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I. EXECUTIVE SUMMARY

This paper analyzes the founding and bankruptcy of Solyndra, LLC of Fremont, California. In 2005, Solyndra was founded by a technologist, Dr. Chris Gronet, based on semiconductor deposition method developed by Miguel Contreras at the National Renewable Energy Laboratory. Consequently, it was taken over by professional management with strong financial connection, access to approximately $3 billion including about half a billion dollars backed by the Department of Energy's loan guarantee.

Solyndra's competitive advantage was a large portfolio of patent protecting its Solar rod design which could be installed similar to florescent tubes used in lighting. Further during the period, Solyndra had a price advantage due to the high cost of polysilicon.

This paper identified three questions which are answered as of September 2009 (Date of Loan Guarantee):

1. In September 2009, should the Energy Department (i.e. U.S. Government) have made the $535 Million Dollar Loan a Guarantee based on Solyndra's technology and its prospects for success?

Solyndra's success was based on its unique technology which made it lower cost and easier to install than competition and had the added advantage of not using. In 2009, due to changes in economic condition, increased low cost imports from China, and the drop in the price of polysilicon, the economic prospects for Solyndra had diminished significantly. Therefore, it is reasonable to question the validity of the Energy Department's making a subordinated loan guarantee to Solyndra.

2. Would it have made a difference if the loan was unconditional rather than tied to FAB II?

The loan restrictions required that the company to make a large investment in a manufacturing technology and infrastructure that was already uneconomic in comparison to competitors' products and market demands. The shift from an entrepreneurial startup where flexibility is a critical success factor was removed since the loan guarantee forced Solyndra to continue to invest in FAB II even though the market realities had changed. An unrestricted loan would have allowed Solyndra to conserve capital, avoid building FAB II, reduce their "burn-rate", and perhaps avoid bankruptcy.

3. Should Solyndra have pursued a different strategy to survive and prosper?

Solyndra had grown their overhead much faster than their market, coincident with decreasing demand and increasing competition starting in 2008. Solyndra clearly had sufficient capital to invest in numerous forms of solar technology. By conserving cash, they could have acquired or partner with a traditional solar manufacturer at a discount during the eventual shakeout of smaller companies. Also, it would have provided Solyndra with additional time to re-position itself for success.

II. BACKGROUND

The United States has a vested interest in a stable and reliable supply of energy to businesses, citizens, and to the government. The management of energy began to form in the 1930's when the government sponsored such projects as Hoover Dam and the Tennessee Valley Authority. As industrial America grew during the 20th century and as the United States was involved in two world wars, petroleum energy became an increasingly important component of the American Industrial engine. Furthermore, petroleum-based energy is one of the few energy sources that could be import ed with relative ease. It was the availability of "cheap oil" during the first half of the 20th century that helped the U.S. industrial engine achieve such great success.

As a consequence, the price of oil has driven much of the United States energy policy during the past 60 years. The average price of oil had been $28.52 in 1948 (in adjusted 2010 dollars) and had remained in about the same levels over the next 50 years except for the oil spikes during the Middle East conflicts [19]. During the past 10 years, the price of oil has increased from approximately $30 per barrel to the current price of approximately $ 90-100 per barrel. (See Figure 1, "Crude Oil Prices, 2010 Dollars" [19]).

FIGURE 1 – Crude Oil Prices (2010 Dollars)

The 1970's energy shocks laid the foundation for government involvement in energy policy. From 1970 to the mid 1980's, the government invested significant money in energy conservation, shale oil energy conversion, coal gasification, photovoltaic energy and other energy sources. These investments did not result in any significant breakthroughs, but did result in some larger oil companies venturing into the alternative energy space. [20].

From the period of 2008 to present, a recent increase in the price of oil, coupled with a recession, has resulted in renewed interest in renewable energy. Furthermore, the promotion of the scientific theory of "Global Warming" has resulted in political and economic pressures to move from hydrocarbon fuel sources to alternative energy sources. This pressure resulted in tax credits in the United States for renewable energy. For example, the "boom and bust" cycle of wind power investments can be directly linked to Federal Tax Credits [21]. Federal Tax Credits are available when the United States Congress passes specific legislation that changes the tax code, the changes to the Code usually favoring a particular industry or technology. Investors then allocate financial resources to renewable energy startup companies based on demand driven by two sources: fundamental economic considerations and tax policy considerations.

FIGURE 2 – Cost per watt of Solar PV

At the same time the price of oil was rising, the price per watt of solar electricity was plummeting. (See Figure 2, [25]). This decrease in the price per watt of solar power gave solar proponents the ability to predict that at some point the cost of solar would significantly decrease.

As a result of these policy considerations (tax and otherwise), a significant amount of research and development has been invested in the last decade by universities, national laboratories, and private companies. This drive has been shared by numerous countries that view alternative energy as great source of clean energy and will result in employment for their citizens. The United States government is using public funding and policy to support the emerging alternative energy companies [11][12]. For example, on June 30, 2011, the US Energy Secretary Steven Chu announced that the Department of Energy will offer $4.5 billion in loans guarantees to three photovoltaic solar generation facilities.

This paper is focused on one photovoltaic company, Solyndra [15]. Solyndra's differentiator was a technology for capturing light using a cylindrical solar unit design using thin film solar cell technology. It was founded in 2005 by Dr. Ch ris Gronet who held many of the patents in development of a cylindrical solar energy collector in 2005. Brian Harrison, as CEO, then grew the company to over 10,000 employees with over $2.5 billion in funding. Solyndra was also very much in the public eye with a reception for President Obama at its factory opening of FAB II in May 2010. Harrison has since returned to Numonyx B.V, a Swiss manufacturer of integrated circuits.

In September 2009, a $ 535 Million Dollar loan guarantee was extended to Solyndra by Department of Energy. Less than two years later, in September 2011, Solyndra filed for bankruptcy. The ensuing scandal exposed that during Solyndra's short existence; it received over $2 billion dollars in private funding and a $535 million in federal loan guarantee, but was not a viable entity.

The technology management question is whether Solyndra should have continued to focus on their novel technology as a niche player, or use the investment capital to fund the manufacturing of panels that used conventional techniques.

III. KEY QUESTIONS

This paper will be analyzing the Solyndra case as of September 2009, the date Department of Energy extended the loan guarantee to Solyndra, in order to answer the following three critical questions:

4. In Sept. 2009, should the Energy Department (i.e. U.S. Government) have made the $535 Million Dollar Loan a Guarantee based on Solyndra's technology and its prospects for success?
5. Would it have made a difference if the loan was unconditional rather than tied to FAB II?
6. Should Solyndra have pursued a different strategy to survive and prosper?

IV. SOLYNDRA'S TECHNOLOGY

The conversion of solar energy into electricity can be technically solved by active conversion systems (the direct conversion of light into electricity) or passive conversion systems (the indirect conversion of light energy into electricity. In direct conversion systems, solar cells are typically fabricated as flat wafers (i.e. solar cells). These solar cells are mounted in grid fashion to form solar panels. Each solar panel is typically installed in a grid fashion on a structure to capture the sun's rays and convert the solar energy into electricity. The underlying material used to capture the solar energy can be silicon, cadmium telluride, cadmium sulfide, or other materials. All "solar panel" solutions have operating drawbacks. First, dirt and debris collects on the panel surface. Second the attachment of the panels to a surface (typically a roof) may damage the structural integrity of the roof, especially in periods of high wind and snow. Solyndra employed a key technical differentiator known as the solar rod. The advantage of the solar rod is that the solar installation is less expensive and produces more power than conventional panels. Solyndra's solar rod is shown below (see Figure 3):

Figure 3- Solar Rod

The solar rods are fabricated using a thin film semiconductor material. The semiconductor material is made of copper, indium, gallium, and selenium (copper indium gallium diselenide.) This thin film design is more efficient than conventional silicon technology with efficiencies as high as 19% [18]. Solyndra designs and manufactures the proprietary cylindrical modules.

The mechanical architecture of the rods allows sunlight to be captured in all radial directions. This 360-degree photovoltaic surface allows for the conversion of direct, diffused, and reflected sunlight into electricity. (See Figure 4).

Figure 4 – Light Absorption of Solyndra Solar Rods

The manufacturing process involved the deposition of the semiconductor material on an interior glass tube, then encapsulating the deposited material within another glass tube, and then making the electrical with electrical connections. The end product resembled a fluorescent light bulb. Miguel Contreras, senior scientist at the National Renewable Energy Laboratory, had developed part of the technology used by the semiconductor deposition method used by Solyndra.

Solyndra's key intellectual property is U.S. patent number 7,394,016 "Bifacial Elongated Solar Cell Devices with Internal Reflectors" [2][4][6][10]. The key claim in this patent involves a solar cells fabricated from (A) a plurality of elongated solar cells, wherein elongated solar cells in said plurality of elongated solar cells are arranged in a parallel or a near parallel manner thereby forming a planar array having a first face and a second face; and (B) a plurality of internal reflectors (see Figure 5). .

FIGURE 5 - Bifacial Elongated Solar Cell Devices with Internal Reflectors

This intellectually property was supported by manufacturing capacity. Solyndra initially built a fabrication facility in Fremont (FAB I). Later in 2010, a second and much larger facility was built in Fremont (FAB II). FAB II was much bigger with state of art manufacturing technology that is able to produce the "Solar Rods" in extremely larger volumes. The total manufacturing size after completion of FAB II reached 800,000 Square Foot [15].

As described earlier, a key selling point was that the new form factor that allowed for much denser and easier installation on commercial roofs. If the roof is painted white then the cylindrical shape is able to collect energy in 360 degrees and its form factor allows for easy installation and maintenance. Below is a picture of typical installation (see Figure 6).[15]:

Figure 6 – Solyndra installation form factor

Solyndra's solar rod design has many advantages for generating solar power on the flat rooftops of big-box stores, warehouses, and other commercial buildings. First, ordinary flat solar panels suffer from wind interference. Solyndra's panels are built of rows of rods that wind can pass through, decreasing wind loads and making it unnecessary to bolt or weigh down the panels. Second, the cylindrical design that absorb light in a concentric manner. This is contrasted with flat solar cells that work best with direct light. The Solyndra design does not require tracking systems as a part of the curved surface is facing the sun directly resulting in absorption of the large share of the solar energy. Furthermore, with highly reflective white roofs, the non exposed part of curvature can also absorb reflective light expanding the exposure.

Solyndra's cylindrical design also collected less dirt, water, snow and other airborne particles resulting in a cleaner surface [15]. Research shows that energy loss due to soiling on Solyndra systems is approximately half of that for conventional flat panels. (See Figure 7).

FIGURE 7 – Effect of rain and dirt

Solyndra's founder and CEO, Chris Gronet, predicated that within a few years, the company plans to produce solar systems that generate electricity competitive with the average cost of electricity in the United States (about 10 cents per kilowatt-hour) by optimizing manufacturing and increasing production volumes.

It is this novel technology that resulted in significant VC and government investment. It was this over investment in an ea rly stage technology that led to poor decision making and over expansion of overhead before the market was ready to absorb the overhead.

V. MARKET & COMPETITIVE LANDSCAPE

Solyndra received numerous awards and recognition including appearing on the MIT Technology Review list of the "50 Most Innovative Companies in the World", the 2010 Wall Street Journal list of the "Top 10 Venture-backed Clean-Tech Companies", and Wall Street Journal list "The Next Big Thing: Top 50 Venture Backed Companies", and a 2009 Excellence in Renewable Energy Award from Renewable Energy World Magazine [15]. Solyndra claimed to have over 1000 installations in 2011. Additionally, Solyndra had the advantage of a large patent portfolio to protect their manufacture and installation value proposition.

In September 2009, at the same time when Energy Department made the loan guarantee and the company was impacted by important economic trend. The price of polysilicon, a key input component in making traditional flat panel solar panels, had been increasing for several years. .Solyndra's technology did not use the polysilicon as contrasted with its main competitors in China and Europe which gave Solyndra a significant advantage. It was estimated that polysilicon compromised 25% of the input costs. The lack of use of polysilicon gave Solyndra a tremendous input cost advantage. This advantage plus the fact that its panels were cheaper to install than other types of panels was great competitive advantage [12].

But the price of polysilicon did not stay elevated for long. Polysilicon prices decreased sharply from February 2008 ($47 5 per kilogram) and to May 2009 ($73 per kilogram) [12]. This price reduction was apparently not factored into the economic projections presented for the loan guarantee. This noticeable lack of due diligence shows that before Solyndra had received the September 2009 federal loan guarantee, a major part of its cost proposition had been undermined, if not eliminated completely.

Meanwhile, the Europeans and Chinese were investing tens of billions dollars in support of their solar industries both in the form of sponsoring manufacturers, but also by giving credits to consumers of the panels. Unfortunately, the use of subsidies as a basis for the business model was fundamentally flawed. As countries such as Italy, Spain and Germany cut back dramatically on their subsidies for solar power (due to the credit crunch) this precipitated a slow-down in solar consumption which started in 2008. This slow-down dramatically reduced demand for the solar cell output which resulted in an oversupply as the demand for solar power dropped.

By late 2009, when the Obama administration was finalizing its deal with Solyndra, the perfect storm was in place as it relates to Solyndra's opportunity to succeed:

- Price of solar panels had dropped by half due to reduction in price of polysilicon and the increased production from the heavily subsidized Chinese manufacturing working on reducing the last pennies out of their conventional technology.

- Demand for solar panels had been reduced due to economic slowdown and loss of government subsidies for solar power installation.
- Solyndra has borrowed and spent beyond the proven market potential to build facilities with over 800,000 feet of manufacturing floor. At capacity, it would produce 1 million cylindrical solar modules per week. This far exceeded any proven demand for its product and major reason for the hugh financial burden on the company.

VI. ANALYSIS

The Analysis is focused on the decisions made during the time period of September 2009. This was the date that the Department of Energy's guaranteed financial guarantees for FAB II. In 2009, Solyndra was developing a new technology that competed with a highly subsidized Chinese manufacturing base. The Chinese manufacturing base enjoys two benefits: access to cheap capital and low labor costs. Furthermore, the Chinese government had made it a priority in emphasizing renewable energy (China is heavily dependent on foreign oil and has little domestic production). Also, in 2009, the market for energy in general and for solar energy specifically was depressed due to the world economic slowdown that started in 2008.

10. SWOT ANALYISIS of SOLYNDRA'S PROSPECTS FOR SUCCESS

A Strength Weakness Opportunities and Threats (SWOT) analysis of Solyndra's position as of September 2009 would have allowed the government to better evaluate the decision to make the loan guarantee (see Figure 7). A SWOT analysis involves creating a grid that identifiers the internal strengths and weaknesses (the top quadrants) and the external opportunities and threats. This creates a qualitative visual aid in determining the risks and benefits of the opportunity.

Strength	**Weakness**
• New technology with large patent protection • Does not use of polysilicon • Large manufacturing facility, ability to scale rapidly	• Too big of cost structure for the proven market • Executive focus on publicity and funding rather tha market development • Overfunding encouraged overspending on overhea • Loan Tied to FAB II
Opportunities	**Threats**
• Lower cost of installation • Ease of installation and maintenance • Job Creation in California • Utilize existing capital investment and unique technology to address specialized application (i.e. high wind applications)	• Chinese subsidized manufactures with lower cost o and labor • Solar panel market softness reduces demand • Large capital investment, causing a unsustainable rate

FIGURE 7 – Solyndra SWOT Analysis as of September 2009

The SWOT analysis as of September 2009, clearly illustrates significant risks to Solyndra's business model. First the weakness quadrant indicates that Solyndra had grown too big resulting in excessive expenses [26]. These expenses were directly related to the building of FAB II (the large manufacturing plant). The majority of the FAB II expenses were related to equipment that was used to fabricate the solar panels and not to expenses related to facilities acquisition (acquisition of real property). Further, as this manufacturing equipment was proprietary, it is unlikely to have significant resale value to other manufacturers. From the point of view of any person who provided credit to Solyndra, this would have been extremely risky, as the assets may have only been able to sell for less than scrap value.

11. ANALYSIS OF WHETHER THE INVESTMENT SHOULD HAVE BEEN UNCONDITIONAL

The key motivator for the building of FAB II was the extension of credit by the Energy Department. The credit was extended with the condition that FAB II be constructed. This requirement served one important goal of the government: that "jobs" would be created in the 2010 timeframe. The unfortunate aspect of this was that FAB II credit additional overhead expenses that made the panel fabrication uneconomical. First, new fabrication facilities are expensive to fabricate and test. During construction, knowledgeable production engineers would be called upon from the current production to help with assembling the new fabrication lines. This "talent borrowing" would further lower existing product ivity.

12. ANALYSIS OF SOLYNDRA'S STRATEGIC OPTIONS

Only a decade earlier, Silicon Valley experienced a classic "bubble", known as the "dot com bubble". As money was extended to companies with dubious business strategies, the valuation of startup corporations soared until 2000, and then collapsed in 2001. Silicon Valley was faced with a wave of corporate bankruptcies. But a number of successful companies escaped the dot-com bubble by conserving investors cash, laying off all but key employees, and then followe d-up by making strategic acquisitions at fire-sale prices.

Here, Solyndra had plenty of capital in 2009. It was clear that a "solar bubble" had formed that would result in the bankruptcies of smaller manufacturers. Solyndra could have used the cash to diversify their product line to other, less risky, product configurations (such as "flat panels"). Additionally, Solyndra could have widen its technology advantage by investing on the next generation products. This would have allowed Solyndra to benefit from both types of technologies and allow itself additional time to re-position for survival and success.

VII. GOVERNMENT's REACTION TO SOLYNDRA

There is view that the government involvement was due more to the members of Solyndra having political influence than to the inherent advantage of Solyndra's superior technologies. This criticism has often been leveled at defense contractors at the end of major military conflicts. A classic example was the Hughes H-4 Hercules heavy troop transport aka "Spruce Goose" that was finished after World War II. The Government's investment in a large plane that was never used in WWII led to a political firestorm and eventually Howard Hughes testimony in front of a Senate subcom mittee. [24].

There is some evidence that RockPort Capital Partners was the 4th largest investor in Solyndra and reportedly used its seat on a Pentagon technology panel to promote Solyndra for a US Navy Contract. [23]. Other ancillary evidence exists of "improprieties", but no conclusive "smoking gun" has emerged. Although the President's visit to the Solyndra Factory in 2011 (just prior to bankruptcy) was politically embarrassing, President Obama was able to place the blame of Solyndra on Energy Secretary Chu.

As there is no financial exposure to government officials for the misallocation of taxpayer funds (with the exception of lowered prospects of reelection), there is little incentive to allocate those funds to commercially viable projects. The real risk is that the improper allocation of capital will remove engineers from pursuing more viable projects that have a higher rate of return and/or better impact on technology. One way to reduce this potential impact is to invest in a number of market participants with similar technological underpinnings. This type of investing reduces the downside risk, but along diminishes potential upward gains.

For example, on June 30 2011, the Energy Department provided loan guarantees, of approximately $4.5 billion, to support three alternating current Cadmium Telluride (Cd-Te) thin film photovoltaic (PV) solar generation facilities. These recent announcements were of the same magnitude as Solyndra. For example, the Department of Energy was involved in no less than three major projects: 1) a conditional commitment for a $680 million loan guarantee to support the Antelope Valley Solar Ranch 1 project; 2) and a conditional commitment for partial loan guarantees of up to $1.88

billion in loans to support the Desert Sunlight project; and 3) conditional commitments for partial loan guarantees of $1. 93 billion in loans to support the Topaz Solar project. Interestingly enough, First Solar, Inc., with headquarters in Tempe, Arizona, is sponsoring all three projects and will provide Cd-Te thin film solar PV modules for the projects from a new manufacturing plant that has begun construction in Mesa, Arizona, as well as from its recently expanded manufacturing plant in Perrysburg, Ohio, which serves as its primary hub for engineering, research and development.. This creates a no-lose situation for the Energy Department, insofar that one of their "bets" (e.g. investments) is bound to succeed.

It is not surprising that one of the many renewable-energy projects supported by loan-guarantee programs and the 2009 federal stimulus bill—which budgeted $45 billion for energy—would fail. The U.S. Department of Energy's loan guarantees program is designed to fund innovative, cutting-edge companies. Such companies are risky, and some inevitably fail, as any venture capitalist can tell you (hence the need for a federal guarantee in the first place). Even more predictable is that the downfall of Solyndra is being held up by politicians and some in the media as an excuse to question federal support for clean energy.

VIII. Conclusion

This paper identified three key questions and here are conclusions with respect to each of the three questions:

a. In Sept. 2009, should the Energy Department (i.e. U.S. Government) have made the $535 Million Dollar Loan a Guarantee based on Solyndra's technology and its prospects for success?

Solyndra's success was based on its unique technology which made it lower cost and easier to install than competition and had the added advantage of not using. In 2009 due to a change in economic conditions, increased low cost imports from China, and the drop in the price of polysilicon, the economic prospects for Solyndra had diminished significantly. Therefore it is reasonable to question the validity of the Energy Department's making a subordinated loan guarantee to Solyndra.

b. Would it have made a difference if the loan was unconditional rather than tied to FAB II?

The loan restrictions required that the company make a large investment in a manufacturing technology that was already uneconomic in comparison to competitors' products. The shift from an entrepreneurial startup where flexibility is a critical success factor was removed since the loan guarantee forced Solyndra to continue to invest in FAB II even though the market realities had changed. An unrestricted loan would have allowed Solyndra to conserve capital, avoid building FAB II, reduce their "burn rate", and perhaps avoid bankruptcy.

c. Should Solyndra have taken a different strategy to survive?

Solyndra had grown their overhead much faster than their market coincident with decreasing demand and increasing competition starting in 2008. Solyndra clearly had sufficient capital to invest in numerous forms of solar technology. By conserving cash, they could have acquired a traditional solar manufacturer at a discount during the eventual shakeout of smaller companies.

Finally, it is important for the government to provide leadership and support for universities, basic/applied research and streamlining regulatory and policies to support development of new technologies and businesses. But government due to its size, levels of decision making and need to set and follow long-term policies is ill suited to the entrepreneurship and new business investment. New business and entrepreneurship requires flexibility to adapt quickly to the market and technology shifts. Most successful business dramatically change their strategy multiple times from their founding until they find success in the market. The loan guarantees and its associated restrictions were impediment to Solyndra's success by reducing its flexibility!

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