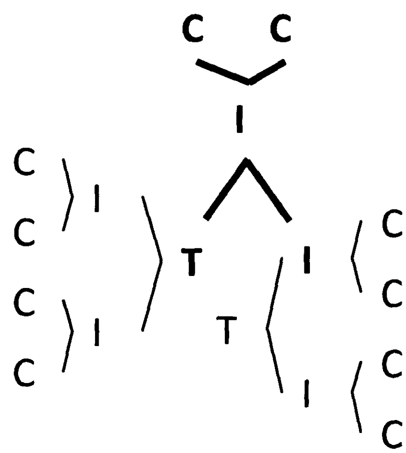
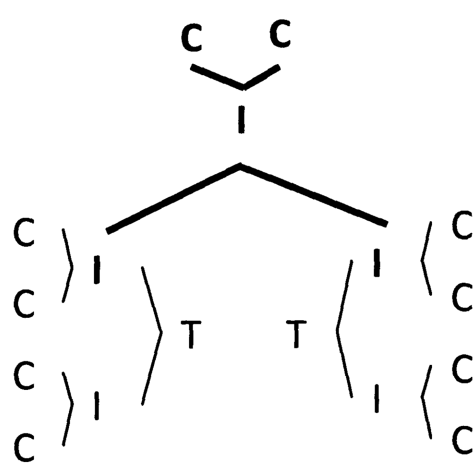
Level of Development

Describe technology's current stage of development	Conceptual design phase, with detailed description of future research needed in order to create first test system (in year 3 of project). Each PI (principle investigator) is responsible for research in 1 or more of the 4 components of the plant (optics, nanoparticle laden salt, receiver/storage tank, prediction/optimization of CSPond thermal environment). A 3-year timeline exists (year 1: subsystem research and optimization; year 2: system integration and optimization; year 3: test and design theory evolution).
Describe progress toward patenting the technology	Not yet known.
Describe technology's progress toward demonstrating commercial potential	Technology development remains in early stages, although theory and initial data points to solid improvement in efficiency (performance) and cost of such a system over traditional solar thermal facilities. This may happen in year 3, when a model demonstrated performance (hence no known demonstrated commercial potential yet).
Describe the owner's current ability to commercialize the technology	Contingent upon backing of commercial entities such as VC's, CVC's, etc. It seems there is interest from several companies in the energy sector (both alternative energy sector and oil & gas sector). Funding/support from at least 2 companies: Trinity Industries, and Fundacio b_TEC (Barcelona, Spain)

Technology Documentation

- Copies of any issued or submitted patents, disclosure statements, and trademark or copyright certificates.
- Copies of papers and/or new articles addressing this technology.
    - "Concentrated Solar Power on demand: CSPond" Report
- Presentation material on this technology.
- Other technical and descriptive information.

Appendix 3: 3 Common TIC combinations (Claro et al. 2008)

Type of combination	T-I-C network example
T – T A new technology arises from the combination of both technologies, enabling the development of a new T-I-C tree.	
T-I The infusion of the technology on an existing implementation results in a new version of the implementation, with improved performance, lower cost or a new function. This new version of the implementation can be directed to currently served commercialization opportunities, providing improved satisfaction, or to new commercialization opportunities, that couldn't be served previously.	
I – I The combined use of the two implementations results in an improved use of one of them, with improved performance, lower cost or a new function. This enables better serving current commercialization opportunities, or serving previously unaddressable commercialization opportunities.	

Appendix 4: TIC Scorecard

Each TIC Linkage's strengths should be assessed on each criterion, on a scale of 0-10. These criteria are adapted from Kakati, M. (2003).

Criteria	TIC Linkage 1	TIC Linkage 2	TIC Linkage 3
Characteristics of entrepreneurs			
Creativity			
Enthusiasm/capacity for work			
Competence in the field of endeavor			
Capability of sustained intense effort			
Ability to evaluate and react to risk well			
Ability to articulate in the discussion			
Attention to detail			
Familiarity with the target market			
Leadership quality			
Resource-based capability			
Managerial capability			
Technical capability			
Marketing capability			
Input sourcing capability			
Competitive strategy			
Quality strategy			
Cost strategy			
Innovation strategy			
Customization strategy			
Implementation characteristics			
Protection			
Market acceptance			
Developed to functioning prototype			
Early stage of development			

Commercialization opportunity characteristics			
Established distribution channel			
Untapped market potential			
Access to well-established distribution channel			
Opportunity growth rate			
Stimulate existing opportunity			
Familiarity with industry structure			
Competition present in the first years			
Creates a new segment			
Financial consideration			
Investment could be made easily liquid			
Sales			
Market share			
Marketing cost			
Production cost			
General and administrative cost			

Appendix 5: Opportunity Development Tool

* The highlighted issues are those that were used in the Opportunity Development section of the thesis

Intellectual Property:

Issue	Explanation of Issue	Assessment		Uncertainty	Addressing Uncertainty			
					How	Value	Cost	Dependencies
Possibility and enforceability of patent protection	Can a patent be used as a means of intellectual property protection for this technology?	Current						
		Goal						
		Develop						
Possibility and enforceability of copyright protection	Can copyrights be used as a means of intellectual property protection for this technology?	Current						
		Goal						
		Develop						
Possibility and enforceability of trade secrets	Can a trade secret be used as a means of intellectual property protection for this technology?	Current						
		Goal						
		Develop						
Possibility and enforceability of trade mark	Can a trademark be used as a means of intellectual property protection for this technology?	Current						
		Goal						
		Develop						

Technology:

Issue	Explanation of Issue	Assessment		Uncertainty	Addressing Uncertainty			
					How	Value	Cost	Dependencies
Uniqueness relative to competing technologies	How unique is the technology compared to existing technologies?	Current						
		Goal						
		Develop						
Potential for multiple applications	What is the platform potential of this technology?	Current						
		Goal						
		Develop						
Success of technology development	How successful is the development of this technology?	Current						
		Goal						
		Develop						
Stage of technology development	At what stage of development is the technology in?	Current						
		Goal						
		Develop						
Stage of technology demonstration	What level of technology demonstration has the technology undergone?	Current						
		Goal						
		Develop						
Market acknowledgement of technology relevance	Is there any proof from the market (acknowledgment) that this technology is desired?	Current						
		Goal						
		Develop						
Level of dependency on complementary technologies	What is the level of dependence that this technology has on other technologies?	Current						
		Goal						
		Develop						
Level of knowledge codification	Is knowledge tacit or explicitly documented?	Current						
		Goal						

Implementation:

Issue	Explanation of Issue	Assessment		Uncertainty	Addressing Uncertainty			
					How	Value	Cost	Dependencies
Network externality effects	The more customers in a network, the more value for each customer?	Current						
		Goal						
		Develop						
Positive feedback effects	Does the use of this implementation induce other potential customers to use it further in the future?	Current						
		Goal						
		Develop						
Implementation requires changes in infrastructure	What is the level of infrastructure (i.e. existing buildings, access to power transmission/water) change required to adopt this implementation?	Current						
		Goal						
		Develop						
Likelihood of establishing an early dominant design	How likely is this new implementation to maintain its dominance over related implementations?	Current						
		Goal						
		Develop						
Relevance and possibility of backward compatibility	How easily is this implementation incorporated or integrated with existing implementations?	Current						
		Goal						
		Develop						
Ability to influence thought leaders	How likely is this implementation to galvanize thought leaders to embrace/promote it?	Current						
		Goal						
		Develop						
Ability to set or benefit from standards	Are current industry standards set up in a way that benefits the use of this implementation?	Current						
		Goal						
		Develop						

Commercialization opportunity:

Issue	Explanation of Issue	Assessment		Uncertainty	Addressing Uncertainty			
					How	Value	Cost	Dependencies
Commercialization opportunity size	What is the commercialization opportunity size?	Current						
		Goal						
		Develop						
Commercialization opportunity growth	How quickly is the commercialization opportunity growing?	Current						
		Goal						
		Develop						
Sunk costs in older implementations	Are there any investments in previous implementations that cannot be recovered, and hence inhibit changing to a new one?	Current						
		Goal						
		Develop						
Recurrence of demand	How cyclical is the demand?	Current						
		Goal						
		Develop						
Experience of users with implementation	How experienced are the users with the use of this implementation?	Current						
		Goal						
		Develop						
Customers' perception of risk in adoption	What level of risk do customers believe that the incorporation of this implementation entails?	Current						
		Goal						
		Develop						
Base of experience required before widespread adoption	What is the expertise required from the user for effective use of this implementation?	Current						
		Goal						
		Develop						
Alignment between beneficiaries and buyers	Are beneficiaries and buyers the same entity? If not, what is their relationship?	Current						
		Goal						
		Develop						

Lead users exist and are identified	Do lead users (customers who are willing to buy product as soon as it is offered) exist, and have they been identified?	Current						
		Goal						
		Develop						
Ability to influence opinion leaders	Can the thoughts of opinion leaders be influenced?	Current						
		Goal						
		Develop						
History of supplying to this commercialization opportunity	What is the history of supply to this commercialization opportunity? Has it been sporadic, successful, large, etc?	Current						
		Goal						
		Develop						
Customer power	What is the customer's power (many alternatives, etc.)?	Current						
		Goal						
		Develop						
Implementation leverageable for other commercialization opportunities	Can the features of this implementation be used to tap other commercialization opportunities?	Current						
		Goal						
		Develop						
Commercialization opportunity leverageable for implementations	Can access to this commercialization opportunity be used to create other implementations?	Current						
		Goal						
		Develop						
Commercialization opportunity resources leverageable for communication (events, associations, word of mouth)	How easy is it to advertise this implementation in this commercialization opportunity?	Current						
		Goal						
		Develop						

Sales and Marketing:

Issue	Explanation of Issue	Assessment		Uncertainty	Addressing Uncertainty			
					How	Value	Cost	Dependencies
Level of education or training required	Is this implementation readily useable or does it require significant training/education?	Current						
		Goal						
		Develop						
Level of change required in usage patterns	Does the use of this implementation require a significant change in usage patterns for this application?	Current						
		Goal						
		Develop						
Level of customization required	How customized does this implementation have to be for each customer?	Current						
		Goal						
		Develop						
Transaction complexity and costs	How difficult and expensive is it to sell this implementation to a customer?	Current						
		Goal						
		Develop						
Distribution channels established	Have distribution channels been established? If not, how easy is it to establish them?	Current						
		Goal						
		Develop						
Ability to achieve critical mass with distributors	Can distributors reach a critical mass of customers for this implementation?	Current						
		Goal						
		Develop						
Freedom to access customers	How "protected" are customers (i.e. customer loyalty to other implementations, regulatory limitations, etc.)	Current						
		Goal						
		Develop						
Support service for users	What level of support services is required for the users?	Current						
		Goal						
		Develop						

Regulation and Competition:

Issue	Explanation of Issue	Assessment		Uncertainty	Addressing Uncertainty			
					How	Value	Cost	Dependencies
Regulatory environment	What is the status of relevant regulation for this technology, implementation, and commercialization opportunity?	Current						
		Goal						
		Develop						
Capacity of established firms to react	How able are competing firms to respond to this new implementation offering? Is it easy or difficult for them to change/adapt their operations?	Current						
		Goal						
		Develop						
Likelihood of competition for dominant design	How likely is a battle for a dominant design to occur? Will competitors' implementation designs co-exist with this one, or will there be a fight for a single dominant design?	Current						
		Goal						
		Develop						
Exclusionary business networks	Do existing business networks make it difficult for introducing a new implementation into this commercialization opportunity?	Current						
		Goal						
		Develop						
Direct competition	What is the level of direct competition?	Current						
		Goal						
		Develop						
Indirect competition	What is the level of indirect (i.e. from related industries) competition?	Current						
		Goal						
		Develop						
Motivation and capacity of competitors	How motivated are competitors to "fight" this new implementation? How able are they to put up a "bruising" fight?	Current						
		Goal						
		Develop						
Order of entry and lock-out effects	Is it possible for first movers to prevent other players from entering the industry?	Current						
		Goal						
		Develop						

Likelihood of imitation	How likely/easy is it for competitors to imitate this implementation?	Current						
		Goal						
		Develop						

Operations:

Issue	Explanation of Issue	Assessment		Uncertainty	Addressing Uncertainty			
					How	Value	Cost	Dependencies
Resources requirements	What are the resource requirements for developing/implementing this implementation? Significant?	Current						
		Goal						
		Develop						
Process requirements	What are the process requirements for developing this implementation?	Current						
		Goal						
		Develop						
Supplier power	Does the supplier have the "upper hand" in the contracts (materials may be in high demand)?	Current						
		Goal						
		Develop						
Availability and access to suppliers	Are suppliers available and accessible?	Current						
		Goal						
		Develop						
Supply costs	What are the supply costs for this implementation's components?	Current						
		Goal						
		Develop						
Supply response time	How quickly can suppliers respond to a delivery request?	Current						
		Goal						
		Develop						
Supply quality	What is the quality of the materials/implementations being supplied?	Current						
		Goal						
		Develop						
Supply range and volume flexibility	How wide is the range of implementations/materials that	Current						
		Goal						

	suppliers can provide? How easily can they supply large amounts of a implementation/material?	Develop						
Supply scalability	How scalable is the supply?	Current						
		Goal						
		Develop						
Infrastructure development (communication, transportation, distribution, service)	How developed are necessary infrastructure components for the creation/use of this implementation?	Current						
		Goal						
		Develop						
Costs to develop cospecialized or complementary assets	How expensive is it to develop complementary assets?	Current						
		Goal						
		Develop						
Cost of implementation assets	How expensive are the implementation assets (i.e. machinery, plants, other implementation facilities)?	Current						
		Goal						
		Develop						
Operations costs	What are the operating costs?	Current						
		Goal						
		Develop						
Operations response time	How quickly can operations respond to changes in implementation requirements?	Current						
		Goal						
		Develop						
Operations quality	What is the operations quality?	Current						
		Goal						
		Develop						
Operations flexibility in range and volume	How easily can operations be changed to respond to differing volume and range requirements?	Current						
		Goal						
		Develop						
Operations scalability	How easy is it to scale up or down	Current						

	operations (increase or decrease implementation levels)?	Goal						
		Develop						
Improvement/learning to reduce costs and improve productivity	What is the operations learning curve (ability to reduce costs and/or improve productivity)?	Current						
		Goal						
		Develop						
Power of organized labor	What is the power of labor unions for the required crafts/trades?	Current						
		Goal						
		Develop						
Access to skilled labor	How accessible is skilled labor for the required crafts/trades?	Current						
		Goal						
		Develop						

Team and Management:

Issue	Explanation of issue	Assessment		Uncertainty	Addressing Uncertainty			
					How	Value	Cost	Dependencies
Enthusiasm, courage and desire for success	What is the development team's level of enthusiasm, courage (risk attitude), and desire for success?	Current						
		Goal						
		Develop						
Creativity	What is the creativity level of the management team?	Current						
		Goal						
		Develop						
Work capacity	How much work can the development team do (limited by size and ability of team)?	Current						
		Goal						
		Develop						
Leadership	How strongly does the development team exhibit leadership?	Current						
		Goal						
		Develop						
Communication skills	How easily/masterfully does the development team communicate?	Current						
		Goal						
		Develop						
Size	What is the size of the development team?	Current						
		Goal						
		Develop						
Management expertise	How much management expertise does each member of the development team have?	Current						
		Goal						
		Develop						
Expertise in R&D and implementation development	What level of expertise in R&D/implementation development does the development team have?	Current						
		Goal						
		Develop						

Expertise in commercialization and customer service	What level of expertise in commercialization/customer service does the development team have?	Current						
		Goal						
		Develop						
Expertise in the industry	What level of expertise in the industry does the development team have?	Current						
		Goal						
		Develop						
Other expertise relevant to venture	Are there any other expertises that the development team can bring to the table?	Current						
		Goal						
		Develop						
Ability to evaluate and react to risk	How developed is the management team's ability to evaluate and react to risks?	Current						
		Goal						
		Develop						
Ability to manage collaboration and networking	How developed is the management team's ability to collaborate and network both within and outside of the firm?	Current						
		Goal						
		Develop						

Funding and Financials:

Issue	Explanation of Issue	Assessment		Uncertainty	Addressing Uncertainty			
					How	Value	Cost	Dependencies
Reputation with financial community	What is the development team's reputation with the financial community?	Current						
		Goal						
		Develop						
Access to low cost of capital	Does the development team have access to low-cost capital? How much?	Current						
		Goal						
		Develop						
Difficulty to make investment liquid	Can the investment be easily liquidated (sold off)?	Current						
		Goal						
		Develop						
Previous rounds of investment	What was the performance of this implementation or this development team in previous rounds of investment?	Current						
		Goal						
		Develop						
Future rounds of investment	What is the anticipated performance of this implementation or this development team in future rounds of investment?	Current						
		Goal						
		Develop						
Sales	What are the required sales levels? What is the sales performance level thus far?	Current						
		Goal						
		Develop						
Commercialization costs	What are the commercialization costs associated with advertising this implementation?	Current						
		Goal						
		Develop						

Production costs	What are the Production costs of this implementation?	Current						
		Goal						
		Develop						
General and administrative costs	What are the overhead (general and administrative) costs associated with running the company?	Current						
		Goal						
		Develop						
Profits	What are the profit levels of this venture?	Current						
		Goal						
		Develop						
Return on investment in 5 years	What is the ROI in 5 years for this venture?	Current						
		Goal						
		Develop						
Time to break-even	What is the time period required to break even (to recover investment cost in this venture)	Current						
		Goal						
		Develop						