Literature Review of Market Barriers to Solar Technologies

A. Introduction

Before supplying a new technology to a specific market, it is important to understand the various barriers to the uptake of that technology. This is particularly true for market barriers, as these reflect directly on the likely success of the technology from an investment perspective.

The literature on barriers to green technologies is vast. In order to narrow the scope of this inquiry, a few parameters were applied to keep the literature review within the scope of the project goal. The direct project goal is to ascertain the market barriers to solar technologies for residential and businesses properties, including a few of the largest industries, within the eThekwini Municipal area. Large-scale solar projects, such as solar farms or programmes over 100MW are considered to be outside the scope of this research.

Solar technologies differ from conventional energy supply in that they have to be customised to provide specific solutions for different individuals or businesses. This is relevant to both solar thermal and solar electricity generation technologies. The load profile (energy consumption), location, orientation of ground/roof slope, available area, and tariff structure need to be taken into account when determining the optimal solar solution to implement. Given these complexities, it is also important to understand how solar technologies are understood and perceived by the consumer base, as limited knowledge or misconceptions often form the basis for market barriers.

In order to ascertain why individuals or companies do not invest in solar technologies, the question that must be asked is 'What are the market barriers to solar technologies?' This literature review intends to answer this question from the perspective of the theory on the topic.

B. Review Purpose

This literature review is intended to provide background information on barriers to solar technologies. This information will inform a survey of the potential residential and commercial solar market in eThekwini Municipality. The results of this survey will be used to answer the research question 'What are the market barriers to solar technologies?'

The focus of the literature review is on identifying specific barriers to the deployment of solar technologies. For the purposes of this review, 'market barriers' have been broadly interpreted to include all barriers that affect the likely uptake and demand for solar technologies, including technical and non-technical barriers. Within the literature, all barriers which have ultimately resulted in a lack of investment in that technology were included as being within the scope of the analysis, considering they ultimately form barriers to the solar market.

The primary market for this type and size of renewable energy technology has been identified as residential properties and businesses investing in solar systems. The common solar technologies in today's markets for individual properties are solar water heaters (SWHs) and photovoltaic systems (PV) for electricity generation. Solar technologies referred to within this review encompass both technologies, unless otherwise specified.

C. Methodology

International literature on barriers to solar technologies was used as the basis for this research, specifically within the USA and Europe, as this is where the majority of practical experience has taken place. As the key international body representing renewable energy, the International Renewable Energy Agency (IRENA)'s technical document on market barriers formed the main basis for the analysis. IRENA's research in this area was then compared and contrasted with other industry standards, including experience and approaches from international and local solar organisations and groups.

Specific focus was given to American studies, given the emphasis placed on the Solar America Communities programme in relation to the design and development of the Durban Solar City project. Literature on market barriers in the United States was therefore specifically analysed to understand best practices and principles within this geographic context. Lastly, academic articles and South African contextual literature on the various barriers were assessed to ascertain the local applicability of the main global arguments put forward. There is a limited body of literature on market barriers to solar PV within the South African context. Literature on solar water heaters is more extensive and therefore forms the main focus within the South African context for this reason.

Due to the vast quantity of relevant literature and time constraints in completing this review, such that the analysis coincides with sending out the survey, it is noted that this review is a summary of key strategic literature and is not comprehensive.

D. Literature Review

Within the literature concerning market barriers to solar technologies, it is possible to discern recurring themes across a variety of contexts. While barriers differ depending on the context, the main recurring barriers can be grouped under four themes. These four key barrier themes are as follows:

1. Financial
2. Information/awareness
3. Inertia
4. Market perception barriers

While the above barriers are distinct in many ways, there are also various overlays and connections between them. For example, what may appear on the surface as purely a financial barrier to the customer might actually be caused by a lack of information, which in turn will inform that customer's perception of the specific technology. Ultimately, the choice of whether to invest may therefore be the result of a combination of barriers.

Market barriers can be both technical and non-technical. The majority of market barriers fall under the non-technical category. This is evidenced by the non-technical nature of the key barriers highlighted above. This context is best explained by Sovacool (2009: 372) who summarises the challenges facing renewable technologies today as “more about culture and institutions than engineering and science.”

Many authors identify economic/financial and information/awareness conditions as the most significant barriers to consider in relation to solar investment. This is because the perceptions around solar energy are inextricably linked to a limited understanding of the technology, from both a product and financial perspective. This combination of factors often results in inertia to invest.

Market barriers can also be classified in institutional, capacity, social, environmental and policy terms. For the purposes of this review, a variety of barriers have been condensed into the main overarching themes, as outlined above, so as to identify the most strategic barriers to market investment. The cost of the technology is usually stated as the main market barrier and will therefore receive the most attention in this review.

1. Financial Constraints as a Market Barrier

The main market barrier, identified in the majority of the literature, is the cost or perceived cost of the technology (Margolis & Zuboy, 2006; Miller et al, 2012; IRENA, 2013). Cost related barriers can be further considered in relation to perceptions around the economic viability of the projects and the inability to access the finance to cover the initial investment (UNEP Risø, undated).

The American alliance, Clean Energy Group (2009: 6) supports this perspective, explaining that the two major cost barriers from a consumer market investment perspective are the “high up-front and out-of-pocket costs and long payback periods [which] deter them from installing solar energy technology.”

Specific cost related barriers to the uptake of solar technologies are further examined in the South African context below.

1.1. Cost as a Barrier to Solar Technologies

South Africa’s abundance of cheap coal poses a major challenge to the successful implementation of renewable energy (RE) technologies. For the successful uptake of RE as an alternative energy option, affordability is a prime consideration. Affordability depends on the type of technology, policy direction and investment considerations (Kaggwa et al, 2011). All of these aspects have a direct bearing on the price that will ultimately be paid by the consumer.

The competitiveness of solar technologies depends on the following:

a. Customer Tariff
b. Solar Irradiation (Location)
c. Initial Investment Costs
d. Financing Terms and Conditions

Price and perceptions around the economic viability of the technology are inextricably linked. On balance, if the customer base perceives the technology as effectively creating a financial saving on their energy costs, then they are far more likely to invest in the technology than for any other reason, such as the green energy provided by the technology, or the energy independence that the technology might provide**.**

a. Customer Tariff

The unit production cost and consequently the unit price attached to solar energy is high in comparison to the price offered by Eskom or municipalities. The different tariffs provided by eThekwini Municipality for typical customers are listed in Table 1 below. These tariffs are compared to the Solar Power Purchase Agreement (PPA) tariffs that were developed in a study by Suntrace to determine the financial viability of small and mid-scale solar projects for the eThekwini Municipality (Westphal & Zuñiga, 2013). The following main assumptions were made in the model:

- The duration for the PPA is 20 years
- The equity Internal Rate of Return is 18%
- Utility and commercial installations are debt funded. The utility leverage is 70/30 and commercial is 50/50

Table 1 below provides a summary of solar PV energy tariffs for different end-user installations, as compared to the eThekwini Municipality tariffs:

Table 1: Comparison of Tariffs for Solar PV Installations

PV Plant Tariffs vs. eThekwini Municipality Tariffs			
	Utility	***Commercial***	***Residential***
Solar PPA Tariff (indexed), (R/ kWh)	1.747	2.367	3.316
Solar fixed PPA tariff (not indexed), (R/ kWh)	2.618	3.556	5.024
eThekwini Municipality tariff ex. VAT, (R/ kWh)	0.75	1.267	1.029
Plant capacity, (kWp)	10 000	500	3

(Source: Westphal & Zuñiga, 2013)

This table shows that solar PV is not a financially attractive option for any of the eThekwini Municipality customers that were evaluated. According to the assumptions made in the financial model, solar PPA tariffs would be at least twice as high as that which consumers pay for conventional supply from eThekwini Municipality.

While the Suntrace study concluded the solar was not financially attractive for those evaluated, in certain countries the perception that solar is far more expensive than conventional electricity is not accurate. This is particularly true for countries which have good solar radiation and high electricity tariffs. In some of these contexts, residential solar PV systems have already reached parity with retail electricity prices (IRENA, 2013). However, cost becomes a significant market barrier to solar PV technology in contexts where installation choice becomes a trade-off between the solar investment cost and electricity tariffs. When the electricity tariff is relatively low, such as in South Africa, the initial investment required for PV can be perceived as too high in relation to the return on investment. If the electricity tariff is relatively high, then the attractiveness of the initial investment improves. The perceived saving relative to the current electricity tariff is important in improving the attractiveness of the alternative energy supply, relative to the potential financial saving it can offer the customer. Essentially, it is not just the actual difference in cost between the conventional and alternative energy supply that matters to the consumer, but rather if the difference is perceived as significant enough to make the investment worthwhile.

Yang (2010) argues that the costs of SWHs are more on a par with grid parity in many places when compared with PV. In this case, this would confirm the significance of cost as a primary barrier to PV. Hankins (2013) confirms that the issue of financial barriers is not unique to South Africa and that Africa as a continent is behind in solar technologies due in general to financial barriers. On a continent with abundant solar resources, this may seem surprising, specifically assuming that the financial savings would be higher in Africa than elsewhere, and thus assumedly reducing the financial barrier to the technology. However, a lack of cost reflective electricity tariffs, compounded by regulatory, political and institutional barriers, has deterred widespread solar investment in Africa. In addition, the return on investment that the solar technology can provide is entirely dependent on the solar radiation resources available, and this differs greatly by location.

b. Solar Irradiation (Location)

Solar radiation resources vary greatly depending on location and thus deliver different results depending on locational factors. According to the tariffs from the model in the Suntrace study, there would appear to be no perceived financial benefits from switching to an alternative source of electricity supply for eThekwini Municipality customers. However, Westphal & Zuñiga (2013) state that the figures used in the financial models were conservative and the inputs need to be evaluated further to reflect current market status.

The solar irradiation at a particular location determines the amount of energy that an installation is able to potentially generate for a defined area. This in turn lowers the payback period for the installed systems. eThekwini Municipality has some of the lowest annual solar irradiation figures in the country. This will have implications regarding the financial benefit to the customer base installing the technology, specifically in terms of the potential financial saving achieved from investing in the solar technology.

c. Initial Investment Costs

PV is currently one of the most costly options for solar energy (Teunissen, 2013). The cost of PV systems typically include the PV modules, the inverter to connect the system to the grid (if applicable), the power control systems and energy storage devices (where appropriate) and the installation in residential or commercial buildings or in utility scale plants. This differs depending on the scale of installation, with larger systems benefitting from economies of scale.

IRENA's (2013) Technology Brief elaborates on this by explaining the cost behind PV systems. IRENA estimates that the cost of the actual PV module typically ranges between 30-50% of the total cost of the system. Remaining costs result from the Balance of System (BOS) and installation costs. BOS is the cost of the solar technology that contributes to a growing percentage of installation expenses. BOS refers to all the costs associated with a PV system, except for the module, including costs such as "permitting, interconnection, and incentives" (Miller et al, 2012: 6). It is because of these inherent costs that many consumers perceive RE technologies, such as solar PV, to have a higher capital cost when compared with conventional energy technologies.

The cost of installing a PV unit can be "as low as 20% for utility-scale PV plants, 50-60% for residential applications, and as a high as 70% for off-grid systems, including energy storage (usually batteries) and back-up power" (IRENA, 2013: 3). Given that solar installation does not happen in isolation, but involves a PPA between the consumer and the municipality, the cost of solar has to be understood from this perspective.

Margolis and Zuboy (2006), writing on behalf of the National Renewable Energy Laboratory (NREL), a component of the U.S Department of Energy, clarify that the main issue with the electricity market is that it is designed with conventional, centralised power plants in mind. As long as this is the case, monopolised electricity sales will remain cheaper. This is also the case within South Africa, where Eskom has been the sole supplier of electricity until the recent introduction of the Renewable Energy Independent Power Producer Procurement (REIPPP) Programme by the Department of Energy (DoE).

Due to the significance of the actual cost of the solar system as an initial market barrier, module efficiency and energy efficiency issues in general then become a key consideration. This is particularly relevant where a simple saving from an energy efficiency measure compares with the more complicated saving resulting from an investment in a solar technology. Where this is the case, it is likely that the saving from implementing an energy efficiency measure will cancel out any perceived or real value in considering the solar investment. Ultimately, where the energy efficiency saving is on a par (or greater than) the saving from installing solar, then the solar technology is likely to lose out on a cost basis once again.

d. Financing Terms and Conditions

As discussed above, solar energy installations have a high initial capital cost. The high costs may require that the installations be debt funded. The market for renewable energy technologies is relatively new. This lack of maturity leads to higher volatility and thus to greater risk for lenders. As most renewable energy technologies are still in their infancy, they entail an additional technology risk. The challenges that the technologies would face in South Africa are still unknown. The financial institutions will factor all these risks into their credit conditions, which will raise the cost of lending.

In addition, a lack of competition among South African financial institutions may have led to reluctance to explore new fields of lending activity in the past. As there is generally a lack of experience with renewable energy projects, it is difficult to obtain funding on the private capital market (Pegels, 2010).

However, over the past three decades, the cost of solar PV has been declining steadily. As solar technology costs reduce over time, strategic marketing to inform consumers and change their perceptions is a key strategy to overcoming this market barrier. IRENA (2013) acknowledges that the growth in the current market is driven mainly by the combination of financial incentives and reductions in PV costs.

Greater PV cost reductions mean that both residential and commercial grid-connected systems have significantly increased in their economic attractiveness. This would suggest that slowly, this barrier to solar PV is beginning to shrink. In order for this declining barrier to achieve maximum impact, the second barrier to PV investment needs to be analysed, namely limited customer information and awareness.

2. Information/Awareness as a Market Barrier

The second strategic market barrier to solar technology uptake is a lack of clear information and limited consumer awareness around the technology. Often this generates negative perceptions based on a limited understanding of the cost or limited knowledge about how the technology works in practice. A basic understanding of solar technology is helpful in order for the customer to be able to comprehend the potential benefits.

As previously explained, there is limited research on solar PV within the South Africa context. However, local research on a lack of information and awareness is demonstrated by a study conducted by The University of Cape Town's Energy Research Centre (ERC), in which it is deduced that one of the main barriers to implementing solar water heaters was that many people either did not know about, or have a negative perception of solar water heaters.

2.1. Lack of Knowledge or Awareness

Consumers also often lack knowledge about conventional electricity supply options, their own electricity consumption and the environmental implications of both. This leads to what Fuchs and Arentsen (2002) refer to as a consumer 'lock-in' whereby the customer does not query their electricity supply or the possible alternative options available.

Owen (2006) adds to the discussion from the perspective of limited awareness and how this connects to the financial barriers discussed above. The majority of the public are not aware that the externalities of fossil fuel electricity are not factored into the actual cost. Brown (2001) takes this a step further by describing how many consumers who are aware that externalities are not factored into the equation do not actually understand the implications of the negative externalities from conventional energy.

In the South African context, Prasad (2007, 3) explains how "general environmental awareness is limited when compared to European countries." This knowledge deficit is another contributing factor towards why solar technologies are not widely disseminated, despite these technologies being particularly suitable in the country due to the high solar resources available.

However, even given the choice, often those consumers who are regarded as aware will inaccurately compare conventional with renewable options at surface value. This is where outreach programmes to educate consumers are important in not only informing communities and businesses, but also changing perceptions. If these negative externalities of fossil fuel based electricity were factored in, then the playing field would be far more even between conventional and renewable energy costs. Taken even further, the ancillary value of PV needs to be disseminated, such that customers understand the intrinsic value of their investment, for example, how it improves the value of their home and supports their energy security.

2.2. Inconsistent Information and Community Involvement

Where there are inconsistencies in the information being given to the consumer, this leads to negative perceptions of the technology. Linked to this is a lack of stakeholder/community participation in energy choices and energy efficiency/RE projects, particularly from the outset of these types of programmes (Margolis and Zuboy, 2006). Limited community involvement at the outset can lead to greater gaps in the knowledge and understanding of the target market. Communities which are directly involved in a specific solar programme from the outset are far more likely to understand and therefore invest in the technology. Failure to adequately include communities leads to what Choi (2009) calls a communication shortfall, which re-establishes knowledge gaps in green development. As this shortfall is perpetuated, inconsistencies and thus gaps in the knowledge base continue to grow.

A sub-set to the information barrier that has been identified in most of the international literature is a lack of trained, qualified installers (Brown, 2001; Sidiras & Koukios, 2004). In Europe and North America, inadequate workforce skills and training has been identified as a key problem, including a lack of qualified installers and inspectors (Dymond, 2002). However, as the solar technology market has matured in recent years, this issue has likely decreased significantly. Within the South African context this is most specifically relevant for the SWH market, in which the availability of trained, qualified installers has improved considerably in recent years.

The Clean Energy Group (CEG) (2009) in the USA has researched responses to information campaigns to promote solar technologies. When it comes to providing consumers with information, details such as the advancement of the technology, the environmental implications and advantages and even specifics around energy independence are not as successful in motivating people as statements about savings on monthly utility bills and how incentives and rebates can reduce the cost of the technology.

Even where consumers are aware and knowledgeable and likely to save financially by investing in the technology, they may find the technicalities of RE challenging or due to limited incentives, do not perceive the effort required as worthwhile. This barrier is described as inertia, and is considered further below.

3. Inertia as a Market Barrier

The decision to invest in PV is often a difficult one because the information around the technologies is not necessarily consumer friendly. Dymond (2002) describes this as the difficult path to PV, because current investment in PV systems requires significant consumer knowledge in order to make an intelligent PV purchase decision.

This example shows the interconnectedness of the various barriers in preventing investment. Where information is supplied, but regarded as inconsistent, when coupled with the complexities of the system, many consumers are unsure who to trust, or believe, and so instead do nothing.

3.1. Inertia Resulting from Technical Complexities

Inertia as a barrier to PV investment is linked to a variety of factors. The CEG (2009) attributes consumer inertia to the complex and time consuming nature of purchasing and installing PV systems.

Added to this are the inherent complexities of connecting the system to the grid which many consumers do not understand is an inherent part of the process. Where consumers do understand the finer nuances of connectivity, Brown (2001) explains that the inertia stems from a lack of interest as energy is often a low priority issue, particularly with conventional energy remaining relatively cheap.

3.2. Inertia Resulting from Limited or Inadequate Policies and Incentives

Inertia as a barrier can be bottom up, in relation to the consumer, but also top down in terms of inefficient government policies or a lack of incentives. Many authors stipulate the importance of the correct municipal policies in overcoming inertia in relation to solar PV. Often inertia is linked to a lack of "adequate codes, standards, and interconnection and net-metering guidelines" (Margolis and Zuboy, 2006: 6). Oliver & Jackson (1999) place high priority on the correct policies to support investment in renewable energy technologies.

In the South African context, Michaelson (2011) confirms that South Africa is lagging behind in global solar uptake levels due to a lack of market growth, sometimes linked to inefficient government policies.

4. Public Perceptions as a Market Barrier

There are two main issues identified in the literature around public perceptions to solar technologies. The first is aesthetic concerns whereby consumers, usually residential customers, think that the actual system on their rooftop looks unattractive or their neighbours will think they are spoiling the aesthetic appeal of the neighbourhood (Faeirs & Neame, 2006).

The second issue is the perceived reliability and credibility of solar PV. This applies to both residential and commercial contexts. This is a particular concern in areas where the technology is not common or prevalent. It is not always apparent why a specific technology is not prevalent in a specific area or community. Confusion as to why this absence exists can contribute to misconceptions about the technology's performance and capabilities. From a reliability perspective, lack of solar PV is often perceived as proof that the technology is not up to the task of supplying the required power needs (Dymond, 2002; CEG, 2009).

Neuhoff (2005) explains how the variability in output for technologies, such as solar, count against the technology. This relates specifically to where the output of the technology cannot be accurately determined, due to the variability of the supply. The supply is considered variable due to its dependence on available solar radiation and so it is often sold at a lower rate than it should.

Often, where knowledge about how the actual technology works is lacking, this leads to skewed perceptions that such variability will result in an unstable energy supply. Often the customer does not understand that this technology will complement their current energy supply and so actually result in a more consistent supply. This is of specific relevance in a context like South Africa where power outages are a constant reality (Roane, 2013).

E. Conclusion

Solar technologies have come a long way in recent years. While there are still significant market barriers to the technology, as highlighted by the international and South African literature, these barriers are starting to decline.

Market barriers in the literature were classified into four themes:

1. Financial
2. Information/awareness
3. Inertia
4. Market perception barriers

Financial barriers were identified as the greatest barrier to investment. This was found to be specifically true for contexts where the consumer tariff for conventional electricity is considered to be relatively low. This outcome is further exacerbated in contexts where solar irradiation is low, thereby extending the payback period and making the return on investment less attractive. Added to this are high initial investment costs and difficulties obtaining the finances required for such an investment. However, as the price of the technology decreases and the cost of conventional electricity continues to increase, the attractiveness of such an investment increases proportionately.

Information and awareness are important in removing barriers to solar technologies. The two areas to be addressed in this regard are: 1) a lack of knowledge or awareness; and 2) inconsistent information or a lack of community involvement. Where these two factors exist, the potential market is unlikely to invest as knowledge gaps and uncertainties remain or increase.

However, even where communities or individuals are aware of nuances, consumers may still fail to invest due to inertia. This inertia can result from the technical complexities of the solar technology, often combined with limited or inadequate policies and incentives to encourage investment.

Finally, perceptions towards the technology are an important fourth barrier. This can either be perceptions about the attractiveness of the actual physical system, or doubts about its credibility or reliability.

As the solar technology market develops and customers are exposed to a range of products and options, knowledge and understanding of the technologies and how they operate is also likely to expand. In turn, this will lead to greater credibility for the technologies, and ultimately, a positive change in consumer perceptions.

While the literature around market barriers suggests that these barriers are likely to diminish over time, it is important to ensure that the barriers in each specific context have been addressed. This literature review therefore informs research to be conducted on market barriers to solar technology deployment within the eThekwini Municipal area.

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