Subsidies for solar home systems in South Africa: principles and policies

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Executive summary

Recent developments in South Africa's electricity industry point towards an increasing role for solar home systems (SHSs) in the future, raising important policy questions around possible government subsidisation of SHSs. This report investigates several issues of principle as well as policy implications related to SHS subsidies.

To begin with, eight possible motivations for SHS subsidisation are outlined and the economic rationale for each is tested. Of all the possible motivations for SHS subsidisation, only one stands out as incontrovertible, namely the avoidance of environmental and health costs which are otherwise incurred. Two further motivations could justify some public subsidy of SHSs: firstly, the beneficial effects of educational programmes on television, and secondly, the need for government to kick-start the SHS industry and in particular, to overcome impediments and barriers to its growth.

A fundamental constraint on more widespread demand for SHSs in South Africa is the high degree of cross-subsidisation of new grid electricity consumers by other grid consumers. The present value of these subsidies for an average rural consumer is in the region of R4 400. If levelised over 15 years, this represents an equivalent monthly subsidy of around R43 (or R33 for the low estimate and R52 in the high estimate). Given that the supply costs for medium-sized SHSs are of a similar order of magnitude, and that SHSs presently receive no subsidy, it is clear that the 'levelling of the playing fields' as regards these subsidies is critical.

Using other studies' estimates of environmental and health externalities, estimates are made in this report of the range of avoided costs which might be attributed to SHSs. In the case of paraffin poisoning which might be reduced following installation of a SHS, the central estimate yields an NPV of R247, or R2.40 per month over 15 years at a discount rate of 8%. In the case of global climate change which would otherwise be induced by emissions of carbon dioxide from alternative energy mixes, the NPVs of avoided damage costs associated with the use of a SHS are in the region of R51, R162 or R320, depending on the energy mix against which they are compared. Taken together, these values constitute around 15% of the cost of a medium-sized SHS.

In the two other cases with some economic rationale - namely, the value of educational and similar benefits related to increased access to television, and the value of removing barriers to growth of the SHS industry to give it a kick-start - the state of empirical knowledge does not permit any economic quantification to be made at present. Nonetheless, indications are that the value of these social benefits will be positive and may therefore justify some additional subsidy support by government.

Finally, the above levels of subsidy, under various SHS investment scenarios, are compared to those which are currently transferred to grid electricity consumers. From this, it is evident that the total 'justifiable' SHS subsidy would be outweighed by existing (de facto) grid cross-subsidies by a factor of 16. This emphasises the importance of resolving the institutional and structural policy questions regarding the electricity industry and particularly the position within it of the SHS programme. Failing the resolution of those institutional and financing questions, an efficient allocation of resources between grid and SHS electrification is unlikely to materialise.

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1. Introduction

Since 1991, electricity distributors in South Africa have been engaged in an extensive infrastructure investment programme, involving the extension of the national electricity grid to over 1.5 million homes by the end of 1995 (NER 1996: 13). This electrification programme is driven, in large measure, by the connection targets set by the government's Reconstruction and Development Programme (RDP), and by the now-disbanded National Electrification Forum (NELF), both of which envisaged connections occurring at a rate of 450 000 to 500 000 per annum for the latter part of this decade.

Although the RDP explicitly stated that 'both grid and non-grid power sources (such as solar cells and generators) should be employed' (ANC 1994: 33), in reality, efforts have been heavily biased towards grid connections.

More recently, however, increasing saturation of urban residential areas, where the costs of grid supply are lower, has led to rising incremental costs of supplying grid electricity. Furthermore, the government has established an agency, 'Renewable Energy for South Africa' (REFSA), which has as its mission: 'to provide energy to that sector of the population which does not have access to the national electrification grid, or other affordable sources of energy, by utilising renewable energy technology' (REFSA 1996: 4).

It is against this background that this report considers one of the central issues in the development of public policies for the grid and non-grid electrification programmes: namely, that of subsidisation. The report forms part of a larger programme of work undertaken by the Energy & Development Research Centre, under the overall title '*Scheme for large-scale implementation of solar home systems in South Africa*'. The particular objectives of this report are as follows:

1. to outline the economic principles which ought to guide public policies around subsidisation;
2. to evaluate the possible justifications for SHS subsidies from an economic perspective;
3. to describe, quantify and analyse the *de facto* situation of subsidisation of grid electricity supplies in South Africa;
4. to consider what subsidy (if any) might be justifiable for solar home systems in South Africa.

Each of these objectives is addressed in a separate section of this report. In the remainder of the document, reference is usually made to 'solar home systems' (SHSs) as the relevant non-grid renewable energy technology, although many of the principles and issues would apply equally to other supply and demand-side energy strategies or technologies.

2. When, in principle, can subsidies for SHSs be justified?

Policy formulation on the question of subsidisation is complicated by the fact that there are many approaches and points of departure which can be taken, reflecting a diversity of views, ideologies, priorities and intellectual approaches. For purposes of this report, the underlying approach is based on the objective of achieving the optimal allocation of society's resources between competing demands - in other words, the issue is approached primarily from an economic, public policy perspective. This is not to say that other rationales for subsidisation do not exist - for example, reasons based on political patronage or institutional interests, merely that these are evaluated in this document against criteria of allocative efficiency.

2.1 Definitions

To begin with, it is necessary to define the term 'subsidy'. Many definitions exist (see, for example, Prest 1974), but for present purposes, a subsidy is defined as it relates to energy services: a transfer payment or financial flow, which has the effect of reducing the price paid by a consumer for a given energy service to a level below that which would otherwise have prevailed.

A subsidy is generally thought of as originating from the pool of fiscal resources controlled by government, although it may also include 'implicit subsidies' where no cash transfers take place, but where a commodity or service is favoured over others (for example, through VAT exemptions). Also important for purposes of this report, are cross-subsidies: in this case, the financial resources are not necessarily allocated by fiscal authorities, but may be collected and re-allocated by a single organisation such as an energy supplier which has different customer categories.

It is also useful to conceptualise subsidies as negative taxes: instead of increasing the cost to the end consumer of a service, as a positive tax does, the opposite occurs.

For purposes of this report, the mere provision of finance does *not* necessarily constitute a subsidy: if government provides loan finance to cover all or some of the up-front capital investment costs, and subsequently recovers those costs in full, including real finance charges equivalent to the opportunity cost of capital, then no subsidy exists. Only if the financier does not recover all its costs can a subsidy be said to exist.

2.2 Theoretical justifications for subsidies in general

In practice, economic theory is more frequently used by policy advocates to bolster arguments *against* than *for* the use of subsidies. The basic rationale underlying this view is that subsidies tend to introduce distortions into relative prices at a micro-economic level, whilst often causing unsustainable fiscal pressures at a macro-economic level. Both may result in a sub-optimal allocation of society's resources. This kind of scenario is illustrated by the pricing policies of many Latin American and African electricity utilities in the 1970s and 1980s, in which average prices were far below cost recovery levels, with the effect that utilities incurred financial shortfalls which had to be met from government funds. The latter, in turn, were often based on increased levels of public borrowing.

It should also be noted that the overall policy climate towards subsidies has cooled considerably in the 1990s, and it has become more difficult for many governments to introduce or even maintain significant subsidies. This is especially true in markets which are largely global in nature.

Against this background, it is important to note that there are many cases in which sound economic rationale exists for the selective use of subsidies. At the broadest level, two sets of economic justifications exist for their use (Mackenzie 1991: 60):

- to offset or correct for market failures, such as where the market-determined provision of energy supplies includes a greater mix of dirtier fuels compared to cleaner fuels than would have been the case if all the costs of those dirtier fuels had been carried by their consumers;
- to re-distribute income, such as where society values additional income for the poor more highly than additional income for the wealthy, and where the relevant commodity or service accounts for a large share of the budget of the poor.

With regard to the latter objective, price subsidies tend, in practice, to be a blunt instrument for redistribution, since most commodities or services are not consumed exclusively by 'the poor' (however defined) and therefore benefit consumers also in the non-target group. Further, not all members of the target group may consume the particular item. Nonetheless, where tax systems or direct transfer payments (such as social security) are weak or absent, price subsidies can be a reasonable 'second best' means of redistributing income.

A significant rationale for subsidisation arises in the case of public goods. Public goods (or services) are defined as those with two essential features: non-rivalry of consumption (in other words, consumption by one person does not diminish the amount of the good which is available to others) and non-excludability of consumption (the good or service is available to everyone in the area in which it is supplied irrespective of a person's willingness to pay for it) (Johansson 1987: 3). Examples of 'pure' public goods are not common in reality, but include enjoyment of an attractive view, or general security and safety in the streets of a city.

In principle, government expenditure is often required to ensure the provision of such public goods (and also 'impure' public goods); effectively amounting to their subsidisation. Thus, for instance, one of the basic roles of government is to ensure a general level of safety and security for its citizens through expenditure on defence and policing. Whilst this category of public expenditure has been extensively analysed in the literature, and carries strong economic justifications, it is not especially pertinent to the case of solar home systems, which are private goods (there is both rivalry and excludability in the consumption of a SHS).[1] Consequently, this 'public goods' rationale is not considered further in this report.

Another relevant way of analysing the question of subsidisation, particularly where the focus is on a defined project or programme, is by considering its overall effect on society in terms of the benefits and costs which will result. Thus, in performing a cost-benefit analysis of a particular project, it will be economically desirable if it has a benefit-cost ratio greater than one. Even where the stream of costs included in the analysis includes a subsidy, if the benefit-cost ratio is still greater than one, it would be economically attractive to proceed with the project. Where there is more than one potential project competing for the same resources, however, some rationing of resources and ranking of projects would have to occur to determine which combination of projects is pursued. In this case, a critical question would be whether there are more productive uses to which the subsidy resources could be applied.

2.3 Possible justification for SHS subsidies in South Africa

Against the general background provided above, it is possible to present a number of possible reasons why SHS subsidies may be economically justifiable in South Africa. These arguments are sometimes offered - though not always with sound economic logic - by stakeholders in the renewables and other industries and may be summarised as follows:

- SHSs are environmentally sustainable;
- SHSs reduce or avoid the environmental costs of supplying energy from 'dirtier' sources;
- the SHS industry requires a kick-start to achieve long-term viability;
- SHSs offer a superior quality of service compared to non-electric alternatives;
- grid electricity receives a subsidy and therefore so should SHSs;
- a subsidy from government will provide a clear signal of its policy support for SHSs;
- SHSs meet basic energy needs and should therefore be subsidised;
- SHSs can facilitate access to educational programmes on television which have significant social and health benefits.

All of the above arguments have been advanced in favour of subsidies at some or other point; however, it is important that they be evaluated from an economic perspective. As will become apparent below, the logic underlying some of them is, at best, opaque. Moreover, there are overlaps between some of these points, but for the sake of simplicity and completeness, each point is dealt with separately.

2.3.1 SHSs are environmentally sustainable

Much of the motivation for the use of SHSs, especially in the industrialised countries, stems from the concerns of environmentalists, who point to the environmental or ecological unsustainability of bulk energy supply systems which are still heavily dependent on fossil and nuclear fuels. The fact that SHSs utilise a renewable resource, in the form of the sun's

[1] The use of photovoltaic systems for communal facilities, on the other hand, contains elements of public good provision.

energy, to provide households with an electricity supply, makes them attractive from this point of view. Indeed, in South Africa, the bulk electricity supply system is based almost entirely on coal and nuclear resources: 92% and 7% respectively in 1995 (Eskom 1996: 78). On the grounds that SHSs utilise a renewable resource to produce useful energy, it is sometimes suggested that they should enjoy financial support from government, in the interests of 'sustainable development'.

On its own, however, this justification is not compelling. In the first place, it is not entirely correct: the relevant issue is not simply the generation of electricity, but the entire life cycle of SHSs from their production to their disposal. Thus it has to be acknowledged that the production of SHSs requires the consumption of non-renewable resources such as the metals and plastics used in solar panels, cables and batteries. Secondly, the disposal of SHSs at the end of their useful lives also poses environmental problems, including those related to the disposal of batteries and their contents, which may be highly toxic. The use of solar power is therefore not completely environmentally benign.

Finally, the mere fact that SHSs use solar power does not make them any more desirable, at least in economic terms, than alternatives which are based on non-renewable resources. Bulk electricity generation, for example, where it is based on coal, is considerably cheaper than electricity from SHSs and, moreover, coal reserves in South Africa are sufficient to last well beyond any current planning horizons (two hundred years or more). In this context, there can be no economic justification for SHS subsidisation simply because a SHS uses a renewable (solar) resource. Sustainability, by itself, would carry a heavy cost penalty for many decades to come if it were the sole or main criterion for government subsidy policy. Rather, as will be suggested shortly, the choice should be based on the relative economics of satisfying an energy service in a given (rural) location using either SHSs, when all their environmental impacts are accounted for, or conventional energy supply options, when all their environmental impacts are accounted for in a similar fashion. This issue is addressed below.

2.3.2 *Avoided environmental costs of dirtier energy supplies*

In this view, government support of renewables is merited since their use avoids or reduces the negative environmental effects of using energy which would otherwise have been supplied by more polluting fuels. In effect, the use of a SHS as a substitute for paraffin, candles, batteries or even coal-based grid electricity is held to avoid a number of negative environmental and health effects, which have significant economic consequences.

Although this motivation is sometimes implicit in the 'sustainability' argument (described in section 2.3.1 above), it is also completely different in its rationale and implications. To the extent that such costs may be avoided by the increased use of SHSs, a clear economic justification may exist for a subsidy, provided that:

- the avoided costs (arising from paraffin, candles and batteries) must be `external' in nature; in other words, those costs are externalities which are not captured in the prices of fuels purchased by consumers, but are incurred by other members of society, either locally or globally; and
- the value of the subsidy is less than or equal to the value of the external costs so avoided.

Where these conditions are satisfied, strong grounds may exist for a degree of subsidisation of SHSs, in order that these external costs may be reduced or avoided altogether. This issue is explored quantitatively in section 4 of this report.

2.3.3 *The SHS industry requires a kick-start to achieve long-term viability*

This view places importance on achieving significant economies of scale and on encouraging 'learning-by-doing' in the PV industry in the short- and medium-term, as the basis for ensuring that it can survive on its own in the long-term (as argued, for instance, by Caldwell 1994, cited by Drennen et al 1996). Typically, it is argued that there is considerable uncertainty in the industry and that initial support by government is required to overcome this, and that in the longer term, the industry will become self-sustaining. In many respects, this is the kind of rationale which has prevailed in some US states, notably California, where renewables industries have received direct and indirect fiscal support.

To an extent, the rationale behind this argument is based on an *a priori* assumption that growth of the SHS industry is desirable. Clearly, this is so from the perspective of industry members and supporters, but from a public policy perspective, this assumption needs to be tested against whatever criteria government has adopted in its development strategy. These criteria may include some or all of the following: labour-intensity of the industry, potential to generate export earnings, degree of involvement of small, medium and micro-enterprises (SMMEs), overall environmental performance, and future growth potential of the industry. There has been no analysis to-date of the performance of the South African SHS industry measured against these criteria, and so no conclusion can be made as to whether the SHS industry stands out as deserving more government support than other industrial sub-sectors.

A more compelling rationale is that the SHS market currently faces a number of market distortions or barriers, such as the absence (or excessively high cost) of rural credit facilities, the scarcity of skilled SHS entrepreneurs and service providers, and the absence of large-scale training facilities for SHS providers and field-workers. In the light of these impediments to the growth of the SHS market, there may be good reason for government to intervene in the market to overcome these barriers. In each case, however, the nature of government's support should be targeted directly towards overcoming the impediment, for example, through support for the training of technicians and entrepreneurs who will service the SHS market, or the support of retail credit facilities in rural areas where these are absent. A more general approach of subsidisation, on the other hand, in the hope or expectation that after a few years the SHS industry will sustain and grow its market share, is much more risky and less defensible from an economic point of view.

Given that government will be loath to financially support the renewables industry indefinitely because of the fiscal burden this represents, an important pre-condition for any government attempts to kick-start the industry is that they should have a clearly defined and limited time-frame of existence. Moreover, this should be clearly communicated to stakeholders from the outset. In effect, therefore, any government support would attempt to strengthen the underlying infrastructural capital base (human resource, financial, etc.) before it withdraws from the industry, which will then have to operate on a more competitive basis with other supply options.

On the whole, there is some motivation for government support of the SHS sector in order to kick-start it. Unfortunately, the provision of start-up financial support for the industry also carries several risks, with no guarantee that it will ultimately bear fruit on a sustainable basis. For instance, it is possible that firms will be attracted to the industry by the initial subsidisation, but will leave as soon as those subsidies are withdrawn or phased out. Further, practical mechanisms for allocating initial start-up support will present equity problems: why should some firms and/or consumers benefit from subsidies in the early years of a SHS programme, but not those investing or purchasing in later years once subsidies have been withdrawn? This serves to underlines the point made in the previous paragraph, namely that if there is to be government support, it should be aimed at removing impediments and obstacles to SHS investment, in particular the building of human capital in the form of training and the provision of rural credit facilities, which will provide lasting benefits to all SHS customers.

2.3.4 SHSs offer a superior quality energy service compared to alternatives

In this view, solar electricity delivers a much higher quality energy service than the alternatives which it usually replaces, such as candles, paraffin lamps and batteries, and therefore merits some subsidisation to improve the quality of energy services delivered to households. This motivation is sometimes presented in the following terms: 'households currently spend R*x* on SHS-relevant energy services; because SHSs deliver a better quality service, and are therefore worth more than Rx, government should subsidise them in order to make them more affordable'.

In fact, this argument contains two separate apparent motivations: one based on the 'superior quality service', and the other based on overcoming the 'affordability problem'. The latter issue is addressed separately in a later section and so the present discussion is concerned with the 'quality of service' issue.

It is important to stress that there is *no economic basis* for subsidising a SHS simply because it provides a better quality energy service than the alternatives, be they candles, paraffin or other fuels. Rather, this is the very reason why households are usually willing to pay more for a SHS than they are for existing supply options (see, for example, Hofmeyr 1996: 25, Acker & Kammen 1996: 95). In principle, a consumer's willingness to pay for a solar home system, provided this is based upon full knowledge of the services which the system can provide, already includes his or her implicit valuation of all the services which the SHS can provide. Consequently, in a market-based economy, it would be expected that the price of a SHS, as negotiated between suppliers and consumers, would reflect the value to the consumer of the benefits delivered by the SHS - thus neither the need nor justification would exist for government to subsidise the price of the system.

Clearly, an 'efficient market' is a hypothetical condition which seldom exists in the contexts where SHSs may be used in practice. Some common market failures include:

- consumers often do not have full information about SHSs and alternatives, most commonly believing that SHSs can supply more electricity than they are in fact capable of doing;
- suppliers may have monopolies in particular areas of supply, or at the very least, are able to influence the price of a SHS in a particular market.

The effect of both of these failures would be to increase the price of a SHS above that which might prevail in a more efficient market. Neither case, however, would provide justification for a price subsidy - if anything, government's efforts should be directed towards correction of these problems themselves (such as through the provision of information to consumers, or regulation of monopoly profits).

2.3.5 *Grid electricity is subsidised and therefore so should SHS be subsidised*

It has been well-established that South Africa's national electrification programme is premised on a significant degree of cross-subsidisation from wealthier to poorer electricity consumers (Eberhard & van Horen 1995: 120, Davis 1996). Moreover, the extent of this cross-subsidisation has increased in relation to the level envisaged at the commencement of the programme, primarily because new consumers' electricity consumption levels have been lower than expected. Thus considerable resources are being directed to the electrification programme, principally by Eskom, but also by local authority electricity distributors.[2]

A common theme in policy development around renewables involves the 'levelling of the playing fields' in terms of subsidies, taxes and other mechanisms of government support (or penalty). On this basis, it might be argued that SHSs should also be subsidised to the same degree as grid electricity, in order that it can be set on an equal footing.

This logic, however, is not sound. Although it is clear that there is a serious bias in the current system in favour of grid electricity and against SHSs, the introduction of an equivalent subsidy for SHS would amount to the introduction of another distortion in the price system, and would not necessarily have the desired effect in the long term. Put differently, 'two wrongs will not make it right'. In the long term, it is most unlikely that large subsidies can be sustained for both the grid and non-grid electricity sectors, without causing major disruptions elsewhere in the energy economy, and so the introduction of subsidies for

[2] Quantification of these subsidies is the focus of section 3.

SHSs simply because they exist in the grid supply system is not a sustainable economic strategy.

Thus, although there is no economic logic in this argument, it remains a fundamentally important issue for the SHS programme; it is therefore considered in more detail in sections 3 and 5 of this report.

2.3.6 *Government subsidies will be evidence of policy support*

In this view, an important effect of government subsidisation of SHSs will be to provide a credible signal to consumers and market participants that the government strongly supports SHSs. This might reduce the level of uncertainty facing potential investors in the industry and therefore encourage them to take investment risks of their own.

In one respect, it is difficult to contest this view: if government is prepared, in the conservative fiscal regime which currently prevails at national level, to expend resources on SHSs, it would be reasonable to assume that this must be an important priority for government. This would undoubtedly be a positive signal for potential market participants.

The question which has to be considered from a public policy perspective, however, is whether there are other means through which government is able to provide the same signals to the industry and consumers, but without incurring considerable resource costs or without producing other consequences which may be unintended. Such means could include, for example, clear policy statements about government's support for SHSs, including the limits on continued grid electrification in rural areas. Clear policy statements, backed by sufficient analysis, could go a long way towards providing positive signals to potential SHS investors and consumers.

Nonetheless, it is not impossible that even such policy pronouncements would not be sufficient: for example, this could be the case if the level of expectations that Eskom will supply rural households with grid connections is so high as to be unaffected by policy statements. In that case, the provision of subsidy finance for SHSs would provide a very clear signal of government's true intentions.

2.3.7 *SHSs meet basic energy needs and should therefore be subsidised*

Lighting services can be regarded as one of the basic energy needs, and because solar home systems provide (inter alia) these services, it might be said that SHSs should receive public policy support. Essentially, this argument follows from the fact that the government has placed a high priority on meeting the basic needs of the poor, in order to bring about a more equitable distribution of income.

Evidence on this score is mixed. On the one hand, lighting ranks behind cooking and space heating in the hierarchy of basic needs; this is even more so in the case of powering radios and televisions which are much less critical demands. Moreover, when SHSs are compared with non-energy sector services, such as provision of clean water and sanitation, it is evident that the services satisfied by SHSs are middle-order needs. This suggests that subsidisation of SHSs may be a poor instrument of redistribution.

On the other hand, lighting is an energy service consumed by all households, including the poor, for whom it constitutes a reasonably large portion of the household budget. Thus targeted subsidies could have positive distributional implications.

Survey data on households' demand for SHS-relevant services provide interesting results. In one survey of 90 households in Southern Transkei, Eastern Cape province, Hofmeyr (1996) found that demand for lighting and media services (which would be displaced by SHS) was income inelastic - in other words, demand increased less than proportionately as income increased. This is evident from Table 1.

Table 1 Income elasticity of demand for SHS-relevant energy services
(data extracted from Hofmeyr 1996)

	Average h/h income (p.m.)	% increase	Average exp. on SHS-relevant fuels	% increase	*Income elasticity*
Low income	R452	-	R21	-	-
Mid income	R1 030	128%	R25	19%	*0.15*
High income	R2 925	184%	R32	28%	*0.15*

Although these results represent a single rural sample and therefore cannot be too widely generalised, an income elasticity of only 0.15 suggests strongly that the services being satisfied are more in the nature of necessities than luxuries.[3] Thus strategies to provide these services more effectively would have positive effects on the poor, for whom this expenditure would represent a relatively large share of their budgets.

Other evidence from the same survey, however, suggests that SHSs embody a shift away from basic energy needs towards (relative) luxury goods. Using the same three income categories as in Table 1, it was found that a greater percentage of high income households were willing to pay more for a SHS than they currently paid for equivalent services: 79% were willing to pay more (amount unspecified) for a SHS, compared to around 50% for the low and mid income groups (Hofmeyr 1996: 24). In other words, demand for SHSs increases in higher income groups, suggesting that it is more than a simple substitute for SHS-relevant services (lighting, media, etc.). This therefore comes back to (and confirms) the earlier contention, namely that SHSs provide a higher quality service than the alternatives.

To conclude then, it would appear that SHSs may satisfy basic needs, but that they also represent a higher quality service for which those who can afford it, are willing to pay. As a means of improving the income distribution for the poor, subsidies of SHSs are probably relatively blunt instruments. Subsidies for the poor might therefore be more productively directed at other goods and services which meet higher priority basic needs, such as securing fuelwood supplies, and providing potable water and adequate sanitation services.

2.3.8 SHSs facilitate welfare gains through access to educational media programmes

An important benefit of providing access to television and radio services may be the educational effects of programmes concerned with health issues, news, skills transfer and awareness of world events. The question, in considering whether this benefit might justify a subsidy from public funds, is not whether the benefit is real or not, but whether it is something which is already considered by households in their resource allocation decisions about their willingness to pay for SHSs.

If this benefit is an unintended consequence of a decision to purchase a SHS, then it is likely that household demand for SHSs would be below the optimal level. In effect, therefore, a subsidy could have the effect of capturing the external benefit - in other words, it could realise those potential educational benefits which would otherwise have been foregone.

If, on the other hand, households are fully aware of these benefits which will result from acquisition of a SHS, then there would be no external benefit and no justification for a government subsidy of SHSs on these grounds.

There is scant evidence on which to make a judgement on this issue. However, it is probably fair to assume that the relatively limited experience of rural households with SHSs and, more particularly, the low levels of access to television services in lower-income rural areas, means that most households are probably not fully aware of these potential educational benefits. Thus there may be some rationale behind government support of SHS, provided

[3] Demand for luxuries, on the other hand, is generally income elastic (>1): as income increases, so demand increases more than proportionately.

this results in an increase in the number of television sets in use and, of course, that full advantage is taken of programming schedules to increase the educational impact of television programmes.

2.4 Summary of arguments for and against subsidies

This section has outlined a number of reasons which are sometimes presented as motivations for government subsidisation of SHS, and has evaluated their economic merits. It was clear that the rationale was mixed; for purposes of clarity, the conclusions of the analysis are summarised qualitatively in Table 2.

Table 2 Evaluation of possible motivations for SHS subsidies

Motivation	Can this, in principle, justify a SHS subsidy?				
	Yes	Maybe yes	Unclear	Probably not	No
SHSs are environmentally sustainable					✓
SHSs avoid the environmental costs of 'dirtier' energy supply options	✓				
SHSs offer a superior quality of service compared to alternatives					✓
the SHS industry requires a kick-start to achieve long-term viability		✓			
grid electricity receives a subsidy and therefore so should SHSs					✓
a subsidy from government is a clear signal of its policy support for SHSs			✓		
SHSs meet basic energy needs and should therefore be subsidised				✓	
SHSs can facilitate access to beneficial educational programmes on television		✓			

In the sections which follow, some consideration is given to empirical scenarios: firstly, regarding the extent to which the current playing fields are not level, and secondly, regarding subsidy amounts which may be justified.

3. Electricity subsidies: the status quo

3.1 Introduction

In the previous section, it was suggested that the mere presence of subsidies in the grid electricity system does *not* represent adequate justification for subsidisation of non-grid electrification. Simultaneously, however, it is important for policy purposes that there are no fundamental incentives or biases in the financing system which are counter-productive from government's perspective. Consequently, it is important to make explicit the extent to which such distortions may exist in the system at present; in other words, the question must be asked 'how level are the playing fields at present?' This question forms the focus of this section.

Subsidies to grid electricity consumers fall into two main categories:

- direct financial subsidisation of the costs of supply, mostly in the form of cross-subsidies from other consumer groups to newly-electrified consumers; and
- implicit subsidisation of electricity supply in the form of environmental costs which are not borne by consumers, but are incurred instead by other groups in society. Put differently, some of the costs of supply are not internalised and reflected in electricity prices, thus representing, in effect, an implicit price subsidy.

The consequence of both of these forms of subsidy is that the prices paid by grid electricity consumers for those services are lower than the real economic costs of supplying them. Since these apply only to grid consumers and not to SHS consumers, the financing system contains an implicit disincentive against SHSs.

3.2 Financial cross-subsidies for grid electricity consumers

As noted earlier, it has been well-established that the accelerated electrification programme currently underway entails a significant degree of cross-subsidisation from large and long-established consumer groups to newly-electrified customers. Perhaps less well-known, is the financial scale of the cross-subsidy which presently occurs and which is expected to continue for the foreseeable future.

One expression of this cross-subsidy is the net present value (NPV) of the electrification programme. Early estimates put this figure at around negative R18 billion (Eberhard & van Horen 1995: 116), slightly lower than more recent estimates of negative R21 billion (Davis 1996). The latter figure equates to an average NPV per new customer on the grid of around negative R3 500.

With the benefit of several years' experience, it is possible to make fairly accurate assessments of the likely net financial effect of grid electrification investments. Table 3 lists a number of key variables affecting the economics of grid connections, and shows NPV results for different capital cost scenarios. Sensitivity analyses have shown that the financial results of the electrification programme are especially sensitive to capital costs, amongst those variables over which some degree of control can be exercised (Eberhard & van Horen 1995: 125, Davis 1996), and so this is taken as the independent variable in the following scenarios.

Table 3 Financial NPVs of grid electricity connections under various scenarios

	Low	Central	High
Capital cost (R)	3 000	4 000	5 000
Connection fee	50	50	50
Fixed monthly operating cost (R)	25	25	25
Variable supply cost (c/kWh)	10.00	10.00	10.00
Tariff (c/kWh, excl. VAT)	25.28	25.28	25.28
Starting consumption (kWh/month)	90	90	90
Annual consumption growth (%)	15%	15%	15%
Peak consumption (kWh/month)	250	250	250
Losses (%)	15%	15%	15%
Time period (years)	15	15	15
Discount rate (%)	8%	8%	8%
NPV (R)	-R3 392	-R4 392	-R5 392
Levelised NPV over 15 years (R/month)	-R33.02	-R42.76	-R52.49

The negative NPVs thus obtained range from R3 392 in the low case, to R4 392 in the central case and R5 392 in the high case. The result from Davis (1996) falls within this range. Effectively, this means that for every new electricity consumer, the net financial cost to the electricity supply industry over the lifetime of the assets (taken as 15 years) will be around R4 400. Given that there is no external subsidy from the fiscus, this means that all of this amount takes the form of a cross-subsidy from other consumers.[4]

Expressing the NPV as an annuity (that is, levelised over 15 years at a discount rate of 8%) is also instructive, since this represents the equivalent net monthly cost of new customers under the assumptions listed above. In the central case, this represents an effective monthly subsidy of just under R43, with lower and upper cases of R33 and R52 respectively. This is of a similar order of magnitude to supply costs for SHSs, which are in the region of R30 to R40 per month over a 15 year period (calculated from Hochmuth 1996: 21).

Thus it is clear that there is a considerable disincentive for SHSs in the present financial landscape in South Africa, particularly whilst electricity distributors continue to give preference to grid connections (even at lower capacities) over SHSs. In this context, it is not at all surprising that rural households are loath to commit themselves to investing in SHSs when there is even a small possibility that they will be supplied with grid connections in the future (see, for example, the experience in Folovhodwe, Northern Province, as described in Geerdts 1996). With the prospect of receiving an electricity supply which benefits from a cross-subsidy in the order of R40 per month, clearly any rational consumer will not elect an unsubsidised SHS (all other things equal). Removal of this fundamental barrier to SHS investment is critical to sound resource planning decisions in the electricity sector. Whilst it is beyond the scope of this study to consider these issues in detail, they are fundamental to the success of the SHS industry and are therefore addressed briefly in the final section of this report.

3.3 Implicit environmental and fiscal subsidies to grid electricity consumers

Internationally, considerable attention has been directed in recent years to the quantification of externalities: costs incurred in the bulk generation of electricity, but which are not borne (or recovered) by producers themselves.[5] In South Africa, there has been only one economic analysis to-date of externalities in electricity generation, and even that study was severely curtailed in its scope (Van Horen 1996a). Nonetheless, it is possible to obtain an indication of the approximate scale of externalities incurred in the generation of grid electricity. As noted earlier, these are relevant insofar they cause the price of grid electricity to be unfairly favoured compared to the price of SHSs.

Five main externalities have been quantified for electricity generation in South Africa, using Eskom's power stations as the focus of analysis (Van Horen 1996a: 67):

- morbidity and mortality effects in coal mining;
- sub-economic pricing of water consumption in coal power stations;
- morbidity and mortality effects of air pollution from coal power stations;
- damage costs arising from greenhouse gas emissions; and
- fiscal subsidies directed to the production of nuclear electricity.

[4] It is beyond the scope of this report to assess the degree to which this subsidy is economically justifiable. Nonetheless, it is probable that, even placing great weight on redistribution towards the poor, a more efficient allocation of these resources would involve a smaller electricity subsidy and more resources for other services (such as rural water supplies).

[5] For a review of international externality studies, see Van Horen (1996a: 21-31).

Damage cost estimates (in 1994 Rands and c/kWh) were derived for each of the above categories. For present purposes, damage costs attributable to climate change (which were by far the largest of the above effects) will not be included, because of the high degree of uncertainty which applies to these estimates. Taking the remaining four externalities into account yields an estimated external cost (in the central case) equivalent to 7.1% of average Eskom tariffs for 1994, or 3.2% of domestic prepayment tariffs (calculated from Van Horen 1996a: 85); in other words, this is the amount by which grid electricity prices under-account for environmental and fiscal effects related to the production of that electricity. Importantly, this probably represents the lower bound of actual external costs, because numerous externalities were not included in the scope of the analysis referred to above: notably acidic deposition (acid rain), visibility impacts of pollution emissions, air and water pollution from coal mining, and environmental risks from the nuclear fuel cycle. The low and high cases in the original study would have yielded adjustments of 2.6% and 5.8% respectively.

Applying this 'adder' of 3.2% to prepayment tariffs at their 1996 levels, means that there is effectively an implicit subsidy of 0.8 c for every kWh consumed. Using the same consumption growth scenarios as in the previous section, this amounts to an NPV of negative R148, equivalent to a monthly annuity (at 8% over 15 years) of just R1. For the low case, this would have been an NPV of negative R122 or R0.80 per month, and for the high case negative R271, equivalent to R1.80 per month. Clearly, these amounts are not nearly as significant as the direct financial subsidy to grid consumers, but they should nonetheless feature in the analysis, both as a matter of principle, and because these amounts would increase if all major externalities were included in the scope of investigation.

3.4 Summary of existing subsidies to grid electricity consumers

The above two categories of subsidy are summarised in Table 4, for each of the low, mid and high estimates.

Table 4 Summary of direct financial and implicit subsidies applicable to grid electricity consumers

	Low	Mid	High
Direct financial cross-subsidy	R33.02	R42.76	R52.79
Implicit externalities	R0.80	R1.00	R1.81
Total	R33.82	R43.76	R53.60

The inclusion of implicit externalities causes only a marginal change to the results, with the total subsidy in the central case amounting to approximately R44 per month on a levelised basis. Clearly, it is critical for policy-making purposes that further consideration be given to the 'levelling of the playing fields' in this regard - although this is beyond the scope of the present report, this issue is addressed briefly in the concluding section. In the next section, an indication is provided of the approximate scale of subsidies which might be justified on the grounds outlined earlier.

4. SHS subsidies: what amounts can be justified?

Of all the possible motivations for SHS subsidisation, only one stands out as incontrovertible, namely the avoidance of environmental and health costs which are otherwise incurred. It was also suggested in section 2 that two further motivations could justify some public subsidy of SHSs: firstly, the beneficial effects of educational programmes on television, and secondly, the need for government to kick-start the SHS industry and in particular, to overcome impediments and barriers to its growth.

Ideally, public policy decisions about the financial support of SHS programmes should be based on rigorous quantification of the likely costs and benefits of such a programme. This, however, requires a greater amount of underlying information about the costs and benefits of SHSs compared to alternatives than currently exists. Nonetheless, a certain amount of empirical information does exist, and this can be used to provide some indication of the scale of subsidies which are economically acceptable.

4.1 The value of avoided environmental costs

Two categories of environmental costs are pertinent here: those incurred in the local environment and those affecting the global environment, specifically global climate change caused by anthropogenic greenhouse gas emissions. Each of these categories is considered below.

4.1.1 Avoided costs in the local environment

SHSs are used by households primarily for lighting and powering radios and television sets, and therefore substitute for candles and paraffin lamps in the case of lighting, and batteries (dry cell and car) in the case of radios and televisions. To the extent that candles, paraffin and batteries currently cause negative environmental and health costs which are not accounted for in their prices (externalities), and to the extent that SHSs eliminate or reduce the use of these fuels following their installation, then an incremental benefit will arise. Since this is an 'external' benefit which will be captured by the use of a SHS, it would be efficient for government to provide fiscal support to a SHS programme, up to the value of those avoided costs.

Unfortunately the empirical information about the external costs of using candles, paraffin and batteries is incomplete and subject to high levels of uncertainty. One South African study has attempted to quantify the environmental and health costs of several externalities arising from household energy consumption, the relevant externalities for present purposes being fires and burns from accidents with candles and paraffin, and paraffin poisoning in infants (Van Horen 1996b). Although the external costs of other household externalities were estimated to be extremely high - notably the health costs of air pollution from wood use, and the opportunity costs of wood collection - the use of SHSs will not bring about any reduction in wood consumption and so these costs will be unchanged.

Based on data regarding the scale and extent of morbidity and mortality from fires caused by accidents with candles and paraffin, external costs were estimated to be in the region of R1.7 billion per annum nationally (Van Horen 1996b: 168). By far the largest part of these costs, however, were attributable to fires occurring in dense informal settlements in urban areas of the country, where the close proximity of shacks constructed from flammable materials exacerbates the severity of any fires. In considering what portion of these costs, if any, would be avoided by the use of SHSs, it seems most unlikely that there will be any major benefit, since this problem is primarily an urban phenomenon. Given that the SHS programme is targeted at deep rural areas, where the nature of house construction and village settlement patterns is not susceptible to fires in the same way as urban areas, it can be assumed that the avoided costs will be negligible.

In the case of paraffin poisoning, however, indications are that the prevalence of poisoning among infants who mistakenly drink paraffin, is at least as high in rural as in urban areas (Ellis 1994: 727). Based on reported rates of hospitalisation and mortality for paraffin poisoning, as well as approximate data on the quantity of paraffin used for lighting in rural homes, it is possible to provide an indication of the approximate order of magnitude of avoided costs. This is summarised in Table 5.

Although these results mask high degrees of aggregation and approximation, they nonetheless provide some indication of the value of these benefits. The amounts are not highly significant, representing about 6% to 8% of the levelised monthly costs of a SHS system for the central case (calculated from Hochmuth 1996: 21). For the low case, these represent only 1% to 2% of SHS costs, but are much more significant in the high case, amounting to between 26% and 35% of typical SHS costs.

Table 5 Estimates of avoided costs of paraffin poisoning due to SHS use

	Low estimate	Central estimate	High estimate	References
Total costs of paraffin poisoning	R65 m	R262 m	R961 m	Van Horen (1996b: 163)
Average external cost (per GJ supplied by paraffin)	R3.49	R14.18	R51.95	Van Horen (1996b: 170)
Average external cost (per litre of paraffin)[6]	R0.12	R0.50	R1.85	-
Average paraffin consumption for lighting (l/month)	5	6	7	Hofmeyr (1996), Geerdts (1996)
Average substitution of SHS for paraffin lighting	80%	80%	80%	Hochmuth (1996: 10), Geerdts (1996)
Avoided external costs for paraffin lighting (R/month)	R0.48	R2.40	R10.36	

4.1.2 Avoided costs in the global environment

The use of SHSs can potentially have positive global environmental effects, particularly where these replace more carbon-intensive fossil fuels in the household energy mix.[7] Indeed, photovoltaic programmes have been undertaken in several developing countries, largely on the basis of their anticipated global environmental benefits (for details on the Zimbabwean case, which received finance from the Global Environment Facility, see Drennen et al 1996).

There are two elements which determine the scale of any subsidy which might be justified on this basis: first, the physical quantity of greenhouse gases (GHGs) which will be avoided by SHSs, measured in tons of carbon or carbon dioxide.[8] Secondly, the economic value (in Rands) of expected damages caused by emissions of GHGs have to be estimated. Whereas there is a low level of uncertainty about GHG emission factors for various energy sources, the economics of GHG damages remain highly uncertain and are subject to a wide range of estimates (which, not surprisingly, enjoy nothing close to consensus among various analysts and interest groups). Nonetheless, it is possible to provide a very approximate indication of the range of avoided global damages which may result from the use of SHSs instead of alternative energy mixes, although it has to be emphasised that these are highly uncertain values.

The quantity of GHGs which will be avoided by the use of a SHS depends on the particular energy mix which it displaces. For present purposes, four energy mix scenarios can be described:

- *SHS-wood:* a SHS meets all lighting and media needs, with the large thermal requirements for cooking and heating being met by wood;
- *wood-paraffin-candles:* there is no SHS; lighting and media services are met by paraffin and candles;

[6] Based on an energy content of 35.6 MJ/l (Van Horen 1996b: 169).

[7] A full description of the effects of emissions of greenhouse gases (particularly carbon dioxide and methane) on global climate change processes, is beyond the scope of this report. For more details, see Rowlands (1995).

[8] For present purposes, other GHGs such as methane and nitrogen oxides are ignored as they are of negligible relevance in the case of SHSs and alternatives.

- *limited grid-wood:* there is no SHS, and instead lighting and media services are met by grid electricity, but with no significant electricity use for cooking and heating services;
- *grid-limited wood:* there is no SHS, but with more substantial grid electricity use, for all lighting and media services, as well as a portion of cooking and heating services.

It can be safely assumed that the net CO_2 emissions from wood combustion are zero (IPCC 1995: 1.85),[9] and so the relevant fuels are paraffin and grid electricity.[10] Although the use of a SHS emits no CO_2 in its operation, over its life cycle it will have positive net emissions due to the use of carbon-intensive energy in the manufacturing process, installation, travel and maintenance activities; however, in the absence of empirical estimates of these emissions, they are assumed to be negligible over the life-time of a SHS. Table 6 contains estimates of the quantity of energy and CO_2 emissions which pertain in each of the above scenarios.

Table 6 CO_2 emissions from paraffin and grid electricity under four household energy mix scenarios

	SHS-wood	Wood-candles-paraffin	Limited grid-wood	Grid-limited wood	References
Quantity of fuel (p.m.) - paraffin: lights - paraffin: other - grid electricity	 0 l 8 l 0 kWh	 6 l 8 l 0 kWh	 0 l 8 l 50 kWh	 0 l 0 l 120 kWh	 (Hofmeyr 1996)
Emission factors - paraffin (kg CO_2/l) - grid electricity (kg CO_2/kWh)	 3.19[11] 1.21[12]	 3.19 1.21	 3.19 1.21	 3.19 1.21	 See footnotes
Annual CO_2 emissions (t) - paraffin: lights - paraffin: other - grid electricity	 0 0.306 0	 0.230 0.306 0	 0 0.306 0.726	 0 0 1.742	
Total annual emissions (tons)	0.306	0.536	1.032	1.742	
Avoided annual emissions (tons)	-	0.230	0.726	1.436	

It is evident from the last row in Table 6 that the CO_2 savings of a SHS by itself, when compared to the *ex ante* scenario in which it substitutes for paraffin, are relatively small at 0.230 tons per household per annum. When compared to a typical scenario in which a household consumes a small amount of grid electricity, however, the GHG savings more than treble. The fourth scenario probably represents the upper limit of possible CO_2 abatement, which is where a household's electricity consumption, if it had a 20 Amp grid connection, would grow steadily to a level of 120 kWh, meaning that it would be satisfying

[9] Where wood is used sustainably, this is correct; even where the biomass stock is being depleted unsustainably, it is simply the case that the carbon content is being liberated somewhat earlier than would naturally have been the case.

[10] No reference has been located in the literature for GHG emissions from candles; these are assumed to be negligible.

[11] Calculated as follows: calorific value of 44.75 TJ/kt, multiplied by emission factor of 19.45 tC/TJ, multiplied by their molecular ratio of CO_2/C which is 44/12 (IPCC 1995: 1.21-1.22).

[12] Calculated as follows: total Eskom CO_2 emissions in 1994 of 142.9 million tons, divided by total units produced from coal power stations of 148 003 GWh, and assuming total transmission losses for rural consumers of 20% (Van Horen 1996a).

considerably more energy services than is technically possible with the average photovoltaic system.[13] In effect, the presence of the SHS in a household, in contrast with a medium-level grid supply would represent a ceiling on the amount of electricity which could be consumed, and therefore would avoid a substantially higher level of GHG emissions.

In attempting to translate the above physical quantities into economic values, a range of estimates can be used. As pointed out earlier, the science of greenhouse economics, although the subject of much attention at present, remains very young and the divergence of estimates is in the scale of several orders of magnitude. Following the low, central and high values drawn from the literature by Van Horen (1996b: 114), of $5, $22 and $44 respectively per ton of carbon, these equate at the current exchange rate of R4.38/$1 (and based on the molecular conversion ratio of 12/44), to values of R5.97, R26.28 and R52.56 per ton of carbon dioxide for the low, central and high cases respectively. Rounding these values to the nearest Rand gives R6, R26 and R52 per ton of CO_2 respectively. Taking the central value and applying it to the calculation of avoided emissions from Table 6, yields the values in Table 7.

Table 7 Value of avoided CO_2 emissions from paraffin and grid electricity under four household energy mix scenarios, for central estimate of CO_2 damage costs

	SHS-wood	Wood-candles-paraffin	Limited grid-wood	Grid-limited wood
Avoided annual emissions (tons)	-	0.230	0.726	1.436
Estimated damage costs per ton of CO_2 (central case)	R26	R26	R26	R26
Avoided damage costs per SHS per annum	-	R5.98	R18.88	R37.34

It is evident from the above that the scale of avoided global environmental costs is modest using currently-available estimates of GHG damages. This conclusion is not surprising, given the relatively small amounts of fossil-fuel energy which are displaced by SHSs, and suggests that SHS may be an expensive mitigation option from a GHG perspective. Experience in Zimbabwe corroborates this conclusion (Drennen et al 1996: 14). Nonetheless, it remains the case that SHSs do have global environmental benefits, which may warrant an amount of incremental government support on these grounds.

4.2 The value of educational benefits from access to television and radio

Another effect of SHS investments which may have positive benefits for households, is the educational effect of increased access to television (and to a lesser extent, radio) services amongst rural households. The extent to which a real incremental benefit will result depends on two factors: firstly, whether households which acquire SHSs also acquire television sets for the first time; and secondly, whether the overall effect of access to television is beneficial in terms of improved education and information transfer.

Quantification of the value of these effects is extremely difficult and lies beyond the scope of this report. Nonetheless, some assertions can be made. Firstly, it is likely that the number of households with televisions will increase. In Hofmeyr's (1996: 30) Transkei study, the main reason why households demanded SHSs was reported to be so that they could gain access to television; in Hochmuth's (1996: 14) Kwazulu-Natal study, television services were ranked

[13] Clearly, this is not comparing 'apples with apples', but this is intentional: different technical supply options will lead to different energy mixes and therefore emissions scenarios.

less highly, although were still an important SHS-relevant demand. Variances in the ranking of demand for television are probably due to variations in the existing levels of television ownership as well as the extent to which these are already powered by car batteries.[2]

Secondly, the social effects of television are both positive and negative. Positive effects have been discussed already and relate to educational, news and similar programmes. Negative effects, however, are less direct but are no less significant, and include changing consumption behaviour due to exposure to advertising, marketing and films (MRC 1995: 85). Although the effects have not been proven, indications are that the incidence of domestic violence, smoking and consumption of alcohol and non-traditional foods increases with television exposure, thus impacting negatively on social welfare. Whether the net effect will be positive or negative is a function primarily of television programming and advertising policies, but it might be reasonably assumed that, on balance, the broadcast content in South Africa would have more benefits than disadvantages, particularly in view of the shift towards more educational programming material.

Finally, the preceding discussion leads to the conclusion that there could be material social benefits resulting from wider access to television in South Africa (over and above the value of households' expressed demand for television). If this is the case, some subsidy might be justified on these grounds, but the present state of knowledge about the subject precludes economic quantification of these benefits.

4.3 The value of removing barriers to SHS market growth

It was suggested in section two that there is valid justification for government to support SHS investment in order to kick-start the industry, provided this support is targeted at overcoming the barriers and impediments which characterise rural markets. Possible measures could include initial training of SHS service providers and technicians, support of rural retail credit facilities and provision of education and information programmes for rural consumers. Clearly, strategies such as these could have a strongly positive effect on the scale of SHS investment, and could build a lasting base of human and technical capital in the long term.

However, quantification of the value of these kinds of strategies, or of the benefits which will accrue from them, is difficult or impossible for present purposes. There is little evidence upon which to base any estimate of the scale of resources which could be well-spent by government, and so for purposes of this report, the issue is highlighted and stressed in qualitative terms. Importantly, non-quantification should not be mis-interpreted to reflect a zero valuation.

5. Summary and conclusions

Of all the possible motivations for a SHS subsidy, only three were underpinned by sound economic rationale, and only one, namely the avoided environmental costs of paraffin and electricity use, could be quantified for purposes of this report. Although the uncertainties inherent in such a quantification exercise must not be overlooked or ignored, the results can nevertheless provide an indication of the expected benefits of SHSs.

5.1 Summary of results

Two sets of environmental costs were expected to be avoided through the use of SHSs: at the local scale, the costs of paraffin poisoning, and globally, the costs of human-induced climate change.

In the case of paraffin poisoning, the central estimate of avoided costs was in the region of R2.40 per month; if this is considered to be an annuity over the lifetime of a SHS, then its net present value can be calculated. Using a real discount rate of 8% and a lifetime of 15 years, this yields an NPV of R247 for the central estimate - of the order of 10% of the cost of a medium-sized SHS. For the low estimate, the NPV is just R49, whereas in the high case, it is much higher at R1 064. The wide range of estimates reflects the fact that these estimates are based on highly aggregated data with considerable inherent uncertainties.

In the case of global climate change, estimates of avoided costs were made for three scenarios (although the values are highly uncertain): where a SHS is compared with a typical unelectrified rural household, the avoided costs are around R5.98 per annum. These avoided costs are R18.88 and R37.34 when compared to scenarios where grid connected households use 50 kWh/month and 120 kWh/month respectively. These amounts translate into NPVs over 15 years (at 8%) of R51, R162 and R320 respectively - modest, but not inconsequential amounts.

Taking the second last scenario (NPV of R162) and aggregating it with the avoided costs of paraffin poisoning (central estimate) of R247, yields a total NPV of R409 in respect of the avoided environmental costs associated with the use of a SHS. This is equivalent to a monthly annuity of R2.73 over 15 years at 8%. If government were to provide an effective subsidy of R409 per SHS installed (under whichever dissemination model(s) are ultimately deployed), the direct costs to the fiscus would be as follows under the three scenarios analysed by Davis (1996):

- *5% penetration of unelectrified rural population by 2011:* for a total of 90 000 systems over this period, the subsidy would total R37 million, peaking at R3.7 million;
- *20% penetration:* the total subsidy would amount to R147 million, peaking at R14.7 million;
- *50% penetration:* in this case, the total subsidy would amount to R368 million, with a maximum annual expenditure of R36.8 million.

Comparison of these amounts, even in the most ambitious scenario, with the present scale of cross-subsidies in the grid electricity system, reveals that the SHS scheme would continue to be swamped by the grid electrification scheme in terms of subsidy levels. With NPVs for each new grid customer of about negative R4 392 (equivalent to R42.76 per month - see section 3.2) the *de facto* annual cross-subsidy for grid connections exceeds the 'justifiable' subsidy for SHS, equivalent to R2.73, by a factor of 16. Competition on this basis is not possible.

5.2 Implications for the structure of the grid electricity and SHS industries

The above analysis serves to emphasise the importance of resolving the institutional and structural policy questions regarding the electricity industry and particularly the position within it of the SHS programme. The financial playing fields are, at present, acutely uneven with severe constraints facing a large-scale SHS programme. The lack of integration between the electricity distributors' grid connection programmes and the SHS industry's efforts represents a fundamental barrier to achieving increasing economies of scale in the SHS sector.

Consequently, a critical policy issue which has to be addressed is the present separation of institutional responsibility for grid electricity investment from SHS investment. This separation will not lead to a least-cost allocation of resources. Under the present structure of the industry, Eskom is able to heavily cross-subsidise its low-level grid consumers, but SHS consumers do not receive an equivalent transfer. As noted earlier, this scale of subsidy cannot be economically motivated, but is driven largely by political and equity concerns. Whilst those goals may be satisfied, the exclusion of the SHS industry means that this may happen at greater cost to society than is necessary.

It was suggested earlier in this report that the mere existence of large subsidies for grid consumers in rural areas does not justify an equivalent or similar subsidy for SHS customers. Nonetheless, failure to rectify the fundamental institutional and financing isolation of the SHS industry from the remainder of the electricity industry, means that an efficient allocation of resources between grid and SHS electrification is most unlikely to materialise.

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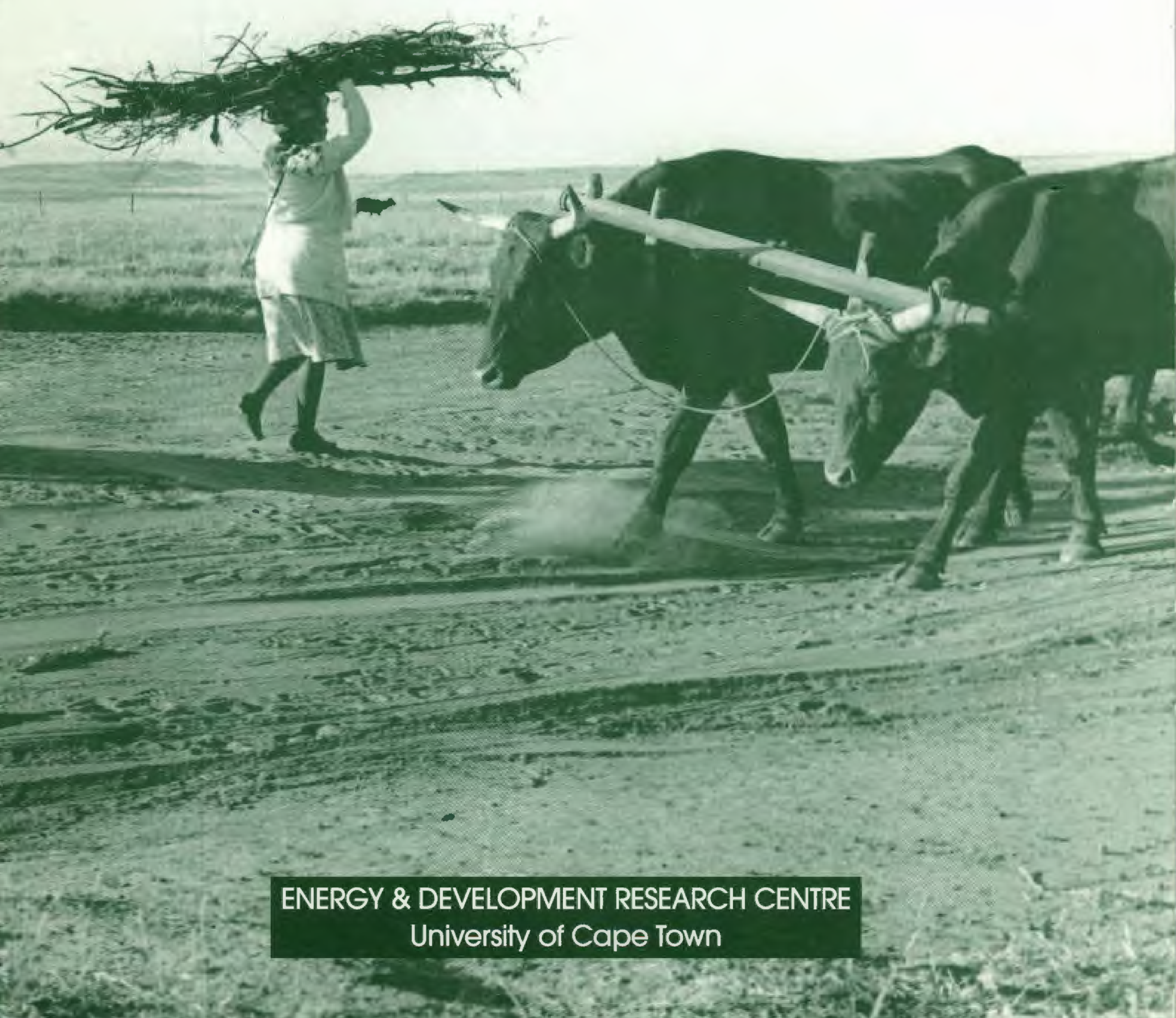

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