Investment Bubble: Exploration of the Clean Technology Industry

By

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Abstract

The clean technology industry (including recycling, renewable energy, information technology, green transportation, electric motors, green chemistry, lighting, etc) has been one of the fastest growing sectors, and billions of dollars have been poured into the industry from investors and governments worldwide. Having been through two boom-bust cycles in the 21st century alone, many investors are worried whether the industry is worth the investment. The concern mainly comes from overheated investment into the industry and investors' overly high expectations. This study will compare the clean technology industry with the dot-com industry in 2000, and perform an industry valuation analysis and then compare the result with the current investment level. By building a discounted cash flow model of selected companies in the solar photovoltaic (PV) sector, the equity value is calculated and compared with the current market cap of the company set. In addition, this thesis will see what assumptions have to be met for the current investment level, and whether those assumptions are realizable.

Key words: energy, renewable energy, clean technology, solar PV, investment bubble,

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1. Introduction

The Renewable Energy industry (including recycling, renewable energy, information technology, green transportation, electric motors, green chemistry, lighting, etc) has been one of the fastest growing sectors. Accordingly, the magnitude of investment has been growing immensely. Investment in new renewable capacity increased from 40 billion in 2005 to 211 billion in 2010, which represented a 39% year over year increase. Another indication is the venture capital investment into the industry, as venture capital and private equity investment can profoundly encourage technology innovation and the diffusion of it (Florida and Smith, 1990). Venture capital investment totaled $2.9 billion in 2006, which represented a 78% increase over the 2005 investments of $1.6 billion and a 140% increase over 2004 investments of $1.2 billion (Koester, 2007). Despite a drop in the overall investment in 2008, it still achieved a 40% increase in 2007 (Subramaniam, 2009). Moreover, due to the energy shortage concern, governments across the globe have been pouring billions of dollars into the industry. This abnormal investment growth can be found in most of the investment bubbles in history. As a result, many investors are concerned that the renewable energy industry is the next investment bubble. The clean technology today and the technology industry in 2000 are very similar, since both are based on technological breakthroughs to change people's lives globally. As a result, when assessing the investment bubble in the renewable energy industry, an examination of the dot-com bubble would give us some insights.

This research is carried out to evaluate the investment bubble of the renewable energy industry. The main approach of this research will be to examine the context first and build a valuation model on a specific sector in the industry based on the knowledge on the environment. To examine the context, I need to first take a closer look at the dot-com bubble to find how and why the bubble was formed, and look into whether the renewable energy industry is showing similar trends. Then I analyze traits of different sectors in the renewable energy industry and find a promising sector to build the valuation model on. Lastly I perform some sensitivity analysis to test different assumptions and their impact on valuation. General economic background is the main theme to be studied in detail in the dot-com bubble.

The purpose of testing the investment bubble of the renewable energy industry is to avoid the tragedy of wealth evaporation. Studying the experience of the dot-com bubble will allow investors to examine their own investment behaviors and have a better understanding of the rationale of public investment. By better understanding the investment activities, investors will be able to make better decisions and be more cautious about an over-heated investment opportunity, thus avoiding the potential disaster. From government's perspective, understanding what factors trigger over-heating investment will make them more cautious when making policies and provide more appropriate guidance to investors. For companies, they can better position themselves against a possible bankruptcy situation.

This thesis will add much to the academic world. Up to now, there are few scholarly articles that examine the investment overheat of the clean tech industry, so my research would be able to add to this field, and potentially encourage more studies around the topic. It will also create a framework in terms of analyzing the investment in an industry. It creates a way of building revenue for the solar energy industry, and it applies the DCF (discounted cash flow) model (typically used on individual stock) to an industry. Furthermore, this research paper provides a potential answer to the decline of investment deflation in the renewable energy industry since 2008.

The rest of the paper is organized as follows. Section 2 of this prospectus reviews the literature on the dot-com bubble in 2000 and also the current condition of the renewable energy industry together with different traits of important sectors. This includes some research reports from multiple authoritative sources, including U.S. Department of Energy and REN21 Renewable Energy Policy Network. The next section provides the details about how I build the valuation model which includes the hypotheses I plan to test, a description of measures that I need to test on and how I collected the data. The fourth section includes the actual analysis of the data. In the final section I draw conclusions from the analysis and revisit the assumptions made with some sensitivity analysis to explore other assumptions.

2. Literature review

The main purpose of this section is to show how the existing academic literature provides a framework for my research on whether the clean technology industry is the next dot-com bubble. As mentioned in section one, past work has not looked at my question specifically, but there is extensive research on different technologies and policies in the renewable energy industry and also on the analysis of the dot-com bubble. Therefore some academic articles will be on the topic of the dot-com bubble in 2000, which will provide me with a structure of why and how the bubble was formed and the catalyst; the rest of the articles will be on renewable energy industry to provide ideas about promising sectors and as well as data to be applied into the model. Thus this section is divided into three parts: economic background comparison, analysis of the renewable energy industry, and applying the model to test the investment bubble.

2.1 Economic Background and Society Influence on the Technology Industry Growth

To forecast whether there is investment bubble in a certain industry or not, it is crucial to understand the context that the industry is in and how that will influence the industry in the future. At the beginning of the technology industry, the entire industry was booming fast, which triggered the investment overheating of the industry (Goodnight & Green, 2010). This trend can be found in all past industries that went through the boom-bust cycle. Economic bubbles appear when the economy is booming and there is abundant credit in the economy for business, and the dot-com bubble started in this situation in the 1990s in the US. (Goodnight & Green, 2010) Three elements included in his argument are general economic booming, government investment in the industry, and the promise of a bright future by the general media. In the 1990s, the Federal Reserve interest rates were lowered, and foreign capital was attracted to the US. Restrictions on the investment and commercial banking were also weakened or removed, and 30 billion dollars of Cold War peace dividends were redirected toward an "Information Superhighway" that promised to link ''computers in Government, universities, industry and libraries'' (Goodnight & Green, 2010, p. 122). Big name media reported the digital revolution as a zillion dollar industry and that the sweeping innovations would change all aspects of people's lives (Goodnight & Green, 2010). This is closely related to my research topic because this will help me understand the potential risk for the renewable energy industry to overheat in the future, and compare the two industries' different contexts.

First of all, the renewable energy industry is deemed as the solution to the energy crisis. It is estimated that oil and gas reserves will last for about 46 and 59 years, respectively, at current production rates, while coal will last for about 118 years. Nuclear energy is far from a perfect substitute not only because it is dangerous and costly, but also because the CO_2 emission from the entire process is comparable to an equal-sized gas burning power plant (Van Leeuwen and Smith, 2005). Thus the best option that's left for us is renewable energy. This is shown in the global theme of "go-green" and the government support of the industry. After the Fukushima nuclear disaster in 2011, environmental activists are pushing for bolder steps to further commercialize the renewable energy technologies.

That leads to the second pattern of potential bubble environment: government support and investment. While only a few countries had support policies in 1990s, the number of countries more than doubled from 55 in 2005 to 118 in 2011, and governments all over the world have been advocates for the industry. In 2011, developing countries invested more than developed countries in clean technologies, and this shows that there are even more global government supports than in the dot-com bubble. One of the reasons behind the policies supporting the development of the renewable energy is the potential that it will create new industries and new jobs (Martinot, 2012).

Even with the financial crisis, the global new investment in the renewable energy industry has constantly increased year after year for the past 6 years from 22 billion in 2004 to 211 in 2010, which represented a 46% annual growth in investment (see figure 1). With the recovery of the economies and incentives from the government, institutional investors are better positioned to invest. In the US, with quantitative easing and operation twist policies, the interest rate is at its historical low for the past 60 years. This is very similar to the dot-com bubble time. Most of the corporations have much cash on their balance sheets and can borrow money at a cheap price; thus, the investment activities have been very active. With a global “go-green” theme, big corporations have invested heavily in renewable energy initiatives, and this will substantially help industry growth. With all the factors mentioned above, it is reasonable to assume the growth in the investment trend will continue in the foreseeable future.

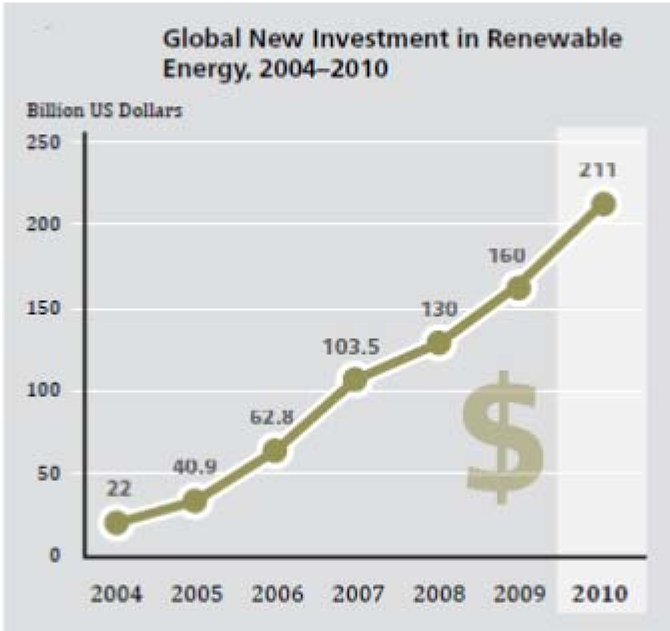


Figure 1. Global New Investment in Renewable Energy, 2004-2010
Source: REN21 Renewables 2011 Global Status Report

The only complication in the matter is the debt crisis in the US and Europe, which creates a shortage of government funding for innovation projects. However, this can be mostly offset by the private sector interest.

From the three factors examined above, the economic condition seems to be good for potential formation of an investment bubble. As a result, I will look into the renewable energy industry in more detail and identify key technologies to focus on next.

2.2 Renewable Energy Industry Analysis

According to International Energy Agency, there are three generations of renewable energy technologies (IEA, 2007):

- The first generation is the group of technologies that are widely in practice, including hydropower, biomass combustion, geothermal power and heat.

- The second generation is the group under research and development, partially under commercialization, including solar heating and cooling, wind energy, solar photovoltaic, and modern forms of bioenergy.
- The third generation is emerging technologies that are still under development, including concentrating solar power, ocean energy, enhanced geothermal systems, and integrated bioenergy systems (IEA, 2007 Annex II).

In both the *Renewables 2011 Global Status Report* and *The Economics of Renewable Energy,* different technologies are examined in great detail including their current conditions and future outlook.

One characteristic that most of the renewable energy technology has in common is its large fixed costs up front and low or even no variable cost, since most of their energy comes from nature. With the mixture of different costs, the price of the end product, energy, is typically higher than traditional non-renewable power plants. Table 1 is a brief summary of the typical plant capacity and cost; by comparison: in 2010, the U.S. average electricity retail price per kilowatt-hour is 9.83 cents (EIA, 2012).

Status of Renewable Energy Technologies: Characteristics and Costs

Technology	Typical Characteristics		Typical Energy Costs (U.S. cents/kilowatt-hour)
Power Generation			
Large hydro	Plant size:	10 MW–18,000 MW	3–5
Small hydro	Plant size:	1–10 MW	5–12
On-shore wind	Turbine size:	1.5–3.5 MW; Rotor diameter: 60–100 meters	5–9
Off-shore wind	Turbine size:	1.5–5 MW; Rotor diameter: 70–125 meters	10–20
Biomass power	Plant size:	1–20 MW	5–12
Geothermal power	Plant size: Types:	1–100 MW; binary, single- and double-flash, natural steam	4–7
Solar PV (module)	Efficiency:	crystalline 12–19%; thin film 4–13%	–
Solar PV (concentrating)	Efficiency:	25%	–
Rooftop solar PV	Peak capacity:	2–5 kW_{peak}	17–34
Utility-scale solar PV	Peak capacity:	200 kW to 100 MW	15–30
Concentrating solar thermal power (CSP)	Plant size: Types:	50–500 MW (trough), 10–20 MW (tower) trough, tower, dish	14–18 (trough)

Table 1. Status of Renewable Energy Technologies
Source: REN21 Renewables 2011 Global Status Report

Geoffrey Heal examined the economics of different technologies in detail, based on a different measure: levelized cost of electricity, or lcoe. This is defined as: “the constant price at which electricity would have to be sold for the production facility to break even over its lifetime, assuming that it operates at full capacity” (Heal, 2009). Since this is only internal cost, to get the full picture, I also need to take the external cost, including CO_2, SO_2 emission, etc., into consideration. Table 2 is the social cost estimation in Europe conducted by the European Commission. Intuitively and shown in the graph, the renewable energy technologies social cost is substantially lower than the conventional technologies.

EXTERNAL COST FIGURES FOR ELECTRICITY PRODUCTION IN THE EU FOR EXISTING TECHNOLOGIES[1]
(IN € CENT PER KWH*)

Country	Coal & lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	PV	Wind
AT				1-3		2-3	0.1		
BE	4-15			1-2	0.5				
DE	3-6		5-8	1-2	0.2	3		0.6	0.05
DK	4-7			2-3		1			0.1
ES	5-8			1-2		3-5**			0.2
FI	2-4	2-5				1			
FR	7-10		8-11	2-4	0.3	1	1		
GR	5-8		3-5	1		0-0.8	1		0.25
IE	6-8	3-4							
IT			3-6	2-3			0.3		
NL	3-4			1-2	0.7	0.5			
NO				1-2		0.2	0.2		0-0.25
PT	4-7			1-2		1-2	0.03		
SE	2-4					0.3	0-0.7		
UK	4-7		3-5	1-2	0.25	1			0.15

* *sub-total of quantifiable externalities (such as global warming, public health, occupational health, material damage)*
** *biomass co-fired with lignites*

Table 2 External Cost Figures for Electricity Production in the EU
Source: Geoffrey Heal, 2009

Below (figure 2) is a graph of the renewable energy share of global energy consumption for 2009. The most attractive technologies are being discussed further in the following text.

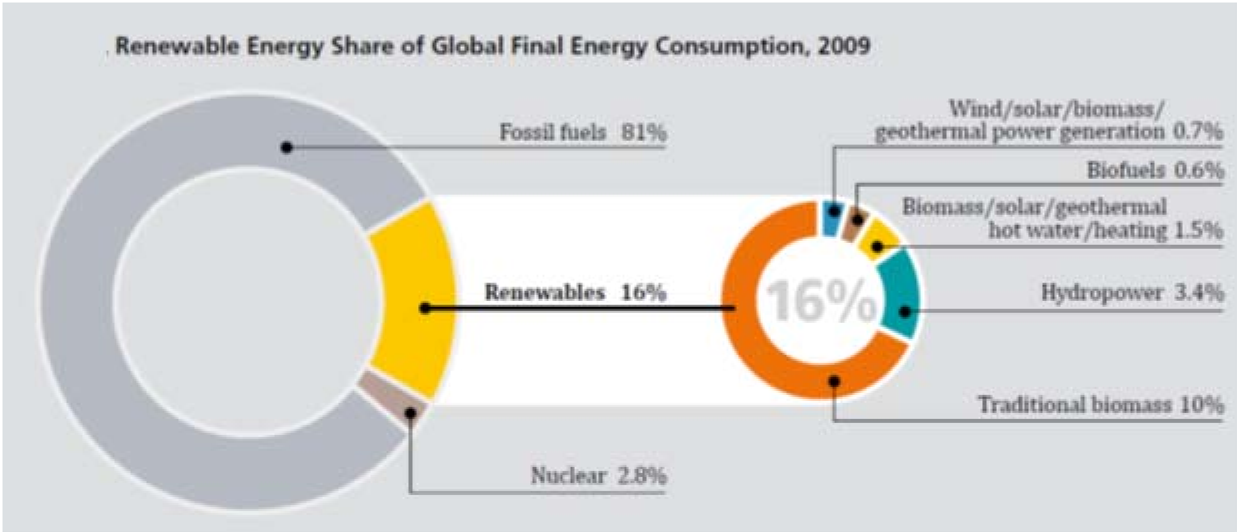


Figure 2. Renewable Energy Share of Global Final Energy Consumption
Source: REN21 Renewables 2011 Global Status Report

Traditional biomass is the largest component of the renewable energy source, making up 62.5% of the total renewable energy consumption in 2009, which represents 16% of the total global energy consumption. Traditional biomass is used in two ways: direct consumption or conversion into energy products like biofuel. Direct usage, such as combustion, is marked with low efficiency and unsustainability and is only used for non-commercial purposes (Goldemberg, 2004). The conversion into energy products, otherwise known as indirect usage, is not a source of power but rather a replacement for fuel. Corn-based ethanol is one example, but it has been more of an excuse for agricultural subsidies than for environmental and power purposes due to its low efficiency and effectiveness (Hahn and Cecot, 2008). According to Geoffrey Heal (2009), sugar-based ethanol is more competitive with gasoline when the oil price is within the range of $50-60 per barrel, and land does not seem to be a restricting factor. Since traditional biomass does not generate electric power and this research focuses on power providers, further discussion is beyond the scope of this paper.

The second largest component of renewable energy sources is hydropower, providing 21.25% of all renewable energy consumption, or 3.4% of global energy consumption (see figure 2). It includes hydropower, wave and tidal energy. Shown in Table 1, hydropower is very competitive with electricity costs. However, due to the complexity of the ecosystem and the hydropower system's impact on it, the trend now is removing hydropower stations rather than building more. Similar to hydropower, wave and tidal energy both try to capture the kinetic energy of moving water even though the equipment is quite different, and both of them are under experiments. Even though the cost is likely to fall with experience, it depends vastly on unusual geological structures. As a result, it's more likely to provide energy for local usage rather than meeting global demand. (Martinot, 2012)

Wind/solar/geothermal power generations are grouped together as they only represent 0.7% of global energy consumption and a small percent of the renewable energy consumption: 4.375% (see figure 2). Nevertheless, their growing potentials seem to be more promising.

Geothermal technology has been in use for a long period of time, and it is based on the theory that temperature under the surface of the earth is constant. This heat is extracted by circulating water downwards to heat it up, and the only cost is the electricity used to pump water. Technologies associated with the process include: dry steam, flash steam, binary, and Enhanced Geothermal Systems (EGS). The first three technologies take advantage of the natural process in which water is heated by hot porous rocks, while EGS pumps cold water to fracture hot underground rocks and forms a reservoir to heat it. In principle, this power source is enough to meet the entire power demand. Moreover, power can be constantly generated, avoiding the intermittency problem posed by solar and wind. However, there are disadvantages to all the technologies above; dry steam, flash steam and binary are restricted to seismically active areas, while EGS requires deep drilling, which is very difficult in practice. Furthermore, it is suggested that the EGS sites could be cooled through heat extraction and become unusable over a decade (Heal, 2009).

Wind energy is very widely used in practice; it converts the kinetic energy of the moving air into a usable form of energy. The kinetic energy is proportional to the third power of wind speed, which means stronger winds contribute significantly to wind power generation. Wind energy is further divided into on-shore wind and off-shore wind, with off-shore winds typically being stronger than on-shore winds. Since wind is stronger in areas that are distant from population where the demand lies, the grid that transports the electricity is a necessary infrastructure. Thus even though wind is much stronger and more regular at off-shore locations, the grid investment to transport electricity makes it more expensive to use an off-shore wind farm (Heal, 2009). Besides grid investment, the other factor restricting the use of wind energy is intermittency, since enough energy cannot be generated to meet the demand when wind is not strong enough. Nonetheless, wind energy is one of the energies that are most competitive with coal in terms of cost.

Last but not least, solar energy also plays an important role in the renewable energy field. Solar energy is abundant, “The energy in sunlight striking the earth for 40 minutes is equivalent to global energy consumption for a year” (Zweibei 2008). Another merit about solar energy is that unlike wind energy, it can be extracted from anywhere on earth. Thus, the main issue is how much energy can be captured and how efficiently can I convert it into a usable form. There are currently two types of solar renewable technologies: solar photovoltaic (PV) and concentrated solar power (CSP). Solar PV collects solar energy with photo-electric panels and generates electricity directly, while CSP concentrates sunlight with mirrors and use it to generate high-temperature heat to drive a turbine to produce electricity. Solar PV is currently more widely used and the cost is expected to be competitive with coal in the period 2015 to 2020. Nevertheless, it introduces significant intermittency issues, when sunlight is not sufficient in cloudy days or in the evenings, solar energy cannot be extracted while electricity usage reaches its peak. This has been a main barrier for solar energy to be the base load energy source, which are the energy plants that will produce at least the minimum amount of power for customers. Instead, it has been mostly peaking power plants which only handle the spikes in customer demand. On the other hand, CSP conversion is much more efficient; thus the cost is lower than solar PV. Even though intermittency issues are also presents in CSP, it could be potentially overcome by converting solar energy into melted sodium chloride (Heal, 2009).

From the research above, solar energy seems to have the most potential to be the energy of the future; however, the investment in the infrastructure and ways to solve intermittency issue (e.g., energy storage) are key to its success. For the purpose of this paper, since CSP is still under development, solar PV will be the focus to test investment bubble.

2.3 Investment Bubble Identification

Lubos and Pietro (2005) argued that there was no investment bubble in the late 1990s in the technology stock, and the high valuation is due to the uncertainty in the earnings of the stock. They used the Gordan growth model as an illustration: $P/D = 1/(r-g)$, with P as the stock price, D as the next dividend payment, r the discount rate and g the dividend growth rate. When g is uncertain, which represents the uncertainty of the future, P/D rises significantly as the uncertain increases because $1/(r-g)$ is convex in g. They then applied this idea to a different model: market value to book value of equity (M/B). They run the model with estimated and observed inputs, and they find the Nasdaq price in the late 1990s can be justified with the increased risk, which is due to some traits of the technology and the market at that time.

Furthermore, the model can also produce the price drop after reaching the peak, which they believe is due to the lower realized profit, causing investors to revise their expectation of future profitability downwards. In fact, the model produced an even larger price decline than observed (Pastor, 2005). The method they used may not be directly applicable to my research, but it did inspire me to choose the model used in this paper.

3. Study Design

My thesis is to examine the rationality of the investment level in the renewable energy industry. Inspired by Lubos and Pietro (2005), the research will be conducted on aggregate information, namely, the industry level. The discounted cash flow model (DCF) will be used to estimate the rational investment level, and the total market cap of the companies will be used as a comparison. I can also use the model backwards, namely, to get to the current market capitalization, the assumptions being made, and test the possibility of the implied assumptions. Some of the inputs of the model include: revenue growth or net income growth, annual depreciation, capital investment, change of working capital, discount rate, and capital structure.

First of all, I need to pick a number of companies that are good representations of the industry. After examining the indices that are tracking the industry, I decided to use the RENIXX® World index. It is a global stock index composed of the world's 30 largest companies of the renewable energy industry with more than 50% of revenues coming from the wind energy, solar power, bioenergy, geothermal energy, hydropower or fuel cell sector (International Economic Platform for Renewable Energies 2012). Nine of the firms specialize in wind energy, and 15 specialize in solar energy. According to REN21, among the 15 solar companies, nine of them has market share of more than 2%, and those nine companies will be the focus set of the companies representing the industry.

Net Income Growth

For net income growth, sales revenue is first estimated through the industry growth and the market share of the companies in focus. Industry growth can be reasonably and accurately estimated by using authority sources like the U.S. Department of Energy. Lastly market share is estimated by examine the concentration of the industry and historical patterns.

Depreciation and Capital Investment

The depreciation rate is derived from the capital investment, which is based on the stage of the company. With the estimates from the authority sources, I can estimate when the industry will mature and require less capital investment.

Working Capital

Since the industry is very investment heavy up front, the on-going capital needed is very minimal so is the change, thus for the purpose of this model, I assume that change in net-working capital will be zero.

Capital Structure

For capital structure of the industry, I will take a look at the current capital structure and use the average leverage as the industry norm. Over the course of industry maturity, I will deleverage the industry as it decreases the construction of the power stations and pay back debts.

Discount Rate

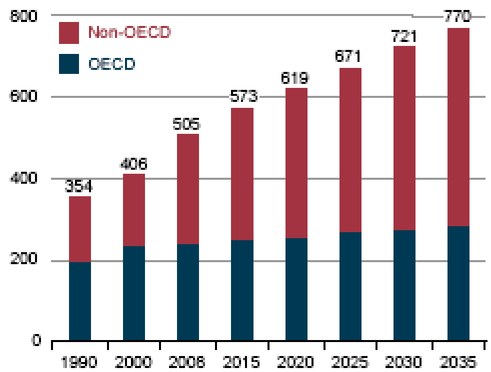
For the discount rate, weighted cost of capital is used here with most of the inputs(cost of equity, cost of debt, tax rate) being the average of all companies. Conversation on risk-free rate and market premium has been under discussion for years; for simplicity purpose, I used 3.5% for risk free rate, and 6.0% as market risk premium. This is used by the Carlson Growth Fund, and it is within the consensus reasonable range.

The advantage of the DCF model is it is widely used in the academic and practical world, thus it is easily understood by the audience. The advantage of this method is that it avoids predicting the probability of an individual company's success. Since I look at the industry, the competition among companies becomes unrelated and the prediction of the industry is relatively more estimable. Another advantage is the flexibility of the model. This means that I can fix certain factors and come up with an implied output and test whether it is within a reasonable range.

The disadvantage is the accuracy of the inputs. Since most of the inputs/drivers are estimated, it is only possible to lock them in a reasonable range rather than having a fixed number. Besides, most of the prediction can only account for the conservative condition; it excludes the possibility of any significant technology breakthrough that can possibly take the industry to another level. This may result in lower reasonable investment as there are investors that are speculating on the technology breakthrough. Since I am testing the investment bubble of the industry, to minimize the impact of this shortfall, the estimation will be in favor of generating higher valuation of the industry. Sensitivity analysis will also be performed at the end of the study to complete the research.

4. Analysis

According to the study design above, I first look at how much energy solar power generation will provide in the future. According to the International Energy Outlook 2011 by the EIA, world energy consumption has been and will be growing at roughly at 1.7% (see table 3 and figure 3).



Year	OECD	Non-OECD	Total	Growth
1990	198.6	155.1	**353.7**	1.39%
2000	234.5	171.5	**406.0**	2.76%
2008	244.3	260.5	**504.7**	1.84%
2015	250.4	323.1	**573.5**	1.56%
2020	260.6	358.9	**619.5**	1.62%
2025	269.8	401.7	**671.5**	1.45%
2030	278.7	442.8	**721.5**	1.30%
2035	288.2	481.6	**769.8**	1.30%
			average	1.74%

Table 3, Figure 3 World Energy Consumption 1990-2035(quadrillion Btu)
Source: International Energy Outlook 2011

In the meantime, electricity generation will be growing at around 2.5% for the next 10-15 years, and renewable energy source like wind and solar will be growing at 5% for the same period (see table 4 and figure 4).

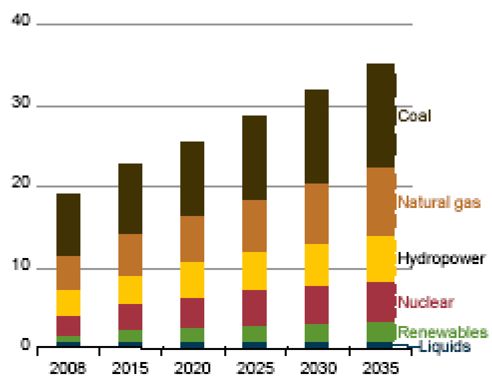


Figure 4, World net electricity generation by fuel type 2008-2035(quadrillion btu)
Source: International Energy Outlook 2011

	Liquids	**Other renewables**	**Nuclear**	**Hydro-electricity**	**Natural gas**	**Coal**	**Total**
2008	1.0	0.5	2.6	3.1	4.2	7.7	**19.1**

2015	0.9	1.3	3.2	3.8	4.9	8.5	**22.7**
2020	0.9	1.8	3.7	4.5	5.6	8.9	**25.5**
2025	0.9	2.1	4.2	4.8	6.5	10.2	**28.7**
2030	0.8	2.4	4.5	5.2	7.5	11.5	**31.9**
2035	0.8	2.6	4.9	5.6	8.4	12.9	**35.2**

	Other renewables	**Total**	**Total Growth**	**Renewable Growth**	**Renewable %**
2008	0.5	**19.1**			2.83%
2015	1.3	**22.7**	**2.4%**	**13.4%**	5.78%
2020	1.8	**25.5**	**2.4%**	**6.5%**	7.03%
2025	2.1	**28.7**	**2.4%**	**3.6%**	7.47%
2030	2.4	**31.9**	**2.2%**	**2.2%**	7.47%
2035	2.6	**35.2**	**1.9%**	**1.8%**	7.42%

Table 4, World net electricity generation by fuel type 2008-2035(quadrillion Btu)
Source: International Energy Outlook 2011

According to the Renewables Global Status Report 2011, in 2010, the renewable power capacity for the world was 312 gigawatts, while the solar PV existing world capacity was 40 gigawatts. This implies that solar currently takes up 12.8% of the total existing capacity. Applying that percentage into the table above, I can assume that solar generated electricity of 12.8%*0.5=0.064 quadrillion btu. Since the industry is highly fragmented, like mentioned before, with the help of RENIXX® World index and market share information (figure 5), nine top companies in the industry are grouped together for the purpose of the analysis. Those nine companies include: Suntech Power, First Solar, JA solar, Trina Solar, Yingli Green Energy, Q-Cells, Motech Industries, Renewable Energy Corp (REC), and SunPower. Those companies together, which is the subject of this paper, make up 40% of the market share, thus I can estimate that they produced 0.064*0.4 = 0.0256 quadrillion btu.

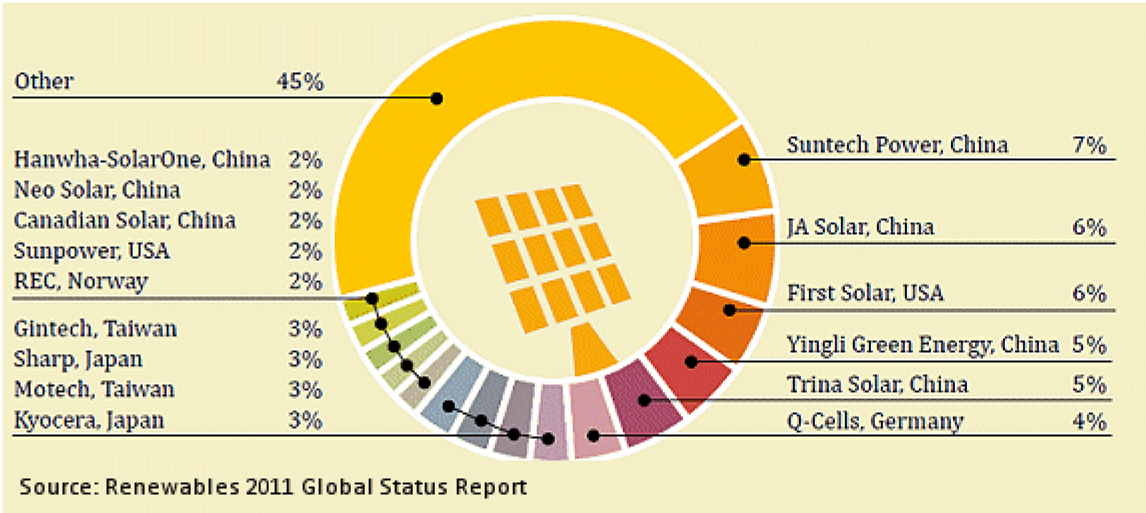


Figure 5, Market Shares of Top 15 Solar PV Cell Manufacturers, 2010
Source: REN21 Renewables 2011 Global Status Report

In order to make it more comparable to the electricity generation by other sources, thus I need the production in kWh, I can make use of the capacity information. To calculate the annual revenue of the solar PV industry, added capacity instead of existing capacity is used, as all the existing solar manufacturer business models are selling the modules. These modules generate new capacity, instead of selling the output: electricity, which depends on existing capacity. According to the 2011 Global Status Report, the added capacity of Solar PV in 2010 is 17 GW globally. When the sunlight generates electricity on the solar cells, it creates direct current (DC), and to use the electricity generated, I need to convert it into alternating current (AC) since most of the home devices use AC instead of DC. In the report “Solar Energy Technologies Program -- Multi-Year Program Plan 2007-2011”, the U.S. Department of Energy stated that the typical conversion efficiency nowadays is 95%, rising from 90% in 2005, with limited improvement upside of 97% in 2020. As a result, the total capacity to generate usable electricity is

$$17 \text{ GW} * 95\% = 16.15 \text{ GW}$$

Also from “Understanding the Cost of Solar Energy”, I can estimate there are approximately 3.6 peak sunlight hours per day, which is the equivalent amount of time in a day when solar irradiance averages 1,000 w/m^2. This factor varies based on the geographical location and the weather, but for the purpose of the analysis, I use it as a proxy to calculate annual electricity generation. With 365 days a year, the existing capacity will generate:

16.15 GW * 3.6 hours * 365 days = 21,221.1 GWh = 21,221,100,000 kWh.

According to Solarbuzz, the solar electricity cost is 16.59 ¢/kwh for the industrial installed system in February 2011 in sunny climates, and it continues to decline each month. In the meantime, industrial end-users spent $1.96 million out of the overall spending of $2.24 million, which represents 87.31% of the total spending (see table 5). For simplicity, I round up the cost to 17 ¢/kwh for 2010 due to higher costs of residential and commercial users and higher costs historically. Since the costs of the users are the revenue of the sellers/manufacturers, the estimated revenue of the industry is:

21,221,100,000 kWh * 17 c/kWh / 100 c/dollar = $3,607,587,000

Solar Electricity Sunny and Cloudy in US cents per kWh			
Residential Installed System	$14,810	↘	-1%
Sunny Climate	30.96	↗	1%
Cloudy Climate	68.11	↘	-1%
Commercial Installed System	$269,353	↘	-2%
Sunny Climate	21.28	↘	-2%
Cloudy Climate	46.83	↘	-1%
Industrial Installed System	$1,955,330	↘	-1%
Sunny Climate	16.59	↘	-1%
Cloudy Climate	36.49	↘	-1%

Solar Energy sosts for end users 2011
Source: Solarbuzz

With the average product life span of 15 years, the sales revenue of the modules of the industry should be:

$3,607,587,000/year * 15 years = $54,113,805,000

With the nine companies taking up 40% of the revenue of the industry, the total revenue of the nine companies should be:

$54,113,805,000 * 40% =$21,645,522,000

This is in line with the reported total revenue of $18,192,734,800 of the nine companies, according to Bloomberg. The error could be due to the rough assumption with the efficiency, market share, cost of energy and the average life span. This confirms the assumption that the revenue depends on the added capacity, which can be used to predict the future revenue growth. With the same formula, I can identify the key factors that will influence the revenue growth in the future: market share of the nine companies, the cost of energy, and added capacity; below I will examine each factor carefully.

A. Market Share:

According to the EIA, the number of solar PV cell/module manufacturers has increased very quickly from 2004 to 2009, from 19 to 101, which represent a 40% annual growth in the number. As a result, the market is getting more fragmented as more companies have access to the license for building solar plants. In the meantime, to generate the economies of scale, some companies are also getting bigger through integration and organic expansion. The industry doubled in revenue from 2007 to 2008, and the nine company set in the set lost to the new manufacturers for two years, while slowly recovering their market share in 2010 (see table 6). Rather than predicting which company will be the industry leader and which one will go bankrupt, 40% will be used as the average market share for the nine companies through the life span of the company set. With this number, it is assumed that by calculating the market share with the possibility of different scenarios (they all go bankrupt or they are the only survivors in the industry with a total of 100% market share and anything in between), the aggregate market share is 40%.

	2009	2008	2007
Industry Revenue(millions)	38,647.0	37,631.0	15,295.0
9 company set(millions)	10,719.72	11,368.56	6627.89
Market Share	27.7%	30.2%	43.3%

Table 6. Market Share for 2007-2009
Source: Bloomberg and Frost & Sullivan

B. Cost of Energy

By using the formula to calculate the revenue earlier backwards, the cost of energy for the past few years can be estimated. The implied growth represents a 13.1% annual decrease from 2008 to 2011. From a Solarbuzz chart, I can see the trend is continuing in 2012, with the cost decreasing month by month. According to Frost & Sullivan, "the module prices are likely to decline at a CAGR of 9.7% from 2010 to 2017" (101), and this rate can be directly transferred into the cost of energy. I will use 3% after 2017 (for comparison purposes, the annual decline in 2017 is 7.5%). This is intended to capture the slim chance of technology breakthrough taking place in the near future that will significantly decrease the price of solar energy.

C. Annual Added Capacity

From table 7 I can see wind growth was faster historically, however, starting from 2003, solar has been growing faster than wind with accelerated growth rates. This trend will continue in the foreseeable future. With the existing growth rate of solar and wind, together with the estimate of the renewable energy industry growth, I estimate that by 2030, solar will take up 33% of the total renewable energy capacity.

Existing World Capacity	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Solar	0.7	0.8	0.9	1.2	1.4	1.8	2.2	2.8	3.9	5.4	7	9.5	16	23	40
Growth		14%	13%	33%	17%	29%	22%	27%	39%	38%	30%	36%	68%	44%	74%
Wind	6.1	7.6	10	13.5	17.4	24.2	31.3	39.4	47.6	59.3	74.6	94	121	159	198
Growth		25%	32%	35%	29%	39%	29%	26%	21%	25%	26%	26%	29%	31%	25%

Table 7, wind and solar power, existing world capacity 1996-2010(gigawatts)
Data extracted from Renewables Global Status Report 2011

According to Frost & Sullivan, even though the industry will still grow at a rapid pace, the growth level in 2010 is not sustainable. They estimated that the global PV market will grow at a CAGR of 25% from 2010 to 2017. As a result, I set the estimates at 25% between 2011–2017, 10% between 2018-2020, 5% between 2021-2025 and 4% between 2026-2030, and I assume that it will grow at 2% in perpetuity after 2030; this is in line with the EIA estimates. The ladders are set to match with the EIA estimates of the total renewable energy industry growth. In the meantime, experts have estimated that the average module lifespan will increase to 20 years in 2015.

With the assumptions above, the industry revenue is predicted as below, along with the estimates of Frost & Sullivan.

Industry Revenue (in millions)	**My Prediction**	**Frost & Sullivan**	**Company Set**
2011	$ 37,023.95	$ 45,758.70	$ 14,809.58
2012	$ 43,719.59	$ 40,963.40	$ 17,487.84
2013	$ 42,110.71	$ 43,226.50	$ 16,844.28
2014	$ 45,295.64	$ 46,119.70	$ 18,118.26
2015	$ 55,545.88	$ 51,645.90	$ 22,218.35
2016	$ 59,901.53	$ 59,820.70	$ 23,960.61
2017	$ 73,773.99	$ 68,791.80	$ 29,509.60

Table 9. Industry and Company Set Revenue Prediction (2011-2017)

The prediction created with my model is very consistent with that of Frost & Sullivan with some minor differences, so this can work as a support of the model used.

By looking at the past net income of the company set that was created, the net income percentage seems to have very little variation year after year. As a result, for simplicity purposes, I will use 12% to yield the net income from annual revenue.

	2010	2009	2008	2007	2006	2005
Net Income	3690.3735	-1660.6902	2011.9304	1334.2451	540.3693	94.8923
Net Income %	12.1%	(14.0%)	14.1%	14.9%	15.4%	7.7%

Table 10. Net Income Analysis

In order to calculate the value of the company set, I need to calculate the annual free cash flow (FCF), thus interest expenses (after tax), depreciation, capital expenditures and other non-cash expenses are adjusted to net income. The cost of debt for the companies is calculated using the interest expenses each year divided by the average liability of the company, the conservative average interest rate for the nine companies is 4% (see table 11).

	2010	2009	2008	2007	2006	2005	2004	2003	2002
Cost of Debt	4.2%	5.1%	3.7%	3.9%	3.5%	5.2%	5.3%	3.6%	4.5%

Table 11. Cost of debt Analysis

To take out the tax shield (10%) from the interest expense, I only add back 90% of the interest expense. Assuming the amount of debt will grow at the same pace as the revenue growth, I adjust the net income with the after tax interest expense amount. Before discussing the other adjustments, I will take a look at the historical cash flow.

No trends or patterns were identified for the relationship between revenue/net income and capital expenditure and other non-cash expenses. However, as a general rule, capital expenditures are intended to increase future revenue. When the revenue increases, companies are selling more modules, thus they need more manufacturing capacity, thus capital expenditures will increase. By looking at the future revenue/capacity growth of the company set, I identify that the revenue will peak out in 2017. After that, the industry will be growing at a slower pace, so manufacturing capacity need not be expanded. With all the assumptions from the EIA and Frost & Sullivan, I can reasonably expect the industry will be mature in 2017. There is huge volatility in the non-cash expenditures for the past couple years (see table 12). Instead of predicting the trend, I will assume that after the industry becomes mature in 2017, the non-cash expenditure adjustment to free cash flow is negligible. Thus FCF after year 2017 will be the after-tax interest adjusted net income.

Millions	**2010**	**2009**	**2008**	**2007**
Non-Cash Adjustment	-1511.4975	1448.5707	-1891.1202	-966.7584

Table 12. Non-cash adjustments to FCF 2007-2010

Historically, almost all of the nine companies have been generating negative cash flow since they went public, and the aggregate absolute amount has been growing until 2008 when it peaked at -3.5billion, which forced them to take a substantial amount of debt. It then shrank to 405million in 2010 as the economy went sour. For 2011, only two out of nine companies reported enough information as of 03/07/2012 to calculate FCF, and it already amounted to -951million. Inferring from this, it is very unlikely that the cash flow will turn positive before 2017 during the expansion. To make an aggressive estimate, my predictions for FCF is -500million for 2012 and 2013, -300million for 2014 and 2015, -100million for 2016 and 2017, and afterwards it will equal after-tax interest adjusted net income. This is very aggressive compared to historical values, and it will generate a favorable valuation for the company set.

The last number needed to calculate the present value is the discount rate. Weighted Average Cost of Capital model is used in this analysis. Capital structure, cost of equity and cost of debt are needed for the calculation. Since the companies have been generating negative cash flow, it is not expected that they will deleverage any time soon. So for simplicity and inferred from the past debt structure of the firms, I will set the Debt/Asset ratio to 45% going forward.

	2010	**2009**	**2008**	**2007**	**2006**	**2005**
Debt/Assets	46.6%	49.1%	43.4%	34.8%	30.2%	46.1%

Table 13 Debt Structure 2002 - 2010

Cost of debt has been calculated previously to be 4%. Cost of equity is calculated using the Capital Asset Pricing Model: Re = β * Rp + Rf. Beta (β) is the sensitivity of expected return to the market expected return, Rf is the risk free rate, and Rp is the risk premium. β is the weighted average beta of the nine companies (see table 14), which is 1.47 as of February 2012. Since there are no universal values for those, I'll use the average number the public use. Risk free rate is set to be 3.5% and risk premium is 6%; this is consistent with the Carlson Growth Fund (the biggest student fund in North America).

	beta	**market Cap (millions)**	**Weights**	**beta prop**
Suntech Power	1.83	558.51	7.48%	0.136820621
First Solar	1.39	2,793.50	37.40%	0.519796069
JA Solar	1.39	316.16	4.23%	0.058828969
Trina Solar	1.78	612.07	8.19%	0.145844686
Yingli Green Energy	1.60	589.57	7.89%	0.12627718
Q-cells	1.80	81.61	1.09%	0.019631838
Motech Industries	0.72	896.99	12.01%	0.086214747
Renewable Energy Corportaion	1.74	738.02	9.88%	0.17170677
SunPower	1.73	883.74	11.83%	0.204663374
	1.47	7,470.17		

Table 14. Beta Analysis as of 02/07/2012

Thus Cost of equity for the company set is:

$$Re = \beta * Rp + Rf = 1.47 * 6\% + 3.5\% = 12.32\%$$

WACC then is:

$$WACC = E/V * Re + D/V * Rd * (1-T) = 55\% * 12.32\% + 45\% * 4\% * (1-10\%) = 8.396\%$$

Discounting all the predicted future cash flows with this discount rate, I get to an enterprise value of 9.335 billion. With minimal cash on their hands and the 45% D/A ratio, the implied aggregate equity value is 5.134 billion for those nine companies.

5. Discussion

As I can see from the table (see table 14) above, the current market cap for the company set is 7.47billion, which is almost 50% of overvaluation. For the equity valuation to match the current market investment level, the company will have to generate a cash flow of 39% more than the after-tax interest expense adjusted net income, which is neither unlikely nor sustainable in the long run. Furthermore, this is based on very conservative assumptions. If the cash flows are kept at -500million until 2017, which seems more reasonable given the track record, the equity value would be 4.686billion, indicating a 60% overvaluation. Moreover, investment in the industry has already decreased by 22.5 billion, which represents a 75% decline, over the past two years with the financial crisis (see table 15). The valuation in 2009 should be been even lower as there were two substantial negative cash flows added in and all positive cash-flows are even more distant in the future.

(millions)	market Cap (Feb 2012)	Market Cap (Dec 2009)	Decrease %
Suntech Power	558.51	2980.78	81.3%
First Solar	2,793.50	11400.86	75.5%
JA Solar	316.16	963.4	67.2%
Trina Solar	612.07	1881.88	67.5%
Yingli Green Energy	589.57	2348.22	74.9%
Q-cells	81.61	1920.16	95.7%
Motech Industries	896.99	1431.12	37.3%
Renewable Energy Corportaion	738.02	5137.98	85.6%
SunPower	883.74	2298.68	61.6%
Sub Total	**7,470.17**	**30363.08**	**75.4%**

Table 15. Market Cap Analysis (Dec. 2009 v.s. Feb. 2012)

Another variable in the model that is hard to predict is the perpetuity growth rate. It's currently set at 2%, the same number as the renewable energy growth rate and the energy growth rate after 2030 estimated by the EIA. To get to the current valuation of the company set, and keep all the other factors fixed, the perpetuity growth rate will have to be 6%. Since the EIA has estimated that the renewable energy will not outgrow other energy sources (coal, natural gas, nuclear, etc.) after 2030, the solar energy sector will have to outgrow other renewable energy sources. As examined in the introduction and literature review, solar energy could be one of the leading renewable energy sources, thus a higher perpetuity growth rate could partially explain the valuation. But 6% is still too high for growing in perpetuity, which means it will double every 12 years, and will grow 17 times bigger every 50 years. Even if it holds true, it could not explain the investment valuation in 2008.

6. Conclusion

Per the analysis performed above, even though the investment bubble already deflated with the financial crisis, I believe it still exists in the solar energy industry. This analysis could even be applied to other sectors of the renewable energy industry, as many of them have a similar model. Even though the clean technology is key to a sustainable future, an overvaluation in the equity price may not be the best or most efficient way to support the industry. When the technology breakthrough is not anticipated even by industry experts, the government subsidies, which mostly take place in the form of tax deduction, will not justify the high valuation of the renewable energy industry.

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Appendix A

Usable Life	15
Peak Hours	3.6
Days/Year	365
Lifespan	

	15	15	16	18	20	
	25%					
	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Total Capacity(GW)	53	70	87	105	127	153
Added Capacity(GW)	13	17	17	18	22	26
efficiency	95%	95%	95%	95%	95%	96%
Usable Capacity(GW)	12.35	16.15	16.15	17.1	20.9	24.96
Year GWh	16228	21221.1	21221.1	22469.4	27462.6	32797.44
Cost of Energy(c/kWh)	15	14	12	11	10	9
Industry Revenue(millions)	$ 37,024	$ 43,720	$ 42,111	$ 45,296	$ 55,546	$ 59,902
Market Share	40%	40%	40%	40%	40%	40%
Annual Revenue(millions)	$ 14,810	$ 17,488	$ 16,844	$ 18,118	$ 22,218	$ 23,961
NI %	12%	12%	12%	12%	12%	12%
Net Income(millions)	$ 1,777	$ 2,098.54	$ 2,021.31	$ 2,174.19	$ 2,666.20	$ 2,875.27
Interest Expense Add back	450	531	512	551	675	728
FCF	$ 2,227	$ 2,629.92	$ 2,533.14	$ 2,724.73	$ 3,341.32	$ 3,603.33

Appendix A

Usable Life	15
Peak Hours	3.6
Days/Year	365
Lifespan	

		10%			**5%**
	2017	**2018**	**2019**	**2020**	**2021**
Total Capacity(GW)	188	207	228	251	263
Added Capacity(GW)	35.461	18.8461	20.73071	22.803781	12.54207955
efficiency	96%	96%	96%	97%	97%
Usable Capacity(GW)	34.04256	18.092256	19.9014816	22.11966757	12.16581716
Year GWh	44731.92384	23773.22438	26150.54682	29065.24319	15985.88375
Cost of Energy(c/kWh)	8	8	8	8	7
Industry Revenue(millions)	$ 73,774	$ 38,032	$ 40,580	$ 43,750	$ 23,340
Market Share	40%	40%	40%	40%	40%
Annual Revenue(millions)	$ 29,510	$ 15,213	$ 16,232	$ 17,500	$ 9,336
NI %	12%	12%	12%	12%	12%
Net Income(millions)	$ 3,541.15	$ 1,825.52	$ 1,947.83	$ 2,099.98	$ 1,120.34
Interest Expense Add back	897	462	493	532	284
FCF	$ 4,437.82	$ 2,287.77	$ 2,441.05	$ 2,631.73	$ 1,404.03

Appendix A

Usable Life	15
Peak Hours	3.6
Days/Year	365
Lifespan	

					4%
	2022	**2023**	**2024**	**2025**	**2026**
Total Capacity(GW)	277	290	305	320	333
Added Capacity(GW)	13.16918353	13.8276427	14.51902484	15.24497608	12.80577991
efficiency	97%	97%	97%	97%	97%
Usable Capacity(GW)	12.77410802	13.41281342	14.08345409	14.7876268	12.42160651
Year GWh	16785.17794	17624.43684	18505.65868	19430.94161	16321.99096
Cost of Energy(c/kWh)	7	7	7	6	6
Industry Revenue(millions)	$ 23,772	$ 24,212	$ 24,660	$ 25,116	$ 20,465
Market Share	40%	40%	40%	40%	40%
Annual Revenue(millions)	$ 9,509	$ 9,685	$ 9,864	$ 10,046	$ 8,186
NI %	12%	12%	12%	12%	12%
Net Income(millions)	$ 1,141.07	$ 1,162.18	$ 1,183.68	$ 1,205.58	$ 982.30
Interest Expense Add back	289	294	300	305	249
FCF	$ 1,430.00	$ 1,456.46	$ 1,483.40	$ 1,510.85	$ 1,231.04

Appendix A

Usable Life	15
Peak Hours	3.6
Days/Year	365
Lifespan	

	2027	**2028**	**2029**	**2030**
Total Capacity(GW)	346	360	375	390
Added Capacity(GW)	13.3180111	13.85073155	14.40476081	14.98095124
efficiency	97%	97%	97%	97%
Usable Capacity(GW)	12.91847077	13.4352096	13.97261799	14.53152271
Year GWh	16974.87059	17653.86542	18360.02003	19094.42084
Cost of Energy(c/kWh)	6	6	6	6
Industry Revenue(millions)	$ 20,645	$ 20,826	$ 21,010	$ 21,195
Market Share	40%	40%	40%	40%
Annual Revenue(millions)	$ 8,258	$ 8,331	$ 8,404	$ 8,478
NI %	12%	12%	12%	12%
Net Income(millions)	$ 990.95	$ 999.67	$ 1,008.47	$ 1,017.34
Interest Expense Add back	251	253	255	258
FCF	$ 1,241.87	$ 1,252.80	$ 1,263.82	$ 1,274.94

Appendix B

2011Net Income																			
$ 2,227	$ 2,630	$ 2,533	$ 2,725	$ 3,341	$ 3,603	$ 4,438	$ 2,288	$ 2,441	$ 2,632	$ 1,404	$ 1,430	$ 1,456	$ 1,483	$ 1,511	$ 1,231	$ 1,242	$ 1,253	$ 1,264	$ 1,275
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
FCF	(500)	(500)	(300)	(300)	(100)	(100)	4,974,047	5,307,308	5,721,886	3,052,626	3,109,100	3,166,618	3,225,200	3,284,867	2,676,509	2,700,063	2,723,823	2,747,793	2,771,973
PV FCF	(26)	(1)	(0)	(0)	(0)	(0)	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

Perpetual FCF

Base FCF	2,771,973
WACC	8.4%
Perpetual Growth Rate	2.0%
Base Year	2012
Perpetual Start Year	2030
Perpetual Value	44,205,955
PV of Perpetual Growth Period	5,588,024

WACC	8.3960%
Rf	3.50%
Rp	6.00%
Beta	1.47
Sm Cap Rp	0.00%
D/A	45%
Rd	4%
Tax Rate	10%

Total FCF

Value of FCF	5,587,997

% FCF/NI 100%

Intrinsic Value

Cash	
Debt	2,514,598.51
After-Tax ESO Liability	
Value of Equity	3,073,398 million

Debt % 45%

Current Market Cap	7,470
Over Valuation	(99.8%)