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The Feasibility of Building Integrated Photovoltaic Systems for Single Residential Buildings in the Western Cape, South Africa

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ABSTRACT AND KEYWORDS

Purpose

This study aims to determine the feasibility of making use of Building Integrated Photovoltaic (BIPV) Systems in single residential buildings in the Western Cape with the aim of applying it in this region.

Design/methodology/approach

Information required for the case studies and qualitative research was collected from up-to-date product specifications from suppliers and specialists, journals of research by others, and from interviews with PV specialists and representatives from the national utility provider. The case studies were conducted to measure the generating capacity of BIPV systems, determine system requirements for residential application, and to compare BIPV system costs with conventional electricity costs. The qualitative research was undertaken to identify polices that could be used to promote the usage of BIPV systems in South Africa.

Findings

In spite of global PV developments and high industry growth rates, the financial feasibility of the usage BIPV systems in South Africa remains

poor. Policies implemented by the National Energy Regulator (NERSA) for the promotion of clean energy generation seem to be inadequate and will have to be reconsidered.

Value

The study aims to promote the application of BIPV systems, which will have beneficial results for both the South African economy and the environment.

Keywords:
BIPV systems, single residential buildings, financial feasibility, promotional policies

1. INTRODUCTION

90% of South Africa's electricity is generated from coal-fired power stations – a very inefficient method for electricity generation. This has led to an energy crisis which has had devastating effects on the economy in recent years. Furthermore, this method causes excessive carbon dioxide emissions which lead to a global rise in the earth's temperature (Engineering News, 2009; Eskom, n.d.).

Authorities are looking to renewable resources for a solution. The Department of Minerals and Energy (DME) has set a target of 10 000GWh of energy to be produced from renewable energy sources such as wind, solar and hydro energy by 2013. Benefits that this target will bring include the following:

- *the net impact on Gross Domestic Product will be as high as R1.071 billion per year*
- *additional government revenue of R299 million*
- *stimulate additional income and creating more than 20 000 new jobs*
- *contribute to water savings of 16.5 million kilolitres, which constitutes into a R26.6 million saving*

In spite of the potential for solar generation in South Africa, the uptake of PV technologies have remained limited.

2. PHYSICAL FEASIBILITY

2.1 South Africa's generation potential

The DME suggests that South Africa's solar resource is "one of the highest in the world". Their baseline study shows that South Africa's annual solar radiation levels are between 6000MJ/m^2 and 9200MJ/m^2, and the country is exposed to an average of 2500 hours of sunshine per year, which results in radiation levels ranging between 4.5 and 6.5kWh/m^2/day (DME, n.d.; Eskom, n.d.).

2.2 Building integrated systems

The case studies have shown that, even for extremely demanding households, the space requirements of the required system would be minimal in relation to the probable space available. Maximum power requirements for non-energy conscious households require only 45m2 of solar panels, assuming an optimally inclined surface is used, which could easily be accommodated in the form of a rooftop system. This finding is confirmed by EPIA (Philbin, P. (editor), Bitter, M., Fraile, D., Latour, M., Teske, S., Wolfsegger, C., 2008:17):

> *In central Europe, a 3kW rated solar electricity system, with a module area of approximately 23 square metres would produce (approximately 3000kWh/yr) enough power to meet the electricity demand of an energy-conscious household.*

Building façades would generally have lower generation capacities due to insufficient inclination and exposure to irradiation. Research by the International Energy Association (IEA) has shown that "the architecturally suitable area of building surfaces is 60% for roofs and 20% for façades" (Gutschner, M., Nowak, S., Ruoss, D., Schoen, T., Toggweiler, P., 2002:6).

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3. FINANCIAL FEASIBILITY

In determining the financial feasibility of BIPV systems, the research compared PV systems to conventional generation, taking capital and operating costs into consideration, as well as the time value of money.

3.1 Financial analysis

Table 3.1 shows the estimated BIPV component and installation costs. This estimate is based on averages drawn from pricelists that have been gathered from five of the country's BIPV system suppliers and specialists.

Table 3.1 Estimated BIPV component and installation costs[1]

Component	Estimated cost (excl VAT)	Comments
Modules	R70.00/W	Crystalline silicon modules
Grid-tied inverters	R12.80/W	
Stand alone inverters	R10.50/W	
Batteries	R4.00/Ah	
Charge controllers	R95.00/Amp	including meters
Builders work/Installation	20%	
Connection to the grid	R5 000.00	allowance/system

Technological advances have resulted in extended lifetimes of PV systems, currently estimated at a minimum of 20 years (Philbin et al., 2008). Therefore, the total costs of the three scenarios are determined over 20 year period and then discounted to a present value. The following nominal discount and escalation rates are assumed for all calculations:

- escalation rate per annum for materials and components: **8%**
- escalation rate of conventional electricity: **30%** (CAIA, 2009; Conradie, 2009)
- discount rate: **5%**

Maintenance and operation costs of BIPV systems are minimal, which is partly due to the lack of moving components.

It is considered that the only 'weak link' lies in the batteries that are used for off-grid applications. A well maintained battery will last approximately 15 years. This is the only variable cost that is considered for the case study.

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3.2 The case study

Three different household scenarios were considered, namely, a non-energy conscious household with conventional appliances, an energy conscious household with conventional appliances, and an energy conscious household with alternative appliances, such as gas stoves, gas or solar geysers, and other appliances that don't require electricity.

The power requirements used to estimate the system requirements for each scenario is based on information obtained from various sources, including an informal practical investigation, averages provided by various sources on the internet, working drawings, and data provided by the national utility provider, such as typical kilowatt ratings of different appliances and their usage levels, the daily radiation levels in plane of a solar collector and the conversion efficiency of the modules.

The estimated system requirements for each scenario (see table 3.2) is based on the following:

- Daily radiation in plane of a solar collector in the Western Cape region – 6,30kWh/m²/day (Albuisson, M., Dunlop, E., Huld, T., Suri, M., Wald, L., 2005)
- Average daily hours of sunshine – 6,85 hours (DME, n.d.)
- Based on a conversion efficiency of 20%, 1,26kWh can be generated per square meter per day

Table 3.2 Estimated system requirements

Component	**Particulars**	**Estimated cost (excl VAT)**	
Scenario 1		**Grid-connected**	**Off-grid**
Modules (maximum)	$30m^2$ x $184W/m^2$ = **5 520W**	386 400.00	386 400.00
Grid-tied inverter	3 500W	44 800.00	0.00
Stand alone inverter	3 500W	0.00	36 750.00
Battery	2 220Ah	0.00	8 880.00
Charge controller	325Amp	30 875.00	30 875.00
Builders work	20%	92 415.00	92 581.00
Grid connection	Allowance	5 000.00	0.00
TOTAL		**R559 490.00**	**R555 486.00**

Scenario 2		**Grid-connected**	**Off-grid**
Modules (maximum)	$17m^2$ x $184W/m^2$ = **3 128W**	218 960.00	218 960.00
Grid-tied inverter	3 500W	44 800.00	0.00
Stand alone inverter	3 500W	0.00	36 750.00
Battery	1 260Ah	0.00	5 040.00
Charge controller	184Amp	17 480.00	17 480.00
Builders work	20%	56 248.00	55 646.00
Grid connection	Allowance	5 000.00	0.00
TOTAL		**R342 488.00**	**R333 876.00**

Scenario 3		Grid-connected	Off-grid
Modules (maximum)	$5m^2$ x $184W/m^2$ = **920W**	64 400.00	64 400.00
Grid-tied inverter	3 500W	44 800.00	0.00
Stand alone inverter	3 500W	0.00	36 750.00
Battery	400Ah	0.00	1 600.00
Charge controller	55Amp	5 225.00	5 225.00
Builders work	20%	22 885.00	21 595.00
Grid connection	Allowance	5 000.00	0.00
TOTAL		**R142 310.00**	**R129 570.00**

3.3 The cost of conventional electricity

The current rate charged by South Africa's utility provider to residential households in urban areas is approximately R0.57/kWh2.

The CAIA (2009) and Conradie (2009) both forecast a tariff hike by Eskom of at least 30% per annum leading up to 2012. Thus, the total estimated present value of conventional electricity supplied for 20 years is as follows:

- Non energy conscious household: R282 352.60
- Energy conscious household (conventional): R161 354.58
- Energy conscious household (alternative): R47 558.83

3.4 Grid-connected systems

Grid-connected BIPV can not be compared in isolation to conventional electricity. Unless incentives such as the feed-in tariff are available, BIPV systems will not be feasible for any of the three scenarios.

It can be argued that scenario 1 can adapt their power requirements by increasing energy consciousness to match their power requirement with scenario 2, which will provide the benefit that the excess generated energy can be fed into the utility grid and generate extra income for the household. The present value of the system for scenario 1 as at installation date will therefore be R404 552.00, taking into consideration a feed-in tariff of R2.10/kWh as declared by NERSA.

Therefore, making use of the feed-in tariff will greatly reduce effective system costs. However, the tariff declared by NERSA is not enough to promote the uptake of BIPV. For PV to become attractive to potential investors, the tariff should at least be capable of recovering systems costs before the 20 year period lapses and also provide a certain degree of profit. Dilchert (2009) suggests a tariff of at least R5.00/kWh.

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If the PV system is integrated into the building to such an extent that it replaces conventional building materials, the saving in cost of building materials will also come into play. The research will also have to consider the effect on the market value of the building. This would require extensive research and, due to time constraints, was not dealt with in this study.

3.5 Off-grid BIPV for Rural Development

The case study for rural application concerns a grid expansion project undertaken by Eskom to provide electricity to a large rural region in the Karoo. The project includes the construction of a 93km three phase overhead conductor line, a 35km phase-to-phase staggered vertical conductor overhead line, including twelve 25KVA three phase trip supply points and nine 32KVA phase-to-phase transformer supply points, and installation of a three phase re-closure on the two new lines. Construction costs are estimated at just under R15 million (Conradie, 2009).

The capital cost of this project would not be affordable for the majority of landowners. They have, however, agreed to each make a contribution of approximately R30 000 towards the capital cost of the project.

3.1.1 Financial analysis

It has been estimated that each rural dwelling will require a maximum of $2m^2$ of photovoltaic panels, or a total system cost of R52 295.00 per dwelling (calculated based on variables discussed under 3.2). Assuming that each farm in the project has 10 dwellings for its farm workers, the present value of the costs that will be incurred by each owner over a 20 year period is estimated at R531 990.00.

3.5.2 Connection to the utility grid

In addition to the contribution that each farm owner will make towards the capital costs and the usage charge, a monthly service and network charge will be payable for each transformer supplied (Conradie, 2009). The number of transformers supplied to each farm will range between 3 and 10. In order to keep this study conservative, the minimum of 3 transformers was assumed for all calculations.

It was calculated that the sum total of the capital costs, the annual service charge, the annual network charge, and usage will amount to a present value of R742 000.00, taking into consideration the various assumed escalation and discount rates as was discussed earlier.

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3.5.2 Break-even

Figure 4.2 shows that, when applying BIPV in rural areas, break-even will be reached after approximately 11 years, after which there will be a saving in cost.

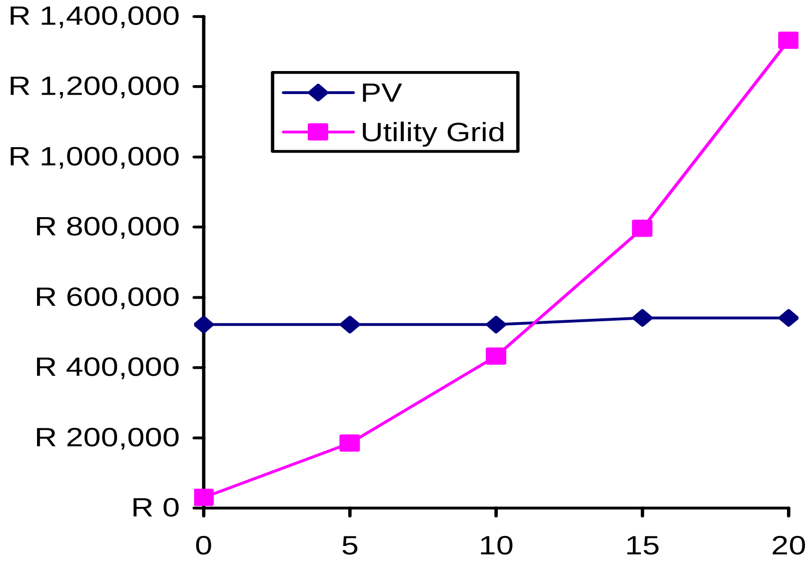

Figure 4.2 Comparison of cumulative cost

4. POLICIES FOR THE PROMOTION OF PV GENERATION

The current global take on global warming has led to political support for the development of solar electricity and promotional frameworks are being put in place in many countries.

4.1 The feed-in tariff and other policies

The feed-in tariff is a mechanism that has been proved, specifically in Germany, to be very successful in accelerating the reconstruction of the electricity supply system (Philbin et al., 2008:58).

The underlying concept of the feed-in tariff is that producers of solar electricity have the right to feed solar electricity into the public grid and receive a premium tariff per generated kWh, reflecting the benefits of solar

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electricity compared to electricity generated from fossil fuels or nuclear power. The producers (investors) will therefore have an immediate return on their investment, and the difference in the generation costs of conventional electricity and solar electricity will effectively be reduced.

The feed-in tariff is not financed through tax, but rather by an extra charge on the electricity bills of the consumers. By using this strategy, all consumers are motivated to invest in solar generation. Furthermore, the producer does not receive a fixed payment per solar module, but rather a payment based on the overall performance of the system. This creates an incentive for the producer to invest in high quality systems with high output levels. In addition to this a "feed-in tariff guaranteed by law over a sufficient period of time" will provide adequate security when trying to obtain finance for the installation of high quality systems (Philbin et al., 2008:60).

Germany was the first country to make use of the feed-in tariff and has been particularly successful in implementing this policy. This has inspired other countries to follow suit. The country is currently in the process of perfecting the policy, and the feed-in tariff for new PV installations is being decreased on an annual basis, which results in a forced reduction of system prices by producers in order to maintain profit margins (Altevogt, J., Despotou, E., Fresneda, A., Helm, P., Juquois, F., Kohler, S., Montoya Rosero, C., Nemac, F., Protogeropoulus, C., Silva, L., Swens, J., Thomopoulus, S., Veigl, A., Weiss, I., 2007:7). Today the PV sector in Germany boasts 10,000 companies, 80 of which are manufacturers, with a turnover of €5.7 billion and export revenues of €2.5 billion. The sector has created approximately 42,000 jobs and invested €175 million into research and development (Philbin et al., 2008:62).

Other policies have also been implemented, which include rebate programs and residential grants, as well as investment tax credit systems. While the feed-in tariff has proved to be the most effective policy for the promotion of clean energy generation, these policies can be considered for applications where grid-connection is not possible, such as in rural applications.

The countries that have identified the promotion BIPV systems as the key driver in promoting the uptake of clean energy generation, and have applied their policies accordingly, have had the most success in recent years (Philbin et al., 2008; Altevogt et al., 2007; Gisler, R., Orthen, S., Stierstorfer, J., Weiss, I., 2006).

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4.2 South Africa's development policy

At a meeting held in March 2009, NERSA approved certain Renewable Energy Feed-in Tariff (REFIT) guidelines. These guidelines include the following (Anon, 2009):

- Different tariffs have been established for the different types of renewable energy available – the tariff for "concentrated solar" is R2.10
- The term of the purchase agreement would be 20 years
- The tariff will be reviewed every year for the first three years and every three years thereafter
- The resulting reviewed tariffs will apply only to new projects
- Carbon revenues will not apply

The effect that this new policy will have on South Africa's renewable energy market remains to be seen.

The mere existence of the policy will not be sufficient to promote renewable energy generation. Now that the policy is in place, action must be taken for its implementation. This includes the approval of proposed PV power systems to be connected to the national grid, as well as the conclusion of purchase agreements for the implementation of the feed-in tariff. Supportive mechanisms must be set for the smooth execution of the administrative processes of these projects in order to attract potential investors. The practicality and efficiency of this policy must be evaluated on a regular basis, and be adjusted to suit the needs of the local market in order to obtain optimum results.

For the feed-in tariff to be successful in South Africa, the national utility provider should provide renewable electricity priority and guaranteed access to the grid. The diversification of electricity resources will create stability within the utility grid and will lead to a reduction in power cuts.

5. CONCLUSION

5.1 Physical feasibility

Physical feasibility cannot be considered to be a limiting factor to the usage of BIPV systems. These systems are in fact an easy to apply, low-risk technology and can therefore be installed anywhere where there is sufficient exposure to light.

Practise notes and a "comprehensive set of rules of thumb" for the application of BIPV to buildings have been developed by the IEA (Gutschner et al., 2002).

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5.2 Financial feasibility

This study suggests that the initial cost of investment, regardless of the system type, is too high for it to be financially feasible, and that the R2.10/kWh feed-in tariff that has been declared by NERSA is not sufficient to promote PV generation in the country. Adding to this, the feed-in tariff is currently not applicable to BIPV systems, as the tariff has been declared only for concentrated solar applications. NERSA must re-consider the feed-in tariff, as the current tariff is meaningless and will be of no value to the South African PV industry. Other countries have demonstrated the effectiveness of commitment from both the political and industrial sectors to achieving a greater contribution of solar electricity to energy generation (Philbin et al., 2008). Perhaps NERSA should consider the strategies used by other countries, strategies which include the promotion of BIPV systems.

As conventional electricity prices increase, and PV generation costs decrease due to technological improvements and an increase in large scale production, the financial feasibility of BIPV systems will increase over the years to come and will also have increased financial feasibility when it is considered as an “alternative building material” which can replace roof tiles, etc. (Philbin et al., 2008:45).

Furthermore, BIPV systems offer other benefits, such as job creation and rural development, over and above the generation of electricity. For this reason, a simple comparison with conventional generation and the unit costs of conventional electricity generation is not necessarily valid.

5.3 Rural application

Off-grid PV systems for rural application seem to be cost competitive and there will be a saving in cost for applications used for more than 11 years, and this could therefore be a viable option for supplying electricity to rural areas and regions that are great distances away from the grid.

Making use of off-grid PV systems would stimulate the development of rural regions, while simultaneously reducing the pressure on the environment and reducing the need for grid infrastructure.

However, according to Philbin et al. (2008:40), the initial investment costs may be a barrier to the uptake of PV systems. A possible solution to the high initial capital requirements could be that government incorporates PV systems into their low-cost housing and rural development schemes.

5.4 Raising awareness

While the value and advantages of making use of PV systems is not discussed in detail in this study, such values and advantages should be made known to the general public and potential investors.

Such advantages include improving the electricity network, job creation, energy payback, climate protection and other environmental advantages. Extensive research has already been done to prove the value of PV generation (Albuisson et al., 2005; Gisler et al., 2006; Philbin et al., 2008). It is merely a matter of sufficiently distributing the findings of this research in order to raise awareness. Philbin et al. (2008:8) suggest the following:

> *One crucial step is to bring a far broader range of actors into the sector, particularly in the investment, finance, marketing and retail areas. At the same time, there is a need to transmit to as wide an audience as possible, the message that solar electricity will bring socio-economic, industrial and environmental benefits to regions which proactively encourage its uptake.*

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