An investment analysis of residential photovoltaic systems in New South Wales, Australia.

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Abstract

This study investigates under which conditions installing a residential solar panel is a good investment for the private consumer in New South Wales, Australia. The study focuses on the economic parameters of the investment decision and treats technical specifications as exogenous.

The main driver of profit in relation to installing residential solar panels is the rising cost of residential electricity prices. Therefore the study undertakes a 25 year econometric forecast of electricity prices. This forecast is composed of three sub-elements, separating general market developments from state-regulated elements. The technical and economic parameters are integrated in a NPV model, which accounts for the determination of the different input variables. The model was set up using Microsoft excel and tests system capacities between 1kW and 6kW. The findings show a positive NPV for all system sizes, a relatively high IRR ranging from 11% to 16% and a payback time of between 10-13 years. A sensitivity analysis is conducted on all the economic variables to assess the robustness of the NPV results. The sensitivity analysis shows that government subsidies are not necessary to generate a positive NPV. Nonetheless the subsidies help make the NPV results more robust. The findings lead to a discussion about the effects and necessity of government subsidies with respect to national objectives of lowering CO2 emissions. The discussion is inconclusive about the full effects of changes in the different subsidy schemes and suggests further research on the matter and culminates with a suggestion of an alternative financing option that could help alleviate consumer liquidity issues.

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Tables and Figures

Acronyms and definitions

ABS - Australian Bureau of Statistics	IPEA - European Photovoltaic Industry Association
AEMO - Australian Energy Market Operator	kWh - Kilowatt/hour
AER - Australian Energy Regulator	LRET - Large-scale Renewable Energy Target
ATA - Alternative Technology Association	MW - Megawatt
BoM - Bureau of Meteorology	NSW – New South Wales
CEC - Australian Clean Energy Council	PVC – Photovoltaic cells
CPI - Consumer Price Index	REC – Renewable Energy Certificate
DNSP - Distribution Network Service Provider	RET – Renewable Energy Target
D+T – Distribution and transmission	SBS – Solar Bonus Scheme
GST - Goods and Services Tax (Australian value-added tax)	SEPQ - Sustainable Energy Policy Queensland
IEA - International Energy Agency	SRET - Small-scale Renewable Energy Target
IPART - Independent Pricing and Regulatory Tribunal (of New South Wales)	STC - Small Scale technology Certificates
	WTP – Willingness to pay

General definitions

- $ refer to Australian dollars
- In this paper the words PVC, solar panel, solar cell and PV system will be used to refer to photovoltaics and will thus be used interchangeably.

1 Introduction

"New South Wales' Independent Pricing and Regulatory Tribunal has confirmed the average electricity bill will skyrocket by between $577 and $918 a year by 2013[1]."

Solar radiation is an almost infinite source of energy compared to the global amount of energy consumed. The solar radiation that hits Earth in one hour corresponds to more energy than mankind use in a year. Thereby offering lots of potential for a clean alternative to the polluting coal or fossil fuel based electricity production. Yet in 2012 less than one tenth of a percentage of global energy production is generated from solar energy[2].

The most apparent reason explaining why not more of the world's energy is being produced through means of natural resources such as solar energy is the economic and the reliability aspect of such sources. Whereas conventional electricity production through means of coal or fossil fuels can be timed to match the demand for electricity, electricity production through natural resources such as sun or wind depends on weather conditions and therefore cannot be timed with demand. When it comes to renewables it is most profitable if generation can be matched with consumption and for this to happen it can be more optimal to have the renewable source locally installed. Whereas the installation of a windmill in the consumer's backyard is rarely desirable, the installation of PVCs on the consumer's roof offers an easy and noise-free clean energy solution. However even if money will be saved in the long run by switching to e.g. solar energy, the short term reality for the individual consumer is that it represents a large investment. Furthermore it does not guarantee to deliver all the energy needed for average consumption, nor deliver it at the time when the consumer needs it.

A recent report by Ernst and Young concludes that by 2016 solar cells will be more economical than conventional energy sources[3]. This argument stands to reason, but we were driven by the

[1] Brooks, 2010
[2] National geographic
[3] Ernst and Young, 2011

wish to do a more case-specific study of this claim. We wanted to examine a micro-perspective of this statement, investigating it at the individual consumer level. The motivation to conduct the study at a consumer level was based on the assumption that consumer choice of energy sources will not change unless the individual consumer can see the economic perspective of shifting. In other words, we believe that in general consumers will make their choice based on minimizing costs. As solar panels have become less expensive and more reliable during the last couple of years it is our assessment that PVCs can be the more economic alternative when it comes to choosing source of electricity. Undertaking an economic evaluation of solar panels can be difficult for the individual consumer, as it requires consideration of a lot of variables and factors. This report therefore gathers all of these considerations and performs the analysis for the consumer, providing a decision-making tool.

Our research into solar energy as an economical alternative to conventional energy sources sprung from a student project at the Technical University of Denmark (DTU), in which 200 students worked on building the zero-energy house FOLD for an international competition in Madrid in 2012. However as FOLD was constructed with a technical objective in mind and not with a marketable economic focus, state-of-the-art solutions were chosen to such an extent that the house became far too expensive to justify an economic assessment of it. From an economic perspective it therefore made more sense to focus on one specific technology used in the house. We nonetheless drew on some of the experiences of the students involved in the project. Especially with respect to which market to investigate further. A market analysis made by DTU and CBS students concluded that Australia was the most suitable market for the FOLD house. Australia is an interesting case-study with respect to sustainable energy sources and electricity prices for two reasons. The first being the large amount of sunshine hours and the corresponding need for air conditioning, which is a massive electricity user, the second being the political framework in Australia. Australia ratified the Kyoto Protocol in 2007 and considers itself to be a forerunner within green energy as well as ambitious about lowering carbon emissions. Accordingly the Labour government led by Prime Minister Julia Gillard has implemented a carbon tax that will be payable from July 1st 2012. The tax will affect prices in general but especially prices of electricity. Additionally both the Australian federal government and several Australian states have experimented with incentive programs to promote solar cells for the individual consumer.

For the above reasons as well as the fact that Australia has some of highest electricity prices in the developed world[4], this country was chosen. Yet as prices and policies vary from state to state, we wanted to be even more specific in our research and chose New South Wales (NSW) for our case study. NSW was chosen as it is the largest state and has the biggest population size as well as holds the largest city of Australia, Sydney.

1.1 Research question

The overall purpose of this study is to make an investment analysis of solar cells for the private consumer, based on the development of residential electricity prices in NSW the next 25 years, which is the average lifetime of the solar panels currently on the market. The paper will conclude with a suggestion of whether or not a PV system is an economically sound investment. In order to make an evaluation of solar cells as a profitable investment, the paper will commence with a basic description of the electricity market in NSW and a forecast of retail electricity prices, which will be grounded on our assessment of the factors influencing residential electricity prices on a longer horizon.

Research question: Under which circumstances does investing in photovoltaic systems offer a positive return for the individual consumer in New South Wales, given the development of electricity prices?

This question will be addressed by the help of three sub-questions:

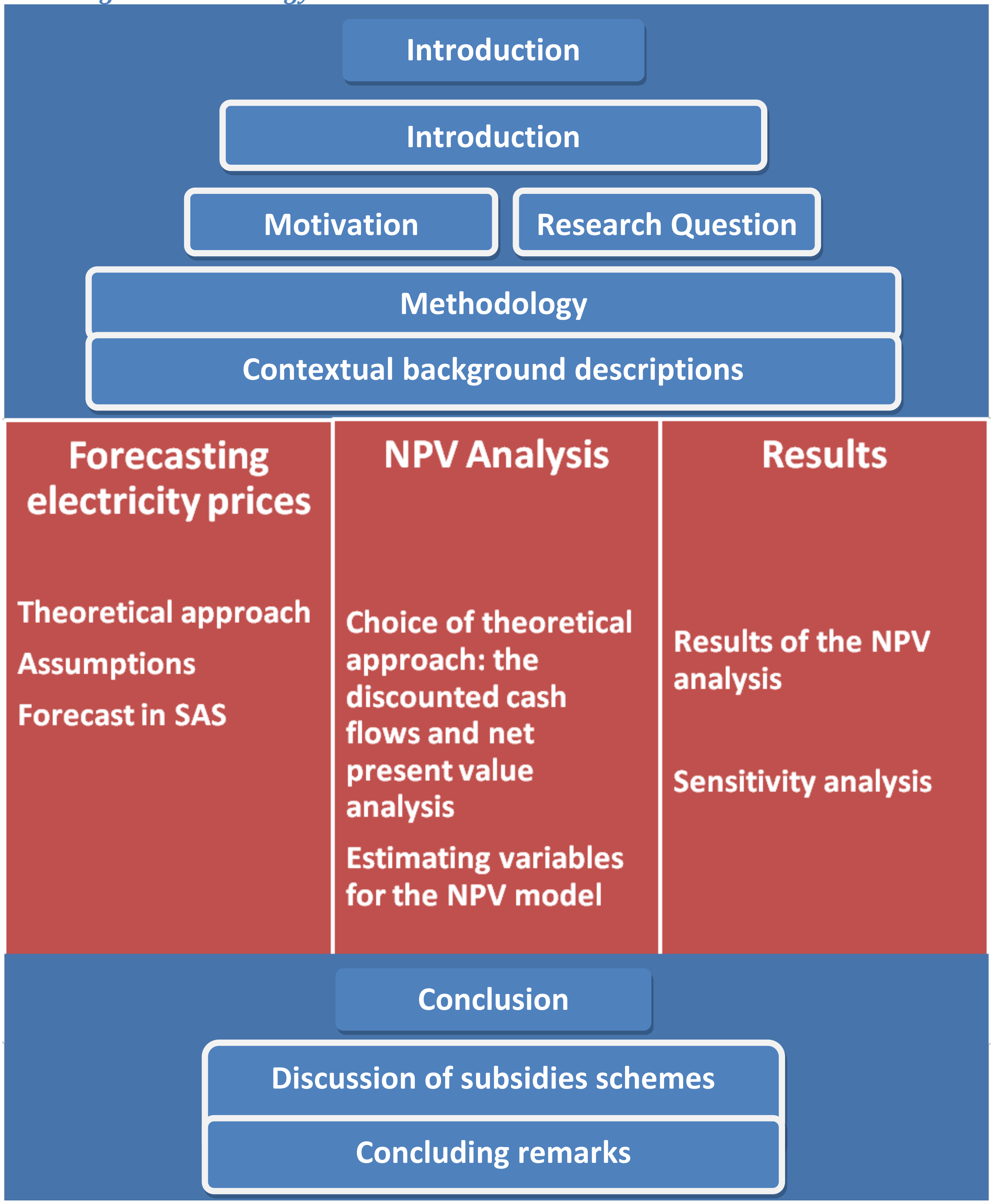
1. How will retail electricity prices in NSW develop over the next 25 years?
2. How should photovoltaic panels be evaluated as an investment?
3. Have government incentive schemes helped make PVCs an economically viable investment for the individual consumer?

1.2 Methodology

The thesis has five parts: The introduction, the three analytical parts and the conclusion. The structure is illustrated in the below figure.

[4] Nolan, 2012

1.2.1.1 *Figure: Methodology*



We employ three distinct methods.

The first part provides descriptions of New South Wales in terms of its electricity market as well as the political aspect related to the electricity market. Additionally, the section provides brief explanations of solar panel systems and how they work. This section uses data and complimentary information to provide a descriptive analysis and builds a framework within which we conduct our study of photovoltaic panels.

The second part presents an econometric time series analysis of retail electricity prices in NSW. The aim of this section is to create a forecast of retail electricity prices for the next 25 years. The forecast is composed of three elements; the historic development of prices and the development of the two new variables which will affect retail electricity prices in the future. These are distribution and transmission costs and the implementation of the carbon tax. The accuracy of using the historic development of prices to predict future electricity prices was tested by performing a forecast of the latter 25% of the historic data based on the former 75% of the data. This forecast was only done to assess the accuracy of the historic data and does not account for how future variables such as the carbon tax and distribution and transmission costs will affect prospective prices.

The third part consists of the NPV model framework. Here we discuss the choice of our theoretical framework based on investigations of conventional approaches used in economic analyses of electricity as well as how these approaches were adopted to fit the objectives of this paper. Thereafter we discuss the variables used in our analysis. The variables are defined as accurately as possible according to logical reasoning, academic justifications and supported by methodological assumptions used in official reports and analyses.

1.2.2 Data Collection and data transformation

The data used for this paper were extracted mainly from two databases, one being the Australian Bureau of Statistics (ABS) and the other being the Australian Bureau of Meteorology (BoM). Additional information regarding the electricity market in NSW was derived from official government websites, fact sheets and reports, mainly by AEMO (Australian Energy Market

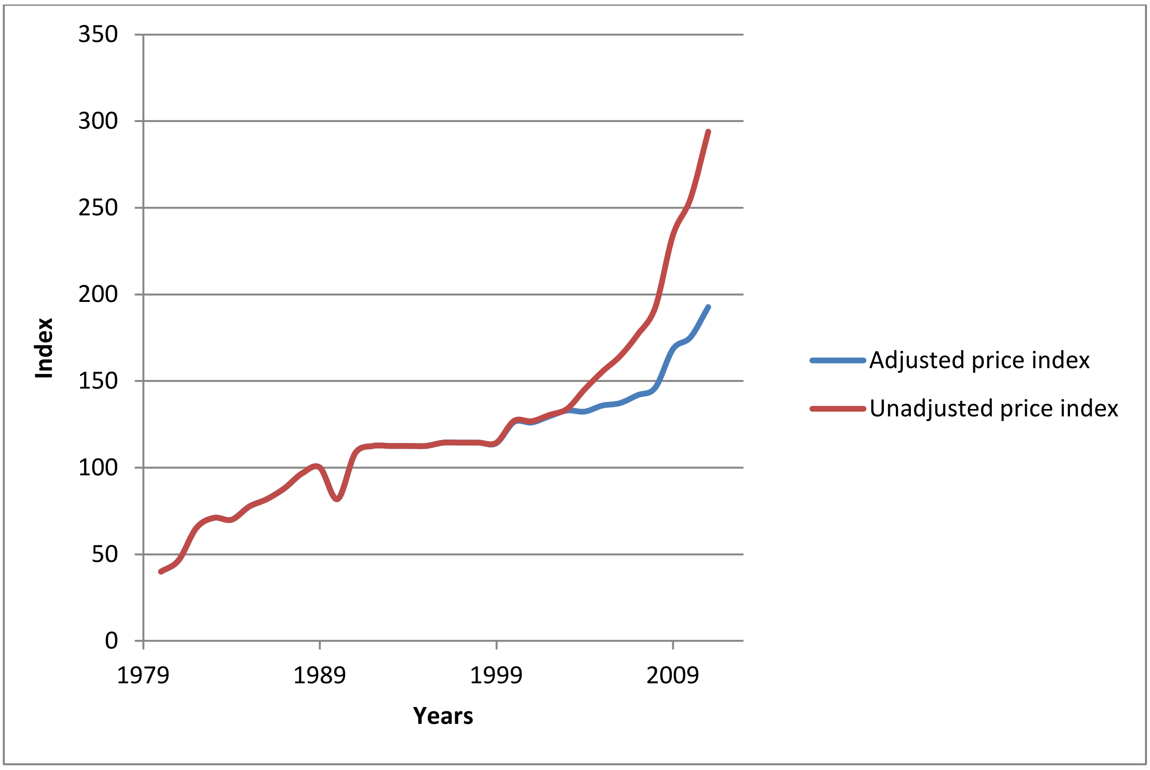
Operator) and IPART (Independent Pricing and Regulatory Tribunal) as well as journal articles and clean energy blogs.

The analysis of this paper is contemporary, meaning that the investment analysis is made based on present day prices, political schemes and current future outlooks. However for the forecast historic data was used. These data vary in time horizon between the different data sets, as it was not always possible to find and extract data for the same time period for different variables. The data set containing historic retail electricity prices spans from 1980-2011, whereas the dataset containing historic prices on distribution and transmission covers the period 2004-2014 (the latter two years of this period being forecasted).

1.2.3 Index corrected

An additional aspect of data collection was the need to transform certain data from indices to real values. For the electricity price forecast we constructed a model that divides the total electricity price into three parts: the historic development of retail electricity prices, distribution and transmission (d+t) costs and the carbon tax. This division was made so that the model can forecast the three parts individually, as each component is assumed to show a different behavior. As distribution & transmission costs have been the cause of large increases in the final retail price, the model was constructed to allow for separation of the effects of these two elements. The carbon tax is a variable affecting retail prices, as of July 2012 and is deemed to have significant influences on the total retail electricity price in the future, therefore we also wanted to isolate the effects of this variable. The separation of distribution and transmission costs and the carbon tax also enables the model to generate sensitivity analyses on assumptions involved in forecasting these factors. This was necessary as distribution and transmission costs are assumed to impact future retail prices more than they have historically. The index of historic prices is an expression for the final retail price, including the part represented by distribution and transmission costs. To avoid counting distribution and transmission costs twice in the forecast it was necessary to "clean" the historic data for the components represented by d+t costs to obtain a "pure" price upon which a base-case forecast could be conducted. This way it was avoided to have the costs of d+t represented in both the projection of historic data as well as the additional forecast made separately for these two specific components. Hence for the initial forecast of retail electricity prices the model removes the effect of distribution and transmission costs on final electricity prices one year at a time. This method was chosen to make sure that the accumulated effect was properly accounted for. The effect obtained from removing distribution and transmission costs on the index of historic prices is shown in the chart below.

1.2.3.1 Figure: Electricity price index adjusted and not adjusted for costs of d+t



The chart shows that over the 13 year period, for which we have data on distribution and transmission costs, the index drops from 294 to about 192 when distribution and transmission costs are removed from historic prices. This is a total drop of more than 100 index points. The charts also shows that adjusted for the distribution and transmission component, the index only increases by about 78 points in the 13 year period, compared to an increase of 179,6 points when the index is not cleaned for d+t costs. A difference in increase of 230% which highlights the significant impact distribution and transmission costs have had on retail electricity price in NSW in later years.

1.2.4 Transforming index numbers into nominal price levels

For the forecast, the historic prices of retail electricity were only available as an index. However as other variables such as distribution and transmission costs and the carbon tax were expressed in real numbers, it proved necessary to transform the index into real numbers, in order to have coherence between the different components of the future prices. The transformation of the index was done using the average 2011 retail price of 25 cents per kWh and dividing it with the index number for 2011 of 294 to find index 100 in real terms. From there on the index number of each year was used to calculate the corresponding retail price expressed in real terms. On a final note, it should be highlighted that using the average 2011 retail price of 25 cents per kWh we used the flat rate pricing scheme. Thereby not taking into consideration how prices would alter if instead a PowerSmart Home, capable of differentiating between electricity consumption in peak times and off-peak times, had been used. A further elaboration of flat rates versus PowerSmart Homes will follow in the cash flow section of the NPV model framework.

1.2.5 Deriving the amount of electricity generated through solar energy

To create the cash flow variable of the NPV model, it was essential to estimate the average amount of solar energy in NSW as well as the proportion that can be transformed into electricity. The data for this analysis was estimated from the Australian Bureau of Meteorology[5]. The Bureau of Meteorology has solar exposure data dating back to 1990 on a daily basis. Unfortunately there were some missing days of recorded data throughout the years, especially in the earlier years. Here it was assumed that there was no significant effect on the average amount of solar exposure from these missing data. The data is in the format of daily solar exposure MJ/m^2, which was changed into kWh/m^2 to make it comparable with the standard way of measuring electric consumption. The data was transformed from MJ to kWh based on the following[6]:

- 1 joule (J) = 1 watt•second = 278•10^{-6} watt•hours
- 1 watt•hours (Wh) = 3600 joule
- 1 kWh = 3,6 MJ

[5] Bureau of Meteorology (b)
[6] Bureau of Meteorology (b)

Accordingly we divide MJ/m^2 with 3,6 to transform it into kWh/m^2.

Unfortunately solar panels are unable to transform all the sunlight they absorb into electricity. There is a significant energy loss in the transformation process, mainly due to the heat production. We found two different sources providing information about the percentage of energy loss ascribed to the transformation process. The sources gave two different estimations. This could be due to two reasons; one is that the sources have different assumptions about the technology while the other is that they have different paradigms. A government source estimated the generation loss to be about 20%[7], while a solar brokerage firm has a slightly higher estimation at about 25%[8]. As the government has an incentive to make it attractive for new investors to install solar panels, it is plausible that they would set the expected loss slightly lower than empirical data suggests. The brokerage firm on the other hand can also be expected to have an unofficial agenda when informing about energy transformation loss. In general the brokerage firm will have two incentives. The first one being to make it more attractive for new investors to buy solar panels and the second one being to make existing investors buy more. With respect to the latter motivation, the brokerage firm could have an incentive to exaggerate the energy transformation loss, as this could potentially stimulate customers to buy more panels, in order to ensure sufficient electricity production for their house. Without knowing how each source made their estimation, we assume a generation loss in the midst of the two estimations at 22,5%.

1.2.6 Tilt and orientation

Due to the geographic location of Australia in the southern hemisphere, the optimal amount of solar energy is obtained by having a north-facing solar panel. To get the most out of a PV cell, it should constantly be directly facing the sun. To be able to have a solar cell that constantly faces the sun requires a system that automatically moves on both axes to follow the sun. Such a type of solar cell is significantly more expensive than conventional PV systems and requires a lot more space to work, hence in this report we limit our scope to PV cells that are in a constant fixed position. This generates less energy than the automatically movable PV cell but is a lot more

[7] Choice.com.au
[8] Solarchoice (b)

applicable to private consumers, as it is significantly cheaper and easier to install. Furthermore it does not include movable parts, which generally require more maintenance and leads to a higher number of breakdowns. It is assumed that for the fixed PV cell, the consumer will have it installed at the optimal tilt and orientation to maximize the amount of energy produced.

For a fixed PV cell the optimal angle is equal to the latitude of the location of the house[9], which in the case of Sydney NSW corresponds to an optimal tilt of 33,86°S[10]. Throughout the years lots of dust and dirt will settle on the solar panels which will decrease their effectiveness, unless the PV cells are tilted at an angle greater than 15° where rainfall will have a cleaning effect and sustain the effectiveness[11].

To estimate the amount of energy generated by a PV system, we use data obtained from the Bureau of Meteorology. However as the data on amount of daily solar energy is measured on a horizontal angel it is necessary to transform it into estimated amount of solar energy produced when the PV system is at its optimal tilt. Several methods exist to undertake this transformation, all explained thoroughly in numerous technical reports[12][13], but these methods are fairly technical and require a substantial amount of specified data we do not posses. Furthermore we do not find that it adds any significant value to this thesis to apply a technical approach to obtain a very specific value. Rather we find that applying such an approach would distort our focus from the economical analysis. Thus we used a transformation key, which converts the amount of solar energy generated when the system is at the horizontal angle into the amount generated when the system is instead at its optimal tilt. To derive this transformation key, data from measurement stations in the USA was used. These measurement stations have compared the amount of solar energy generated when the panel was at its optimal tilt to the amount generated when it was in a horizontal position. As the US weather stations are located at about the same latitude as Sydney (NSW), they offer a good estimate for a correct transformation. The mean latitude for these 34 stations was 34,18°N which is close to that of Sydney, NSW which is 33,86°S[14]. The measurement stations found the average change of solar energy when moving from a horizontal angle to a tilt of

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[9] Li, 2008
[10] Bureau of Meterology (a)
[11] Oksolar.com
[12] Li, 2008
[13] Al-Rawahi, 2011
[14] Bureau of Meterology (a)

34,18°, to increase with 12,35% with at standard deviation of 2,05%. To obtain an appropriate estimate of amount of solar energy generated in NSW, assuming a fixed tilt, we multiplied the horizontal data from the Australian Bureau of Meteorology with (1+12,35%)[15]. These 12,35% additional solar energy obtained from tilting the system proved important for our results, as they increased NPV by between 10-25% depending on system size.

1.2.7 Delimitations

A delimitation of this paper is that the model is very specific in geographic and contextual scope. Though the logic and some of the assumptions behind the model developed in this paper can be adjusted to apply to other regions and political realities, the findings and most of the assumptions are specific to New South Wales. Another delimitation is the very technical aspect of investing in solar cells. Due to our lack of profound technical expertise, we are forced to assume the correctness of what we read regarding lifetime of solar panels, the energy lost in the transformation process and the general size and capacity of the different systems. Also as this thesis is an economic analysis and not a technical one, we had to be broad in our incorporations of certain technical aspects such as tilt, loss of performance efficiency, the impact of temperature and the need for cleaning of the system.

This thesis does not contain a specific section on literature review, instead papers, reports and other sources are, where deemed necessary, discussed in relation to the data they have provided as part of the assumptions for the NPV analysis.

A technical delimitation is the fact that this analysis focuses uniquely on rooftop and building integrated solar installations. This means that other sources of solar power, such as solar thermal plants and solar central-station photovoltaic technology are not included in the analysis.

1.2.8 General assumptions for our research and analysis

[15] NREL, 1994

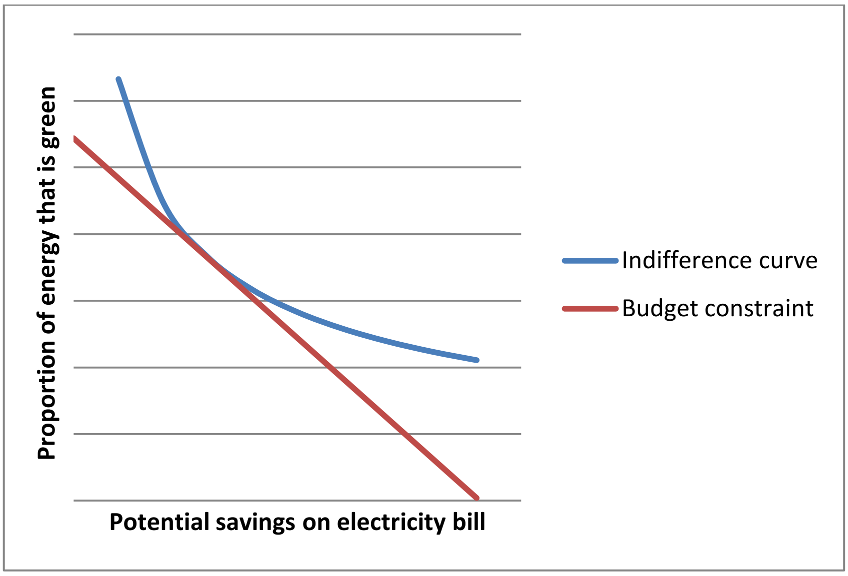
Our analysis is an assessment of whether or not it is economically viable for private consumers in NSW to install PVCs on their roof. That is installation of PVCs on already existing housing, given the development of electricity prices the next 25 years and so this paper does not consider the economic viability of constructing new houses with solar cells. The analysis is made in the summer of 2012[16] and the assessment refers to future consumer decisions. This is important to specify for two reasons. Obviously it is useless to assess whether an investment that has already been made is economically viable, as the investment is a sunk cost. Secondly, the political framework and conditions in NSW with respect to the electricity market changed as of July 1st 2012. One of the major changes was the implementation of the carbon tax – $23 per tonne[17] of CO2, a change that will imply a price increase in consumer prices in general and electricity prices specifically. Another important aspect is the change in the federal government's Solar Credits Rebate Program, which lowered the Solar Credit multiplier from 3x to 2x also as of July 1st 2012[18] and thereby reduced the amount of subsidies provided. These changes will be further explained in the descriptive section.

1.2.9 The investment perspective

In economics rationality deals with optimizing consumption according to individual preferences given a budget constraint. In relation to consumer choices of green energy, preferences could be depicted in accordance with the chart below.

1.2.9.1 Figure: Consumer preferences

[16] Here summer refers the summer period of the Northern hemisphere
[17] Carbontax.net.au
[18] Martin, 2012



The curve depicts the consumer's indifference to choosing a particular level of green energy out of total electricity consumption as opposed to a particular level of potential savings. The straight line is the budget constraint indicating the line along which the consumer can move up and down and choose between respective levels of the two inputs.

Conventional literature on energy economics apply the notion of consumer willingness to pay (WTP) for alternative energy sources. This approach is a different way of expressing the consumer's willingness to sacrifice potential savings to get green energy.

Naturally consumer preferences will vary and therefore so will their WTP, but the purpose of our study which focuses on minimizing the individual consumer's expense on electricity, we will disregard the consumer's WTP. The NPV results will be cost-focused and not encompass the value consumers might attribute to "going green". Only in the discussion will the NSW objective of decreasing CO2 emissions be discussed briefly with respect to subsidy schemes worth implementing.

2 Australia and New South Wales

Australia is a highly developed country, which consists of six states; New South Wales, Victoria, Queensland, South Australia, Western Australia, Tasmania and three territories; Northern Territory, Australian Capital Territory and Jervis Bay Territory, which combined had a GDP of

1.320.057 million Australian dollars as of June 2011. NSW accounted for the largest share with 419.895 million AU dollars or approximately 31,8%[19].

New South Wales holds over 32% of the total population of Australia, with its 7,317,000 inhabitants out of a total of 22,696,000[20]. Expressed in households NSW encompasses approximately 2,7 million households[21], hence the average NSW household counts 2,71 people.

The NSW climate is temperate with a yearly max average temperature of 21,7 C and a minimum average temperature of 13,7 C. The yearly mean daily sunshine hours is 6,8 and the average yearly rainfall is 1214,4 mm[22]. The summer season peaks in December and January, while the winter season reaches its height in June and July. Due to the temperate climate and the rather high average yearly temperature, the biggest need for electricity is fuelled by the need for air conditioning during the summer. Whilst during the winter there is a lesser need for heating as the average temperature in June and July is 13 C and 12 C respectively[23].

2.1 The electricity market of New South Wales

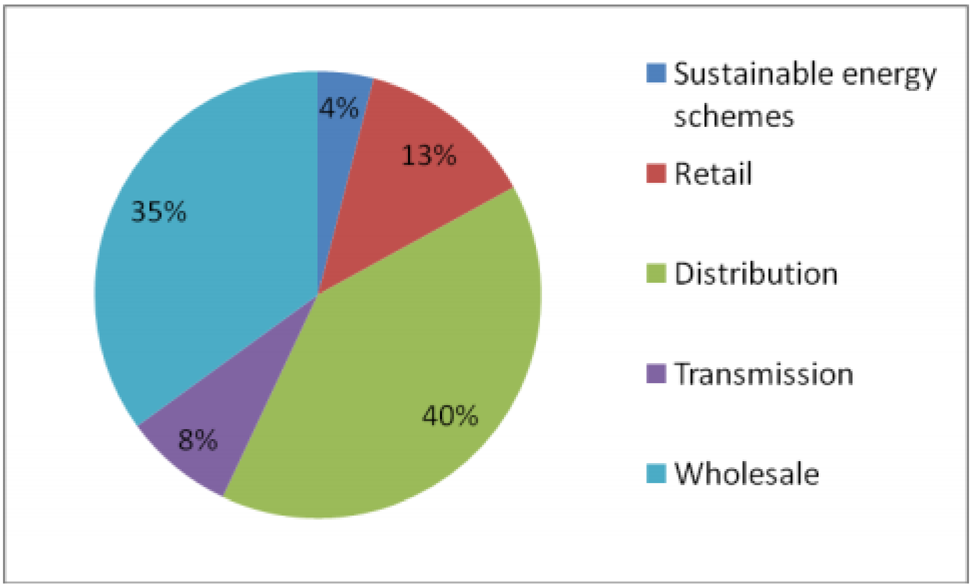
New South Wales is the biggest electricity market in Australia and has roughly 3 million residential customers and 350.000 business customers. Electricity in NSW is generated from a wide range of fuel sources, including black coal, natural gas, coal seam methane gas and renewable energy sources such as hydro, wind, biomass and solar. NSW has around 18,000 megawatts (MW) of installed electricity generation capacity and interconnections with Queensland and Victoria provide additional capacity of about 1100 MW and 1500 MW respectively[24].

As NSW is a scarcely populated state, with 809.444 km^2 and a population density of 9 people[25] per km^2 the electricity market is characterized by a need for distributing even small amounts of electricity across large distances. This means that there are a lot of costs related to the many

[19] Australian Bureau of statistics (a)
[20] Australian Bureau of Statistics (b)
[21] NSW Government (a)
[22] Bureau of Meteorology (a)
[23] Bureau of Meteorology (a)
[24] NSW Government (c)
[25] Australian Bureau of Statistics (b)

networks which make distribution and transmission possible. In general 10% of power generated in Australia is lost during transmission from the generators to private homes. Below is a chart from a NSW government report on electricity network and prices[26] showing the composition of an average NSW electricity bill in 2010/11.

2.1.1.1 Figure: Composition of a typical NSW electricity bill in 2010/11



As can be seen distribution and transmission made up 48% of the average retail electricity price in 2010/11 and as of July 1st 2012, retail prices increased by 8% due to the "*continuing rise in Standard Retailers' forecast network cost*[27] "

Also NSW encompasses "*an aging fleet of power plants*"[28] which needs replacement as well as an increased peak demand, which will most likely call for new investments from 2018[29]. As far goes the 35% made up of wholesale electricity costs, these include the costs of fuel and plants used to generate electricity. Whereas the 13% accredited to retail costs are related to the interface between customers and their electricity supplier and include call centres, customer information services, billing and metering systems[30].

[26] NSW Government (g), p. 13
[27] IPART (a), 2012, p. 12
[28] Dargaville, 2011
[29] AEMO (a), p. 4
[30] NSW Government (g), p. 14

The electricity market is currently made up of three major electricity retailers, Energy Australia, Integral Energy and Origin Energy who all used to be owned by the NSW government. However as of March 2011, the retail part of Integral Energy and Country Energy were sold to Origin Energy, while the retail part of Australian Energy was acquired by TRUenergy. The distribution network of all three was retained by the NSW government and was in the case of Energy Australia rebranded Ausgrid, in the case of Integral Energy rebranded Endeavour Energy and in the case of Country Energy, Essential Energy[31].

In this way the electricity suppliers do not own any wires or poles, but simply purchase electricity wholesale and resell it to the end consumer while paying the network operators a fee for using their networks.

Of the regular network connections Ausgrid has the largest market share of the three Distribution Network Service Providers (DNSP) with 49 %, Endeavour Energy comes in second with 26 % and Essential Energy follows with 24 %[32].

2.1.2 Price levels

Maximum prices that can be charged to households on regulated price plans are set each year by the NSW Government, through IPART. The power companies can choose to charge below or above these regulated rates for customers, if it is done on market contracts, but this rarely happens in practice. Instead most retailers use the regulated prices as standard prices and offer discounts to entice customers[33].

Residential retail prices per kWh vary somewhat from retailer to retailer. Currently (according to 2011 price lists) Energy Australia supplies one kWh for 22,66 cents, for the first 1750 kWh a quarter, after which the price rises to 32,01 cents per kWh[34]. However as an average households consumes between 6500 and 7300 kWh of electricity a year, almost all of the consumption will be priced at 22,66 cents (1750 kWh per quarter adds up to 7000 kWh per year). Integral Energy

[31] Switchwise (a)
[32] Solar Bonus Scheme report, p. 17
[33] Switchwise (b)
[34] Energy Australia Pricing List

charges 24,035 cents per kWh for the first 1750 kWh a quarter, after which the price rises to 26,609 cents per kWh[35]. While Country Energy does not discriminate on amount of consumption and charges a standard price of 28,8508 cents per kWh.

In addition to the per kWh price the retailers charge a *service availability charge* to help cover costs of maintaining networks and distribution. At Energy Australia this charge is set at 52,8 cents a day[36], while Integral Energy has theirs at 65,835 cents a day[37] and Country Energy at 107,8044 cents a day[38]. The service availability charge is not the same as network charges. The network charges include both fixed and variable costs components, so they are incorporated into the service availability charge *and* the consumption charges[39]. Averaged out the price per kWh is approximately 25 cents. This is also the price referred to as the standard price for a kWh in NSW in several reports and journal articles[40][41].

Though NSW has interconnections with Queensland and Victoria, we will not further explore this aspect, as the electricity coming from Queensland and Victoria makes up only about 12,6% of total electricity available in NSW. Additionally as it is the same retailers who provide electricity across NSW, Victoria and Queensland prices are within the same range.

The above price calculations were made assuming the use of flat rate pricing scheme, which does not price differentiate between the price of a kWh in and off-peak times. If instead the customer has chosen a PowerSmart Home, which is a smart grid system allowing the customer to always know the current price of a kWh, he can choose to consume power according the price he prefers to pay. During peak times (2pm-8pm on working weekdays) he would then be charged a price of 44,66 cents/kWh, during shoulder time (7am - 2pm and 8pm - 10pm working weekdays and 7am - 10pm on weekends and public holidays) a price of 18,04 cents/kWh and during off-peak times a price of 10,56 cents/kWh [42]. Using the PowerSmart Home rates as a base for calculating savings on

[35] Integral Energy Pricing Report, p. 9
[36] Energy Australia Pricing List
[37] Integral Energy Pricing Report, p. 9
[38] Country Energy Regulated Retail price list, p.6
[39] IPART webpage (11)
[40] Nolan, 2012
[41] Switchwise (c)
[42] All of the above rates are taken from Energy Australia's July 2011 pricing list, however Integral Energy and Country Energy offer the same system

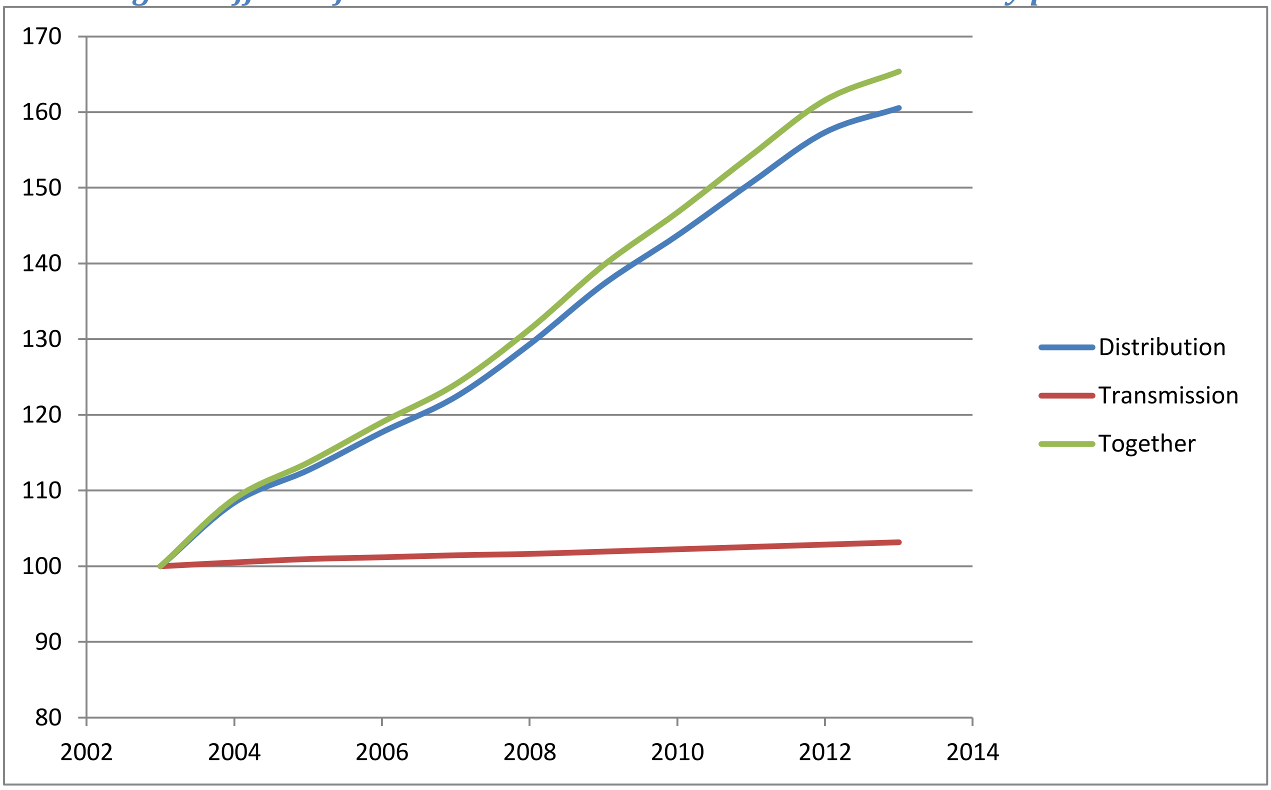
the electricity bill, is somewhat counterintuitive however, as using a smart grid system is supposed to incentivize people to consume energy during off-peak times. But if people start consuming more electricity at off-peak times (10 pm-7am), their savings from installing solar cells will drop, as they no longer use the electricity generated for personal consumption. Accordingly, our analysis will apply the flat rate pricing schemes for the purpose of calculating savings on the electricity bill.

Recently Australia and most notably NSW and Victoria have experienced a massive increase in electricity costs. Contrary to the perception that solar feed-in tariffs, (a subsidy given to people who have installed solar panels) are a major factor in the growing cost of electricity, the bulk of the price increase comes from two sources: the rising price of wholesale electricity, which includes the effects of the carbon tax and the cost of distribution. Namely since 2004 where retailers undertook new investments to comply with new 2005 regulatory determination of increased reliability of electricity[43], distribution and transmission costs have taken a heavy toll on the growth of residential electricity prices.

The below graph, based on data from AER[44], shows the impact the two components have had on prices.

[43] AEMC (a), p.13
[44] Appendix 1

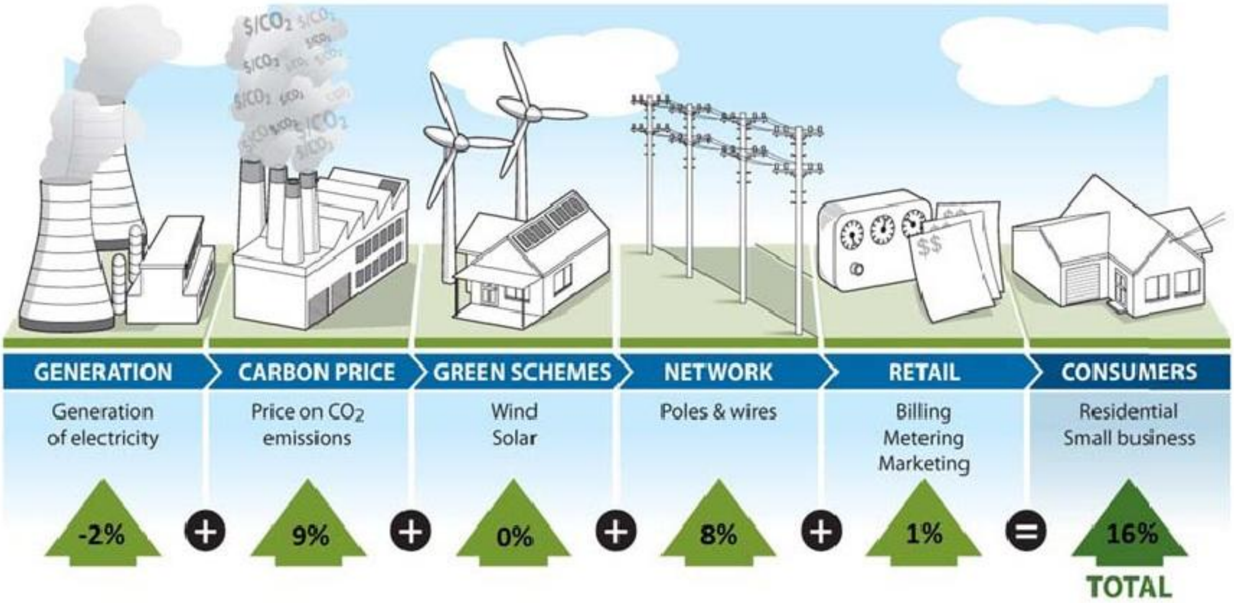
2.1.2.1 Figure: Effects of distribution & transmission costs on electricity prices



As can be seen transmission costs have a relatively small impact on final retail prices compared to increases in distribution costs, yet we chose to isolate all costs related to network maintenance, as these are independently determined by AER.

From IPART's draft report from April 2012 on *Changes in regulated electricity retail prices from 1 July 2012* in NSW follows a chart showing the effects of network maintenance costs and the new carbon tax on final retail price:

2.1.2.2 Figure: Electricity price increase composition



As is also reflected in the above chart of price composition, NSW calls for large investments in distribution and transmission networks and as demand goes up, so does the price of these variables[45]. And as old plants have recently retired, the need for financing new plants has been reflected in increasing distribution and transmission costs of electricity[46].

2.1.3 Solar panels

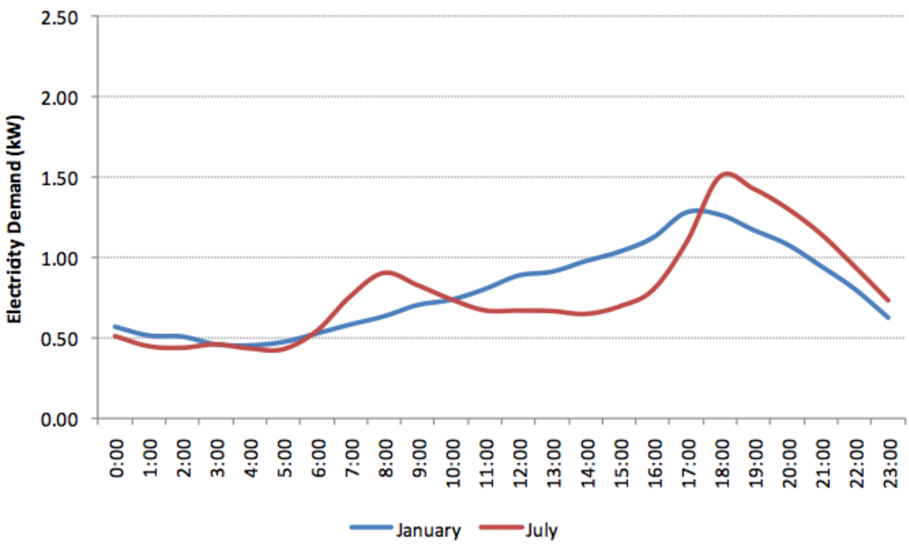
One alternative to buying electricity through retailers is for the consumer to generate his own e.g. through the use of rooftop PV systems. Solar photovoltaic cells function by converting sunlight into DC electric power. This electricity is then sent to a device called an inverter, which converts the DC power into AC power. This step is necessary to make the electricity compatible with the electricity grid. The AC power is then either used by the owner or exported to the grid to be used by the closest consumers. The power passes through a meter that measures every kilowatt-hour of solar energy generated[47], ensuring that the consumer gets paid for the amount he does not use.

2.1.4 Average consumption

[45] Dargaville, 2011
[46] Dargaville, 2011
[47] Dynamic Solartech

According to the Clean Energy Council an average Australian household consumes about 6500 kWh of electricity per year[48], while IPART sets the average annual consumption at 7000 kWh[49] and another government source puts the average NSW household electricity consumption at 7300 kWh a year[50]. With an average 2kW system installed in Sydney generating around 2847 kWh, an average household can then generate around 40% of its consumption through solar panels[51] and this way experience substantial reductions on the electricity bill. It should be noted though that these numbers assume that all of the generated electricity is used for own consumption and in this way the rates assumes that generation of electricity and consumption of electricity overlap perfectly. Below is a chart created by data from Country Energy, showing the hourly residential demand throughout the day.

2.1.4.1 Figure: Hourly electricity consumption for Country Energy consumers



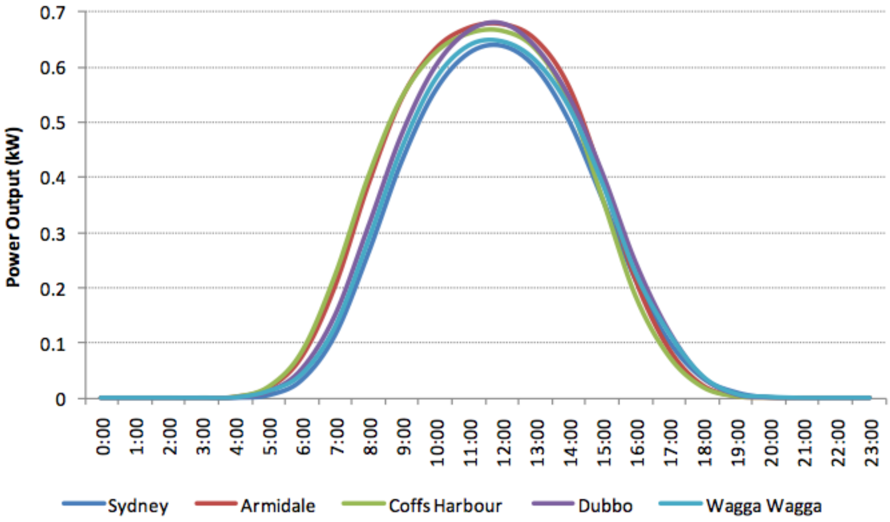
[52]

The two lines indicate the difference in electricity consumption between winter and summer. In winter (June) there is a high consumption of electricity when people get up in the morning and when they come home from work and start cooking. In addition some amount of heating is required. Instead during summer (January) there is less demand during the morning and in the afternoon, but a higher consumption throughout the day, most of which is due to air-conditioning needed to cool down the house consistently throughout the day. To compare the consumption of

[48] NSW Government (b)
[49] IPART webpage (30)
[50] NSW Government (a)
[51] NSW Government (b)
[52] AECOM, 2009, p. 13

electricity to the production that can be generated through PV panels, we look at the nature of solar energy throughout the day.

2.1.4.2 Figure: Hourly solar energy measured at different locations in NSW

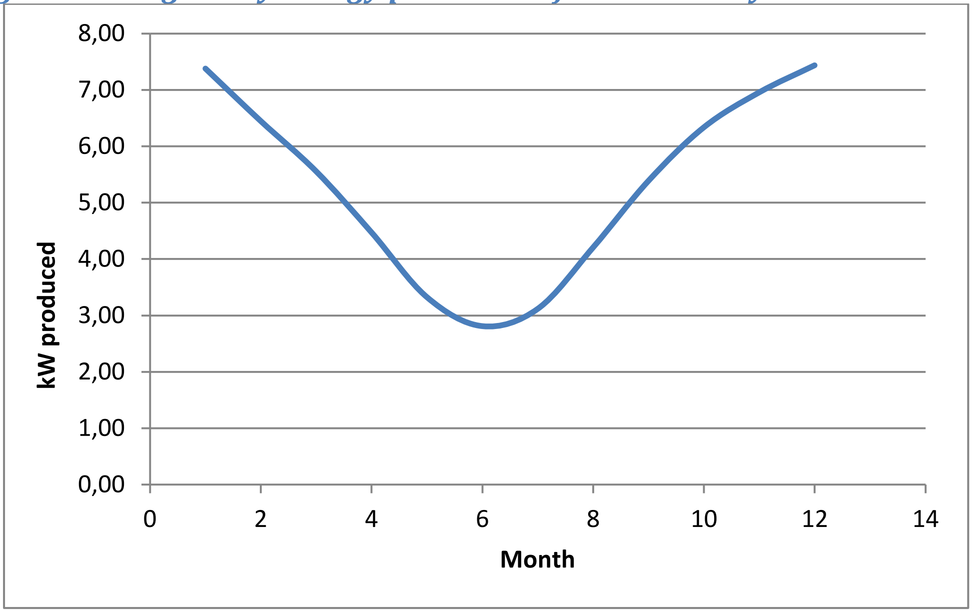


[53]

The chart shows hourly production of energy generated from a 1kW solar cell in different locations in NSW. From the chart it can be observed that solar energy is generated from sunrise to sunset with a peak around noon. If the generation of electricity from solar energy is compared to the consumption of electricity, it becomes clear that solar energy will not be sufficient to provide electricity for an average household, as it cannot supply electricity for e.g. cooking dinner or heating the house at night. Instead the solar energy production is a better match with the summer electricity consumption that reflects a great need for air-conditioning, which increases throughout the day. As the consumption data pertain only to household consumption and we observe a constant rise in electricity consumption during the day in the summertime it is assumed that people leave the air-condition system on while at work to ensure a cool home when returning. Considering the electricity generated through solar panels throughout the year it is, not surprisingly, found that electricity generation is higher in the summer as there are a greater number of sunshine hours as well as favourable weather that minimizes the reflection and absorption of light in the atmosphere. The below chart shows average daily energy production from a 1kW system throughout the year.

[53] AECOM, p. 11

2.1.4.3 Figure: Average daily energy production from a 1 kW system



[54]

From table 2.1.4.1 and table 2.1.4.3 it can be concluded that consumption and generation of electricity have the same seasonal changes during the midday period, which creates an advantage for the NPV result allowing for better matching of generation and consumption continuously throughout the year.

2.1.5 Net versus gross metering

When a household generates electricity through solar panels and exports that electricity to the grid through a meter, there are two ways the meter can account for the amount of electricity, net or gross metering. Under net metering, generated electricity is used to supply the household's own electricity requirements first and then exports any excess electricity generated to the grid. Net meters hence separately record amount of electricity imported from the grid and amount of electricity exported to the grid. Instead under gross metering, all generated electricity is exported directly to the grid rather than initially used on site and the consumer continues to purchase all his electricity from the grid as before. When there is a discrepancy between the price the consumer is charged for 1 kWh (and hence the amount he saves by producing the kWh himself) and the price he receives from selling 1 kWh to the grid e.g. when the buying price is higher than the selling

[54] Appendix 2

price, net metering will be more profitable than gross metering. Therefore this paper assumes the use of net metering.

2.2 The political aspect of solar power

Australia considers itself a forerunner on the renewable energy area and in 2009 and 2010 the Australian federal government and the New South Wales government launched several political incentives schemes to promote sustainable energy, mainly photovoltaics. The incentive schemes, which reward consumers who produce and/or use clean energy are financed by augmenting the prices charged for regular electricity, reflected in the RET (Renewable Energy Target) component of the retail price. This is meant to create a double incentive package for consumers to switch to greener energy sources. However the NSW incentive programmes were closed after only a brief lifetime mostly due to budget constraints. Consumers who signed up in due time are still eligible to benefit from the schemes during the remaining lifetime of the plan. In the following we outline the national and state-run political schemes that are or have been available to residential electricity consumers in NSW.

2.2.1 The Solar Bonus Scheme

In January 2010 the NSW government implemented The Solar Bonus Scheme (SBS), which was an incentive program designed to stimulate the installation of solar panels at the individual consumer level. The system worked by granting every member of the SBS, 60 cents per kWh he generated and sent back to the grid. These 60 cents should be seen in comparison with the average 25 cents, the customer pays per kWh he imports from the grid as well as the average 7 cents the consumer would normally receive from retailers for selling one kWh. The SBS was originally and still is scheduled to run until the 31st of October 2016[55].

Due to the large amounts of applications the NSW government received, the SBS lowered the tariff it paid its members to 20 cents per kWh, effective for new applicants after the 18th of November 2010. Five months later the SBS closed completely for new applicants as of the 28th of April 2011. The closure was due to the NSW government underestimating the number of people

[55] IPART (b), 2012, p. 12

wanting to participate. The original budget which was set at $362 million was far surpassed due to the large amount of applicants and ended up at an approximate $1.75 billion, during the lifetime of the scheme end 2016[56]. The closure however had no effect on tariffs received by households already accepted in the system.

After the NSW government closed the SBS, the individual consumer is paid a price between 6-8 cents per kWh by the retailer for the electricity generated and exported to the grid.

Of course the main objective of installing solar panels is for the consumer to reduce his own electricity bill. However as power generated through solar panels is not constant, there will inevitably be times at which the individual consumer produces more energy than he needs and thus will want to sell. In the same way, the consumer will still after the installation of solar panels need to buy electricity from the grid at normal retail prices, in periods where he does not produce enough to satisfy his consumption.

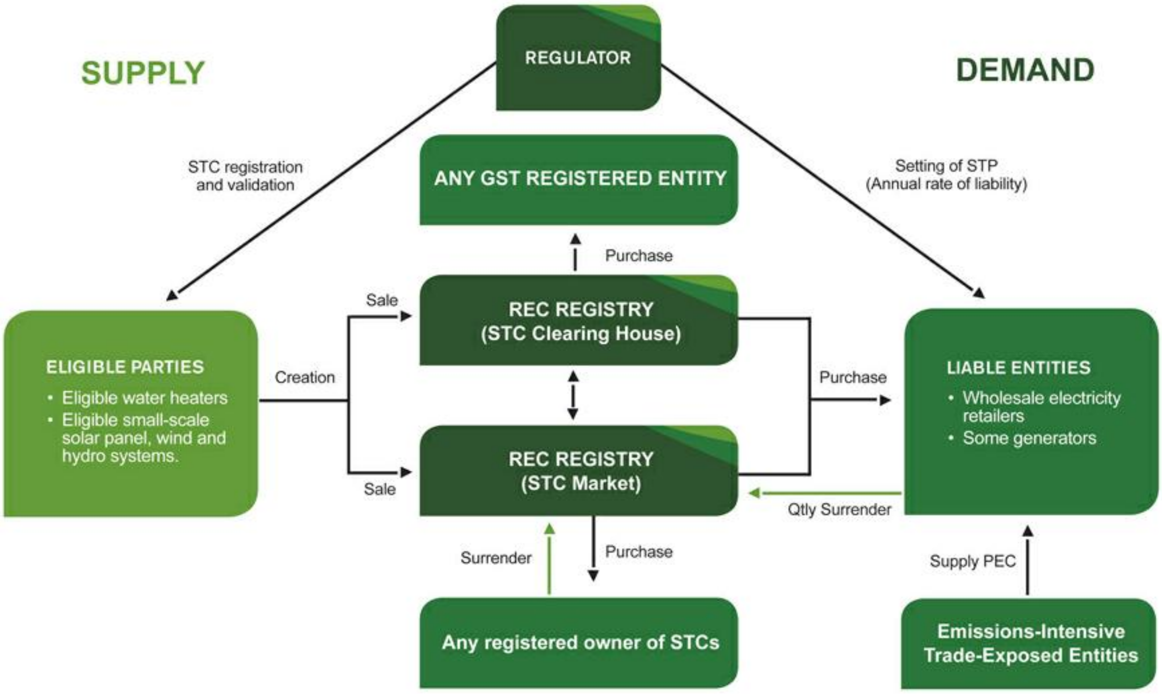
2.2.2 The Australian federal government's solar credit rebate program

The Small-scale Technology Certificates scheme was created by the Renewable Energy (Electricity) Act 2000 (also known as the RET scheme) to make electricity retailers produce a greater amount of energy through the use of renewable energy sources. The way the system works is by financially punishing the suppliers who do not fulfill their quota of green megawatt hour (MWh) production. The suppliers do not necessarily need to produce these MWh themselves, but can choose to purchase them from individual consumers, who have generated them through their personal PV system.

Below is a chart illustrating how the STC market works.

[56] NSW Government (d)

2.2.2.1 Figure: Overview of the STC system



Source: Clean Energy Regulator[57]

One STC is equivalent to one MWh of electricity generated by the consumer's solar PV system. The price of a STC changes according to market conditions. Currently the federal government has set the rate at $40 (less brokerage fees). Any owner of a solar PV power system, can register, sell, trade or surrender STCs for systems up to 100kW.

The most common way the consumer gets paid for his STCs is by assigning his credits to a registered agent in exchange for a financial benefit when he purchase a solar PV system. This financial benefit may be in the form of a delayed cash payment or an upfront discount on the PV system. In this case the consumer will not receive the full amount of $40 per STC, as the retailer handles all the paper work and hence charges a handling fee of approximately $15. Alternatively the consumer can find a buyer himself and sell through The Renewable Energy Certificate (REC) Registry[58]. In this case he will often get a better price, but he will also face a lot of paper work as well as fees. For the purpose of the model it is therefore assumed that the consumer chooses the

[57] Australian Government (d)
[58] Clean Energy Council, p.7

first alternative and receives a price of $25 per STC, which reflects current market conditions ($40-$15 handling fee)[59].

In addition to the STC the federal government runs the Solar Credit multiplier system. This system works by multiplying the number of STCs created by the consumer by X, so that the consumer which is eligible to generate e.g. 41 STC will receive X*41 STCs. The Solar Credit multiplier only applies to the first 1,5kW of system capacity. The multiplier was originally set at 5x, as of 9th of June 2009, then dropped to 3x (1st of July 2011), by July 2012 to 2x[60] and is set to fall to 1x (essentially no multiplier) by first of July 2013[61][62]. The exact multiplier is set according to geographic zones, defined by average hours of sunshine. These zones will be further elaborated on in the cash flow section of the NPV model.

STCs may be created for solar PV systems in batches of one, five or 15 years deeming periods. During these periods the STC multiplier is fixed. Hence if the consumer installs a system and signs up for STCs for a period of 15 years, he can lock in the current multiplier. This is an important element to consider in the investment decision, as it is undoubtedly more profitable to lock in a STC multiplier of 2x for the next 15 years, than to accept a multiplier that will drop to 1x by July 2013[63]. Even more advantageous, it is possible to claim the equivalent of up to 15 years of future REC generation in advance at the time of installation[64], a feature that enables an upfront cash payment that does not need to be discounted and hence will have a larger net present value.

2.2.3 The carbon tax

Australia is one of the biggest per capita green house emitters in the world and recently passed the Clean Energy Bill 2011. A bill that will force the 500 biggest polluters to pay for each tonne of CO2 they emit[65] starting July 1st 2012[66]. Initially the carbon price will be set at $23 per tonne of CO2. This number will increase in real terms by 2,5% in 2013 and 2014, until the carbon price is set

[59] Choise.com.au
[60] Solaronline
[61] NSW Government (e)
[62] Martin, 2012
[63] NSW government (e)
[64] NSW Solar Bonus Scheme Advice, p. 17
[65] BBC, October12th 2011
[66] BBC, October 12th 2011

to be market driven by the 1st of July 2015, though with a price floor of $15 and ceiling of $20 *above* 2015 market price per tonne the first three years[67][68]. The increased costs of polluting, although only targeted at the biggest polluters, will be passed on to consumers by increases in prices, particularly on electricity. Currently this increase represents 9%[69], but according to Truenergy chief executive, Richard McIndoe, the carbon tax will make household power bills double within six years. As he has explained "*uncertainty over what the long-term carbon price might be has stalled capital investment in the industry and halted construction of new power stations*[70]. This prospective gap between the construction of new power stations and the projected increase in demand has already resulted in electricity prices rising by 40% in the past three years he argues. Allegedly the carbon tax of $23/tonne of CO2 emission will not change industry behavior but will double electricity bills for households over six years[71].

Of course there is also a political aspect to the carbon tax. Though the current Australian Labor government, led by Prime Minister Julia Gillard has passed the bill, leader of the opposition Tony Abbott has made his point on the matter very clear "*We can repeal the tax. We will repeal the tax. We must repeal the tax because this is a tax which is going to put up every Australian's cost of living and put at risk every manufacturing job. This is a bad tax. And it's a total betrayal of the Australian public*[72]*"*. Hence it is plausible that the carbon tax, though now implemented might be reversed at a later point, due to a change in government. As the carbon price was not intended to hit residential consumers, the Australian government, concurrently with the implementation of the carbon tax introduced *The Household Assistance Package* which will deliver financial assistance to approximately 9 out of 10 households through personal income tax cuts, increases in pensions and allowances. This assistance will be permanent and is intended to help households adjust to the introduction of the carbon price[73]. It is worth noting that *The Household Assistance Package* is provided based on income and is not related to the individual's electricity bill, hence consumers who choose to install solar panels and this way will not be hit as hard on their electricity bill, will still be eligible to receive the benefits. Accordingly the carbon tax along with the

[67] Peak Energy
[68] CO2 Australia
[69] IPART (a), 2012, p. 12
[70] The Age, 2011
[71] The Age, 2011
[72] Lane, 2011
[73] Carbontax.net.au (b)

compensation package is intended to create a double incentive to prefer PVCs to conventional electricity sources.

2.2.4 The continual decrease in the cost of PVCs

An important aspect of the investment analysis of solar panels is the initial cost of installing them. The increased political initiatives and discussion of profitability of the PVC probably would not have been as topical had it not been for the recent decreases in the prices of solar panels. According to The European Photovoltaic Industry Association (EPIA), reductions are a result of both technological improvements and economies of scale, thus cost reductions can be associated with increasing capacity[74]. A NSW report on the SBS claims that global solar panel prices have more than halved since mid 2009[75], a trend that will allegedly continue as improved technologies make it cheaper to produce PVCs. The International Energy Agency (IEA) who has estimated the 2010 capital cost for utility scale PV facilities to be $4060/kW, expects the capital costs of PVs to drop by 55%-70% in the near future to between $1220 and $1830 a kW. According to their projections 2015 will see a 40% reduction in capital cost and 2020 a 50% reduction[76]. Analyses additionally suggest that the installation costs of solar panels will also decrease significantly by 2016[77]. This way investing in solar cells becomes a progressively more accessible investment for the average consumer. In this context it is worth considering that government schemes might have helped create a transition period, from the time when PVCs were too expensive to be economically profitable.

On the basis of the above description of the electricity market in NSW we will proceed with our forecast of residential electricity prices in New South Wales.

3 Theoretical approach to forecasting electricity prices

[74] Hearps, 2011, p.9
[75] NSW Auditor-general report, 2011, p. 17
[76] International Energy Agency, 2010
[77] NSW Auditor-General report, 2011, p. 33

"Developing predictive models for electricity prices is a relatively new area of application for the forecasting profession[78]".

Estimating the price of retail electricity is essential for a proper assessment of the value of investing in solar panels. Electricity prices and the increase in these are the drivers of value-creation with respect to investing PVCs. The problem with forecasting retail electricity prices is that real-time retail electricity pricing (RTP) changes very frequently e.g. hourly to reflect changes in the market's supply/demand balance. Conducting a forecast on a 25 year horizon will undoubtedly lead to a great deal of uncertainties. This is also well reflected in the literature on electricity forecasts that for the majority part encompasses hourly, daily or at most monthly timeframes. One exemption to this is Borison and Hamm, who have developed a hybrid model that integrates financial as well as engineering data to create a model that improves accuracy and flexibility. This combination should better enable a long run forecast of electricity prices[79], though their focus is wholesale electricity. Borison and Hamm argue that most long-run forecasts of electricity prices make the mistake of simply projecting historic developments into the future, ignoring all the potential future cost-drivers. To avoid this Borison and Hamm integrate expert judgments with respect to future technologies and regulations in their forecast model. Additionally they incorporate forward electricity market prices and results from engineering approaches such as demand and supply simulation. Using Borison and Hamm's approach, we will also incorporate more than historic data projected into the future. Mainly we will focus on incorporating future developments within regulations as well as increased distribution and transmission costs. With respect to forecasting retail electricity prices, using forwards makes little sense, as forwards are made on wholesale electricity and not retail. In addition forwards on wholesale electricity are highly volatile and offer little explanatory power. This is especially true considering that the maximum prices that can be charged by distributors for retail electricity is set each year by the NSW Government through IPART. Furthermore due to the scope of this paper, we will not amalgamate the engineering technique of supply/demand simulation models, as it is too technical an approach.

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[78] Bunn et al, 2003, p. 1

[79] Hamm et al, 2006

We applied Borison's and Hamm's method by initially making a forecast based only on historic prices and afterwards adding the predicted future development of variables that we expect will have impacts on prospective prices. These variables are as previously mentioned increasing distribution and transmission costs and the newly imposed carbon tax. In this manner we acknowledged that prospective prices are not just a projection of past developments, but that they will also reflect additional variables.

3.1 Assumptions applied in forecast

For the purpose of our forecast several assumptions have been employed. Following we will account for each of them.

3.1.1 Carbon tax

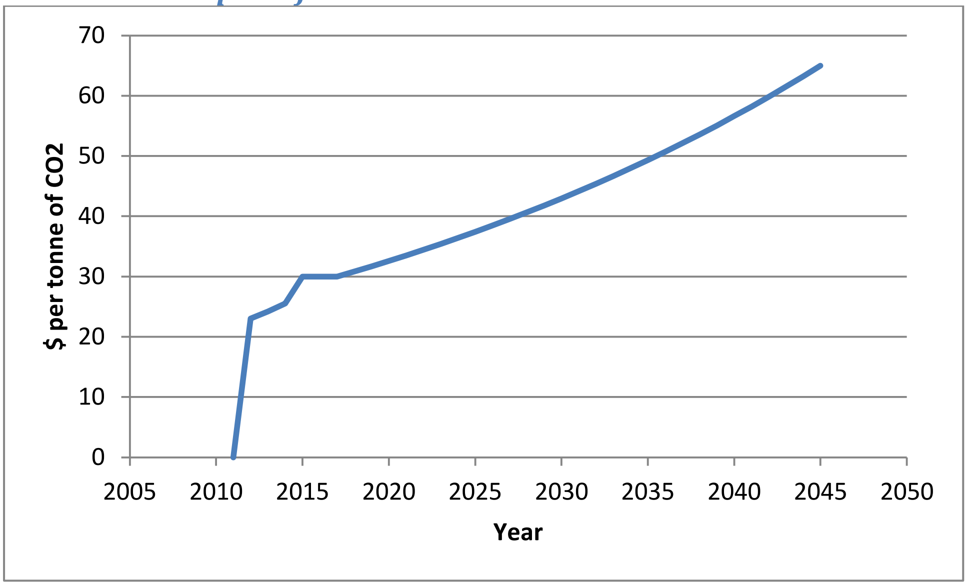
Carbon price assumptions are based on the suppositions made by AEMO and are as follows:

- Fixed carbon pricing starting from 2012–13, at a nominal price of \$23/t CO2-e will initially raise electricity prices by 9%.
- The carbon price will rise by 2.5% in real terms in 2013 and 2014.
- Market based pricing from the 1st of July 2015, though with a price floor of \$15 and a ceiling of \$20 *above* 2015 market price for the first three years[80][81] (market price in 2015 was calculated to be \$25[82]).

To obtain the impact of the carbon tax on the final retail price, a separate forecast of the carbon tax was made, where after its impact on the electricity price was assessed. The first two years following the introduction of the carbon tax were given but after 2015 the carbon tax is to be set according to the market with fixed boundaries. For this forecast we applied the average of the boundaries of the expected carbon tax, which means a carbon tax of \$30 (average of \$15 and \$45). This estimation was then in accordance with AEMO's report locked for three years. After which we set the carbon tax to increase by yearly CPI to avoid a diminishing effect over time. On the basis of these assumptions the development of the carbon tax is shown in the below graph.

[80] Peak Energy
[81] CO2 Australia
[82] Appendix 3

3.1.1.1 Figure: Carbon tax price forecast



[83]

Thereafter we forecasted the effects the projected carbon tax levels will have on final retail prices. In accordance with the first assumption, a carbon tax at a price of $23/t CO2-e causes a 9% increase in final electricity prices. Using this relations shows that a $2,5 increase in the carbon tax, causes an approximately 1% increase in the final electricity price. This relation was used as a benchmark for the following increases in the carbon tax.

3.1.2 Distribution

AER sets the allowed growth in distribution cost for each specific retailer every five years. The distribution cost is set according to what IPART considers fair, based on network calculations submitted by the suppliers. For use in our model we have employed information provided by the latest two AER reports, the first covering the period 2004-2008 and the second the period 2009-2013. In the former, allowed distribution costs are given in the form of a percentage increase in real terms, which means that CPI was added to obtain the full effect. In the latter report the data is given in nominal terms and therefore does not necessitate adjustments for CPI[84][85]. The data from these reports, which are shown below, were applied to calculate the impact distribution costs have had and will have on the final retail electricity price.

[83] Appendix 3
[84] IPART (d), p. 75
[85] Australian Energy Regulator (a), p. 318-324

3.1.2.1 Table: Distribution data

	Country Energy	Energy Australia	Integral Energy	CPI	Total average effect
2004	7% +CPI	7% +CPI	5% +CPI	2,04%	8,41%
2005	2,5%+CPI	1,6%+CPI	1,5%+CPI	2,21%	3,96%
2006	2,5%+CPI	1,6%+CPI	1,5%+CPI	2,70%	4,45%
2007	2,5%+CPI	1,6%+CPI	1,5%+CPI	2,23%	3,98%
2008	2,5%+CPI	1,6%+CPI	1,5%+CPI	3,92%	5,67%
2009	5,36%	7,15%	5,03%	2,41%	6,13%
2010	5,77%	5,28%	3%	2,96%	4,69%
2011	5,54%	5,62%	3,12%	3,17%	4,85%
2012	5,88%	5,96%	0,92%		4,42%
2013	0,00%	4,20%	0,00%		2,04%

To get an estimation of the total average impact distribution costs have on final retail price, the model took a weighted average of the three suppliers. The weighting was determined by the suppliers' respective portion of the total GWh production at the time of the report[86][87].

3.1.3 Transmission

Along with distribution costs AER regulates transmission costs on a 5-year cycle. We have obtained the previous three reports dating back to 1999. The data from these reports show the percentage change increases in transmission costs will have on transmission costs themselves and not like was the case with distribution costs, the percentage change increases will have on the final retail price. We undertook these calculations ourselves to estimate how much changes in transmission costs would cause final retail prices to increase. Using the latest report it was estimated that a 4,8% increase in transmission costs causes a 0,3% price increase in the final retail price. The model uses this ratio to transform the transmission cost increases into final cost increases. In accordance with

[86] IPART (d), p. 197
[87] Australian Energy Regulator (a), P. 24-25

the AER reports, the data for the first ten years are given in real terms, while the latter five years are given in nominal terms [88][89][90] (this is why the CPI rate is not provided for the period 2009-2013).

3.1.3.1 Table: Transmission data

	Transmission	CPI	Total
1999	0%	4,22%	0,26%
2000	0%	4,75%	0,30%
2001	0%	1,26%	0,08%
2002	0%	0,08%	0,01%
2003	0%	1,57%	0,10%
2004	5,47%	2,61%	0,51%
2005	0,61%	6,52%	0,45%
2006	0,74%	2,91%	0,23%
2007	1,19%	3,05%	0,26%
2008	0,76%	2,04%	0,18%
2009	4,80%		0,30%
2010	4,80%		0,30%
2011	4,80%		0,30%
2012	4,80%		0,30%
2013	4,80%		0,30%

As can be seen from the above tables, distribution and transmission will initially raise electricity prices by 4,7% as of July 1st 2012 and will further increase them by 2,3% in 2013. From these calculations the effects of distribution and transmission costs on the forecast of electricity prices are given for 2013 and 2014, but after 2014 estimations of effects proved necessary. To undertake these estimations, it proved crucial to firstly decompose d+t costs. Decomposing on the basis of

[88] Australian Energy Regulator (b), p. 11
[89] Australian Energy Regulator (c), p. 182
[90] Australian Energy Regulator (d), p. 68 & 102

data on the final retail price in 2011 we find that d+t costs accounted for 48% of the total retail price[91]. These 48% were then used to calculate the nominal costs of d+t in real terms and was found to amount to 12,08 cents. Using the data from AER on the yearly increases allowed for distribution and transmission costs in 2012 and 2013, 4,7% and 2,3% respectively, the following calculation was made; 25cents *0,047 = 1,175 cents. These 1,175 cents represent the nominal increase of distribution and transmission costs. This increase was then added to the 12,08 cents representing nominal d+t costs in 2012, for a total nominal cost of d+t of 13,255 cents in 2013. This procedure was repeated for the remaining years to obtain the effects of d+t cost increases on the final retail price.

3.1.4 The relative impact of distribution and transmission on retail prices over time

Though distribution and transmission costs currently account for 48% of the final retail electricity price and is already projected to keep increasing the coming years, it is not assumed that d+t costs will continue to account for the same percentage share of final price for the next 25 years. At first this conclusion could seem counterintuitive as it has previously been argued that one of the main contributors to rising retail electricity prices are increasing network costs. There are two evident reasons that d+t cannot keep growing as a percentage of the final retail price. The first is that if d+t costs continue to make up a bigger and bigger percent of the final retail price it would end up constituting the entire price, leaving nothing left to account for wholesale and retail. The second is that "*Forecast increases in the costs of materials and manufacturing have been a factor in further increasing the cost of undertaking the required capital investment to meet increasing maximum demand and replace ageing assets*[92]". Yet as investments in networks are undertaken to account for either maintenance reasons, upgrade reasons or to meet increased demand, and as these are all temporary factors, a constant level of network investments would be illogical. Especially considering that transmission and distribution costs are made up of the following components:

- Operating expenditure

  and

[91] NSW Government (g), p. 13
[92] AEMC (b), 2011, p. 23

- Capital expenditure, including:

1. Return of capital (depreciation)
2. Return on capital (cost of capital – financing)
3. Tax payments[93]

And that current increases are due to several drivers

- Increase in maximum demand – which requires expansion of capacity
- Higher financing costs following the Global Financial Crisis
- The need to replace aging assets
- Obligations to comply with higher reliability standards (in order to fulfill the 2005 regulatory determination of increased reliability)[94]

All of which are temporary drivers of increasing investments. Also a key factor in explaining why elements such as maintenance, replacement of assets and improvement of capacity, which are costs to be expected, have led to such drastic price increases are the rising costs of the inputs required to undertake these investments[95][96]. The past 5-10 years, costs on aluminum, steel and copper, which are vital inputs in electricity networks, have increased rapidly[97][98], following the general upwards trend of the commodity price index[99]. Moreover as explained by AEMC "*The cost of undertaking capital works has also increased for distribution networks, as a result of higher rates of return on capital investment and increasing input costs. Rates of return on capital in absolute terms are generally over one per cent higher compared to the previous regulatory period, following the increase in debt premiums from 1 – 3% in the wake of the global financial crisis."* And

93 NSW Government (g), p.15
94 AEMC (a), p.13
95 AEMC webpage
96 AEMC (a), p. 1
97 Indexmundi (a)
98 Australian Bureau of Statistics (d)
99 Indexmundi (b)

likewise "*Real increases in the cost of labour of over two per cent each year are also forecast in many jurisdictions over the next three years [2011-2014]*[100]*.*"

Accordingly, though the costs of d+t have been a major cause of recent years' price increases and will continue to account for a substantial part the increases in future years, on a longer horizon, the d+t component of final retail price is expected to drop. This is also the case as from 2012 "*aluminium, steel and copper are forecast to increase at a slower rate or decrease as prices return to long-term average* [101].

In this way, our forecast will assume that in the short run costs of d+t will continue to rise (this is already determined by AER's 5 year report), but on a longer horizon this increase will stagnate. This development is also caused by the introduction of the carbon price, which will make the relative costs of wholesale and retail more expensive and cause these two components to constitute a larger percentage of the final retail price.

Below is a table from AEMO forecasting the difference the carbon tax has on the relative magnitude of the different components of the final retail price.

3.1.4.1 Figure: New South Wales – projected impact of carbon price on total residential electricity tariff in 2012/13 and 2013/14

	Nominal percentage increase between 2010/11 - 2013/14		Nominal price increase between 2010/11 - 2013/14 (c/kWh)		Percentage of total price increase attributable to component	
	No carbon	With carbon	No carbon	With carbon	No carbon	With carbon
Transmission component	34	34	0.59	0.59	8	6
Distribution component	32	32	3.44	3.44	46	36
Wholesale energy component	22	49	1.62	3.65	22	38
Retail component	22	26	0.55	0.65	7	7
Green energy component (total)	513	452	1.31	1.16	17	12
Total	**33**	**42**	**7.51**	**9.48**	**100**	**100**

Source: Australian Energy Market Operator: ***Final Report - Possible Future Retail Electricity Price Movements: 1 July 2011 to 30 June 2014***

As can be seen from the above chart the overall effect distribution and transmission costs have on the final retail price decreases from 54% to 42% with the introduction of the carbon tax. At the same time the wholesale component augments to account for 38% of the increase, when the

[100] AEMC (b), 2011, p. ii
[101] AEMC (b), 2011, p. 23

carbon tax is introduced as opposed to only 22% in the absence of the carbon tax. We therefore find it reasonable to assume that distribution and transmission costs will not continue to have the same heavy influence on retail prices in the longer run, after the introduction of the carbon tax. Rather we find it reasonable that in our forecast of year 2037, costs of distribution and transmission will only account for approximately 28,6% of the final retail electricity price. This number was derived by letting distribution and transmission costs increase by an annual CPI of 2,8% from 2014 and onwards.

3.1.5 Inflation rate

All prices in the model, except index prices, were regulated for yearly increases in inflation. This was done so that the prices in the model would reflect nominal future prices and not 2012 dollars. The CPI rate applied was 2,8%, a rate that was set based on the succeeding justifications. In their *National Electricity Forecasting Information Paper* from December 2011, AEMO uses a CPI rate of 2,8%, which they refer to as the Reserve Bank of Australia's five year forecast[102]. In addition we used data from IPART and their *Review of regulated retail tariffs and charges for electricity 2010-2013*. In this report the CPI index in June quarter on quarter from the period 2003/04 to 2011/12 as well as a forecast of 2012/13 averages a CPI value of 2,8%[103]. Consequently we found this value to be a good estimate of average future price increases. With the implementation of the carbon price, it has been predicted that CPI will increase an additional 0,7%. Yet as the introduction of the carbon tax and its impact on CPI has been known for some time by official regulators it is assumed that AEMO, IPART and the Reserve Bank of Australia have already incorporated this rise in their 2,8% estimate and therefore the 0,7% was not added as an extra increase to our CPI rate.

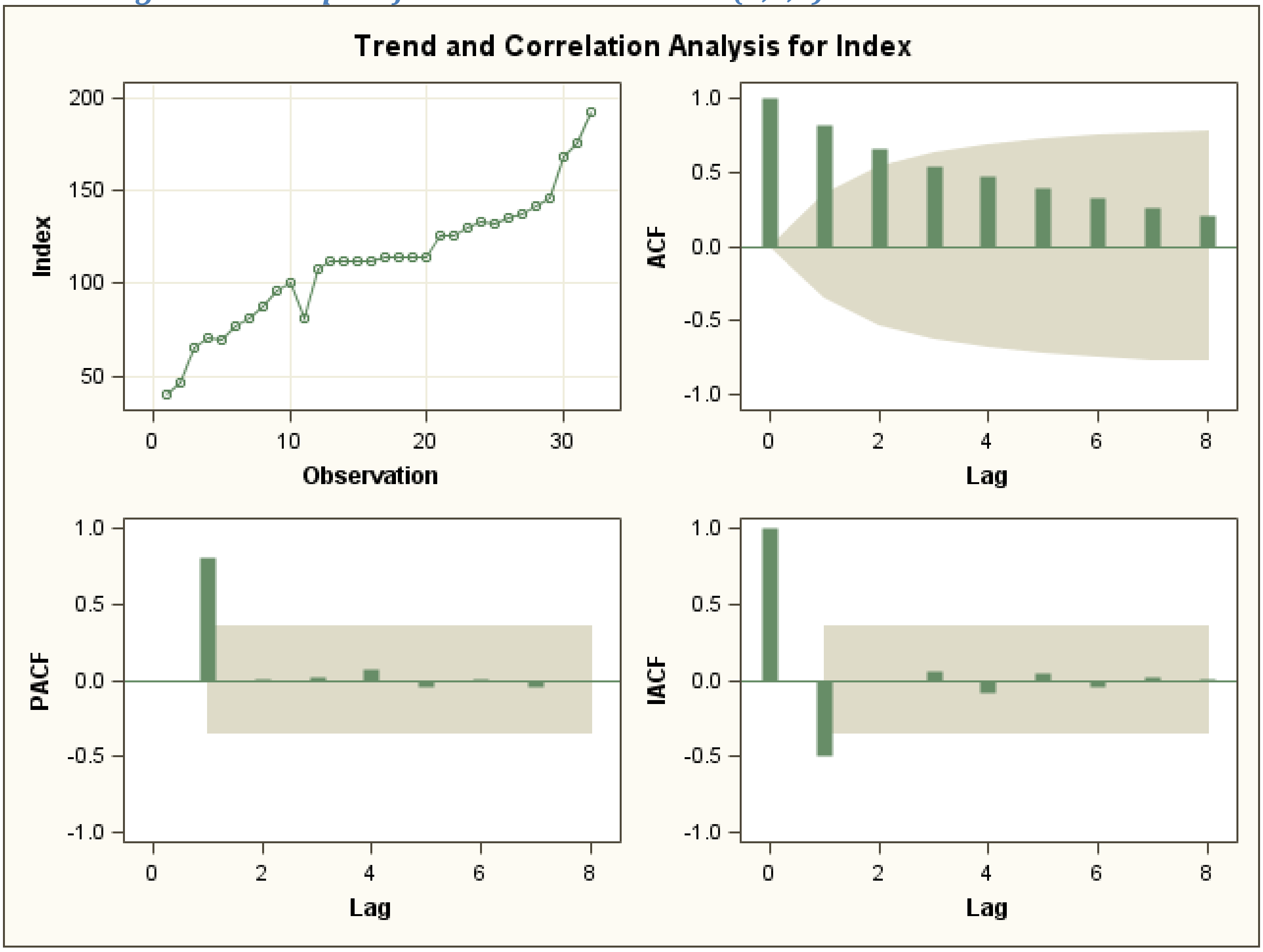
4 Forecast of residential electricity prices

Having established the assumptions behind our forecast, this section will go through the forecast of retail electricity prices for the next 25 years, based on a histroric index dating back to 1980. As the data shows development over time, we work with timeseries analyses and start by running an

[102] AEMO (b), 2011, p. 25
[103] IPART (c), 2010

ARIMA model on yearly index prices of retail electricity from the period 1980-2011. This gives the following graphs:

4.1.1.1 Figure: SAS output of corrected index ARIMA(0,0,0)



From the first graph, we suspect potential problems with non-stationarity, as it has a clear trend. However the ACF chart, though showing a linear decline, is not significant through higher order of lags, which would normally be a sign of non-stationarity. Therefore we need to perform a more formal test for non-stationarity. Here we apply the Augmented Dickey-Fuller test, though to use this, we first have to test formally for autocorrelation, which is done using Godfrey's serial correlation test. Godfrey's general Lagrange multiplier test can be applied to test for autocorrelation and in case this is detected, the model can be adjusted by introducing as independent variables "l" lags of the dependent variable. Once a model without autocorrelation has been obtained, we can rely on the estimation of the variables and decide about stationarity.

We hence need to commence with a LM test of the model, but before we do that it is necessary to consider what kind of model we are dealing with. The model can take on three different forms;

Y as a random walk; $\Delta Y_t = \delta Y_{t-1} + u_t$

Y as a random walk with a drift; $\Delta Y_t = \beta_1 + \delta Y_{t-1} + u_t$

Y as a random walk with drift around a deterministic trend; $\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + u_t$

Considering the nature of the data, which is given on an index, an intersection in "0" makes little sense and when examining the graph, we see signs of a stochastic trend and not a deterministic one. Accordingly we assess that we are dealing with a random walk with a drift model.

Under Godfrey's LM test the $H_0 = p_1 = p_2 = p_3$ = no autocorrelation and H_a= autocorrelation is present.

Conducting the test gives us the following results:

4.1.1.2 Table: SAS output of Godfrey's serial correlation test

Godfrey's Serial Correlation Test		
Alternative	**LM**	**Pr > LM**
AR(1)	0.8829	0.3474
AR(2)	0.8829	0.6431
AR(3)	0.9966	0.8021
AR(4)	1.1862	0.8804

As can be observed none of the lags are significant and we can accept H_0 of no autocorrelation. We therefore move on to the augmented Dickey-Fuller test to test for stationarity, where H_0 = non-stationarity and H_a = stationarity.

4.1.1.3 Table: SAS output of Augmented Dickey-fuller unit root tests

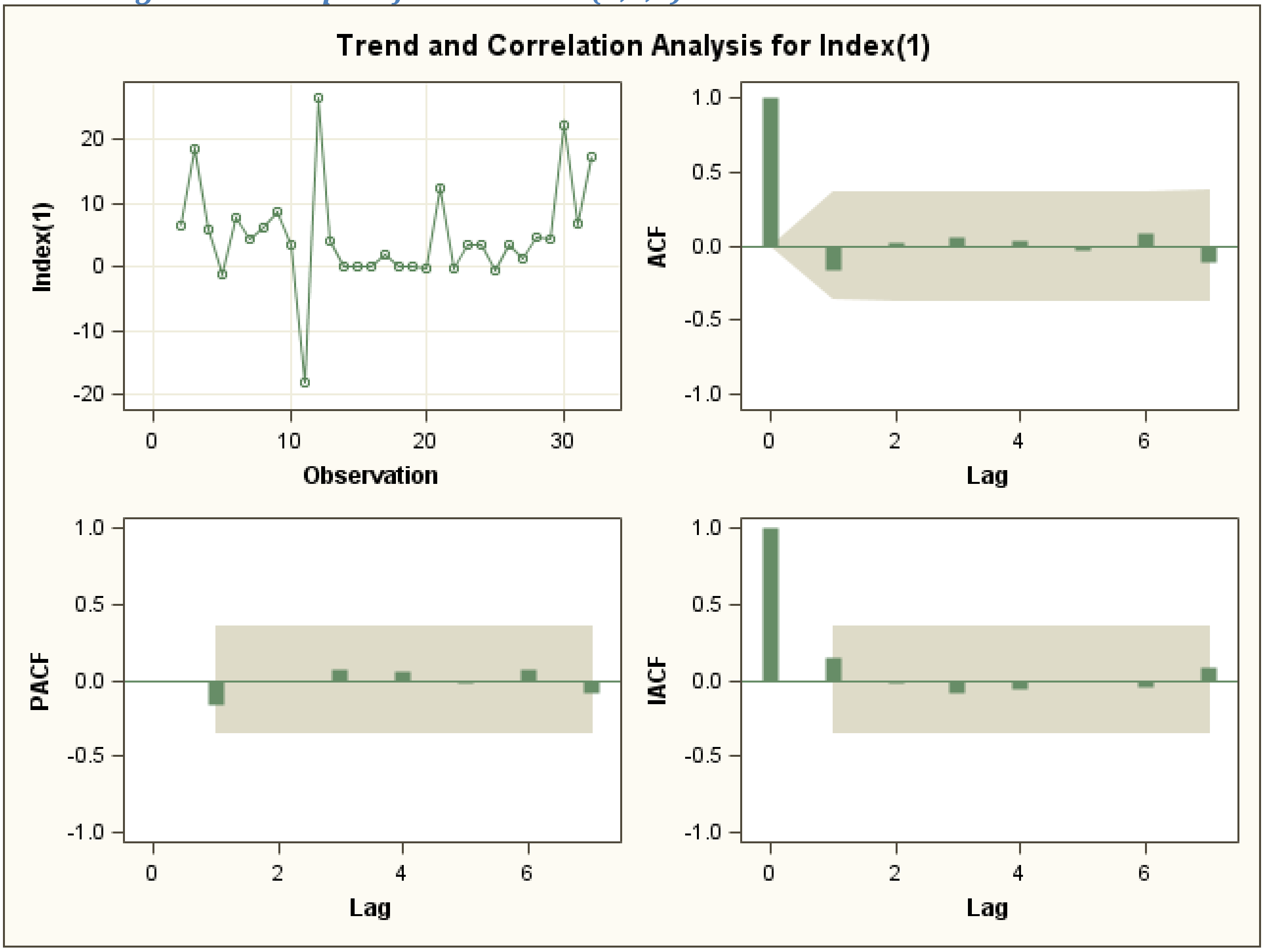
Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**F**	**Pr > F**
Zero Mean	0	1.2682	0.9385	3.11	0.9991		
	1	1.2088	0.9313	3.03	0.9989		
	2	1.1176	0.9182	2.79	0.9980		
Single Mean	0	-0.2962	0.9350	**-0.20**	**0.9281**	5.48	0.0334
	1	-0.0506	0.9491	-0.04	0.9475	5.07	0.0445
	2	1.0121	0.9856	0.77	0.9915	3.74	0.1486

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**F**	**Pr > F**
Trend	0	-10.4765	0.3348	-2.07	0.5430	2.20	0.7425
	1	-11.2965	0.2798	-1.82	0.6719	1.74	0.8307
	2	-8.4183	0.4906	-1.02	0.9251	1.03	0.9609

From our choice of model, we look at the data for "single mean with 0 lag" that shows a tau of **I**-0,2**I** which is lower than the critical value of tau at a 5 % significance level that equals **I**-3**I.** So we cannot reject H_0 and have a problem with non-stationarity. This is also apparent in the tau probability of almost 93%.

Having concluded that the process is non-stationary, it is necessary to find an appropriate transformation of the time series. One way of transforming a time series into stationarity is by taking the first difference. It is not guaranteed that the time series becomes stationary just because the first difference is taken and so the ACF and the PACF must still be verified after the data has been transformed. The ACF and PACF of the ARIMA (0,1,0) looks like this:

4.1.1.4 Figure: SAS output of index ARIMA(0,1,0)



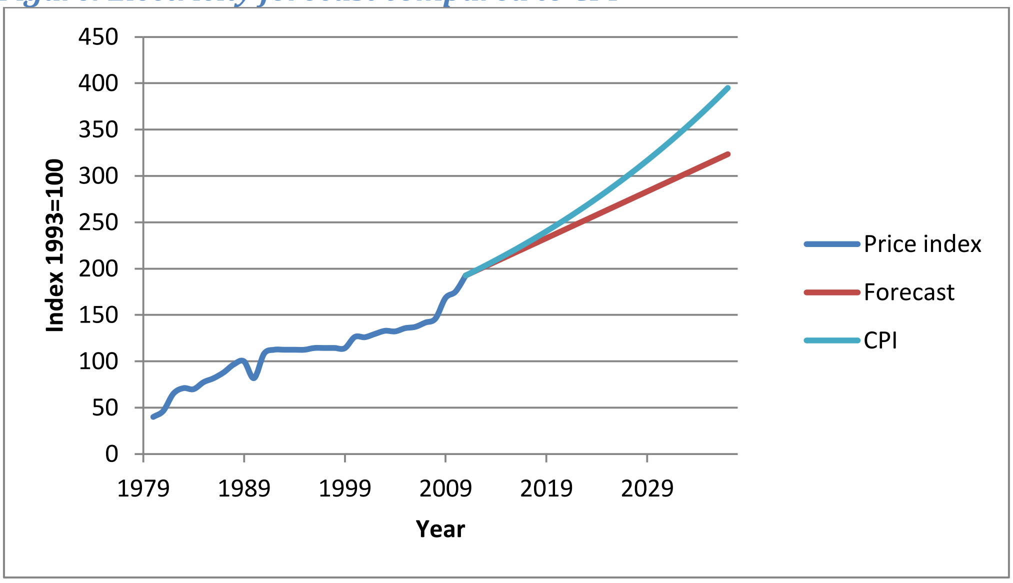
The model now shows no sign of non-stationarity, as there is no trend in the graph and the ACF chart shows signs of quick decline and a wave pattern, which are both signs of stationarity. From our previous test we already know, that there is no problem with autocorrelation, so we move on to the augmented Dickey-Fuller test.

4.1.1.5 Table: SAS output of Augmented Dickey-fuller unit root tests after transforming into first difference

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**F**	**Pr > F**
Zero Mean	0	-25.9706	<.0001	-4.47	<.0001		
	1	-15.9536	0.0025	-2.75	0.0076		
	2	-7.2474	0.0537	-1.46	0.1319		
Single Mean	0	-35.3862	0.0001	**-6.08**	**0.0002**	18.52	0.0010
	1	-35.6680	0.0001	-4.03	0.0040	8.13	0.0010
	2	-32.6016	<.0001	-2.63	0.0990	3.47	0.2136
Trend	0	-35.3280	<.0001	-5.98	0.0002	18.02	0.0010
	1	-34.9567	<.0001	-3.99	0.0208	8.65	0.0116
	2	-27.2637	0.0015	-2.52	0.3176	4.41	0.3270

Here we find an absolute tau value of l-6,08**l** which is bigger than **l**-3**l** that is the critical value at a 5% significance level, so we reject the H_0 of non-stationarity. Since the ACF chart shows no significant lags, we find no reason to test the model for a higher order of "p" lags. In the same way, as there were no significant lags found in the PACF, no reason was found to test for moving averages. Making the forecast based on this model yields a yearly increase of 4,929 in index numbers. However conducting the forecast on this number, creates a prediction which shows a lesser yearly growth than the CPI of 2,8%. A scenario which is highly improbable, as retail electricity prices have historically risen more than the general CPI index. The reason this projection occurs is that the estimated growth of 4,929 is in index numbers, which predicts a constant growth variable independent of the magnitude of the index. On the contrary CPI indicates a percentage change that takes into consideration the relative size of the index. Below is a graph showing the forecast in relation to CPI growth. As explained the latter is greater than the former.

4.1.1.6 Figure: Electricity forecast compared to CPI



[104]

Even if the above model, ARIMA (0,1,0) is statistically correct, we prefer to continue our forecast with a model that takes into consideration the magnitude of the index when forecasting expected growth.

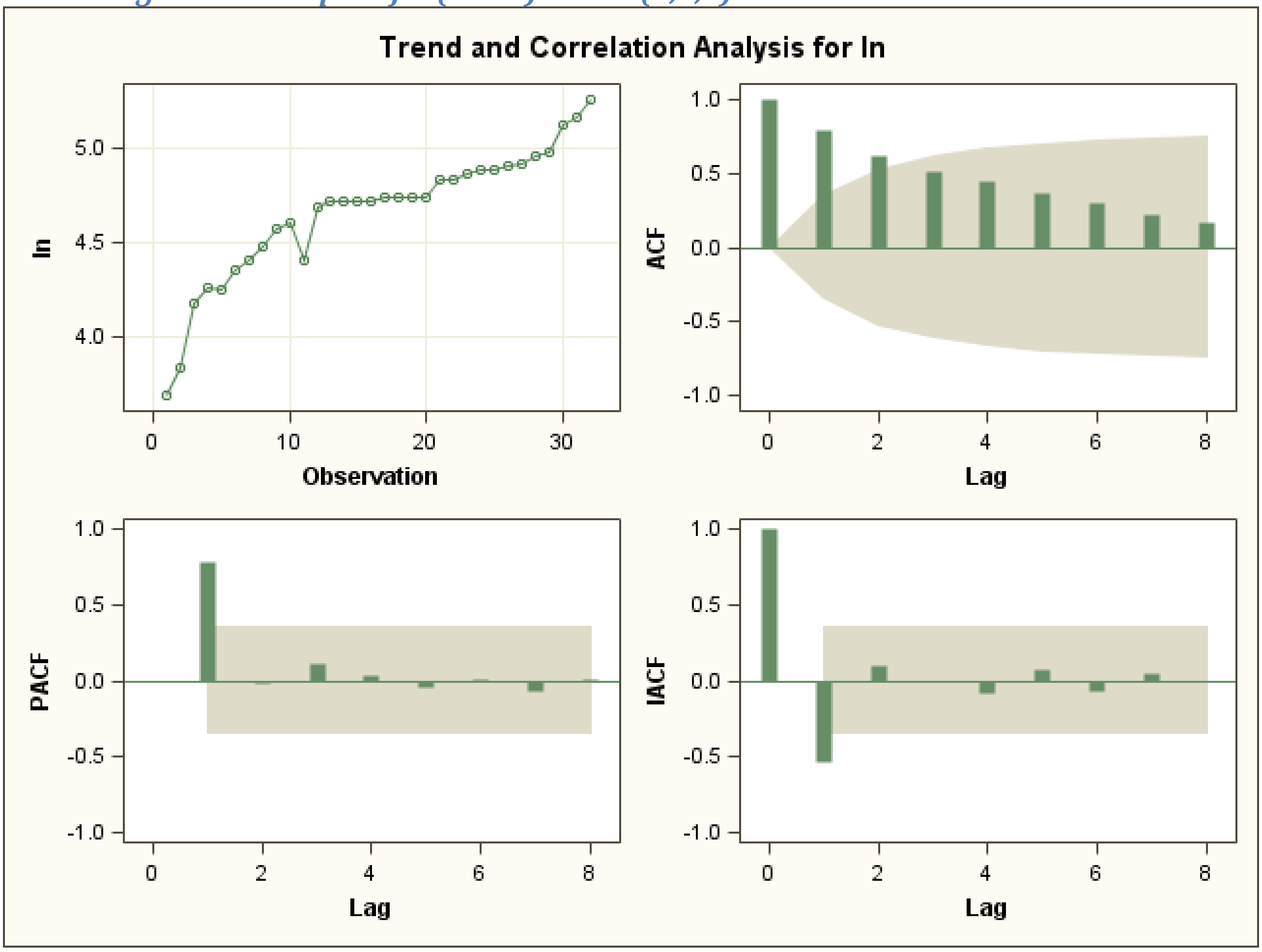
[104] Appendix 3

4.2 Transforming model using natural logarithms

It was preferred to transform the data into natural logarithm numbers, as this would solve the issue of a constant growth variable ignoring the index magnitude.

Converting the model into an LN-model provides the following charts.

4.2.1.1 Figure: Sas output of ln(index) ARIMA(0,0,0)



As expected, we again observe clear signs of non-stationarity, as the ACF declines in wave patterns. Like before we therefore need to conduct a formal test for non-stationarity, yet before this can be done it is necessary to test for the presence of autocorrelation.

As can be seen from Godfrey's LM test for autocorrelation, none of the lags are statistically significant and we continue on with the formal test for non-stationarity.

4.2.1.2 Table: SAS output of Godfrey's serial correlation test

Godfrey's Serial Correlation Test

Alternative	LM	Pr > LM
AR(1)	0.8865	0.3464
AR(2)	1.1636	0.5589
AR(3)	1.2737	0.7354
AR(4)	1.4101	0.8424

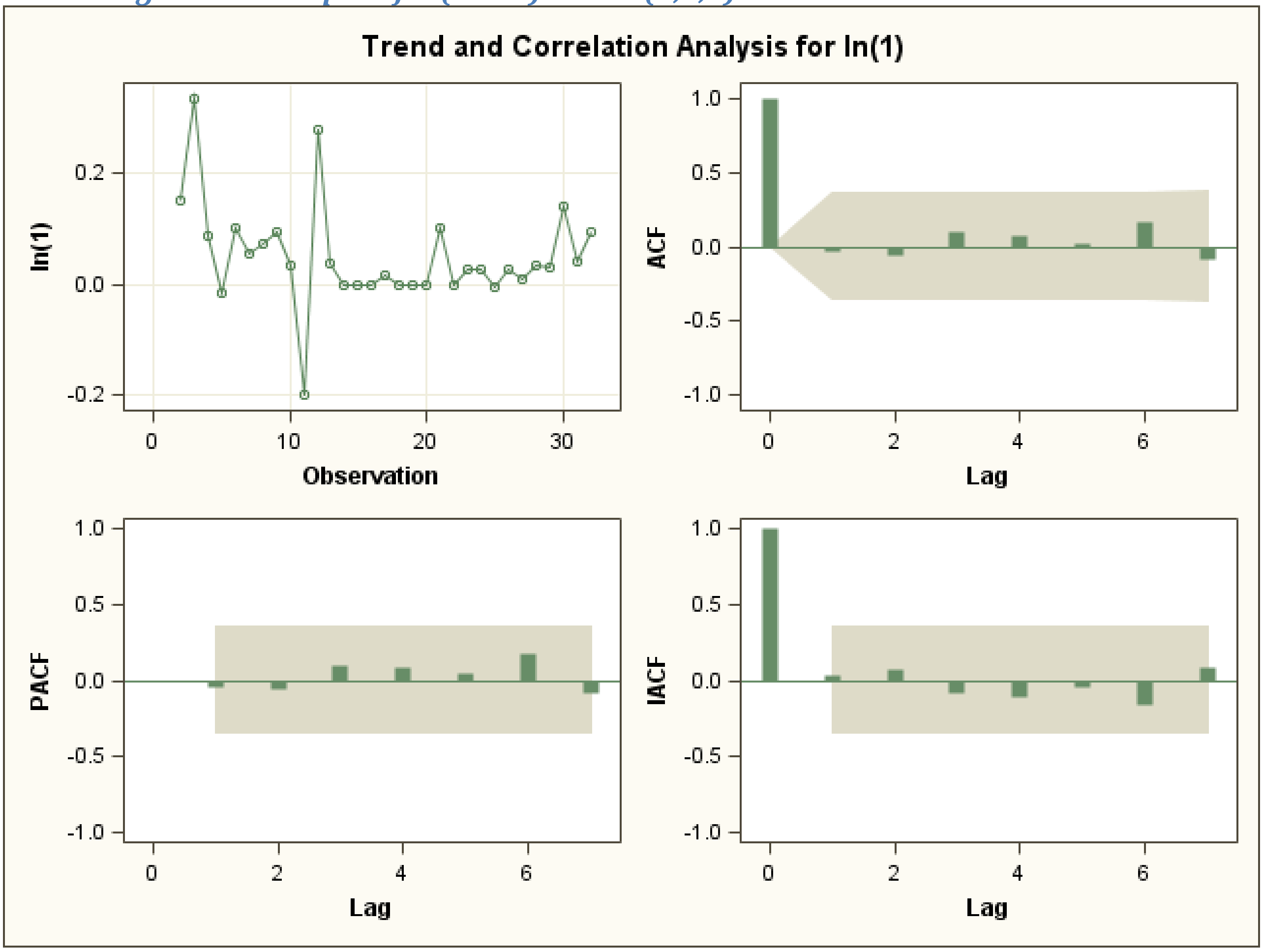
4.2.1.3 Table: SAS output of Augmented Dickey-fuller unit root tests

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**F**	**Pr > F**
Zero Mean	0	0.3173	0.7501	2.80	0.9981		
	1	0.2879	0.7425	2.33	0.9939		
	2	0.2358	0.7320	2.63	0.9970		
Single Mean	0	-3.8732	0.5304	**-2.78**	**0.0726**	9.52	0.0010
	1	-3.7432	0.5452	-2.59	0.1061	7.21	0.0010
	2	-1.6131	0.8120	-1.23	0.6470	4.56	0.0664
Trend	0	-13.1254	0.1865	-4.27	0.0104	10.51	0.0010
	1	-17.0127	0.0662	-5.09	0.0015	14.12	0.0010
	2	-12.2446	0.2240	-2.93	0.1686	4.42	0.3253

As seen from the Augmented Dickey-Fuller test, the model shows presence of non-stationarity, as the tau value is less than the critical value of **I**-3**I**, **I**-2,78**I**.

To correct for the presence of non-stationarity, we transform the model into a first difference model, ARIMA (0,1,0). This corrects the problem and makes the model stationary as can be seen from the below ACF and PACF charts.

4.2.1.4 Figure: SAS output of ln(index) ARIMA(0,1,0)



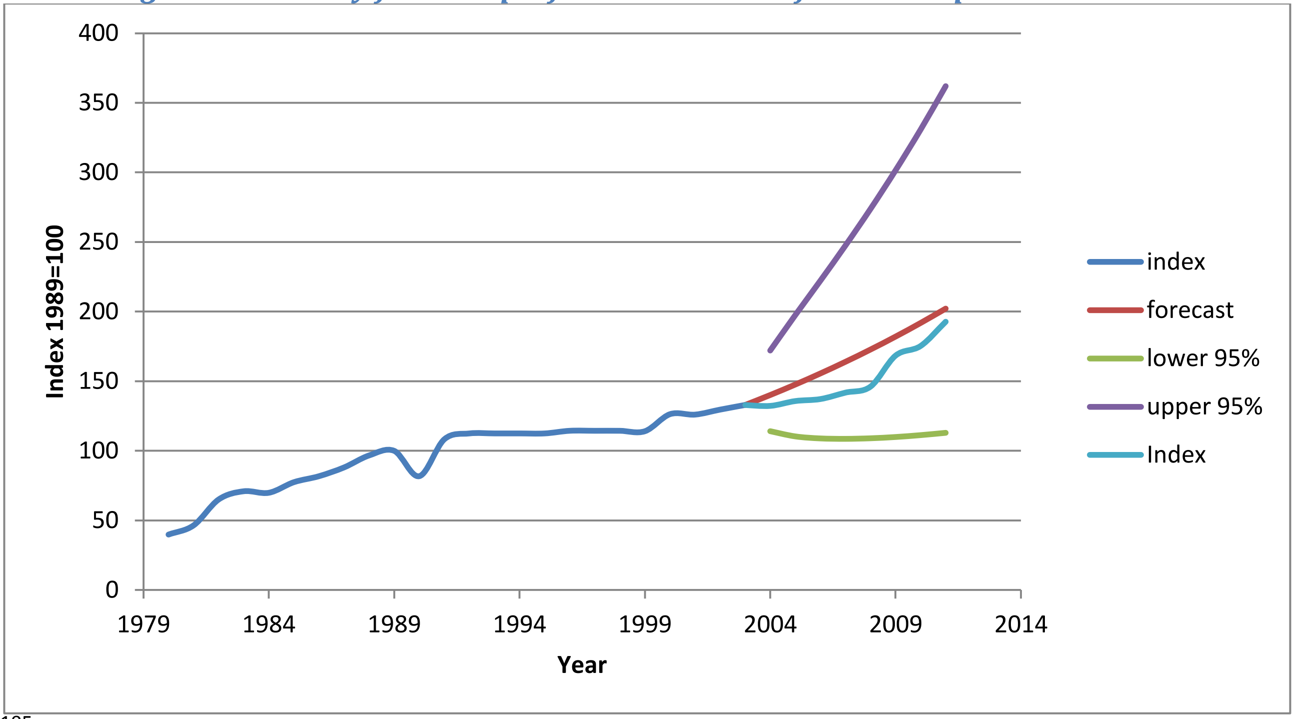
For a more formal test we turn again to the augmented Dickey-Fuller test and find that there is no problem with non-stationarity, as the absolute tau value of **I**-5,6**I** is bigger than the critical value of **I**-3**I**.

4.2.1.5 Table: SAS output of Augmented Dickey-fuller unit root tests after transforming into first difference

Augmented Dickey-Fuller Unit Root Tests							
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**	**F**	**Pr > F**
Zero Mean	0	-24.5393	<.0001	-4.58	<.0001		
	1	-22.8472	0.0001	-4.43	<.0001		
	2	-16.0606	0.0024	-3.26	0.0020		
Single Mean	0	-31.1651	0.0001	**-5.60**	**0.0002**	15.68	0.0010
	1	-38.4640	0.0001	-5.59	0.0002	15.88	0.0010
	2	-42.7617	<.0001	-4.53	0.0012	10.39	0.0010
Trend	0	-32.9465	0.0001	-5.70	0.0003	16.40	0.0010
	1	-40.6509	<.0001	-5.27	0.0010	15.23	0.0010
	2	-43.0711	<.0001	-4.03	0.0193	9.82	0.0010

Since the model is now stationary we continue with the forecast. But first we want to evaluate how accurately the model can forecast. This is done by conducting a forecast based on 75% of the data to see how accurately it describes the actual development; that is the remaining 25% of the data. The graph below shows the forecast, with confidence intervals at a 95% level, compared to the actual remaining 25% of the data.

4.2.1.6 Figure: Electricity forecast performed on 75% of data to explain the last 25%



[105]

Though the forecast shows a larger growth than the actual data, it is still within the confidence interval and we consider the model to be will-fitted for the future forecast. To conduct the forecast for the next 25 years, 100% of the historic data is applied to make the model. The forecast then looks like this.

4.2.1.7 Table: Electricity forecast with 95% confidence interval

Forecasts for variable ln				
Obs	Forecast	Std Error	95% Confidence Limits	
33	5.3119	0.0930	5.1297	5.4942
34	5.3627	0.1315	5.1050	5.6205
35	5.4135	0.1611	5.0979	5.7292
36	5.4643	0.1860	5.0998	5.8288
37	5.5151	0.2079	5.1076	5.9227

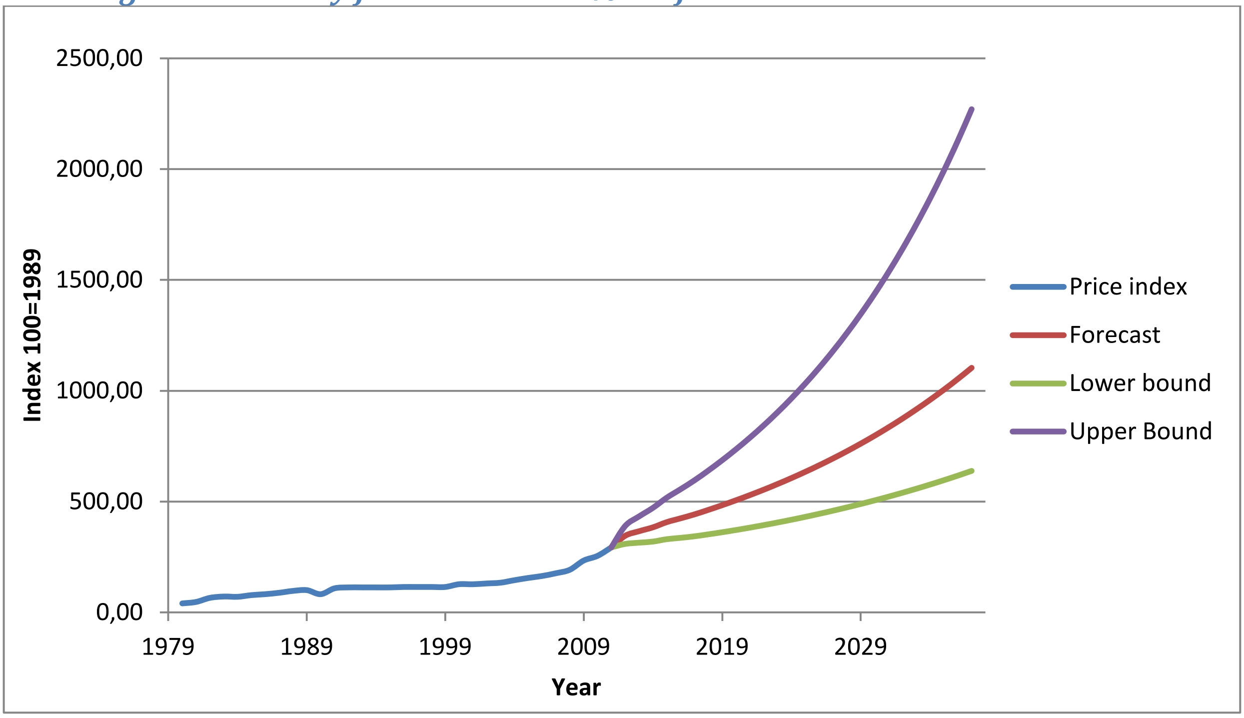
[105] Appendix 3

Forecast of residential electricity prices

Forecasts for variable ln				
Obs	**Forecast**	**Std Error**	**95% Confidence Limits**	
38	5.5659	0.2278	5.1195	6.0124
39	5.6167	0.2460	5.1346	6.0989
40	5.6675	0.2630	5.1521	6.1830
41	5.7183	0.2790	5.1716	6.2651
42	5.7691	0.2940	5.1928	6.3455
43	5.8199	0.3084	5.2155	6.4244
44	5.8707	0.3221	5.2394	6.5021
45	5.9215	0.3353	5.2644	6.5787
46	5.9723	0.3479	5.2904	6.6543
47	6.0231	0.3601	5.3173	6.7290
48	6.0739	0.3719	5.3449	6.8029
49	6.1247	0.3834	5.3733	6.8762
50	6.1755	0.3945	5.4023	6.9488
51	6.2263	0.4053	5.4319	7.0207
52	6.2771	0.4158	5.4621	7.0922
53	6.3279	0.4261	5.4928	7.1631
54	6.3787	0.4361	5.5239	7.2336
55	6.4295	0.4459	5.5555	7.3036
56	6.4803	0.4555	5.5875	7.3732
57	6.5311	0.4649	5.6199	7.4424
58	6.5819	0.4741	5.6526	7.5112
59	6.6327	0.4832	5.6857	7.5797

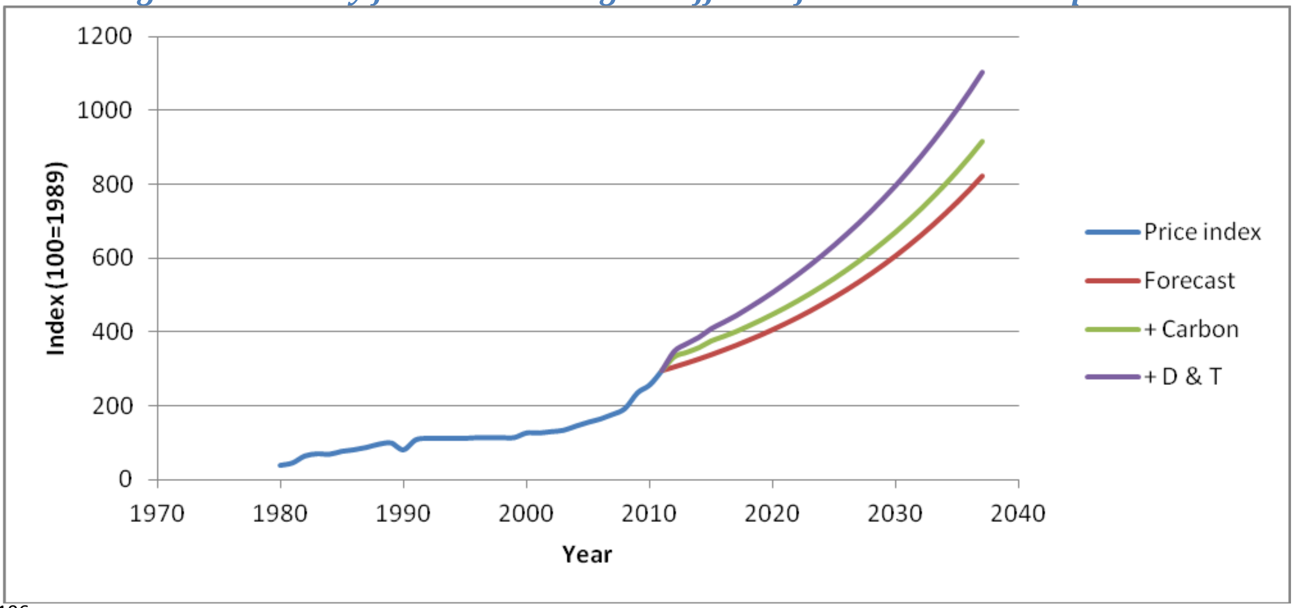
And is illustrated in the below model.

4.2.1.8 Figure: Electricity forecast with 95% confidence interval



Finding the above forecast appropriate for further projections, we proceed to add the effects of the newly introduced carbon tax and increasing distribution and transmission costs. Below is a graph showing the full forecast, decomposed in three elements, the forecast of historic developments, the effects of the carbon tax and the effects of distribution and transmission costs.

4.2.1.9 Figure: Electricity forecast showing the effects of the three sub-components

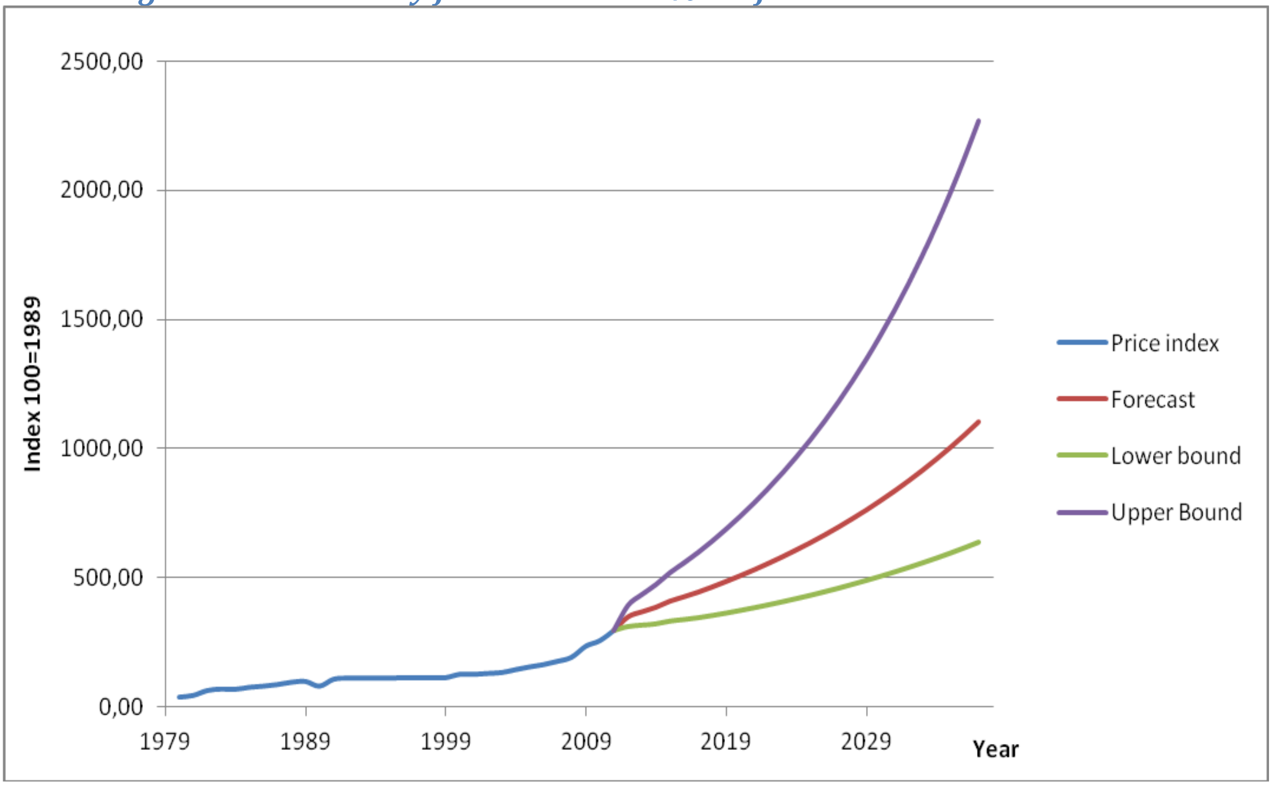


[106]

As can be observed the introduction of the new carbon tax causes projected price levels to increase significantly and likewise do the effects of distribution and transmission costs. Adding all three components together to create the full forecast the below graph is obtained.

[106] Appendix 3

4.2.1.10 Figure: Full electricity forecast with 95% confidence intervals



The forecast appears to have a very high growth rate compared to historic price developments, but it should be noted that the historic growth rate of residential electricity prices has been 6,65% which is greater than the growth rate of 5,44% predicted by the above forecast[107].

5 Choice of theoretical framework: Discounted cash flows and net present value analysis

"*The objective of an economic analysis is to provide the information needed to make a judgment or decision*[108]*.*"

In line with the above stance, it was essential for the analysis that the theoretical framework reflected the main objective. As the main objective for this paper is an evaluation of solar cells as an economically viable investment for the NSW consumer it was therefore fitting to approach the analysis using classical investment theory frameworks. This choice was further supported by the

[107] For derivations of growth rates and upper and lower bounds – see appendix 3
[108] Short et al, 1995, p.9

fact that several economic evaluations of energy matters in general and solar panels in particular have been conducted using an NPV framework[109][110][111], in which relevant framework variables are discussed and evaluated according to the specific context. Many of these analyses start by applying the levelized cost of electricity (LCOE) method as part of their study. The LCOE framework in its essence breaks down the cost per kWh of different electricity-generating methods. It is a framework that "*allows for alternative technologies to be compared when different scales of operation, different investments and operating time periods or both exist"*[112]. Because it enables a comparison of price per kWh it is a framework optimal for comparing the cost of electricity generated through renewable energy and the cost of electricity generated through fossil fuels[113]; "*the economic feasibility of PV projects is increasingly being evaluated using the levelized cost of electricity (LCOE) generation in order to be compared to other electricity generation technologies*[114]*."*

Melbourne Energy Institute defines the calculation of LCOE by means of the below computations:

"The LCOE is determined by the point where the present value of the sum discounted revenues is equivalent to the discounted value of the sum of costs":

$$\sum_{t=0}^{n} \frac{\text{Revenue}}{(1+\text{r})^{\text{t}}} = \sum_{t=0}^{n} \frac{\text{Costs}}{(1+\text{r})^{\text{t}}}$$

Where:
***n** = Project lifetime (yrs)*
***t** = Year in which sale or cost is incurred*
***r** = Discount rate (%)*

By definition this is the point at which the Net Present Value (summation of the Present Values, PV, of the cash flows) for a project is zero:

$$NPV = \sum_{t=0}^{n} PV = 0$$

Where:

[109] Short et al, 1995
[110] Denholm, 2009
[111] Branker et al, 2011
[112] Short et al, 1995, p. 47
[113] Short et al, 1995, p.47
[114] Short et al, 1995

$$PV = \frac{EBIT\,(1-T) + DEP - CAPEX}{(1+r)^t}$$

And:
***EBIT** = Earnings Before Interest and Tax*
***DEP** = Depreciation*
***CAPEX** = Capital Expenditure*
***T** = Corporate Tax rate (%)*[115]

Though this methodology to estimate the value of investing in renewable energy sources is suitable for corporate and government evaluations, there are two main reasons why it does not make sense to apply in a private consumer context. The first is the issue of depreciation, which is included in the above approach, but which is not relevant for the private consumer, as there are no tax-benefits associated with writing off capital expenditures in a household context. That brings us to the second issue which differs between corporate and private investments, taxes. The private consumer pays income tax, hence his tax payments are a function of his salary and not his earnings from saving money on the electricity bill. Namely because most of the cash inflow generated from investing in solar panels come in the form of savings on the electricity bill and these savings are tax-free, there is a difference in the way investments in solar panels should be evaluated from a corporate and a private point of view.
In this context it should be mentioned that the money received from selling electricity back to the grid are usually also tax-free. At least they are tax-free if it can be shown that the system was installed for personal use/hobby and not commercial profit objectives[116]. Therefore this paper will assume that money received from selling surplus electricity to the grid are tax-free. Moreover though the comparative approach of contrasting $/kWh has its advantages with respect to evaluating the economic rentability of solar cells, it provides a too simplistic conclusion for the purpose of this analysis. The reason being that it fails to incorporate the difference between selling and buying price and hence the difference associated with cost savings as opposed to earnings. This shortcoming arises as the proportion of electricity sold versus proportion used will not be a constant, but will vary with the consumption function and the system size. In academic sources the LCOE method has been criticized for being "*deceptively straightforward…"* and

[115] Hearps, 2011, p. 2
[116] Energymatters

showing a "*lack of clarity of reporting assumptions, justifications showing understanding of the assumptions and degree of completeness, which produces widely varying results*[117]*.*"
Lastly it can be argued that the LCOE is in reality just another way of applying the DCF approach, as the LCOE is essentially an alternate form of the IRR method. Instead of estimating the discount factor (r) that sets the NPV model equal to zero, the LCOE estimates the cash flow variable (cf) that sets the NPV model equal to zero. As "*The LCOE is representative of the electricity price that would equalize cash flows (inflows and outflows) over the economic lifetime of an energy generating asset*", we would, were we to apply this framework and keep our objective of a positive NPV, be assuming the following:

Average electricity price > cash-in+ cash-out

Accordingly the LCOE was not chosen for the purpose of our investigation and the focus remained the classical NPV framework. The NPV framework can be criticized for some of the same shortcomings as the LCOE e.g. the need for solid justifications of variable characterization. To avoid this pitfall thorough care will be taken to account for the justification of the variable definition.

5.1.1 The discounted cash flow approach

The conventional literature on investment evaluations includes approaches such as the discounted cash flow (DCF) and net present value analysis (NPV). The DCF approach allows for expression of future values in current-time currency making it possible to calculate the NPV of a series of future free cash flows[118]. This method however assumes that future free cash flows can be estimated with some certainty and that risks related to these cash flows can be quantified in one or more discount rates. Though the DCF framework is functional and easily applicable it holds some noticeable shortcomings. A major limitation of the framework is its deterministic approach in the way that the DCF method assumes a fixed future path for the project. The method assumes that after a company invests in a project it stands back passively and does not intervene at a later stage, even if the project starts losing money. Whereas in real life any project undertaken is

[117] Branker et al, 2011, p. 4471
[118] Brealey Myers & Allen 2006. p. 35-39

continuously re-evaluated and companies can often choose to abandon it if it is no longer economically profitable. Decisions to abandon a project will depend on information required at later stages of the project lifecycle. While at the initial project assessment stage such contingent decisions are not included and are therefore not accounted for in the traditional DCF method. The prospect of having more knowledge in the future and thus the ability to act upon it is therefore not included in the DCF approach which represents a weakness.

The passive approach explained above proves relevant in the context of PVC investments. Not because there is much possibility to intervene at a later stage as there is little value in altering the installation of PVCs when the worst outcome possible, a zero profit generation, merely represents a sunk cost. Yet the deterministic approach becomes appropriate in another context, the option to wait. The investment analysis conducted in the paper assumes that the investment is made in the summer of 2012. Prices of PVCs have decreased significantly in previous years and are expected to continue their decline, meaning that initial capital expenditure will represent a diminishing cash outflow. In addition, NSW subsidy schemes have been closed so only national schemes exist, meaning that there is little funding to lose out on by waiting. This way, though it is hard to quantify the exact measure, the option to wait offers some significant value.

Furthermore the DCF tends to have a negative bias, as higher uncertainty is countered with a higher discount rate. This neglects the fact that risk as a measure is not only the possibility of a negative outcome, but covers a quantity of uncertainty, a dimension which can have both negative and positive deviations[119]. With a risky project, future outcomes can be either lower or higher than expected, yet a risky project is evaluated using a higher discount rate and this results in lower NPV values. Accordingly the DCF approach takes a downwards bias, ignoring the potential upsides to a risky project.

More importantly for this paper the DCF framework was developed for use for in evaluating corporate finance investments and not private consumer investments. The aspect of applying a framework originally intended for corporate decision-making to evaluate consumer investments implies a number of limitations. One of the main limitations is the aspect of adjusting the discount

[119] Jorion, 2007, p. 75

rate variable of the NPV framework from the corporate WACC approach to a more flexible market-based approach.

Yet the fact remains that for financial evaluations, the NPV framework remains a favorite despite its shortcomings. Put in the words of *Guidelines for the Evaluation of Public Sector Initiatives South Australia*:

"*Financial evaluation requires determination of costs and benefits of the initiative as they impact on cash outflows and inflows of an agency during the evaluation period. In valuing costs and benefits, use net present value techniques*[120]*.*"

We proceed with discussing the implications of choosing the NPV framework and commencing with the question of risk.

5.1.2 The question of risk/uncertainty

In A *Manual for the Economic Evaluation of Energy Efficiency and Renewable Energy Technologies*, Short et al. present a four step approach to characterize uncertainty in the economics of a given project[121].

1. Determine the economic measures
2. Determine the parameters that cause the most variation in the economic measures
3. Assess probability for each critical parameter
4. Determine the probability distribution

The first step is used for evaluation. The second is known as *deterministic sensitivity analysis* and involves varying the project parameters to reveal which parameters cause the most variation in economic measures. While the latter steps deal with probability. For the purpose of this analysis the first two steps will be applied. As we have no data on which to form an educated estimation of probability and as we find these latter two steps to add less value to our analysis compared to an expanded analysis of step two, we will not perform an analysis of probability. This assessment is

[120] Treasury and Finance, p.17
[121] Short et al, 1995, p. 38

further rationalized by the fact that most of the parameters are fixed by the NSW government or by the technical specifications of the PV systems and are therefore not composed with any form of frequent variation. With respect to the expanded step two we reckon the possibility of different future outcomes of the numerous variables. Accordingly our NPV framework will apply a sensitivity analysis to enable estimation of profitability under multiple diverse scenarios. Conducting a sensitivity analysis implies testing the sensitivity of the NPV results to potential changes of the implicated variables. This allows to test the robustness of the results and thereby the riskiness. A project is considered more risky if it goes from a positive to a negative NPV with a minor change of the discount rate or lifetime variable, than if it takes a bigger change in the variables to alter the results from positive to negative[122].

We will only conduct sensitivity analyses of the economic variables such as forecasted electricity price, discount rate, CPI and the STCs. This choice was made in accordance with our focus of writing an economic analysis and accordingly not going into detail with how the technological aspects of solar panels affect our results. As explained in our methodology, we trust the economic implications the current technology imply and will not conduct a sensitivity analysis of aspects such as tilt, performance, efficiency loss or weather volatility. Another concern with respect to the issue of uncertainty and risk is assigning it to the appropriate variables in the model and to what extent risks should be reflected in the discount factor. Here Brealey, Meyers and Allen argue that when setting a discount factor without the availability of a beta value it is important to "*Avoid smudge factors. Don't give in to the temptation to add fudge factors to the discount rate to offset things that could go wrong with the proposed investment. Adjust cash-flow forecast first*[123]."

Following this advice the discount factor should first and foremost reflect opportunity cost of capital. The risks involved in the project should instead be assigned to the projected cash flows. In the following we discuss different approaches to setting the appropriate discount factor, drawing on experience from literature on energy investments and where possible specifically solar panel investments.

[122] Treasury and Finance, p. 19
[123] Brealey, Meyers and Allen, p. 246

5.1.3 The social discount rate

When evaluating sustainability projects the private and the public sector differ in their approach to the discounting component. The private sector always concerned with maximizing shareholder wealth, applies a discount factor that reflects opportunity cost of capital comparing the project at hand to potential profits from other available projects. The public sector instead is not concerned with maximizing shareholder wealth, but with optimizing social welfare. Therefore when it comes to sustainability projects, the public sector often applies what is known as the social discount factor (SDF). There are two main approaches found in academia with respect to the estimation of the social discount rate: The social opportunity cost (SOC) and the social time preference (STP)[124]. The former, SOC, deals with the limitation in public funds and the corresponding need to estimate competing public investment requirements. There is thus a notion that the appropriate discount rate should reflect the opportunity cost of capital. The latter, STP, deals with the ultimate goal of every public investment, which is to increase future consumption, i.e. society must refrain from present consumption. The STP discount rate reflects the change in consumption value generated by the respective investment at different time periods. The two approaches, respectively known as financial (or efficient markets) and the welfare approach[125] do not lead to the same appropriate discount rate. Not surprisingly, due to the nature of the investment, many evaluations of solar panels use the social discount factor, either the SOC or the STP, as one of several possible discount rates[126]. Applying a social discount factor involves assessing the potential benefits of eliminating externalities such as pollution. As already mentioned this thesis approaches the PV system as a pure investment decision and therefore disregards potential benefits of lowered pollution as well as ideals of social time preference for consumption.

5.1.4 So which discount rate?

As can be inferred, much debate pertains to the determination of an appropriate discount rate in the context of renewable energy generating assets. The discount factor is especially important due to the inherent capital intensity[127]. A common corporate finance approach to setting the discount rate is the market-based capital asset pricing model (CAPM): **$R=R_f+ \beta$*market premium**. Market based approaches have an essential flaw in the context of investment evaluations of residential PV

[124] Rounboutsos, 2010
[125] Spackman, 2004
[126] Borenstein, 2008
[127] Hearps, 2011, p.3

systems, the need for a beta value. The need for a beta value poses some difficulties as a beta value is an expression of systematic risk or put differently the covariance in asset value that can be explained by fluctuations in the market. Only the variance of return on solar panels is not correlated with the general fluctuations of the market, as the underlying determinant factor with respect to profits is weather conditions. As a result a beta value is not applicable for explaining risks of return on solar panels. Or as Awerbuch puts it "*renewables show low levels of systematic risk, while also possessing attributes such as flexibility, modularity and other properties, not yet entirely understood, which are hard to quantify in terms of cash flow measure*[128]*"*. Also market-based approaches to discount rate determination are usually developed for corporations not individuals. Corporations discount projects using their weighted average cost of capital (WACC), a method which incorporates the financing structure of the company with respect to debt and equity ratios. However consumers do not operate with debt and equity structures in the same way corporations do and so the WACC is not appropriate for evaluating individual consumer projects. In this context of energy technology evaluation Stock et al have asserted that "*The available evidence for deciding on the appropriate discount rate is confusing. …the theoretical basis for determining the discount rate is still strenuously debated.* And "*… published statistics which are necessary to calculate a numerical value for the discount rate are based on varying definitions*[129]*"*. Stocks et al go on to argue for a real discount rate in the range from 2-10% in technology assessments and the Australian Treasury recommends the upper limit of this range[130]. Borenstein instead carries out his analysis using real interest rates of 1%, 3%, 5%, and 7%, of which he argues *"the two lower rates are likely to be more appropriate for evaluation using a social discount rate and the two higher rates are more applicable for an evaluation using the market opportunity cost of capital*[131]*."*

A range between 2-10% or between 1-7 % is quite significant and an alteration in this range can easily turn a profitable project into an unprofitable one. In that respect such a large range of estimates offers little guidance. Instead it might be more useful to adhere to Shimon's logic that

[128] Awerbuch, 1996, p.202
[129] Stocks, 1984, p. 184
[130] Stocks, 1984
[131] Borenstein, 2008, p.22

"*The correct risk-adjusted discount rate for any set of project revenue requirements is their opportunity cost*[132]*.*"

Using the opportunity cost of capital as an indicator to set the discount factor, we assume that the PV system is financed by means of a loan and accordingly set the discount factor equal to the borrowing rate. This approach has also been assumed by AECOM in their advisory report on the NSW Solar Bonus Scheme; *"some households may consider the cost of PV installations a long term investment similar to their mortgage and have a discount rate around 7% post tax nominal*[133]*."*

The average borrowing rate for home investments in National Australia Bank is 7%[134] and this is the rate we will apply as the discount factor. By applying the borrowing rate as the discount factor we thus assume that the financing method is the opportunity cost of capital.

An investment in solar panels has a time horizon of 25 years and therefore compels a certain consumer willingness to stay at his home the full lifetime of the investment. Or at least the investment should ensure that if sold, the price of the house reflects the installation costs of the PVCs. This latter aspect could moderate the commitment load the consumer takes on when installing the PV system. Providentially studies imply that investments in solar panels do reflect in the value of the property. At least one study found "*strong evidence that homes with PV systems in California have sold for a premium over comparable homes without PV systems. More specifically, estimates for average PV premiums range from approximately $3.9 to $6.4 per installed watt (DC)*[135][136]*."* Another study also conducted in California found that solar panels added on average 3-4 % to the value of a home[137]. Or as one source states it "*on average covered the installation costs*[138]". Reasonably a house should be worth more when it can generate an income by itself and so logically a house with solar panels should sell for more than the same house without solar panels. The more difficult question is the premium the house should sell for. One assumption could be that the increase in the price of the house should be similar to the remaining NPV of the PV system. If this assumption holds then the consumer's decision to sell his house

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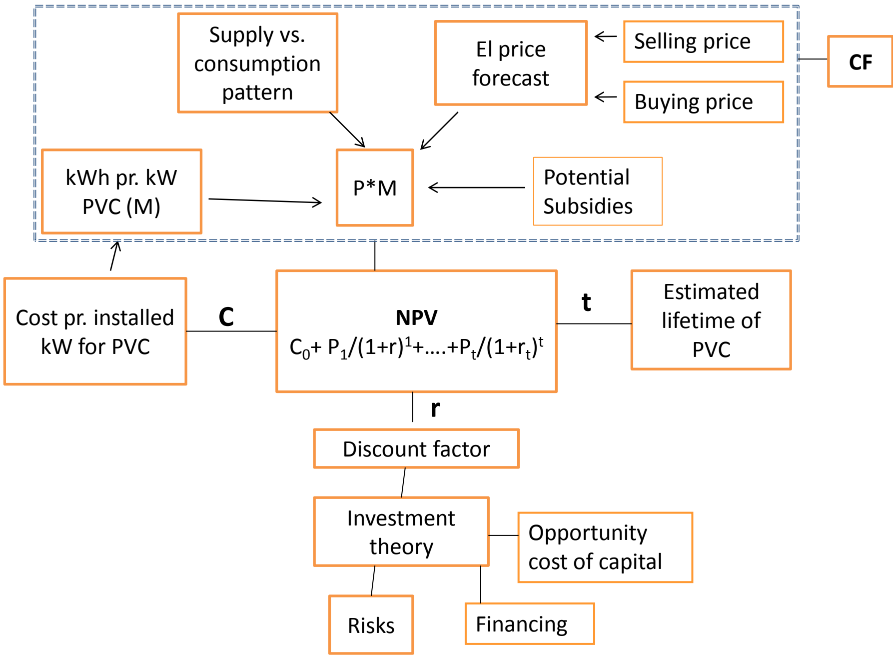
132 Shimon, 1993, p. 25
133 NSW Solar Bonus Scheme Advice, p.22
134 National Australia Bank
135 Hoen, 2011, p. 45
136 Implying that a 1kW system should offer a premium of US $3900-6400
137 Dastrup, 2011
138 Lamonica, 2011

should not have an impact of the economic feasibility of investment in solar cells. We were unable to find specific studies for house premiums in relation to solar panels in Australia. However a report by the Australian Bureau of Statistics concluded that prices of houses in the Australian Capital Territory increased with eco star ratings. The report found that for a house worth $365,000, increasing the rating by half a star would add, on average, nearly $4500 to its price[139]. Hence if eco star ratings increase property value, there is good reason to believe that solar panels would have the same effect. This should reduce consumer unwillingness to invest in PVCs caused by the argument of it being a "locked" investment.

6 The NPV framework

Having performed the forecast of residential electricity prices, which constitute an essential part of the cash flow variable, the paper continues with the NPV analysis. For the purpose of our analysis a customized model of the NPV framework was developed and is illustrated below.

6.1.1.1 Figure: Customized NPV framework



139 Brooks, 2010

As can be seen the model has decomposed the different variables into sub-elements for a better understanding of how each parameter is determined.

6.2 Estimating variables for the NVP framework

In order to use the above framework, proper estimation of the five variables, cost (C), kWh generated per kW PVC (M), cash flows (CF), time (t) and discount rate (r) is needed. Below follows a discussion of how variables were estimated in the most appropriate way.

6.3 Estimating costs

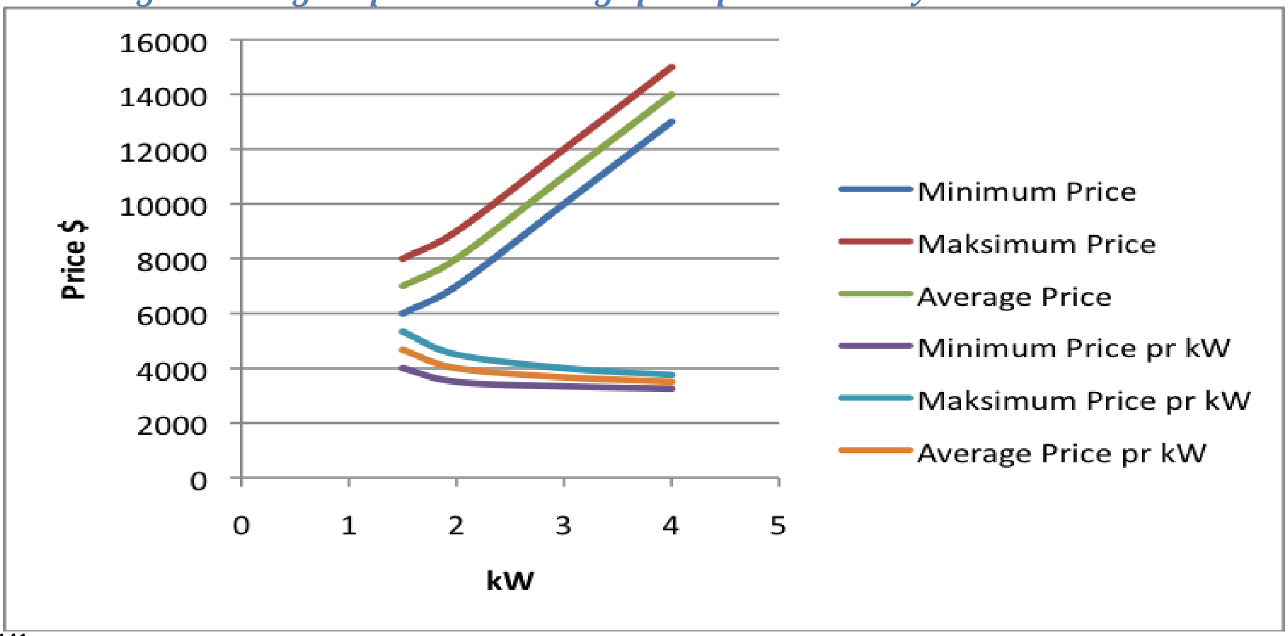
In the NPV framework costs refer to the initial cash outflow the consumer makes when buying and installing the PV system. We conduct an NPV analysis for systems of capacities between 1kW and 6kW, in order to assess the marginal benefit of installing a system with a larger capacity and we will therefore have an initial cash outflow that differs for each system size. Applied in the model, the costs will follow the estimations by the Australian Clean Energy Council (CEC) in a report from April 2012 published in the context of the SBS.

6.3.1.1 Table: Cost range for solar systems of different sizes

System size in kW	Estimated price range	Midpoint
1,5	$6000-$8000	$7000
2	$7000-$9000	$8000
3	$10.000-$12.000	$11.000
4	$13.000-$15.000	$14.000

These prices are based on market conditions as of June 2011 and include the Australian Goods and Service Taxes. For the purpose of benchmarking, it can be noted that other sources, such as Melbourne Energy Institute 's *Renewable Energy Technology Cost Review* reports of residential scale PVC installations in Australia at prices between approximately $4500/kW and $6500/kW, which is between $6750-9750 for a 1,5kW system[140]. These prices are a bit higher, though still within a reasonable range to compare with the CEC's estimates. In our model we will examine systems up to 6kW, for which the CEC has not provided price data, for these system sizes estimations were made based on the average price per kW. The chart below shows the change in price per kW as well as average price per kW.

6.3.1.2 Figure: Change in price and average price pr. kW solar system



141

As the chart shows average price per kW declines in a form that resembles an exponential function. This form of function was chosen due to the assumption of economies of scale, in the sense that some of the costs associated with setting up solar panels, e.g. mechanical parts and installation and labor costs will be identical for a 1kW as for a 6kW system. The extra costs related to a bigger system should then primarily come from the direct costs of the extra solar panels, as system installation costs are already accounted for. This means that the function starts with a high average cost per kW where installation costs will constitute a significant part of the total costs. As the systems increase in size, installation costs constitute a diminishing part of the total price, until

140 Hearps, 2011, p.16
141 Appendix 3

the point where the average price per kW is close to the price for the panel itself. The function was estimated using Microsoft excel's trend line for an exponential function.

$f(kW)=5064{,}1*kW^{-0{,}282}$

6.3.1.3 Table: Estimated costs of solar systems

kW	Average price per kW	Total price
1	5064	5064
1,5	4517	6775
2	4165	8330
2,5	3911	9777
3	3715	11.145
3,5	3557	12.449
4	3425	13.702
4,5	3314	14.911
5	3217	16.083
5,5	3131	17.222
6	3055	18.332

[142]

In addition to the initial cash outflow comes a required replacement of the inverter after 15 years, a cost of $900 per kW[143] or approximately 20-25% of initial costs. This maintenance cost will also be included in the analysis for the different system capacities.

6.4 Estimating annual cash flows

The cash flow variable represents the annual cash flows the consumer will receive by installing a solar panel. The estimation of cash flows is as the model indicates composed of several elements; the projected price of electricity, both selling and buying price, the proportion of electricity

[142] Appendix 3
[143] Choice.com.au (a)

consumed compared to the proportion of electricity produced, as this will determine the value of the kWh produced and the subsidy element in the form of STCs. The following accounts for the estimation of each of these parts.

6.4.1 Forecasted buying and selling price

"*The most significant source of ongoing financial benefit for new PV customers is savings on retail electricity bills*[144]" therefore the forecast we made on electricity prices, both of the buying and selling price, will be import to the economic evaluation of solar panels. The base-case forecast predicted an annual increase of 5,08% of residential electricity prices, an estimate which we found plausible as the Alternative Technology Association (ATA) assumes an annual increase in retail electricity of 5% in their calculations of payback time of solar systems[145]. In addition to that the projected effects of the carbon price and increases in distribution and transmission costs were added to obtain a total predicted growth of 5,44% annually.

Regarding the selling price we were unable to obtain any historical data or predictions regarding its past development. For the forecast we applied the 2011 selling price of 7 cents per kWh and adjusted yearly with CPI so the selling price remained in constant real terms. As we apply a CPI rate of 2,8% the selling price was forecasted using the following formula:

$$selling\ price_t = 7 * (1 + 2{,}8\%)^t$$

6.4.2 Estimating amount of electricity generated and consumed

To estimate the proportion of generated electricity the average consumer uses himself and the proportion he exports to the grid, the average consumption of electricity versus the average generation of it have been mapped out as functions in a system. We proceeded with algebraically estimating the exact amount generated and consumed, to calculate the area underneath the respective functions. The calculations were based on the assumption that the average consumption pattern will remain constant over time. In the following a derivation of electricity generated through solar energy as well as an average consumption pattern will be outlined to account for the cash flow variable.

[144] IPART (b), 2012, p.8
[145] Choice.com.au

For the mathematical estimations it was assumed that solar exposure is distributed as a second-degree function, and that the area underneath the function equals daily sun exposure. It was also assumed that the two interceptions with the x-axis equal sunrise and sunset. By making this assumption it was not taken into consideration that there can be uneven sun exposure during the day. On a cloudless day, solar exposure is distributed according to normal distribution[146]. However the data collected on the amount of sunshine hours does not account for the daily distribution of sunshine hours, e.g. if there is a lot of sunshine hours in the morning and none in the afternoon or if it follows a normal distribution throughout the day. Yet with respect to electricity generation through PV panels, the timing of the solar energy is important as there are bigger economical benefits by matching the production of solar energy with the consumption of the household. For matters of simplicity we therefore assumed that the data we obtained followed a normal distribution. This assumption creates a smooth average without peaks, making the match between solar energy and electricity consumption slightly better than is the case in real life. A complication that arises from assuming that the data follows a normal distribution, all the while estimating the function mathematically using a second-degree function, is that while the former has tails, the latter has none. Yet the assumption of smoothing the average does not necessarily affect the model for better or worse, as this will depend on the consumption function.

As fluctuations in daily sun exposure have significant effects on daily "profits", it was chosen to calculate electricity generation and consumption on a daily basis and not on a weekly, monthly or even yearly average. The problem with fluctuations is that they do not produce symmetrical deviations. Fluctuations above the average only contribute with a small profit gain, since the production then exceeds personal consumption and is sold at the lower selling rate of 7 cents/kWh. On the other hand fluctuations below the average tend to have a larger negative effect on daily profits. This happens as the loss in electricity generated due to lack of sun translates into a consumer need to purchase more kWh from the retailer at a price of 25 cents/kWh. Thus there is a larger downside loss than upside gain for the same variance from the mean. Therefore taking the average of an entire week would cause fluctuations to even out and would create less accurate results.

[146] Marano V et al. Application of dynamic programming to the optimal management of a hybrid power plant with wind turbines, photovoltaic panels and compressed air energy storage. Appl Energy (2012)

For purposes of simplification it was assumed that sunrise and sunset were at the same hour on the same day throughout the years. Though NSW have had daylight savings since 1971, which do not pertain to a specific date but rather to monthly cycles[147], we assume that the shifting of sun exposure compared to average consumption changes even out throughout the year and also throughout the years.

The second-degree function was created from daily solar exposure as well as the two interceptions with the x-axis (sunset & sunrise). Three parameters were used to set up two functions. The first function is the definite integral function, which is equal to daily sun exposure with the limits of sunset and sunrise. The time data was transformed from hours into minutes to make it linear and this way easier to calculate. It was assumed that sunrise is always at X=0, an assumption that can be adjusted later in the process, but which initially will eliminate the problem of estimating a constant term in our function. Hence starting out with a standard second-degree function

$$f(x) = ax^2 + bx + c$$

And removing the constant term we get

$$f(x) = ax^2 + bx$$

This was computed into the anti-derivative and the b-parameter was isolated

$$F(x) = \frac{1}{3}ax^3 + \frac{1}{2}bx^2$$

$$b = \frac{y - \frac{1}{3}ax^3}{\frac{1}{2}x^2}$$

$$b = \frac{y}{\frac{1}{2}x^2} - \frac{\frac{1}{3}ax^3}{\frac{1}{2}x^2}$$

$$b = \frac{y}{\frac{1}{2}x^2} - \frac{2}{3}ax$$

[147] Bureau of Meteorology (d)

This was then used in the definite integral

$$\int_a^b f(x)dx = F(b) - F(a)$$

The definite integral is an expression of the area from sunrise to sunset and since sunrise was set to always be 0 this reads

$$\int_0^b f(x)dx = F(b) - F(0) = F(b)$$

$$\int_0^b f(x)dx = \frac{1}{3}ax^3 + \frac{1}{2}bx^2 = Daily\ sun\ \text{exp}osure$$

The second equation uses the quadratic formula. Again the assumption of adjusting the sunrise to x=0 means that we only need one of the interceptions and that the constant term is removed.

$$\begin{aligned}
x &= \frac{-b - \sqrt{b^2 - 4ac}}{2a} \\
c &= 0 \\
x &= \frac{-b - \sqrt{b^2}}{2a} \\
2ax &= -b - \sqrt{b^2} \\
2ax + b &= -\sqrt{b^2} \\
2ax &= -2b \\
ax &= -b
\end{aligned}$$

The two equations who contain x = sunset and F(x) = daily sun exposure, are used to find the two unknown parameters by means of substitution. First the b-parameter was isolated in the definite integral function.

$$b = \frac{y}{\frac{1}{2}x^2} - \frac{2}{3}ax$$

Then we substituted in the definite integral function.

$$ax = -\left(\frac{y}{\frac{1}{2}x^2} - \frac{2}{3}ax\right)$$

$$ax = -\frac{y}{\frac{1}{2}x^2} + \frac{2}{3}ax$$

$$\frac{1}{3}ax = -\frac{y}{\frac{1}{2}x^2}$$

$$a = \frac{-\frac{y}{\frac{1}{2}x^2}}{\frac{1}{3}x}$$

Now from the daily sun exposure, sunrise and sunset we can find the a- and b- parameters for any given day. This makes us able to create a second degree function that estimates the hourly energy production from solar panels which we can then compare to the consumption function.

6.4.3 Estimating a consumption function for the average NSW household

The following analysis compares the solar production of electricity with the expected consumption function for an average household. This provides an indication of the proportion of electricity produced, used for own consumption and the proportion produced being sold back to the grid.

According to the national Australian electricity rules privacy laws protect residential load profiles, therefore we were unable to obtain direct data on residential electricity consumption in NSW. Instead this analysis is based on residential load profile estimations from Sustainable Energy Policy Queensland (SEPQ). This means that the data used for the consumption function pertains to households in Queensland as opposed to NSW. These data are based on actual load profiles from a substation in Southeast Queensland under the assumption that an average household consumes 21 kWh of electricity per day. A daily consumption of 21 kWh accumulates to 7660 kWh a year, which is slightly more than the expected average for NSW, which as have previously been discussed ranges from 6500 to 7300 kWh[148][149][150]. Yet we consider the expected Queensland

[148] NSW Government (b)
[149] IPART webpage (30)
[150] NSW Government (a)

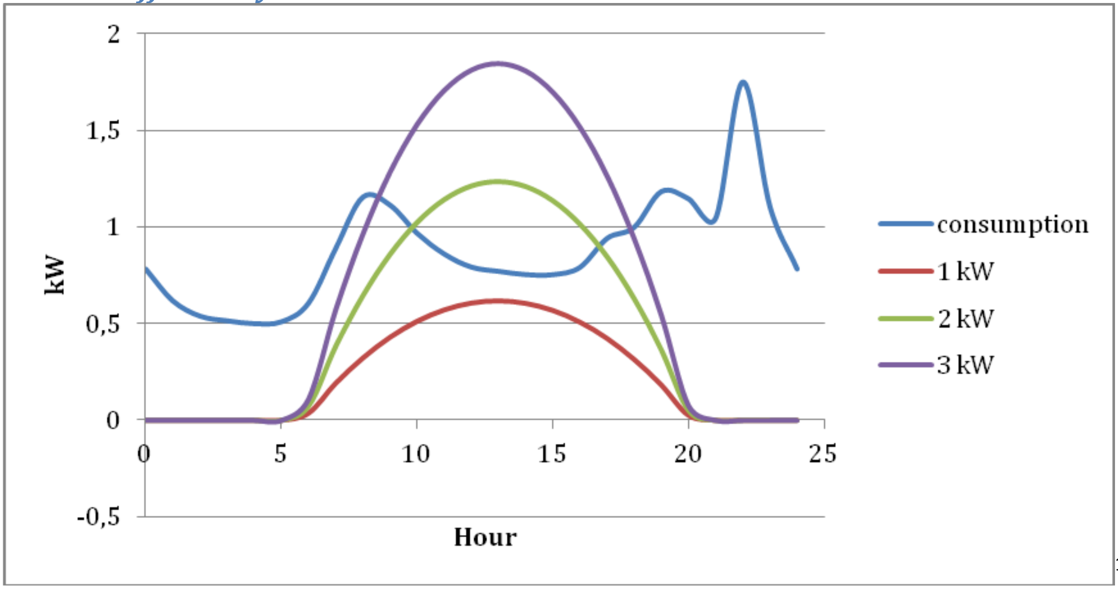
average of 7660 kWh to be an acceptable margin of error[151] to use in our analysis for NSW and hence will proceed with the analysis using data from Southeast Queensland.

The consumption function is composed from hourly estimations where the definite integral ranges from 00:00 to 24:00 and accumulates to 21 kWh. In the function we find two peaks during the day, in the morning and in the evening. These peaks are to be expected, however the consumption function also has a significant spike at 22:00, which is unexpected. The spike at 22:00 is due to a 25 year old system designed to shift loads from the daytime to evening to improve the efficiency of the large coal-fired power stations and turn on the electric hot water systems during off-peak times. This system creating the peak at 22:00 could help explain the higher average daily electricity consumption of Queensland compared to NSW. Yet in all cases the spike at 22:00 is after sunset and will therefore not influence the data.

To compare the consumption function with the expected electricity production, we find the intercept between the two functions. Below is a chart mapping the first data point of solar energy in our data set for three different kW system sizes as well as the yearly estimated consumption function. The data stems from January 1st 1990 and measures the amount of kWh produced by solar systems of 1kW, 2kW and 3kW. The chart clearly shows that on this day a 1kW solar system (the red line) does not produce enough electricity to meet the need of the residential consumer and hence he will need to buy additional electricity from the grid. This inherently implies that all electricity produced from the solar panel is used for own consumption and none is sold back to the grid.

[151] Appendix 6

6.4.3.1 Figure: Comparison of consumption function and energy produced by three different system sizes



[152]

Had the consumer installed a 2kW solar system (the green line) instead, he would have been able to produce more kW than needed for personal consumption during the midday peak generation. From the interceptions with the consumption function it shows that the 2kW system is able to supply all the electricity needed for residential consumption from about 10:00 to around 17:00 while also sell some back to the grid. The solar panel is additionally able to supply a substantial amount in the shoulder periods when the sun is rising and setting. If the residential consumer prefers a bigger system, the chart shows that the 3kW system (the purple line) can supply electricity to fulfill requirements for consumption for a wider interval, yet most of the extra energy produced compared to the 2kW system is sold back to the grid. This implies that the marginal return from the extra kW will be smaller due to the difference in buying and selling price.

The above analysis was executed numerically by finding the two intersections of the consumption and production functions. From the intersections the model was then set up to divide the electricity production into four areas, two areas between the intersections as well as the area above and the area below the consumption function. The area below the consumption function is electricity used for own consumption yielding a higher profit rate, whereas the area above is the electricity produced that is sold back to the grid. Normally when comparing areas between two

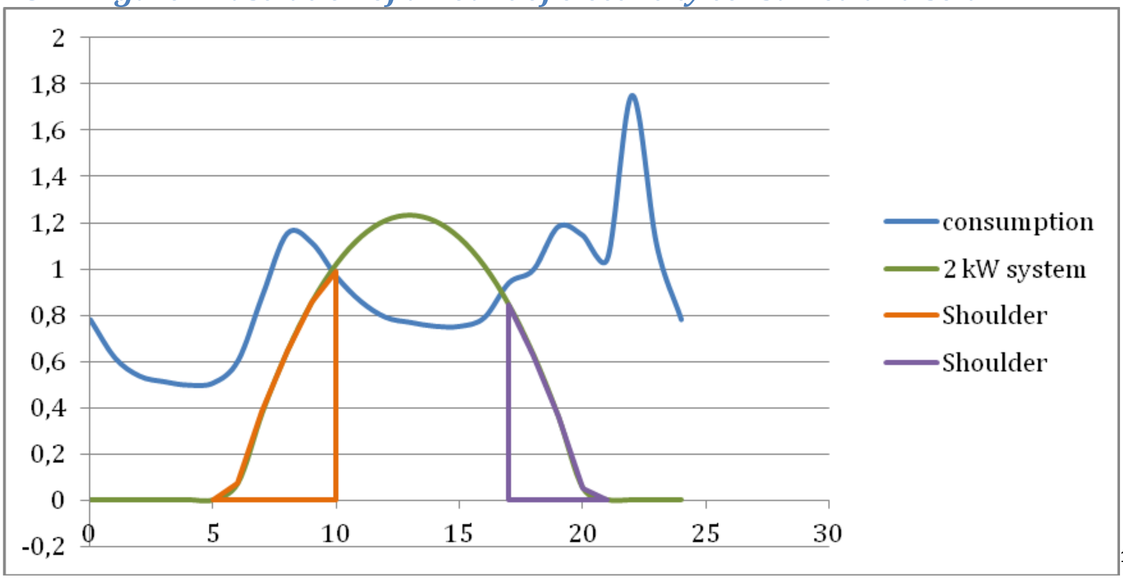
[152] Appendix 5

functions, the most straightforward approach is to take the definite integral for both functions and subtract one from the other. Where the definite integral from a to b is defined as follows.

$$F(b) - F(a) = \int_a^b f(x)dx$$

However in this model the consumption function is not linear, therefore the approach was a little more extensive. First, the area below the consumption function was calculated from the data points by dividing the function into many individual blocks, which were then added together to obtain the total area. The area above the consumption function was calculated by taking the definite integral of the electricity production function from one intersection to the other and subtracting the area below the consumption function.

6.4.3.2 Figure: Illustration of amount of electricity consumed and sold



[153]

The two areas "outside" the intersection, earlier introduced as shoulders, were calculated by subtracting the definite integral from the first to the second intersection from the definite integral from sunrise to sunset.

Next we calculated the proportion of electricity production sold to the grid and the proportion used for personal consumption

[153] Appendix 5

$$\frac{energy\ sold}{total\ energy\ production} = percentage\ sold$$
$$percentage\ used = 1 - proportion\ sold$$

In Microsoft excel the above calculation was made on the entire data set and from this average daily percentage of electricity produced which was used and the average percentage which was sold was calculated for PV systems of different sizes. This calculation constitutes the "M" variable of the NPV model. Below follows a summary of these calculations:

6.4.3.3 Table: Production capacity and % consumed and sold for the different systems sizes

kW system size	1	1,5	2	2,5	3	3,5	4	4,5	5	5,5	6
% Used	1,00	0,97	0,86	0,75	0,66	0,59	0,53	0,48	0,44	0,41	0,38
% sold	0,00	0,03	0,14	0,25	0,34	0,41	0,47	0,52	0,56	0,59	0,62
Average daily amount in kWh	3,97	5,95	7,93	9,92	11,90	13,89	15,87	17,85	19,84	21,82	23,80

[154]

The data clearly shows the conclusion from above, that a 1kW system will not at any point be able to produce enough electricity to meet the average consumption requirements. The 1,5kW system will on clear days provide a small percentage of electricity for sale, but otherwise most of the production will be used for personal consumption. Furthermore the data shows that in systems above 1,5kW every increase in size causes a significant shift towards the proportion of electricity sold. The bigger the system capacity the greater the percentage of electricity production sold to the grid and the lower the marginal profit.

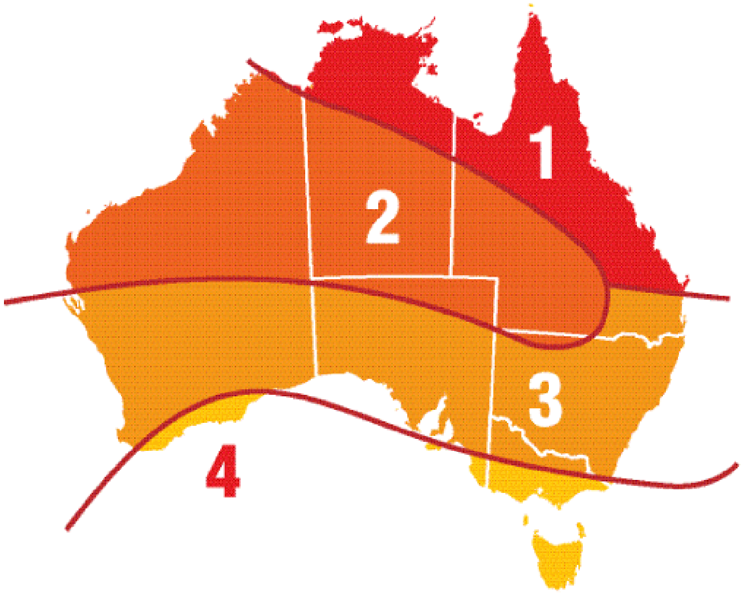
6.4.4 Subsidies as part of the cash flow – STCs

The small-scale technology certificate system is as explained a federal government incentive program that compensates the owner of solar cells financially either yearly or as an upfront 15 years discount when the system is purchased. In our model it was assumed that the consumer

[154] Appendix 2

would choose the upfront discount as it is easier for him and negates the otherwise relevant issue of discounting the future cash flows. The rate used to determine the upfront discount for a binding period of 15 years is calculated from a zone system that divides the country into four zones according to the map below.

6.4.4.1 Figure: STC zones in Australia



[155]

Zones are ranked in expected sunshine hours, so that solar systems in northern Queensland, which on average receives the highest amount of solar energy, also receives the biggest STC discount. This might seem counterintuitive, but should be seen in relation to the objective of the scheme, which was to create heavier incentives for consumers to install solar panels in regions where a larger amount of solar energy would ensure a larger amount of clean energy generation. This means that it is a scheme that provides the greatest amount of subsidies to the solar panels installed at locations where they are most effective. The expected yearly amount of sunshine hours for the four zones is[156]:

1. 1622
2. 1536
3. 1382

[155] Solar Choice (c)
[156] AECOM, 2009, p. 18

4. 1185

As NSW falls almost entirely within zone 3, this is the zone which will be applied in the NPV model. As explained the STC multiplier applies only to the part of the system below 1,5kW and dropped from 3x to 2x as of the July 1st 2012, hence the multiplier of 2 was used in the model. STCs are only measured in whole numbers and are always rounded down to the nearest MW generated. The government accredited quantity of STCs is calculated as follows[157]:

STC= zone rating * multiplier * 1.5 * years + zone rating * (power output – 1.5)* years

The calculated quantities of STCs awarded for different system sizes are shown in the chart below. As the chart indicates, the rounding down procedure of expected MW to the nearest whole number represents a significant negative effect to the consumer. It creates a staircase-like function where there is no economic benefit with respect to the STC system of purchasing systems of 0,5 kW increments if the original plan was to acquire a system of either 1,5kW, 3kW or 4,5kW.

6.4.4.2 Table: STCs for PV systems of different sizes

Solar system size in kW	Expected MW	STC	STC upfront payment
1	2,8	2	750
1,5	4,1	**4**	1500
2	4,8	**4**	1500
2,5	5,5	5	1875
3	6,2	**6**	2250
3,5	6,9	**6**	2250
4	7,6	7	2625
4,5	8,3	**8**	3000
5	9,0	**8**	3000
5,5	9,7	9	3375
6	10,4	10	3750

[157] NSW Government (e)

158

6.5 Estimating the investment lifetime

The investment lifetime is the lifetime of the PV system that is the number of years it can produce electricity. Obviously this timeframe will vary from producer to producer as well as it will vary randomly from product to product. A common estimate is that the average lifetime of PVCs is between 25 and 30 years[159], which is quite a long time for a piece of machinery. As the Australian producer Pure Solar explains it on their webpage "*As solar electric systems have no moving parts to wear out, they last a very long time. Our solar panels are built with a life expectancy of 30+ years and carry a 25 year limited power output warranty. Our inverters generally have a 10-year warranty*[160]*.*"

A determinant factor of the lifetime of PVCs is, as also pointed out by Pure Solar, the warrantee and guarantee that comes with the system. Here a short note should be made on the difference between warrantees and guarantees. With a guarantee the seller is liable to make a complete replacement of the purchased product, in case it was found to be below prescribed standard. Whereas with a warrantee the seller is only liable to repair the product if it defaults. Different sources indicate different standards for guarantees and warrantees on PVCs. One suggests that state-approved solar panels usually come with a performance warrantee of 25 years and a guarantee of 5 years. Additionally the systems should come with a panel material warranty and workmanship guarantee of between 5-10 years[161]. Though several studies show that the maximum warrantee period is 25 years, systems have been found to work for up to 40 years[162][163].

The performance of the PVCs is not constant during its lifetime however, as solar panels tend to lose efficiency each year. According to one source a conservative estimate is to calculate with a 0,25% degradation in efficiency per year for a maximum loss of up to 20%[164]. This constant degradation of efficiency will needless also be incorporated in the NPV model as a factor that

[158] Appendix 3
[159] Landers, 2012
[160] Puresolar
[161] Clean Energy Council, p. 6
[162] Ecupower.com
[163] Godall, 2009
[164] Landers, 2012

reduces electricity generation each year and slowly diminishes the yearly cash flows from savings and sale back to the grid. Though the lifetime of PV systems has been found to be as high as 40 years, a conservative bid was preferred for the NPV model and so we define our t-variable to be equal to the warrantee period of 25 years.

6.5.1 Estimating risks with respect to investing in PVC – the discount factor

Our approach to risk in relation to the discount factor has already been outlined still a short discussion of general assumptions will follow. Several investment analyses of solar panels assume them to be a risk-free investment, an assumption that can be questioned. Even if in the words of financial advisor Noel Whittaker "*These examples* [investment analyses of PVCs] *are based on the assumption that the price of power will keep going up and the sun will keep shining. I reckon that's a safe bet*"[165] we find it disputable that PVCs should be risk-free. None the less it can be argued that several of the obvious risks pertaining to PVCs can be countered.

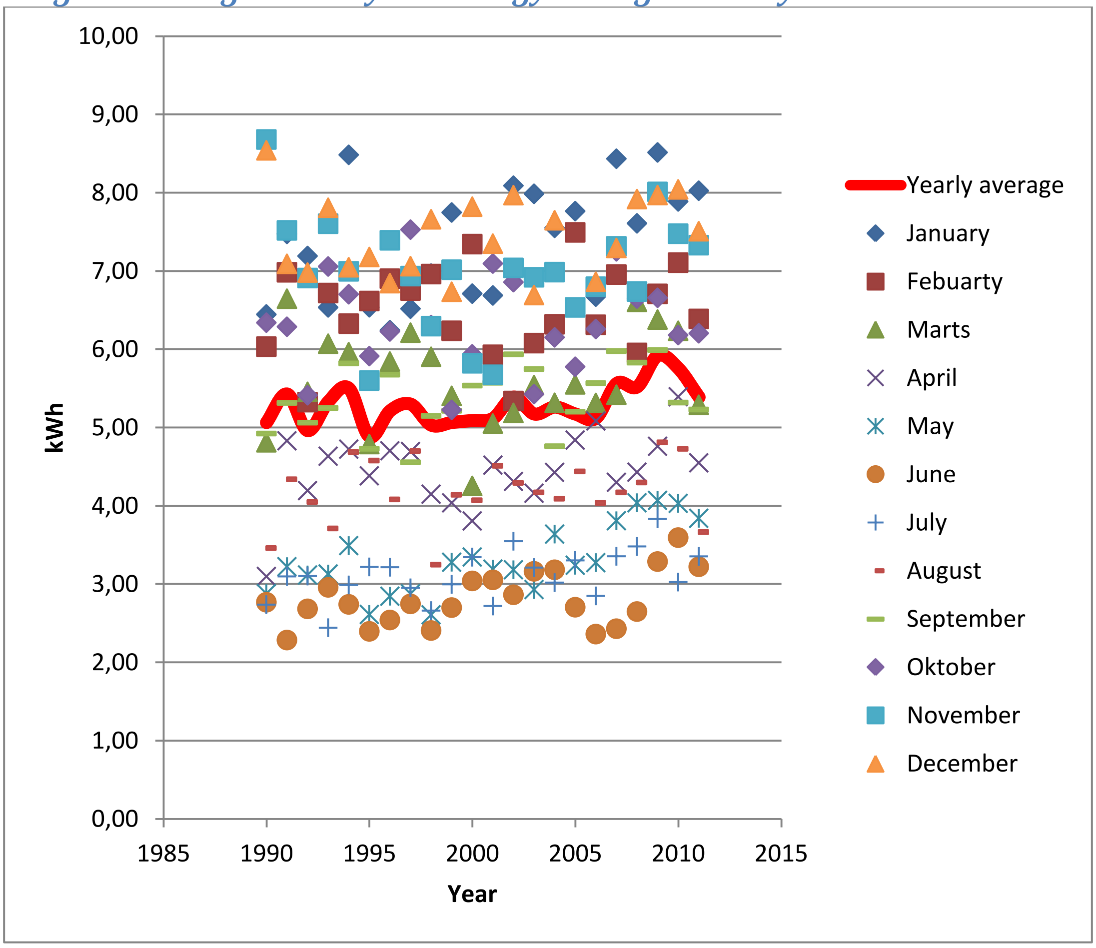
Default: A noticeable risk of installing a PV system is that it defaults. Yet as all state-approved PVC systems come with warrantees of 25 years, this risk should translate into the retailer going bankrupt. A risk that should not be any bigger than the risk of a bank default of the bank where the consumer could place a risk-free deposit account.

Electricity prices: Investing in solar panels is an economically viable solution due to savings on the electricity bill – savings that continue to increase as electricity prices do[166]. If electricity prices were to drop to such an extent that the solar panels would no longer represent savings on the consumer's electricity bill, this would ruin the investment. We argue that this risk is extremely unlikely, as the general development of prices is up and even more so on electricity. More generally prices on commodities tend to fall only if large amounts of natural resources are suddenly discovered or if technology improves to an extent that allows the retailers to produce at a much lower unit cost. However, as electricity is currently generated from fuel sources, which is a limited natural resource we do not expect prices on electricity to decrease below current levels.

[165] Premier Solar Queensland
[166] IPART (b), p. 8

Weather conditions: The unpredictability of sunshine hours and general weather conditions is probably the most apparent risk when investing in solar panels. No doubt there will be periods where sunshine hours are well below average and correspondingly where solar panels will not produce the estimated amount of electricity. Yet with reference to the general historic weather conditions in the chart below, which covers the period from 1990 to 2012, it can be observed that despite the large variation in some months like November and January, which have standard deviations of 0.72 and 0,74 respectively, the overall yearly average has a small standard deviation of 0.27. This represents only 5% of the mean for the period which is 5.3 kWh daily. Most importantly yearly average seems to have a mean reverting pattern, therefore we argue that over a time span of 25 years the good weather conditions will even out the bad and sunshine hours will approach the historic average.

6.5.1.1 Figure: Average monthly sun energy throughout the years



[167]

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[167] Appendix 4

Further investigating the data it can be observed that the daily average on a yearly scale has slightly increased in the the period from 2007-2012 compared to the period 1990-2007. It was therefore chosen to perform a statistical analysis to see if there was a significant difference between the first period and the latter period. The results of mean and standard deviation were as follows:

Mean for the period 1990-2007: 5,18 and standard deviation: 0,17

Mean for the period 2007-2012: 5,62 and standard deviation: 0,21

The statistical test was done using the two-sample t-test for unpaired data where H_0 and H_a are defined as:

H_0:	$\mu_1 = \mu_2$
H_a:	$\mu_1 \neq \mu_2$

And the null-hypothesis that the two means are equal is rejected if |T| > critical value of the t-distribution.

$$T = \frac{\bar{Y_1} - \bar{Y_2}}{\sqrt{s_1^2/N_1 + s_2^2/N_2}}$$

Where $\bar{Y}1$ and $\bar{Y}2$ are sample means, s_1^2 and s_2^2 the sample variances and N_1 and N_2 are the population size of the two different periods. The calculations yield:

|T|=5,18-5,62/√(0,21/17)+(0,17/5) → |T|=2,04

The degrees of freedom= N_1+N_2-2 → 17+5-2 → 20

The critical value of the t-distribution for a two-sided probability with 20 degrees of freedom=2,086

Hence |T|<critical value and we accept H_0 that the two sample means are equal.

In view hereof it was concluded that the difference in average sunshine hours during the latter period can be ascribed to fluctuations from the generel trend and that these will even out over time. Thus the mean of the full sample was used as the expected solar energy mean. Conclusively it can be noted that some might argue that the difference in mean sunshine hours between the two periods is a sign of global warming. But as it is not in the scope of this paper to evaluate if global warming is happening, we will not discuss possible explanations for the recent increase in yearly average of sunshine hours. If anything it can only be said that if amount of sun is changing, then the observed increase in yearly sunshine hours does nothing but lower the risk and increase the profitability associated with investing in solar panels.

Subsidy changes: In 2009 investing in solar panels was made attractive due to both federal and NSW government schemes such as the STCs and the SBS. The SBS has been closed for new applicants, therefore the only current subsidy that exists for new applicants in NSW is the STC and as of July 1st 2013 even these credits will come without a multiplier and only have face value. As such the majority part of the subsidies previously offered has already been withdrawn. Further investigations of the effects of subsidies will follow in the sensitivity analysis.

Consumption changes: This variable, though it obviously has an effect on the rentability of the solar panels, is different from the others as it is an element the consumer has full control over as opposed to weather conditions and subsidy changes, which are external influencers. Including consumption changes as an element of risk would not be meaningful. Changing consumptions patterns will be a choice made by the consumer and as such does not represent an unpredictable and uncontrollable factor that can influence the investment.

Though we have argued that some of the more obvious risk factors can be countered, we still stand critical of the assumption that PVCs are a completely risk-free investment. Yet in line with our previous debate on defining risk we adhere to Brealey Myers & Allen's approach of adjusting the cash flow variable for risks and account for the variance these risks generate by conducting a sensitivity analysis. We remain on the path previously discussed of setting a discount rate equal to the opportunity cost of capital, namely the financing aspect, which puts the discount rate **(r)** equal to the present Australian borrowing rate for home investment which is 7%. This discount rate was assumed to already reflect inflation levels. Nonetheless, when conducting the sensitivity analysis with respect to changes in inflation, the discount rate will also be adjusted. This way the 2,8% will be subtracted from the 7% discount rate, before adding an either lower or higher inflation rate of respectively 1,8% and 3,8%.

6.6 Measuring factors

As explained, our analysis is focused on the results of the model, the net present value of the investment. However looking only at NPV would fail to take into consideration the extent of the initial capital expenditure and could therefore create a preference for the larger systems. This would happen because the larger systems have higher NPVs but accordingly also have a larger initial cash outflow. To overcome this problem the model also measures the internal rate of return (IRR)[168], which is a variable that states at which discount rate a given investment has a NPV of zero. Thereby indicating the rate of return that marks the point of indifference between investing or not. By measuring the IRR the model can compare the profitability of the different sizes of PV systems to find out which one offer the better return. Lastly, the model will also account for the payback time, which is a measure of the number of years it takes before the initial investment has been repaid in discounted cash flows, thereby taking into consideration the time value of money. The payback period is especially functional for psychological reasons, as people tend to prefer knowing how many years they need to wait before their initial cash expenditure has been regained and they start making money. A shorter payback time is also preferred as it limits the uncertainty related to long-run developments of the different variables. The results of the above-mentioned measuring factors will be presented below.

6.7 Results of the NPV model

Having accounted for the input variables of the model, below follows the results as generated from Microsoft Excel.

6.7.1.1 Table: Results of the NPV model

Solar panel size in kW	NPV $	IRR %	Payback time (in years)
1	3462	13,4%	12
1,5	6137	15,9%	10
2	6814	14,8%	11
2,5	7420	14,4%	11
3	7594	13,9%	11

168 Brealey, Myers and Allen 2006, p. 122

3,5	7457	13,0%	12
4	7615	12,7%	12
4,5	7589	12,4%	13
5	7270	11,7%	13
5,5	7437	11,6%	13
6	7633	11,5%	13

[169]

As can be observed all system sizes offer a positive NPV and have IRRs between 11,5% and 15,9% and payback times between 10-13 years. This means that given the conditions applied in the model investing in a residential PV system offers a positive payoff.

6.8 Sensitivity analyses

Having presented the results of the NPV model, we will now account for the uncertainties related to the determination of the different variables. These include the general uncertainty of forecasting on a 25 year horizon and the unpredictability of political and economic conditions. The section thus analyzes the sensitivity of our NPV results to changes in the different economic variables.

The NPV model was constructed around a base case scenario, depicting the development of electricity prices. The base case represents the most likely outcome of events, yet to allow for volatilities the base case scenario was framed by confidence intervals on a 95% level, identifying the upper and lower bound of plausible movements. The sensitivity analysis allows for movements within these boundaries thereby creating a better understanding of the consequences of change in the respective parameters to the final results. The sensitivity analysis will be undertaken on the following economic factors.

- Electricity price forecast
- Discount rate
- STC

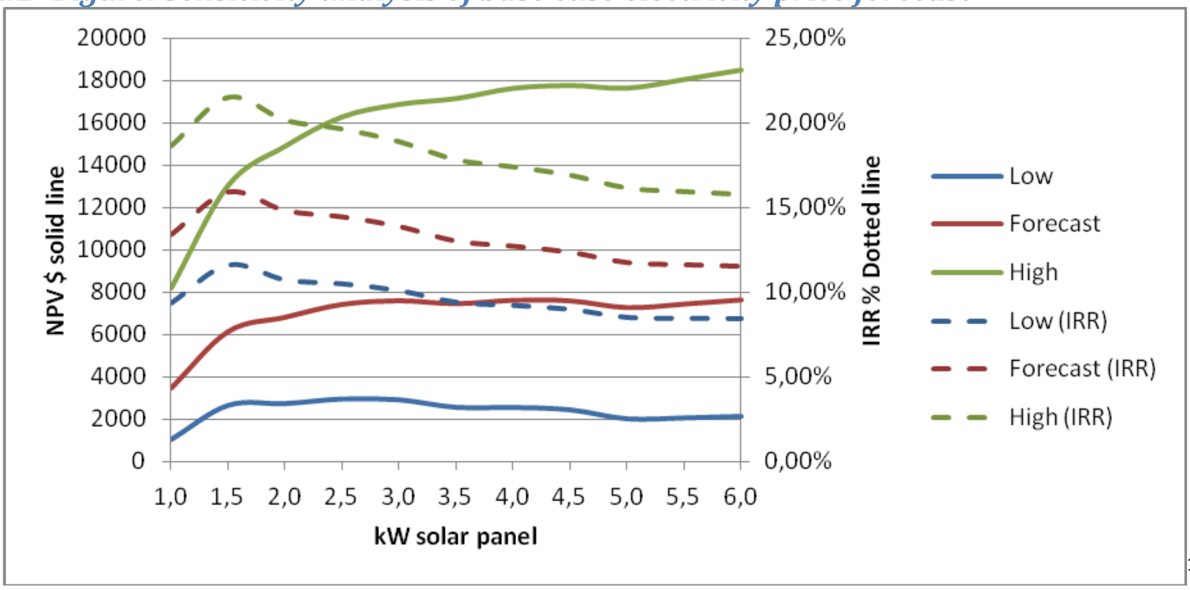
[169] Appendix 3

- CPI

6.8.1 The effects of changes in the forecasted electricity price

The electricity forecast constructed for the model was composed of three sub-elements therefore a separate sensitivity analysis will be applied to each sub-component. First, a sensitivity analysis is conducted on the base case scenario of residential electricity prices, applying the higher and lower boundaries of the 95% confidence interval to account for potential pessimistic and optimistic scenarios. Here it should be highlighted that higher prices of residential electricity correspond to an optimistic scenario for investing in PV panel. This is true as high electricity prices means that the consumer will save more money for every kWh produced and used. This way applying the upper bound as opposed to the base case scenario will, keeping all other variables constant, lead to a higher NPV. On the contrary a drop in electricity prices will cause yearly savings on the electrical bill to decline and create a lower NPV and therefore the lower bound of the forecast represents a pessimistic scenario. Factors that could lead to potential future fluctuations of residential electricity prices include increases in CPI or price changes in raw materials, which could severely affect wholesale costs that account for 35% of the final price. Below is a chart that shows NPV for a range of different system sizes at the three different price levels, the base case forecast, the lower bound and the upper bound.

6.8.1.1 Figure: Sensitivity analysis of base case electricity price forecast



[170]

170 Appendix 3

Despite the fact that the NPV value drops by about 65% from the base case to the lower bound, the chart shows that even at the lower bound forecast, all system sizes in the chosen range will retain a positive NPV. The higher bound predicts a significant increase in electricity prices, which leads to a NPV that is above the initial capital expenditure invested in the PV system. Compared to the base case forecast the upper bound leads to an increase in NPV of about 230%. Concerning the IRR, all three forecasts depict the same shape; peaking at the 1,5kW system to then slowly decline with the increase in system size. Compared to the base case forecast the upper bound shows an average IRR that is 4,85 percentage points higher, while the lower bound shows an average IRR that is 3,63 percentage points lower. Though the lower bound makes the IRR drop to 8,46% and the NPV to $2136 for 6kW solar panel, keeping everything else constant, the PV system remains a positive investment.

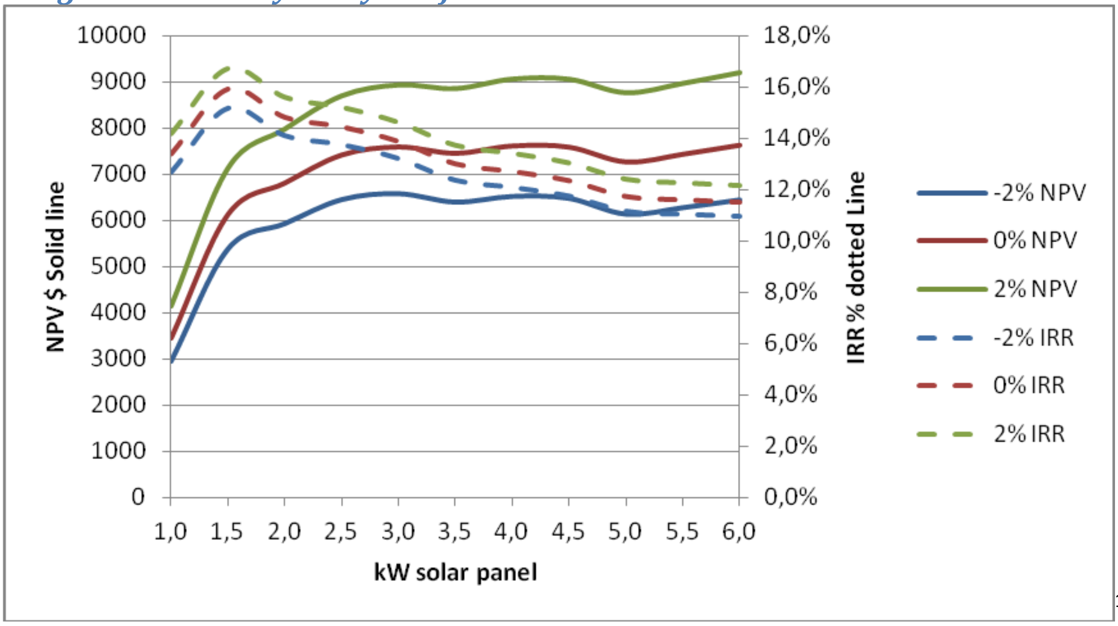
6.8.2 The effects of changes in distribution and transmission costs

The second component of the electricity forecast is the impact of distribution and transmission costs. Factors that could cause these elements to increase include potential heightened requirements to the reliability or the potential replacement of a significant number of power lines following a natural disaster like e.g. a bushfire or a monsoon. In the base case forecast the model takes a conservative estimation of the development of distribution and transmission. It is therefore possible that d+t costs will increase more if the need for replacements increases in comparison to latter years. Contrariwise, as d+t costs represent a fixed payment to maintain the network[171], independently of the amount of GWh in the system, then if more electricity is generated and used without the need for additional investments, the relative impact of distribution and transmission costs on final residential electricity prices will fall and the costs of distribution and transmission per kWh will decrease.

In the base case scenario distribution and transmission are forecasted to increase with inflation, whereas for the sensitivity analysis the model adds a dummy variable of X percentage points to the base case inflation rate of 2,8%. In other words when the sensitivity analysis tests for +2%, this implies that costs of d+t increase every year by CPI+2%. Below is a sensitivity chart for distribution and transmission costs with a dummy of ±2%.

[171] AER (a)

6.8.2.1 Figure: Sensitivity analysis of distribution & transmission costs



[172]

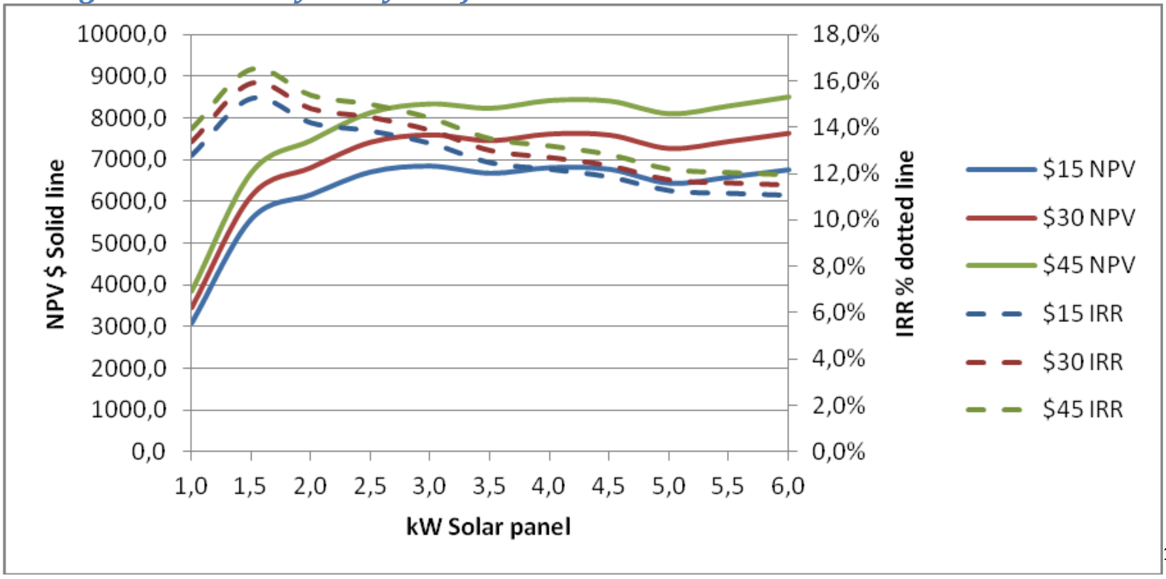
As can be seen in the chart, NPV drops by about 14% when d+t costs decrease 2% from the base case scenario, conversely when d+t costs increase by 2% from the base case scenario it leads to an increase in NPV of about 19%. In general the chart shows that changes in distribution and transmission costs have relatively little effect on NPV, compared to potential changes of the base case forecast of residential electricity prices. The small effect of distribution and transmission costs on NPV also reads in the IRR data, where a ±2% change in d+t costs leads to a 0,73 percentage point increase and a -0,63 percentage point decrease respectively.

6.8.3 The effects of changes in the carbon tax

The last component of the forecasted electricity price is the carbon tax. As the carbon price is set to be fixed at $23 per tonne of CO2, with annual real increases of 2,5% in 2013 and 2014, we have not conducted a sensitivity analysis on this period. Instead as the price will be set by the market from 2015 and is an estimated price, a sensitivity analysis was conducted on changes in the carbon price from 2015. The base case was set at the average of the lower and higher government-set boundaries of $15/tonne to +$20 *above* the 2015 market price, which equals $30 while the lower and upper bound equal $15 and $45 respectively.

[172] Appendix 3

6.8.3.1 *Figure: Sensitivity analysis of the carbon tax*



[173]

The graph shows that NPV follows a mirroring outcome whether the carbon price deviates $15 up or down from the base case of $30. The NPV increases by 10% if the carbon price is at the higher bound of $45, while it decreases by 10% if the carbon price is at the lower bound of $15. Of the three different sub-components of the electricity price forecast the potential changes of the carbon price show to have the smallest effect on NPV. This is also exemplified in the IRR, which changes with ±0,53 percentage point on average, when the carbon price changes by ± $15.

6.8.4 The effects of changes in the discount rate

The second part of the sensitivity analysis is focused on possible changes in the discount rate. As the discount rate applied in the model was set equal to the national borrowing rate of Australia (**r**) any change in CPI will have an effect on the discount rate[174].

Seeing as the borrowing rate is affected by general financial market conditions, the intensification of the European crisis could potentially lead to spill-over effects in Australia. Another feature that can cause significant changes to the Australian borrowing rate is a potential burst of the housing market bubble, which unlike in Europe has yet to happen in Australia[175].

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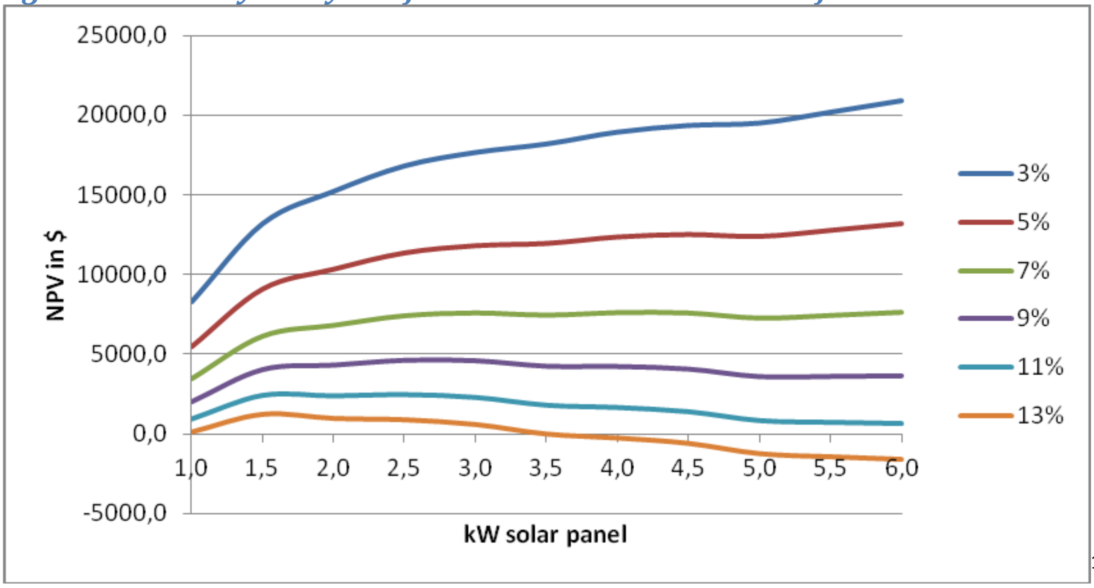
[173] Appendix 3
[174] This is true as the R(nominal)= R (real)+inflation
[175] Crikey

6.8.4.1 Figure: Sensitivity analysis of the discount rate in terms of NPV

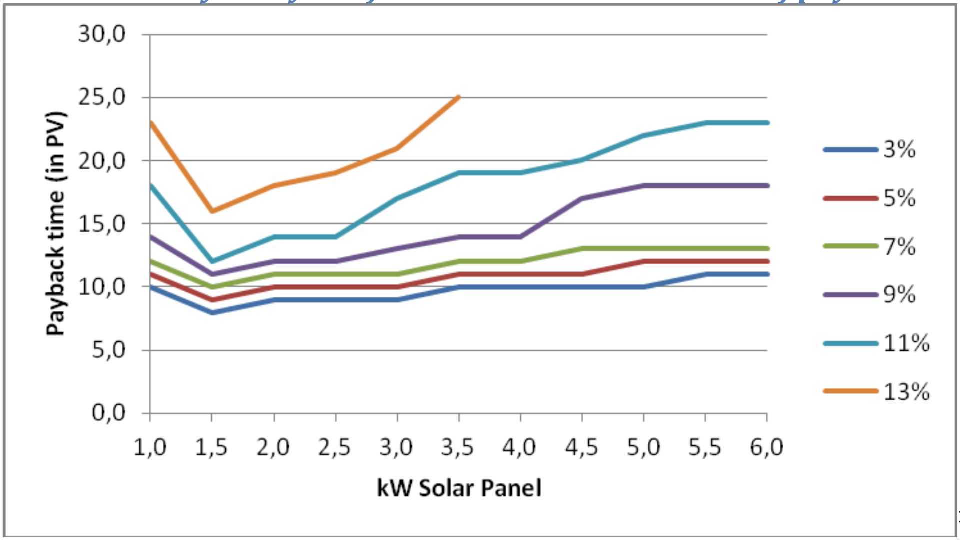


[176]

The sensitivity of NPV to changes in the discount rate shows that a bigger system is more susceptible to changes than the smaller systems both in relative and nominal terms. This development occurs as a larger system is accompanied by a bigger upfront payment and a higher expected payoff throughout the years, thus the importance of time-value of money becomes greater with the increase in system size. While the upfront payment is not affected by increases in the discount rate, the expected future payments will diminish. Yet in general it requires big changes in the discount rate to make PV systems of all sizes unprofitable. As can be seen in the graph, the NPV for the larger systems does not become negative until past a discount rate of 13%. For the exact point of indifference all of the other above charts in the sensitivity analysis have included the IRR, but as the IRR is the discount rate where the NPV equals zero, it is not affected by changes in the discount rate and is therefore not showed in the below graph. Instead of the IRR we have included the payback time, though given in *present* and not *net present* value.

[176] Appendix 3

6.8.4.2 *Figure: Sensitivity analysis of the discount rate in terms of payback time*



[177]

The payback time given in present values will affect the larger solar systems more than the smaller ones exactly like the discount rate. The biggest influence on payback time is the required inverter replacement in year 15, which represents a cash outflow of $900 per kW. This leads to an increase in payback time for those system sizes that would have had a payback time of 15 years or above, without the inverter replacement. On the contrary, systems that have a payback time of less than 15 years are not affected by the inverter cost. Nonetheless, assuming that the consumer wants to continue generating electricity through solar power after year 15, he still needs to replace the inverter, but this replacement would then have a short payback time.

The payback time only changes minimally with movements in the discount rate, as most systems have a relatively short payback time and as the true effects of an increased discount rate do not show until later years. Only with a 13% discount rate, do systems larger than 3,5kW have a payback time of more than the expected system lifetime. This indicates that these systems have a negative NPV, just as was showed in the previous chart.

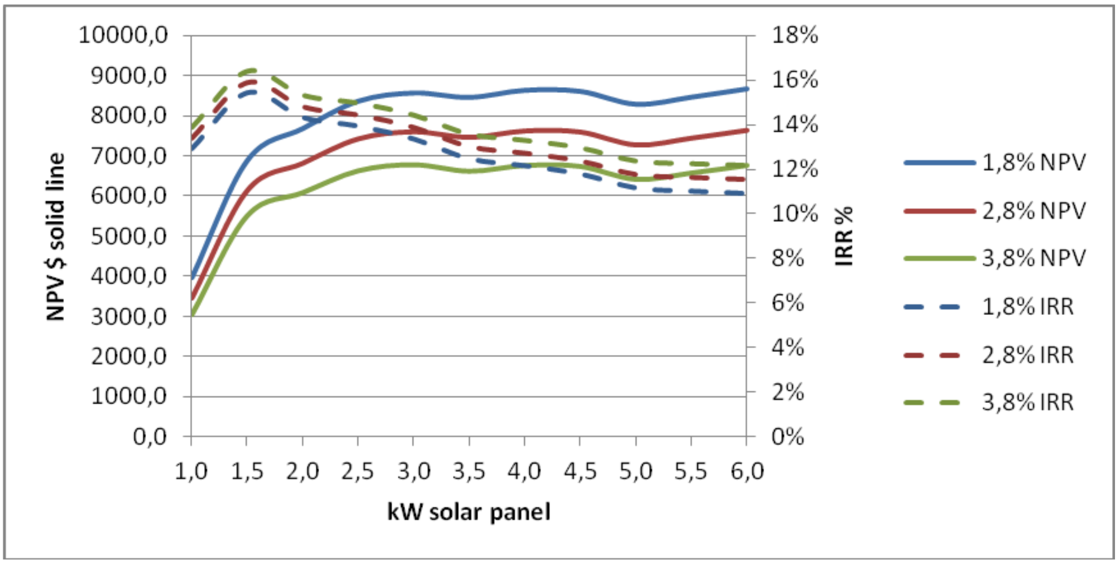
6.8.5 The effects of changes in CPI

CPI affects most of the economic variables in the model, therefore a sensitivity analysis of NPV to changes in CPI is highly significant, as depending on the variable, an increase in CPI can lead to either an improvement or a decline of NPV. In the forecast we applied a CPI rate of 2,8% and for the sensitivity analysis we alternated this variable ±1% - creating a CPI span between 1,8% and

[177] Appendix 3

3,8%. The costs of distribution and transmission and the carbon price are all forecasted with the use of CPI, implying that if CPI increases, the relative impact of the d+t costs and carbon price component will raise, leading to increases in electricity prices and accompanying increases in the NPV. The opposite will happen in relation to the discount rate, as was showed above, a higher discount rate generates a lower NPV. In this manner the effects of changes in CPI essentially boil down to a battle of relative strength of the respective variables.

Figure: Sensitivity analysis of changes in CPI



178

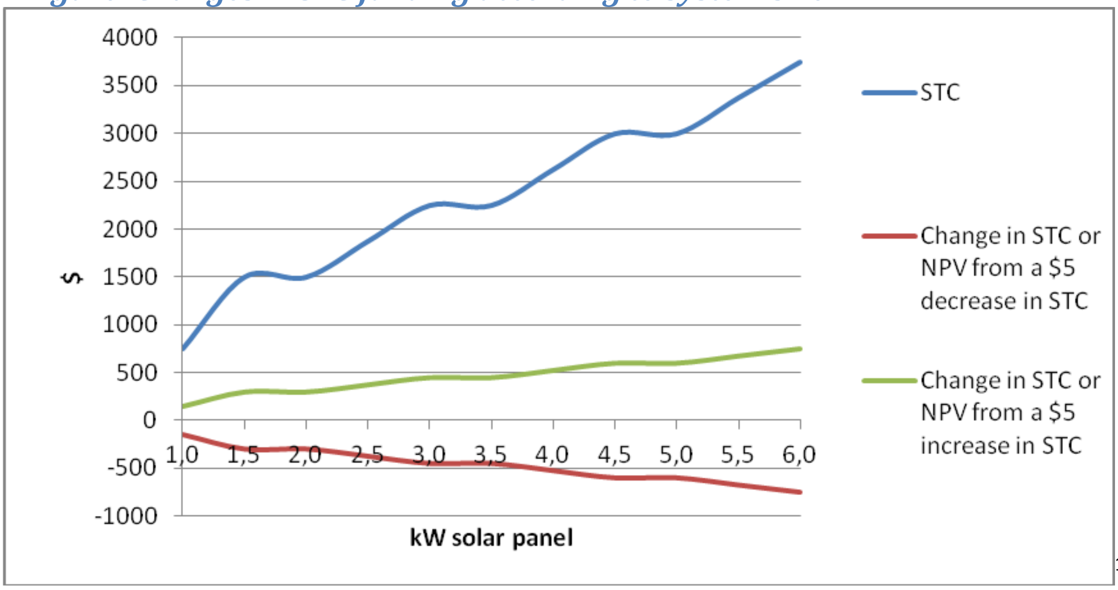
The chart shows that an increase in CPI causes a decrease in NPV, implying that the CPI effect on the discount rate is bigger than that of distribution and transmission costs, and the carbon price. The IRR is oppositely ranked to NPV because the IRR is not affected by changes in the discount rate. Therefore the optimal NPV outcome is found at the lower CPI rate of 1,8% while the optimal IRR is found at the higher CPI rate of 3,8%. The IRR shows a decrease of about 0,53% from a 1% decrease in CPI, while it increases by about 0,55% from a 1% increase in CPI. While the relative effects are larger on the NPV, which on average increases by 13% when CPI decreases by 1% and decreases by 11% with a 1% increase in CPI. This indicates that changes in CPI have a bigger effect on the movements of the discount rate than on the movements of distribution and transmission costs and the predicted carbon tax.

[178] Appendix 3

6.8.6 The effects of changes in STCs

Small-scale technology credits are given for every expected MWh a system produces annually. Additionally the Australian government adds a multiplier for the generated electricity produced from the first 1,5kW. STCs are given per MWh generated and the amount is always rounded down before the quantity of STCs is accredited. This setup means that the payoff from STCs comes in the shape of a staircase as is illustrated in the chart below.

6.8.6.1 Figure: Changes in STC funding according to system size



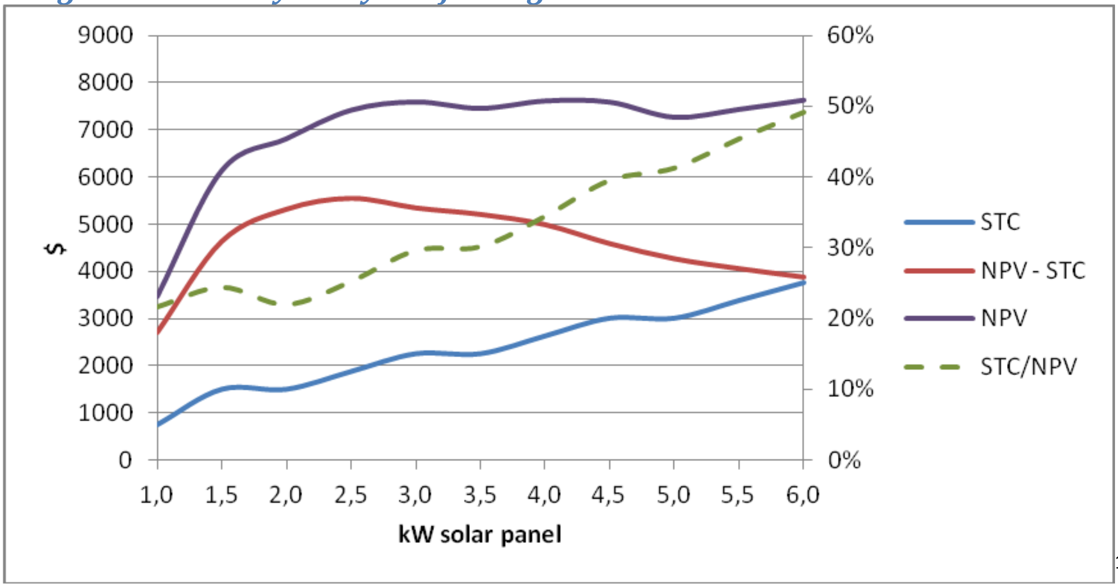
[179]

The chart shows a function that is steeper inclined for systems up to 1,5kW than for systems larger than 1,5kW, due to the effect of the multiplier. The staircase-like function also shows in all of the above NPV charts and indicates that the consumer could obtain a higher NPV by purchasing a bigger system. However the increase in NPV would mainly come from the additional STCs, as the marginal electricity production generated by the larger system would be exported to the grid and earn the lower selling price of 7 cents per kWh. One of the main reasons changes in the STC price have direct effects on the NPV is that the STCs are received as an upfront cash discount and are therefore unaffected by the discount rate.

For a closer examination of the effects of changes in STCs on the NPV, the below graph shows a comparison of the NPV with and without STCs.

[179] Appendix 3

6.8.6.2 Figure: Sensitivity analysis of changes in STCs



[180]

The red line which represents NPV without STCs reflects the fact that as the system size increases the marginal production of electricity is sold back to the grid at the lower rate of 7 cents/kWh and therefore marginal return declines.

The blue line characterizes the dollar value of STCs and reflects the fact that the multiplier only applies to the first 1,5kW and therefore shows a relatively larger increase in the beginning than after the 1,5kW. Yet the dollar amount of STCs continues to increase with system size, to such an extent that the STCs account for the same amount of total NPV as the PV system itself at a 6kW system.

The loss in NPV from selling more and more electricity at the lower price is almost evened out by the simultaneous increase in STCs received by a bigger system. The STCs therefore keep the total NPV at the same level for system sizes of 2,5kW to 6kW. The dotted line indicates how big a percentage STCs constitute of total NPV. As can be seen the 6kW system obtains 50% of its NPV from STCs, while the smaller system acquires about 22% of its NPV from STCs.

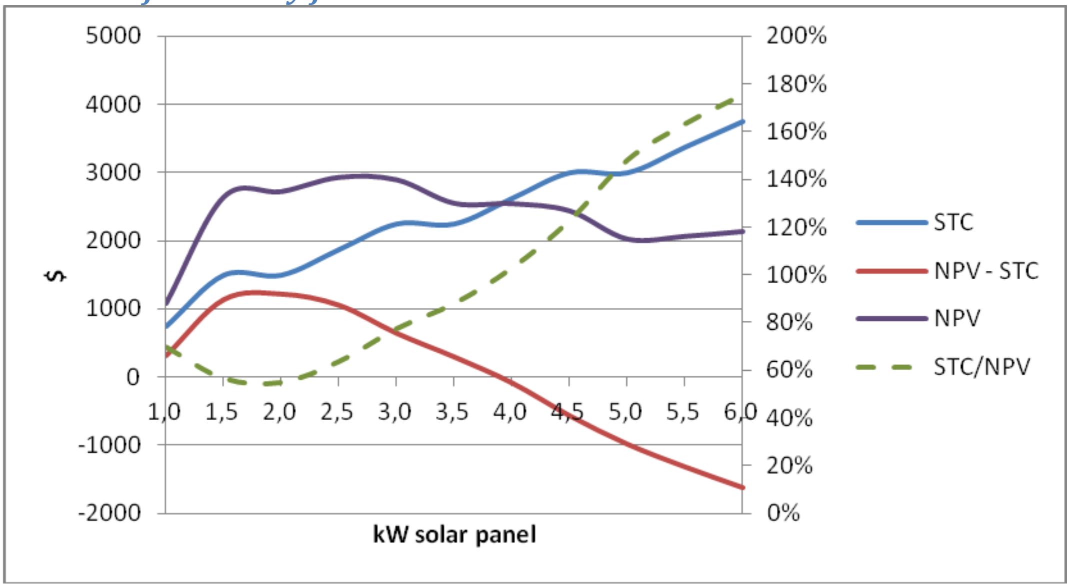
6.8.7 Concluding remarks on the sensitivity analysis

Based on the above sensitivity analyses, we found that the variable having the principal impact on NPV was the outcome of the base case scenario of residential electricity prices, when these were

[180] Appendix 3

forecasted only on the historic price index. Hence to conclude the sensitivity analyses we will quickly examine how changes in STCs affect NPV assuming that the lower bound scenario for electricity prices turns out to be true. As has previously been observed, even at the lower bound of the forecast all system sizes generate a positive NPV everything else kept constant, only now the STCs account for minimum 70% of total NPV for all system sizes. The chart below demonstrates the effect of STCs at the lower bound base case of the electricity forecast.

6.8.7.1 *Figure: Sensitivity analysis of STCs at the lower bound of the 95% confidence interval of electricity forecast*



[181]

At the base case forecast STCs are pure profit, making it more profitable for investors to install solar panels, whereas in the lower forecast the STCs work to cover the losses otherwise incurred by the bigger systems, thereby keeping them synthetically profitable. It can therefore be argued that the STC scheme is not an economically rational system for the Australian government, as the system adds to an already profitable system in the base case and synthetically makes the larger unprofitable systems, advantageous in the lower case forecast scenario.

As the sensitivity analyses have shown, an investment in a PV panel would still be profitable without the STC, everything else held constant. Moreover the NPV remains positive for the smaller systems even if the lower bound of the electricity price forecast is applied and the discount rate

[181] Appendix 3

increased to 8%. We therefore find the results of the NPV model to be quite robust and continue with a discussion of the implications of the different government subsidies.

7 Discussion of subsidy schemes and their objectives

As our results show investing in PV panels as a private consumer offers a positive NPV. This is good news for consumers who can save money on their electricity bill, but what does this finding imply for the NSW government, who initially encouraged the installation of PVCs through different incentive packages? Before answering this question we will briefly look at the incentive structures currently in place to promote alternative energy sources in general and solar energy in particular as well as how these incentive structures work.

7.1.1 Current incentives structures and how they work

Having abolished their own incentive structures NSW is left with national incentive structures, the STCs and the carbon tax. The main difference between these two is that while the STC system is specifically implemented to promote solar panels, the carbon tax targets negatively the use of conventional electricity generation in general. The STCs are an incentive system and not a subsidy, as the STCs form a required currency needed to fulfill the quotas that major energy polluters, including wholesale electricity retailers, must submit to the government (REC registry) each year. However as most of the wholesale electricity retailers are government-operated, the STCs are in the end financed by electricity consumers. The consumers pay for the system through the LRET and SRET schemes, which constitute around 4% of the final retail price on electricity[182]. In this way the STC system is an indirect subsidy, only not financed through taxes, but through electricity prices.

Contrarily, the carbon price raise electricity cost in general, and in this way the carbon price is an incentive structure not directed specifically at promoting alternative energy, but more generally targeted to promote overall electricity savings. This implies that consumers could choose to achieve electricity savings by replacing old electronics with newer energy efficient models as opposed to installing PV panels. All the while still receiving the gains from the *Household*

[182] NSW Government (g), p.13

Assistance Package that accompanies the carbon tax. In this respect the carbon price is a more general incentive mechanism, encouraging homeowners to cut down on their electricity bill.

The intention behind the carbon tax was to create incentives to make power companies invest in carbon neutral options, which could offer increasing returns to scale like e.g. a windmill park. A solution not suited for the average electricity consumer. By investing in carbon neutral assets the power companies could lower their carbon emissions, reducing the amount paid in carbon tax and thereby gain more liquidity to finance the green investment. Yet if we are to believe Truenergy chief executive, Richard McIndoe and his claim that the carbon tax will not change industry behavior[183] then other mechanisms must be applied to reach the desired targets. These alternative mechanisms will be touched upon later in the discussion.

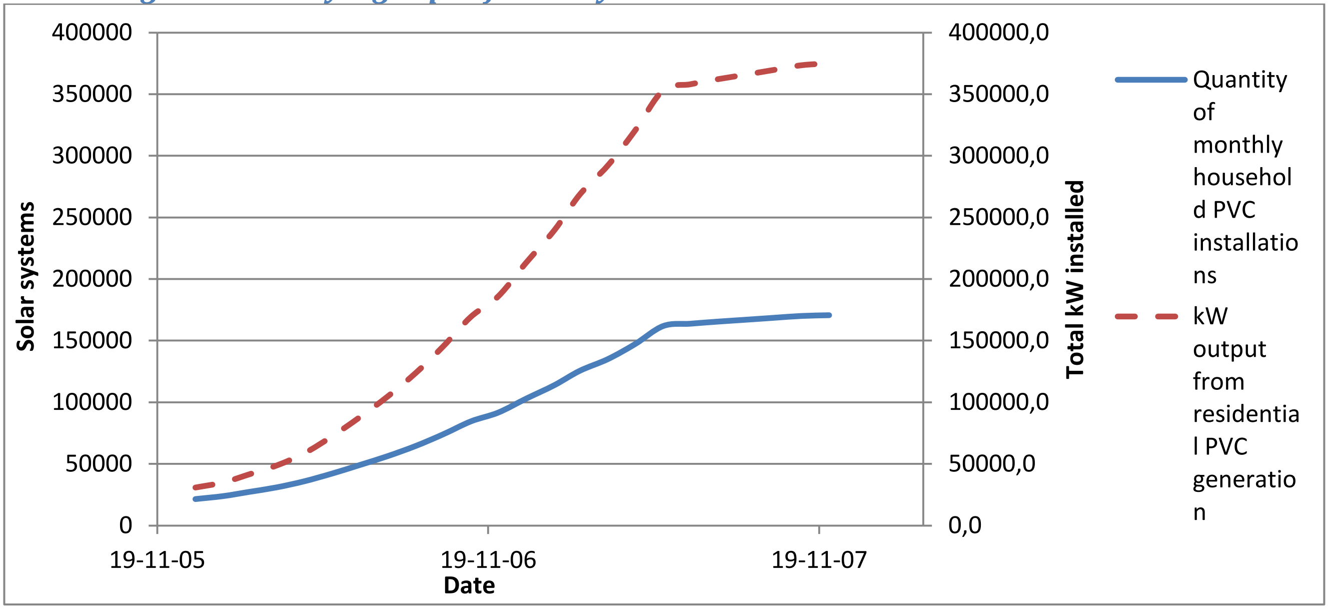
Having outlined current incentive schemes, it will be further examined how past and present schemes put in place to promote PV cells worked and how the development of these affected the number of people who installed PV systems.

7.1.1.1 Small-scale technology certificates and the Solar Bonus Scheme – have they worked?

Below is a graph showing the monthly development of PV systems installed in NSW during the period from January 1st 2010 until December 2011, as well as the kWh capacity these systems had.

[183] The Age, 2011

7.1.1.2 Figure: Monthly signups of solar systems in NSW



184

Before January 1st 2010 there was a total of 19.567 solar systems installed in NSW, so the accumulated 150.977 additional panels installed from January 1st 2010 to December 2011, represented an increase of 671%, which is quite a significant enhancement. In the beginning the number of applicants increased rapidly, but as can be observed, there was a fall in this tendency as of June 2011, from 14.644 applicants in June to 1.896 in July[185], a decrease of 87%. The decrease from June 1st to July 1st 2011 could most likely be interpreted as the immediate effect of the fall of the STC multiplier from 5x to 3x as of July 1st 2011[186]. This implies that subsidies were not an unimportant part of the decision-making process for people who considered installing solar panels. Yet interestingly enough we do not see any remarkable changes in the number of applicants following the lowering of the feed-in tariff from 60 cents to 20 cents as of November 2010, nor with the abolishment of the feed-in tariff all together as of end April 2011. This difference of consequences following the change in the STC multiplier and the change in feed-in tariff scheme could be interpreted in two ways. One interpretation is that the change in feed-in tariffs did not lead to a negative NPV whereas the change in the STC multiplier did, naturally causing consumers to respond to the latter change but not to the former. An alternative

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[184] Appendix 1
[185] Australian Government (c)
[186] Solar Online

explanation could be that consumers are generally more concerned about the upfront cash discount they receive when buying a PV system than the long-term savings the PV system can offer and that they therefore responded more severely to changes in the STC multiplier than to the changes in feed-in tariffs. If this explanation is assumed to be true, it can be argued that the carbon tax will prove to have little effect on consumers' preference for PV system. The logic behind this argument is that both the feed-in tariffs and the carbon tax make the savings associated with each kWh produced greater, but does not affect the initial cash outflow related to the PV system investment.

Since the goal with the NSW subsidies was to increase renewable energy and decrease the overall electricity consumption to lower the carbon footprint, the following will examine how the growth in PV system installations helped achieve this.

7.1.2 Reaching the Kyoto goals by means of residential PV systems

According to the Kyoto Protocol Australia is obligated to cut down CO2 emissions by 5% according to 2000 levels as of 2020[187]. For NSW this means a reduction of 7.660.000 tonnes[188] bringing total amount of CO2 emissions down to 145.530.500 tonnes by 2020 from current levels of 160.000.000, which is a decrease of 15.000.000 tonnes.

Almost 49% of NSW carbon emissions are caused by the energy sector (herein included the generation of energy)[189], mainly due to the fact that Australia has easy access to cheap fossil fuels and has made them itself dependent on coal-fired power generation[190]. The massive use of coal and fossil fuels also means that NSW emits approximately 0,9 kg CO2 per kWh produced[191], which is almost double that of European nations such as Denmark and England, which produce only 0,5 kg CO2/kWh[192][193]. Accordingly there is large potential for Australia to limit CO2 emissions by changing their energy production methods.

187 Australian government (f), p. 2
188 NSW Government (j); 2000 NSW CO2 emissions=153,19 million tonnes
189 NSW government (i)
190 NSW government (i)
191 Australian government (e), 2010, p. 19
192 Energistyrelsen
193 Carbon Independent

Currently New South Wales has a capacity of 358 MW in residential PVCs[194], an amount that offers an annual CO_2 reduction of 465.707 tonnes of CO_2[195], the equivalent of 3% annual reduction of the CO_2 emissions generated by households. Yet which out of the total CO_2 emissions produced by the energy sector of NSW (78.400.000 tonnes)[196] merely represents a 0,6% annual reduction. So in the greater perspective the current number of PVCs installed has little effect on NSW carbon emissions.

The historical data for new solar panel installations in NSW show that the number of applicants has been declining following the change of the STC multiplier the 1st of July 2011. Still an average of about 1450 new households signs up every month with an average PV system size of 2,45kW. If this growth rate is assumed constant until the Kyoto deadline in 2020, it would lead to an increase in capacity of 383,67MW[197], an increase of 107% compared to present day residential PV system capacity. These additional PV cells could provide a reduction of 0,501[198] million tonnes of CO_2 in 2020, which compared to the 5% carbon reduction goal attributes only about 3%.

The current 0,6% reduction in CO_2 is accounted for by 170.544 NSW households[199]. Out of a total of 2,7 million households[200], these 170.544 represent only approximately 6,31%, indicating that there is plenty opportunity for the amount of residential PVC systems to grow. Of course it is not expected that all households are eligible for PVC system installations, as it would for example be hard for apartment flats to install individual PV systems. Still systems could be installed on the roof or as a part of the facade. In New South Wales approximately 55% of all households are located in Sydney[201], yet in the suburbs most people live in houses, so for the purpose of an illustrative example let us assume that 50% of NSW households are eligible for PV panels. If this assumption

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[194] IPART (b), 2012, p. 24
[195] 358 MW*3,96 (av. amount of kWh produced a day)*365*0,9 kg= 465.707 tonnes of CO_2
[196] NSW government (i) – total CO_2 in NSW=160.000.000 of which the energy sector accounts for 49%
[197] 1450 * 9 years * 12 months * 2,45kW=383,67MW
[198] 383,7MW * 3,967 *365 days * 0,9 tonnes/MWh= 0,501 million tonnes of CO_2 a year
[199] Australian Government (c)
[200] NSW government (a)
[201] NSW government (a) – (1,5/2,7*100)=55%

holds and 50% of NSW households installed PV panels it would lead to savings of 4,31[202] millions tonnes of CO_2.

Such a reduction might seem unlikely to achieve by 2020, yet to reach this objective only requires a monthly average sign-up of 10.920[203] new households. Compared to the current monthly average sign-up of 1900, 10.920 signups appear improbable. But the year prior to the drop in the STC multiplier, the period from 1st of July 2010 to 1st of July 2011, the average monthly sign-up was 9.972. Hence given the right conditions, it is not impossible to obtain a monthly sign up of 10.920 households.

As our analysis concluded that residential PV systems offer a positive payoff, we would expect more people to sign up. Yet the change in the STC multiplier proved to have a big effect on number of monthly signups. This suggest that that people refrain from investing in PV panels despite the positive return, due to the large capital expenditure required for which they lack liquidity. If this is the case, an alternative financing option could offer a means to make more people invest in PV systems.

In the following we will therefore discuss the one possibility of an alternative financing method.

7.1.3 Alternative financing option

Presuming that the two parties that have the biggest interest in promoting the use of PV systems are the government and the retailers of the PV systems, it seems most logical that it would be one of these two who would facilitate an alternative financing option. Each of these obviously has their own objective, respectively reducing CO_2 emissions and making profits. Yet as the NSW government has been trying to avoid spending more money on promoting residential PV systems, it is unlikely that it would undertake an alternative funding method, as this could be associated with taking on additional costs. In this respect it can be noted that the STC scheme is a particularly well-suited system, as it alleviates the upfront payment, but at the same time is not a direct cost for the government.

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[202] 50% * 2.700.000 households * 0,00245MW * 3,967 *365 days * 0,9 tonnes/MWh = 4,31 million tonnes of CO_2
[203] (50%*2.700.000)/(9 years*12 month)= 10.920 monthly signups

The retailers of residential PV systems could on the other hand pursue an alternative financing option through what can be perceived as a blue ocean strategy[204]. The blue ocean strategy is a systematic approach to making competition irrelevant and creating uncontested market space. Since PV systems already come with a warranty, one way to pursue a blue ocean strategy could be to take the financing option to a new level. For example a retailer that trusts the quality of his products as well as the financial return his products offer, could choose to install a PV system on the consumers' roof. The PV system would then be property of the retailer for the first 14-15 years of the system's lifetime, meaning that the retailer would take all the risk and of course also the return. All the while, the consumer would continue to pay the normal fee per kWh (the 25 cents in 2012). Instead of the consumer paying the entity of his electricity bill to the electricity provider the consumer would be paying a proportion of his electricity bill to the retailer. After the 15th year the consumer would then take over the solar panels and receive all future savings himself. This financing option means that the consumer would never spend a single dollar, but would only be required to provide a north-facing roof and give the first 15 years of savings from the solar panels to the retailer.

Assuming the existence of two prototypes of electricity consumers who would choose PV systems let us investigate how each one of them would be positioned if choosing the alternative financing option. The two types of consumers could be classified as follows; the environmentally conscious consumer and the economically conscious consumer.

If the consumer is environmentally aware and always prefers to get say 25% of his electricity from sustainable sources it would cost him 33 cent/kWh more a day if he were to purchase it from the retailer[205]. Therefore obtaining 25% of his electricity from a PV system as opposed to purchasing it from the retailer would accumulate to a yearly saving of $120. Conclusively the environmentally conscious consumer should be content with the alternative financing option.

If instead the consumer is not environmentally aware but cares only about the payoff from the investment he should also be content with the alternative financing option. This is the case as

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[204] Blue Ocean Strategy
[205] Energy Australia

system lifetime after the consumer acquires control of the solar panel is 10 years and has an expected NPV of about $4000 given a 1,5kW system.

Therefore if the main problem for consumers is the initial cash outflow as well as the uncertainty of the investment, we assume that if a company offered a "no- hassle" package the consumer would take it. If the retailer believes and trusts it will be a good investment, it should make the consumer more willing to get a solar panel and at the same time question why other retailers were not offering the same. The main concern retailers could have with respect to such an arrangement is the lack of liquidity, as they would not be paid up front, but only receive monthly payments. Hence retailers would need to secure their finance by borrowing money as well as make sure that the money earned on the PV system will match the required down payments and the lifetime of the loan. This should ensure retailers the liquidity to keep producing new PV panels. Of course further research would be needed to calculate the precise length and conditions of the contract between consumers and retailers for the latter to be indifferent between the alternative financing option and the regular selling option.

7.1.4 Suboptimum versus general optimum

Although the above suggests new ways to get more people to install residential PV systems, the fact that the NPV analysis shows PV systems to be profitable even without the STCs suggest that funding small scale renewable energy generation might not be the optimal way to go for the NSW government. IPART has expressed their stance on the matter in a recent report on changes in electricity prices, where they did not find the RET to be cost-effective, especially with respect to the Small-scale Renewable Energy Scheme (SRET). Instead they argued that the SRET "*promotes very expensive emissions abatement and relatively expensive renewable energy production, which has a considerable impact on retail electricity prices*.[206]" Also McHenry, who conducted research of small-scale PV systems in Western Australia, stand skeptical of government funding of small-scale PV systems, which he considers to "*redirect finances away from more effective alternatives suitable for lowering electricity costs and climate change mitigation*[207]*"*. An additional aspect of government funding of private PV systems was pointed out by Mendelsohn, who argues that

[206] IPART (a), 2012 , p.85
[207] McHenry, 2012, p.72

government subsidies to private energy sources can be "*considered unjust, as the excludable private benefits are not available to the general public that provided them*[208]*.*" Here it becomes interesting to return to the idea of consumer willingness to pay for renewable energy sources. As argued in the beginning of this paper, we do not believe that WTP exists on a large enough scale to make a real impact on consumption patterns. Undeniably it can be argued that micro-level generation, though an economic benefit for the consumer is not the optimal way to go for society.

Our investment analysis has only been done for NSW yet the STC is a national scheme. This means that even though STCs are not necessary to make the investment in solar panels profitable in NSW, they might be in other Australian states. As opposed to NSW who closed all solar bonus schemes, most other Australian states still have these. It would therefore be a logical conclusion that investing in residential PV systems would yield an even higher NPV in other states. Of course major contributors making PV cells profitable in NSW are the price of electricity and the amount of sunshine hours. Where the later element is not that different the states across the first varies a lot. Yet the fact that the NPV is positive without the STCs leads us to assume that most if not all the other states would also generate a positive NPV. If this is the case then the STC scheme is not necessary on a national plan to make PV panels a profitable investment.

Instead of channeling the money from the STCs to the owners of solar panels it could be required that the electricity producers acquired the 4% RET component of the electricity price to invest in renewable energies on a larger scale. This could potentially benefit all Australians and would likely offer increasing returns to scale in comparison to household investments. Possible green investments on a large scale could include hydro dams, windmill parks or large solar panel facilities[209].

It could be argued that it should not be necessary to take the 4% RET component and grant it to the electricity retailers to promote green investments as this was the objective behind the carbon tax. The idea behind the carbon tax was exactly to make companies pay for their carbon footprint by taxing them for every tonne of CO2 they emit. And this way create incentives for the companies to invest in carbon-reducing schemes that would lead to lower carbon tax payments. At least in

[208] Mchenry, 2012, p. 72
[209] U.S. Energy Information Administration (EIA)

theory this was the intention but unfortunately the price of the carbon tax is not set high enough to create the proper incentives.

For example if a consumer prefers to get a part of his electricity supplied from a renewable source, he can choose to do so at the retailer in exchange for an additional fee. If the consumer wants 25% of his energy to be green it would cost him 8 additional cents/kWh for these 25%. If instead the consumer prefers all his electricity to be generated through sustainable sources it would only cost him about 5 cents extra per kWh[210]. All the while the carbon tax is currently set at $23 tonne/CO2 which equals 2,3 cents per kg of CO2. This implies that the carbon price per kWh is equivalent to 2,07 cents, since every kWh of electricity produced in NSW emits 0,9 kg CO2. Assuming that the 5 additional cents the consumer must pay to get all of his electricity from sustainable sources reflect the actual costs the retailers undertake in producing this green energy, then the 2,3 cents the retailer pays per kg of CO2 is lower than the costs of altering the energy source. This signifies that the marginal gain from reducing the carbon footprint is not sufficient to finance the investment in renewable energy sources, suggesting that the carbon tax will continue to make it profitable for individual consumers to invest in solar panels. Yet it also signifies that the carbon tax is not set high enough to make the electricity producers change their production methods. Of course it is possible that with time the effects of increases in the carbon price could change this.

7.1.5 Discussion conclusion

To sum up the discussion it was found that solar panels have a positive NPV value even without the STCs, suggesting an inefficient use of funds. Historically the data suggest that changes in STCs have had a significant impact on the number of people signing up for PV systems, indicating that the upfront payment is important to the buyers, possibly due to liquidity issues. We suggested a possible solution for the solar panel retailers, in which they could help consumers finance the PVC installation and thereby boost their sales. Evidently further research is needed to predict the risk

[210] Greenpower

factors for the retailers of taking on such a contract and to calculate the exact terms of such a potential deal. It was also found that the current capacity of residential PV systems has little effect on the NSW carbon footprint and that great efforts are needed for solar panels to have significant impact on lowering the carbon footprint. Last, it was found that though the carbon tax is intended as a new incentive scheme for retailers to change their production methods, the possible benefits of paying a lower carbon price from changing to renewable energies sources is overshadowed by the cost associated with this change.

7.1.6 Perspectives and lessons learned

Our research has been limited to New South Wales, Australia yet some of our findings can be applied for use in other regions. Especially other Australian states could benefit from our conclusions. The most general finding of our research is that driving the investment profitability of PV systems are increases in electricity prices combined with decreasing costs of solar panels. If these two trends continue simultaneously PV systems become positive investments even for countries with less sunshine hours than Australia.

Additionally it was found that government subsidy programs, like the SBS and STCs could be an important part of a transition period until PV systems are profitable on market terms. Since our research found that current monthly sign-ups are moderate despite the positive NPV, we suggest that better information campaigns be made available. This information campaign could come in the shape of official government reports, showing similar calculations and considerations as have been done in our research. It appears that consumers still experience a lot of doubt regarding the profitability of PV systems and have general hesitations towards investing in them due to the uncertainties they associate with such an investment. A proper government investment analysis including clear and coherent arguments could help clarify the questions and doubt consumers have in relation to the investment decision. It is of course important that such consultative reports are undertaken by the government and not a retailer, as the latter can be suspected of misinforming to boost sales. In this respect an official website that could automatically calculate the NPV for different states and cities, given a chosen size of PV system as well as average household consumption could be a good initiative.

Additionally, in order to obtain a better understanding of which factors influence consumer choices of investing in PV panels, further research could be done on consumer sensitivity towards NPV as well as the upfront discount acquired through the STCs. Such research could include the calculation of the NPV and STC part of the investment before as well after each of the different subsidy schemes had been removed. The changes in NPV and the upfront discount from the STC scheme could then be compared to the change in average monthly signups. From this comparison the NSW government could perhaps obtain a clarification of how it should focus its efforts if it wants to increase amounts PV system installations.

8 Conclusion

Our NPV analysis showed that installing a residential PV system is a good investment for the private NSW consumer given the economic assumptions of our model.

These assumptions were as follows:

- An average of 5,44 % annual increase in residential electricity prices for the next 25 years.
- The continual presence of the new carbon price of \$23/tonnes of CO_2, with a real increase of 2,5% in 2013 and 2014 and a market price ≥ \$30/tonnes of CO_2 thereafter.
- Annual inflation of 2,8%.
- Annual increases in distribution and transmission costs in line with inflation.
- A discount rate of 7%.

Given the above conditions, investing in a residential PV system offers a positive return for the consumer of system sizes up to 6 kW. The residential electricity prices were forecast to increase by on average 5,44% annually for the next 25 years. This value was estimated on the basis of the historic developments of retail prices as well as accounting for the effects of the new carbon tax and distribution and transmission costs.

The positive NPV results were found to be robust under the sensitivity analysis, as it remained positive despite changes in the economic variables. The factor influencing NPV the most was the base case forecast of residential electricity prices.

Photovoltaic panels were evaluated as an investment using the classical framework of discounted cash flows to find the net present value. This was done to make sure that the investment accounted properly for the time value of money, as the investment has a time horizon of 25 years. The discount rate was set according to the national Australian borrowing rate, assuming that opportunity cost of capital was equal to the financing source.

Last, it was found that government subsidies are not needed in order to make the PV systems profitable for the consumer. However government subsidies can have been an important element in the transition period, during which time the price of PVCs dropped to a level where the market was sufficient on its own. Despite the fact that residential PV systems are a good investment for the private consumers, the existence of these systems does not currently offer any noticeable contribution to the lowering of CO_2 emissions. Hence for the NSW government to reach the Kyoto targets of lowering CO_2 emissions by 5% below 2000 levels, other mechanisms must be set in place.

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c. http://www.abs.gov.au/ausstats/abs@.nsf/Products/3218.0~2009-10~Main+Features~New+South+Wales?OpenDocument#PARALINK23

d. http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6427.0Mar%202012?OpenDocument

Australian Government

a. http://adl.brs.gov.au/data/warehouse/pe_aera_d9aae_002/aeraCh_10.pdf

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e. http://www.climatechange.gov.au/~/media/publications/greenhouse-acctg/national-greenhouse-factors-july-2010-pdf.pdf

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a. http://www.bom.gov.au/climate/averages/tables/cw_066062.shtml

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Carbontax.net.au

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Dynamic Solartech

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Energi Styrelsen

http://www.ens.dk/da-DK/Info/TalOgKort/Statistik_og_noegletal/Noegletal/Samlet_energiproduktion_forbrug/Sider/Forside.aspx

Energymatters

http://www.energymatters.com.au/government-rebates/feedintariff.php#fit-tax

Energy Australia

http://www.energyaustralia.com.au/nsw/residential/products_and_services/pure_energy

Ecupower.com

http://ecupower.com/solar-benefits.php

Gecko org

http://gecko.org.au/education/solar-information/

Greenpower

http://www.greenpower.gov.au/Homes/Costs/

Indexmundi.com

a. http://www.indexmundi.com/commodities/?commodity=metals-price-index&months=240

b. http://www.indexmundi.com/commodities/?commodity=commodity-price-index&months=240

IPART (question)

http://www.ipart.nsw.gov.au/Home/About_Us/FAQs?dlv_FAQ%20List=(dd_Industries=electricity)

Spreadsheet available for download under question 30

National Australia Bank

a. http://www.nab.com.au/wps/wcm/connect/nab/nab/home/personal_finance/6/1?urid=1337933433993

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i. http://www.trade.nsw.gov.au/energy/sustainable/greenhouse-gas

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Peak Energy

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Premier Solar Queensland

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Pure Solar

http://puresolar.com.au/faq/

Solar Choice

a. http://www.solarchoice.net.au/blog/australia-to-see-37-average-rise-in-electricity-prices-by-2014/

b. http://www.solarchoice.net.au/blog/home-energy-consumption-versus-solar-pv-generation/

c. http://www.solarchoice.net.au/solar-rebates/solar-credits-and-rebates

Solar Online

http://www.solaronline.com.au/solar_rebate_info.html

Switchwise

a. http://www.switchwise.com.au/electricity/suppliers/country-energy/

b. http://www.switchwise.com.au/electricity/sydney-nsw/

c. http://www.switchwise.com.au/blogs/index.php/2011/11/24/ipart-recommends-8-to-10-cents-per-kwh-for-nsw-solar-feed-in-tariff/

The Age, May 22nd, 2011

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U.S Energy information administration (EIA)

http://205.254.135.7/forecasts/aeo/electricity_generation.cfm

10 List of appendices (all appendices are to be found on the CD)

- Excel sheets

    1. Solar panels in NSW
    2. Sun exposure in Sydney, Australia
    3. NPV model
    4. Sun exposure Sydney Australia Variance
    5. Consumption charts

- Emails

    6. Correspondence with Stephen Bower SEPQ

- Calculations
    7. Derivations of growth rates

Gmail by Google

Marc Hohnen <marchohnen@gmail.com>

Average demand in SEQ Homes

9 meddelelser

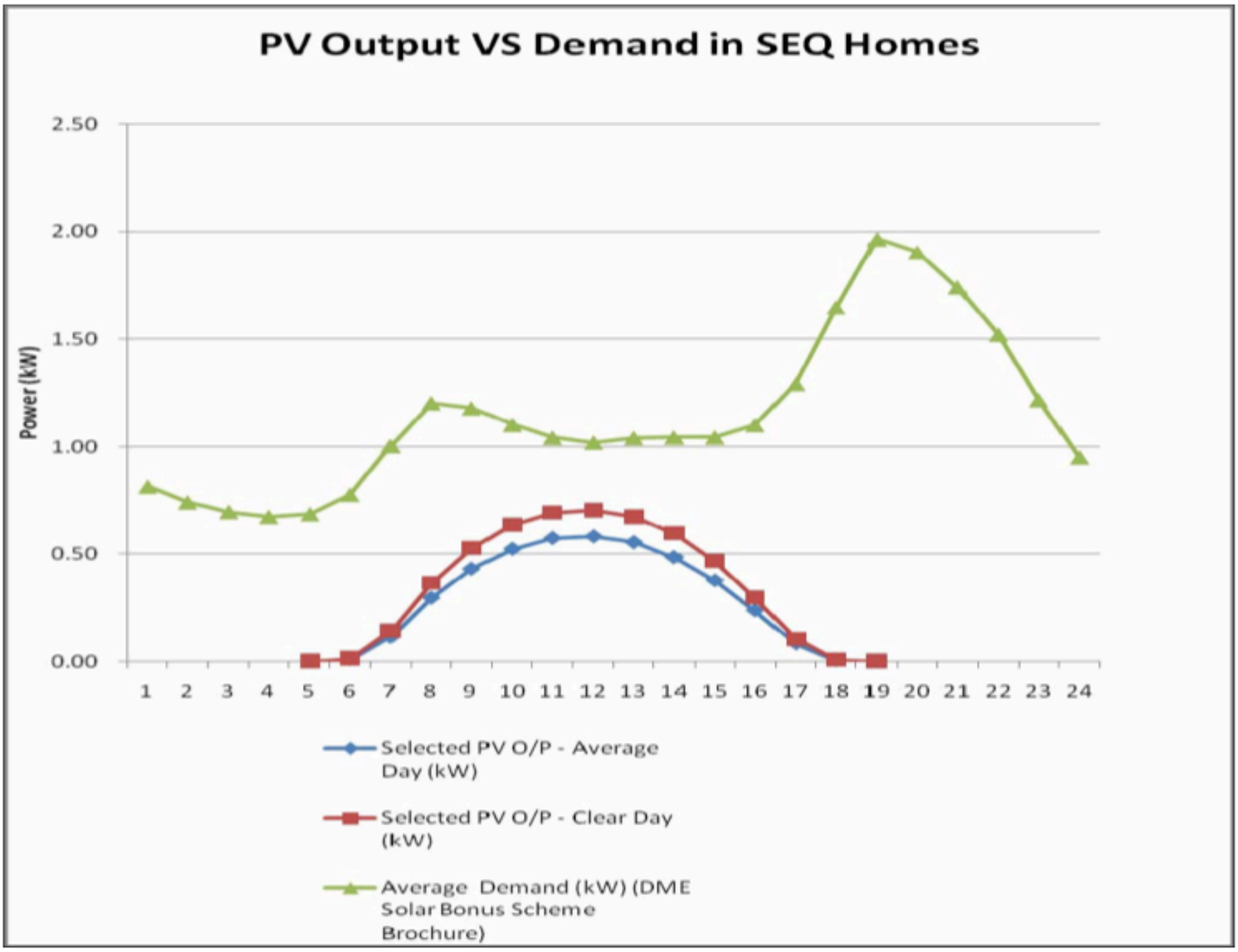
Marc Hohnen <marchohnen@gmail.com> 12. maj 2012 15.42
Til: SEPQ@people.net.au

Dear SEPQ

I am a Danish student at Copenhagen Business School, currently writing my master thesis on the electricity market in Australia with respect to investing in solar power. In that context I am trying to derive a consumption function of average daily residential household electricity consumption expressed on an hourly basis.

I can see you have such a function in your report from 20 august 2008 renewable Energy (Electricity) Amendment (Feed-in-Tariff) Bill 2008.

is there any chance i can get the data from that Average demand function.



All the best

Marc Vinther Hohnen

SEPQ <SEPQ@people.net.au> 21. maj 2012 11.05
Til: Marc Hohnen <marchohnen@gmail.com>

Dear Marc

I don't have this data easily available but would be happy to look for you. I have to request it from the local electricity distributor which means it will NOT be indicative of Australia but a region of Queensland.

In the mean time could you provide some more information to introduce youself; your course of study, the purpose of your thesis and the name and email address for your thesis supervisor.

You can appreciate I need to understand who has made this request for data.

Kind regards
Stephen Bower
SEPQ
[Citeret tekst er skjult]

Marc Hohnen <marchohnen@gmail.com> 21. maj 2012 11.43
Til: SEPQ <SEPQ@people.net.au>

Dear Stephan

Thanks that would be great. i know it would only be from a region of Queensland, but after much research you seems to be the only one with this sort of data with a proper reference to the data, and not just an estimation.

a bit about me

My name is Marc Vinther Hohnen i am writing my master thesis with Julie Yde. we are both studying at Copenhagen Business School (Denmark), in the line of Applied Economics and finance.
Our supervisor is Clinton Levitt
http://www.mpp.cbs.dk/en/Research/Departments-Centres/Institutter/node_3381/Menu/Staff/Menu/Academic-staff/Faculty/Assistant-Professors/cjl.eco
(cjl.eco@cbs.dk)

Our thesis fokus has narrowed down to an investment analyses on solar panels in NSW, after the changes in feed in tariff.
to do this investment analyses, we want to compare hourly solar energy generation to energy consumption to se how much of the energy produced you use for your self and how much you sell back to the grid. we do this because the energy you use for you self could be compared to the price of which you would buy it from the grid, this price is significantly higher then the price you would otherwise get from selling the energy back to the grid. I know your data is from south east Queensland and not NSW, but as i said earlier you are the only one with proper data on an hourly basis. there for i would still be very please if i could get this data, i might then need make some modification to the the data, to adjust for temperature, wealth & etc. if i find statistical difference between the two populations.

I hope this answers your questions, otherwise please ask again
All the best
Marc

[Citeret tekst er skjult]
--
Med venlig hilsen

Marc Vinther Hohnen

SEPQ <SEPQ@people.net.au> 23. maj 2012 13.01
Til: Marc Hohnen <marchohnen@gmail.com>

Dear Marc

Thanks for your reply.
I'm still investigating what is available for you.

Regards
Stephen Bower

> ----- Original Message -----
> **From:** Marc Hohnen
> **To:** SEPQ
> [Citeret tekst er skjult]

SEPQ <SEPQ@people.net.au> 29. maj 2012 14.13
Til: Marc Hohnen <marchohnen@gmail.com>

Hi Marc

A quick update. I have requested residentail profile data from a contact in the electricity distributor. We can only wait to see if they will release some data.
I will wait another week and then reply to you.

I hope these delays will still allow you to complete your thesis.

Kind regards
Stephen

> ----- Original Message -----
> **From:** Marc Hohnen
> **To:** SEPQ
> **Sent:** Monday, May 21, 2012 7:43 PM
> [Citeret tekst er skjult]

Marc Hohnen <marchohnen@gmail.com> 4. jun. 2012 09.27
Til: SEPQ <SEPQ@people.net.au>

Hi Stephan

sorry i have not answered, i been away for a week, but thanks for the update. we still have some time before we have to hand in. So if we can get the data we are still very much interest in it.

All the best
Marc
[Citeret tekst er skjult]

SEPQ <SEPQ@people.net.au> 11. jun. 2012 03.50
Til: Marc Hohnen <marchohnen@gmail.com>

Hi Marc

Well I was unable to get the data from the elctricity distributor. Unfortunately the data for a residential load profile cannot be provided by the electricity distributor because it is protected by privacy laws under the Australian National Electricity Rules (NER).

The load profile you found in the report from 2008 by the SEPQ was an estimate based on a residential substation load profile and the Queensland government had at that time stated that the average house used 21 kWh of electricity per day. IThis is due to the significant penetration of air conditioners in houses in South East Queensland (SEQ). understand this load is still accurate. Recently it was announced that in Australia the residentail load is levelling due to increasing PV penetration and appliance energy efficiency laws that are now providing a significant number of improved domestic appliances.

The data attached is from that 2008 report. The PV data is from actaul from a 1 kW system.

Therefore I can only suggest that you use the same methodology but with an actual profile of a residential substation in a new residential area. The attached page is from a recent report that I cannot give you the source but I can assure you it is accurate and current. Also I don't have the actual data but only the graph. Do note the data is in MVA. Multiply this by 0.9 to get MW. The penetration of air conditioners is high (approximately 2 units per household). This explains the profile difference between Summer and Winter. Please note this profile is typical for South-East Queensland and other sub-tropical areas in Australia. It is not typical in the cooler climates of Australia.

The number of households is 9,300 in this substation area. Therefore you could estimate the graph data and divide by 9,300 to give an average house profile.

I recommend you state in your thesis that load data is not available under Australian law and describe the method you have used to derive a residential load profile for a house in South-East Queensland.

Good luck Marc.

Kind regards

Stephen Bower

> ----- Original Message -----
> **From:** Marc Hohnen

To: SEPQ
[Citeret tekst er skjult]

2 vedhæftede filer

Load profile.docx
65K

SEQ Data.xlsx
10K

Marc Hohnen <marchohnen@gmail.com> 11. jun. 2012 16.12
Til: SEPQ <SEPQ@people.net.au>

Hi Stephen

Thank you very much for the data, the estimated data from the Queensland government is just the sort of data we are looking for. Without the underlying data sheet and source we can not use the second chart, which both included summer and winter, even dough that might have been even better.

in terms of the first graph, do you have any idea why it has a very significant spike at 22 o'clock? it seems like an odd time for an electricity demand spike.

once again thank you very much, this data is a great help to us.

all the best
Marc
[Citeret tekst er skjult]

SEPQ <SEPQ@people.net.au> 13. jun. 2012 13.13
Til: Marc Hohnen <marchohnen@gmail.com>

Hi Marc

Please note the data I sent you was estimated, for each hour of the day, based on the actual 21 kWh/day consumption. Perhaps I did not make this clear earlier.

The graph I sent to you is from an actual substation but I'm sorry I cannot give you the source. But if you choose to use it, you could read the data for each hour off the graph. This is not ideal but is the best I can provide.

The spike at 2200 in the original graph is due to the electric hot water systems being remotely turned on at off-peak times. Unlike Denmark where you have community based hot water supply for heating and showers etc, here every house has a hot water system. The hot water systems are turned on by a low frequency signal that is sent over the power network. It is one of the largest domestic load control systems in the world and controls about 350 MW. Interestingly this system was developed about 25 years ago to shift load from the day time to evening to improve the efficiency of the large coal-fired power stations.

Also today I found a new report, and other reports, released by the Australian Solar Institute. It is a body that promotes and supports solar R&D in Australia. They have some good data on the real costs of PV in Australia.

http://www.australiansolarinstitute.com.au/reports/.aspx

Regards
Stephen

> ----- Original Message -----
> **From:** Marc Hohnen
> **To:** SEPQ
> [Citeret tekst er skjult]

APPENDIX 7

Historical yearly increase in %

$$39{,}9*(1+x)^{31}=294$$

$$x=\sqrt[31]{\frac{294}{39{,}9}}-1$$

$$x=6{,}65\%$$

Forecast yearly increase in %

$$294*(1+x)^{25}=1104$$

$$x=\sqrt[25]{\frac{1104}{294}}-1$$

$$x=5{,}44\%$$

Higher bound yearly increase in %

$$294*(1+x)^{25}=2269$$

$$x=\sqrt[25]{\frac{2269}{294}}-1$$

$$x=8{,}517\%$$

Lower bound yearly increase in %

$$294*(1+x)^{25}=638$$

$$x=\sqrt[25]{\frac{638}{294}}-1$$

$$x=3{,}15\%$$