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# Calabashes for kilowatt-hours: Rural energy and market failure

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ABSTRACT

This paper describes how management and information failures can retard transitions from the traditional use of biomass fuel by low income rural consumers and micro-producers.

In general, societies move away from traditional biomass use as economic development takes place. If one accepts the doctrine of revealed preference (built on the initial work of Samuelson, 1938), then these trends imply that such transitions provide net gains in utility. This paper shows how various "failures" entrench existing fuel use patterns—hindering the transition to new fuel use patterns.

In order to qualitatively discuss how these transitions may take place, an indicative neo-classical description of consumer and producer behavior is used. Three types fuel-transition "driver" are identified. The effect of information and management failures on these drivers, and thus the energy transition, is discussed.

Reference is made to a specific case study in which a partial transition from biomass occurred in response to an intervention to address an environmental management failure (the deforesting of a carbon sink.)

It is concluded that interventions to encourage transitions to cleaner sustainable fuel use may need to recognize and address management and information failures in a systematic manner.



## 1. Fuel transitions

Services derived from fuel and appliances are often termed as 'useful-energy-services' (see Loulou et al. (2004)) and include for example lighting, cooking, crop-drying, etc. Fuel provides a service when it is used in an appliance (such as a kettle or fireplace) or productive technology (such as a lathe or fridge use to preserve foods for sale). There may be apparent anomalies in fuel and appliance selections. While utility flows from the service, some status goods also provide utility in themselves (the designer samovar or pot-belly stove). Moreover, a wealthy household may use an "inferior" woodburning fireplace or barbeque for heating and cooking. Such options provide "recreational" utility, rather than meeting basic needs.

A fuel transition has been described (Elias and Victor, 2005) as a change from one fuel source to another. In this paper the description is augmented to include changes in fuel use *and*, *or* appliance use, i.e. it is not limited just to fuel switching. Examples of this expanded definition of a fuel transition would include the following:

- No change in the *type* of fuel used for a particular service, but a change in the *way* it is used. (e.g. replacing a traditional fuel-wood stove with a more (thermodynamically) efficient wood-stove. Though the stove is changed, wood is still consumed. However, the transition may result in the consumer using less wood to achieve a similar quantity of cooking service, or the consumer using similar quantities of wood, but achieving more of the cooking service.)
- The consumption of a new energy service. An example includes the purchase and use of a battery powered radio for the first time. A new fuel is used, a new appliance owned and a new energy service consumed.
- The substitution of one fuel and appliance for another, e.g. heating water in an electric kettle, rather than in a pot on the stove. The same outcome is attained, but different appliance and fuel used.

Often only fuel switching is considered in the literature, but to do so clearly excludes other important aspects of fuel use.

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Fuel transitions are an integral part of socio-economic development as well as development's impact on the environment. In poor rural areas, households can spend several hours collecting fuel-wood daily—often the unenviable chore of women and children. Over a million people die annually due to indoor smoke (WEC/FAO, 1999) associated with poorly ventilated biomass use. To this one can add the greenhouse gas implications of destroying forests, which act as carbon sinks. Amongst other causes, deforestation takes place from over-harvesting fuel-wood (WRI, 2000; SADID/DWAF, 2002; Scholes and van der Merwe, 2000). Without energy, industrial or commercial activity cannot take place and income generation limited. Without access to, and the transition to, affordable forms of clean appropriate energy, many of the world's poor are 'locked into' livelihoods, which are often unnecessarily environmentally damaging, unhealthy and uneconomic. Producers may be unable to increase their competitiveness, and economic development may be obstructed.

Conversely, after economic development, households and economies generally move away from freely harvested biomass to cleaner[1] and more productive energy sources (Victor and Victor, 2002). We will assume that consumers and producers wish to use more convenient, cleaner, and less costly and more productive forms of energy. Certainly this is the trend of history (Nakicenovic et al., 1998). This is not to say, for example, that households will not in the future derive utility from fuelwood, or that multiple fuel use will not continue, given a choice. However, it is assumed that for the *bulk* of basic needs the household desires to move from one end of the so-called energy ladder[2] (Eberhard and van Horen, 1995) towards the other. (If one accepts the doctrine of revealed preference (built on the initial work of Samuelson, 1938), then these trends imply that such transitions provide net gains in utility.)

It should also be noted that many earlier transitions were "driven" by circumstances of technological development. (For example, the development of, and access to, steam engines drove up the consumption of coal for motive power during the industrial revolution in several now developed countries. Before the steam engine, that transition was not possible.) However, this discussion generally focuses on factors other than technology development. It rather considers transitions in a setting where technologies and their associated fuels exist, but their uptake – for other reasons (such as limited access, etc.) – is hampered.

Moving to a taxonomy to discuss the dynamics of fuel transitions, it is convenient to use the terms "primary", "circumstantial" and "informational" to classify the drivers of fuel transition.

## 2. The primary driver of energy transitions

Neo-classical economics typically describes consumers/households and producers/firms as "maximizers", either of utility or of profits. Over time changes in energy sources and energy using technologies provide utility in differing degrees and at different costs to the consumer. Maximizing utility therefore creates a "desire" for transitions, albeit subject to a household budget constraint. Utility maximization is taken as the 'primary driver'.

The neo-classical system uses perfect competition as a benchmark. This is a system in which there is full and symmetrical information, a single homogeneous product, no market power and frictionless exchange, while both production and consumption are free of externalities. Since these properties are hardly characteristic of the real world, markets do not always work 'as they should'. Collectively, evidences of such instances are called 'market failures' or market "distortions". This paper refers to information and governance failure as such a cause of observed market failure. It does not argue that a market simply "fails".

### 2.1. Energy and utility in production

In the neo-classical description, the *producer* in a cash or barter market will favor fuel-technology options that minimize costs and/or provide new services from which profit can be derived. For example if boiling water is required to make tea in an eating house, the choice between a cooking pot on an open fire or an electric kettle depends only on which of the two can be operated most cheaply (in terms of both money and time). If the eating house owner wants to serve cold beverages, biomass burning technologies are no longer relevant. In this case the purchase of a fridge is not related to cost minimization as much as it is to do with the profitability that could be derived from the new service. Then the choice rests between paraffin, gas or electric refrigerators. All are commercial products so if the services are equivalent the decision is made on the basis of simple monetary cost efficiency alone.

### 2.2. Energy and utility in consumption

Many of the considerations that inform producer choices also inform household fuel choices[3] consumption. Cost again is an important consideration, with relative cost determining the choice between two fuel–appliance combinations otherwise perceived[4] to be identical by consumer. Unlike firms, where only profit maximization is assumed to matter in adopting a new technology, a consumer can derive satisfaction from mere ownership; one may value the status of an electrical fridge even if other cheaper options exist (a fuller analysis of such issues was developed by Liebenstein (1950)). Such "utility" is difficult to measure. It is assumed here, however, that cleaner more convenient energy and appliances that provide new services (associated often with the richer or developed country user) are probably desired.

## 3. Circumstantial 'drivers'

Consumers (and producers) attempt to maximize their utility (or profitability) subject to constraints. As these constraints change, so may their purchases of energy consuming appliances, and their energy usage patterns. Constraints or changes in constraints due to interventions that affect the fuel transition are termed '*circumstantial drivers*'. As these are often constraints

[1] While few fuels are more hazardous to health than "traditional" biomass (see Eberhard and van Horen, 1995), it should be noted that during much industrialization, energy-use was not 'clean'. (Consider for example deadly smog events in London during the early 20th century—fueled in part by "commercial" coal.)

[2] The term energy ladder is often used to describe the generally observed trend of households moving from the use of biomass and candles, to kerosene, to electricity and gas, when meeting basic heating and lighting needs.

[3] In this discussion, entire households are considered as 'consumers'. This note does not attempt to dissect the role of agents within households, though aware that therein lies critical and oft overlooked issues relating to the role of gender. Given that much biomass collection in poor rural areas is undertaken by women, transitions to cleaner, less labor-intensive energy use could play an important part in enhancing their welfare (UNDP, 2001).

[4] Note that perception is important. An otherwise identical good can be perceived to be of higher quality if its price is higher (Shiffman and Kanuk, 1997), or to impart higher status if others cannot afford it. Hence, cost competition between rival services or goods is most important when the goods are perceived as otherwise close to equal.

they may be also be viewed as the converse—as factors hindering the transition process. These can include income, access to appropriate energy, access to undervalued biomass, access to markets and the respective market form, government intervention, climate and custom.[5]

Income plays a clearly observed role in fuel–appliance purchase and use (or energy transition) (Victor and Victor, 2002) and is the first circumstantial driver identified. As incomes increase budgetary constraints relax and demands for new goods and services, including non-agrarian products, increase. The appeal of new appliances and new production technologies induces energy transitions.

Clearly energy and economic transitions are restricted by poor access to appropriate energy. Without improved access to appropriate energy, desired new technology–appliance combinations remain unattainable. For producers this limits potential production activities regardless of the demands for their products. For the consumer, the welfare gains to be had with new energy forms including savings in time may not be realized. The second circumstantial driver is therefore access to appropriate energy (as well as the corresponding appliances and technologies.) A third – and related – circumstantial driver is the extent of access to undervalued biomass. Such access is a feature of commercially unexploited[6] communal land. There are examples, locally and internationally, of well-governed land uses that include community woodlots, and regulated commercial fuelwood cultivation (Williams et al., 1996). However, communal land that is not actively farmed can provide biomass that is freely harvested and effectively under-priced. Note that much deforestation – and with that access to free fuelwood – is the result of agricultural expansion as land becomes used for commercial crop growing (Hyde and Seve, 1993; Allen and Douglas, 1985). Ironically there are also instances where access to free biomass leads to a temporary dependence on it until it runs out[7] through over-harvesting. A fuel transition is then forced. (Examples of the over-harvesting of fuel-wood are included in Hosier and Bernstein (1992), Bluffstone (1998) and Williams et al. (1996), amongst others.)

Barter economies are common market forms in many parts of Africa (OECD, 2004). While barter secures production and consumption opportunities, it also limits choice (Marin et al., 2000). Barter-based markets are likely to limit the penetration of new energy forms, appliances and technologies. Successful barter requires a dual coincidence of wants; consequently many of the goods and services involved in an energy transition have to be purchased from suppliers outside the immediate area using cash. This slows the energy transition. The fourth circumstantial driver identified here is therefore monetized trade – the absence or decline of barter.

Often, institutional intervention can affect fuel usage, ranging from communal banning of dangerous fuels such as kerosene (Mehlwana and Qase, 1999) to subsidized electrification programs (Gaunt, 2002) to international protocols (UNFCCC, 2008), which affect the use of GHG intensive fuel use. This is the *fifth circumstantial driver*: active (rather than inactive) institutional intervention. It should be noted that this can in particular be an important trigger of a transition. Following the construction of a road, for example, an enormous array of otherwise "locked out" activities are possible. All of which will drive energy demands. Similar observations are made with electrification programs. Thus, while conveniently conceptualized in our framework as a "circumstantial driver", we note that active institutional intervention can be disproportionately effective. And, as it is under the control of the policy maker – unlike, for example, the weather – its judicious application is most important.

The *sixth* driver, location and climate affect, demands for the useful energy service of heating and cooling, as can, the *seventh*, household size, in both persons and space. (See Afrane-Okese, 1998, the ESKOM National Load Research Program (Dekenah, 2002) and Louw et al. (2006) for a detailed regression analysis of how these factors affect historical consumption of electricity, as well as by Mehlwana and Qase (1999).

Finally the *eighth* driver in this superficial discussion, cultural custom and norms: these potentially affect the manner in which services, and the manner in which the services themselves are required. (Consider different cooking requirements for different foodstuffs as an example. Appliance and fuel choices in cooking are discussed in Prasad and Visagie (2006) who investigate the cooking of maize in South Africa, and by Berrueta et al. (2008) for cooking Mexican tortillas.)

To summarize, the following *circumstantial* drivers have been mentioned: (1) income and affordability; (2) access to energy-appliance (or production technology) options; (3) management of communal land and access to it; (4) the extent to which the local economy is monetized; (5) institutional and policy intervention; (6) location and climate, (7) dwelling size and (8) cultural norms.

The circumstantial drivers have been discussed in terms of their direct effect on the purchaser of energy and appliances; however, these drivers also have important secondary effects. These are particularly important where they affect income generation.[8] When a micro producer increases output – and increases his associated fuel-technology and labor inputs – the laborer's wage increases may in turn purchase the household new appliances, etc.

[5] Though not the focus of this paper, an important circumstantial driver can be change in the development (and subsequent availability) of technology, such as the cited example of the steam-engine and the industrial revolution.

[6] Note that there may be and often are reasons that make land unattractive for many kinds of production, though it is fertile and arable. These can include the following: missing or no access to markets, restrictive trade policies, barter economics, etc. It is an interesting thought that restrictive trade policies such as international import protection and farmer subsidies in some markets could in fact be halting the transitions of many to more healthy forms of energy use. That said, unless the fuel users benefit economically from the commercial exploitation of the land, new fuels may be unaffordable and a situation of fuel poverty can result. A transition from biomass may occur, but may be less than beneficial.

[7] While those who save whales see utility in having them around, which transcends their market price, if no such relative utility is seen in a communal wooded countryside – perhaps dwarfed by desperate circumstance, poverty and poor governance (Garrett, 1968) – its over-consumption in that circumstance can simply be tragic, but quite rational.

[8] Ruttan (2004) argues that an energy transition can be both the cause and effect of economic growth. In the case of producers, electricity and the new technology options that it brings can help increase profitability and growth (Nyabeze, 2001; Prasad and Visagie, 2005; Vaughan and Xaba, 1996). Producers move to a new 'production frontier'. Meadows et al. (2003) quote a significant number of such instances where this has occurred. In the case of consumers, as incomes increase, modern appliances and fuels become more affordable (Victor and Victor, 2002). Increased electricity consumption is the effect of economic growth. While a potential energy transition may be the cause of economic growth in our framework, it requires the correct conditions to do so. The afore-discussed causes of market failures may slow or halt producer profit that may be gained by access to new fuels and appliances/technologies. Further, electrification may lead to improvements in various human development indicators (HDIs) such as literacy (Kanagawa and Nakata, 2005a,b), which in turn (over longer periods) affects human capital and its profitability. It is therefore suggested that both increasing the use of appropriate energy services and reducing market failure are causal factors of economic growth. Reducing market failure and increasing income are causal factors for energy transitions.

**Table 1**
Summary of failure causes and effects.

| *Failure types* | *Instances* | *Driver* | *Implication* | *Selected notes* |
|---|---|---|---|---|
| Poor consumer information | Consumers unaware of the long term health effects of biomass smoke | Informational | Deflates the full cost of biomass, as full health costs are not internalized | In a study of a Kwa-Zulu Natal rural community in South Africa local residents were asked about health effects associated with fuel-wood burning. Over three quarters reported knowledge of short term effects such as coughing and sore eyes, but none cited any knowledge of long term effects (Lloyd et al., 2004b) |
| | Consumers exaggerate dangers associated with new fuels, such as LPG | Informational | Until use is common, this causes an (irrational) 'aversion' to new fuels | This is not to say that new fuels (LPG, electricity, etc.) are not without risk. However, relative to the risks associated with traditional biomass, they are often significantly lower (Lloyd and Rukato, 2001) |
| Poor supplier information | Suppliers unaware of consumer needs, such as 'stove design' requirements for customary food | Informational | Reduces the potential 'utility' that would otherwise be gained with the use of the new fuel–appliance combination relative to traditional use | The introduction of solar cookers in Africa, though apparently rational due to savings in time budgets, did not result in the expected transition from biomass. It is reported that this was primarily due to the poor "supplier information". Various local customs, including amongst other things, demands for night-time cooking were simply not accounted for (Eberhard, 1993) |
| | Inappropriate project management, including poor knowledge management and poor choice of key performance indicators. (This is often associated with 'supply driven' interventions, such as off-grid electrification.) | Informational | Inappropriate behavior is rewarded. The emphasis is often on 'aspects of delivery' that do not necessarily relate to the sustained *use* of the new fuel. The user is often eventually left with unreliable energy | In South Africa early rural off-grid electrification programs failed, as the key performance indicator was the number of schools provided with PV systems. Surveys months later showed that many of the systems no longer worked – as proper service delivery was not a key performance indicator of the program. Currently the revised off-grid electrification program includes mandatory servicing of PV panels. Similar studies relate poor unreliable grid based electricity supply (Mehlwana and Qase, 1999) to customers 'back switching' to old fuel usage – though reliable electricity, were it available, was preferred |
| Poor government information | Inappropriate pro-poor fuel interventions | Informational | Eligible alternatives to traditional biomass may be under- or inappropriately subsidized. | In South Africa government developed a subsidy to supply a quantum of free basic electricity, for social and health reasons (Gaunt, 2002, 2003. This was intended to encourage consumers to move from traditional fuels including biomass, as well as relatively hazardous fuels such as coal and kerosene. It was shown that a market friendly alternative could provide consumers (for cooking needs) with several times more utility at the same cost by allowing consumers the option of alternatives such as LPG (Howells et al., 2005). Inappropriate subsidies and interventions such as this will result alternatives to biomass effectively being 'under-subsided' limiting their penetration |
| Management: Government intervention | Under-investment in transport infrastructure, providing access to markets | Circumstantial | Limited access to markets dampens local potential producer profit to be made from productivity increases with new fuel–technology combinations. This retards demand for new technology–energy combinations | Note also that a host of potential activities are simply "locked out" without such infrastructure |
| Management: Land mismanagement | Poor 'communal management' preventing any organized agriculture | Circumstantial | Land and therefore the fuel-wood (only in instances where it is in competition with the cash growing crop to be harvested) may be undervalued. | In many rural developing county instances, land is communally owned or at least communally available. Such land is often poorly managed (Gander, 1994). Where wood harvesting on such lands could be profitably replaced by other activities fuel-wood is effectively undervalued. Although land conversion may mean deforestation, increased agricultural production may increase the potential biomass (as crop residues) available for fuel. However as this is likely to correspond to a change from traditional biomass fuel use to a commercial crop residue, using our broad definition an energy transition would occur. Where arable land is effectively not organized it will hinder organized agriculture and associated transitions |
| | No local ecological accounting especially where deforestation is a risk of over-harvesting | Circumstantial | Undervaluing of biomass-harvesting – where harvesting leads to (sometimes irreparable) ecological damage | Due to poor management, land is often degraded by the fuel-wood demands of growing rural and peri-urban settlements (Eberhard, 1992). In Botswana desired species of biomass were over-harvested, though other undesirable species remained. In India |

Table 1 (*continued* )

| *Failure types* | *Instances* | *Driver* | *Implication* | *Selected notes* |
|---|---|---|---|---|
| | | | | it was noted, as well as many other areas, local ecological damage is not 'included' in the cost of biomass harvesting (Dasgupta, 1996). This failure results in the under-pricing of biomass – and price difference to alternatives higher. |
| Management: Barter economics | Prevents potentially efficient alternatives, that may not easily traded, replacing local production norms | Circumstantial | Entrenches the fuel-use (and production possibilities) status quo | Many of Africa's Least Developed Country's rural communities are part of barter economies (OECD, 2004). In several examples, it has been observed that these conditions tend to retard the consumption of electricity post electrification (Ranganathan, 1992). Such economies have been noted to limit the penetration of any new goods or services (Marin et al., 2000) – including commercial energy and new technology, therefore limiting shifts to new economic 'frontiers of production'. Further, if economic growth is hampered, so too is commercial energy consumption required for new equipment, and any further consumption of energy associated with increasing local income |
| Management: No accounting for climate change related carbon costs | Destruction of carbon sinks due to over-harvesting[a] of fuel-wood where deforestation is a risk of over-harvesting | Circumstantial | Undervaluing of unsustainably harvested biomass | Apart from local ecological damage, global damage occurs with the unsustainable over-harvesting of biomass. (Clearly this is not to say that all fuel wood harvesting is "wrong", used sustainably it is both an important renewable fuel and the growing biomass an important sink. Nor is this to say that deforestation is the result of only biomass harvesting.) However, when net biomass is depleted from fuel wood harvesting, so is an important 'sink' for the greenhouse gas Carbon Dioxide (IPCC, 2001). Damage costs for the reduction of these sinks are not accounted for in developing, non-Annex 1, countries. Their non-inclusion will again result in the under-pricing of unsustainably harvested biomass unless policy tools such as the CDM are effective |
| Management: Non-inclusion of external health costs in prices | Third parties pay for the effects of biomass usage | Primary | Biomass usage, which is often associated with high levels of indoor air pollution, is under-costed | |
| Management: Monopoly power of fuel–appliance suppliers | Available appliances are over-priced and new entrants disadvantaged | Primary | Biomass may remain the significantly lower cost option, while competition may have reduced the cost of alternatives | |
| Poor knowledge on the part of micro-producers | Producers unaware of potential profit gains to be made with new fuel/appliance combination. | Informational | Suppresses profitable gains associated with a transition | In Kenya, Kabecha (1999) reports various gaps in entrepreneurial (producer) knowledge that limit gains made by the introduction of modern energy and related technologies – even where opportunities for profitable enterprise were apparently available |
| Management: Lack of financial services | Inability of micro-producers to finance high capital purchases | Circumstantial | Suppresses the purchase of expensive productive technologies with associated transitions (Thillairajah, 1994) | Meadows et al. (2003) cites lack of functioning credit markets and banking facilities, as a critical barrier to the adoption of any relatively 'capital intensive' new technology. It is in this context that micro-finance has found itself a powerful niche as a development enabler. In Zimbabwe (prior to its recent economic collapse), in an effort to address this formally, the national electrification program was faced with the prospect of low sales and pressure to increase grid connections. In an effort to address several common market failures, the utility deliberately targeted entrepreneurs. It is hoped that their access to markets and business knowledge would make them higher volume consumers. Further, attempts to provide "appropriate" technologies as well as low interest financing having been made available (Mpako, 2005) |
| Management: Failure of labor markets to clear | Increased un- and under-employment in local communities | Primary | Suppresses potential economic activities with associated demand for new services requiring new commercial fuels | |

[a] We note however that in some instances increased use of biomass would in fact be preferable from a carbon balance point of view – where it is not over-harvested *(our point of concern)* this is certainly the case. Where increasing the sustainable consumption of biomass is an economic GHG mitigation option, it is likely this will not be consumed 'traditionally', i.e. without ventilation and at low efficiencies.

## 4. Informational drivers

Information can change consumer's attitudes, customs and aspirations (Shiffman and Kanuk, 1997). If information affects the utility associated with fuel/appliance usage, then it will influence consumer demand. In reality consumers and producers rarely have access to full information. In consequence they often use "rules of thumb" and heuristics to aid decision-making. The consequence is "bounded rationality"; the information at hand 'bounding' the behavior of the otherwise "rational agent" (Simon, 1982; Lazonick, 1993). Even when information is available, time may be needed for it to be assimilated and acted on, the period required depending on a number of factors including societal adoption rates and the prevalence of "early movers" (Shiffman and Kanuk, 1997). Less than full information, however, can result in distorted markets and some examples are summarized in Table 1.

## 5. Market failures and drivers

In the preceding section "drivers" of energy transitions were described: primary, circumstantial and informational. In the next section a limited selection of cursory examples are summarized in a table. They illustrate how various types of management and information failure affect the transition driver and thus the transition. Consider, for example, a policy based on incomplete information: a management (governance/informational) failure, the resulting intervention (a circumstantial driver) pushes the energy use pattern in a non-optimal manner and distorts the energy user's choice. The failures described here generally fall into either information or management failures. Included under the broad term "management" we consider not only broad general policy, but also the organization of communities, markets and labor. While not exclusively the case, many such failures can entrench traditional biomass usage patterns—and some of those are cited.

For the policy maker – who may be able to address some of those failures – a difficult question now arises. Is the net benefit associated with addressing the failure in question worth the cost and effort? The policy maker – as well as the new fuel or equipment supplier – should take special care to identify existing failures, potential post-intervention failures, the costs and benefits to be had by addressing these, and carefully plan their interventions.

Next, a short case study is examined. A rural village in South Africa is the target of an intervention designed to correct market failure and promote a shift from the overuse of biomass. The state of the rural community before and after the intervention is discussed. There is a qualitative attempt to interpret some changes in energy use patterns in terms of governance and information failure on the part of consumer and fuel–appliance suppliers.

## 6. A short case study: Nkweletsheni

Households in the community of Nkweletsheni were harvesting biomass at an unsustainable rate. More fuelwood was harvested than regrown as it was free to harvest. Effectively households were reducing the net quantity of biomass and a carbon sink – and the global environmental damages not included in the transactions. With external funding an intervention was made to correct this failure. There were other market-related-failures which may have affected the consumption of fuels both pre- and post-intervention. In both cases these failures would have the effect of encouraging the use of biomass (if the villages intended to move away from this source), but it is difficult to quantify the relative extents of this "encouragement".

## 7. Methodology

The Nkweletsheni community in Kwa-Zulu Natal, South Africa, is typical of some developing country rural communities in several ways. Preliminary studies (Howells et al., 2005) showed that there were several market-related failures identified in the village that would affect a transition from traditional fuel use. These included the observed reduction in available biomass—with no associated penalty. It was being over-harvested for use as fuelwood – and a carbon sink was being reduced with the cost of this loss not being included in the cost of biomass harvesting. An attempt was made to correct this by the introducing subsidized LP Gas. PV solar home systems were included in the intervention to provide households with electricity. Following the intervention, initially promising uptake of new cleaner fuels, consumption levels continued, but dropped, resulting in a 'partial' fuel transition. On investigation it appears that new and uncorrected failures were identified and these would act to suppress the demand for new fuels from wood – were such a transition desirable to the consumer.

This case study was deliberately chosen as data, though only few could be interrogated. Data were collected by four methods. An initial survey[9] with detailed results was designed (Lloyd et al., 2002a) and reported by Lloyd et al. (2004a). A second survey and analysis was (Howells and Dick, 2003) conducted post the intervention and this was later followed by a series of interviews to ascertain the effectiveness of the intervention (Jonsson and Käck 2005). Finally sales and the organization of the implementing company were analyzed (Jonsson and Käck, 2005).

## 8. Nkeweletsheni pre-intervention

The initial survey of domestic energy use in the community took place during 2002. About 150 households were surveyed. According to Lloyd et al. (2004b), the community has a low housing density, below the 50 households per km$^2$ measure used by Eskom and the DME as the limit for future electrification. Houses were modest, with a median number of 3 rooms, and built of either clay or cement blocks, and generally thatched although some had corrugated iron roofs. Fig. 1 shows such a picture. Many in the community are employed, but it was relatively unskilled employment, with a median income of about Rs. 660/month/household.

## 9. Household response immediately after the intervention

Households adopted the PV and LPG systems and following the intervention a random sample of twenty-two households with the systems were surveyed.[10] The sample size represented over 30% of the 71 installations that were in place at that

[9] This survey incorporated novel aspects in order for the data to be used in detailed economic modeling.

[10] While at the time this sample was thought to be random, there was a key independent variable that was not accounted for. This was accessibility. The team carrying out the questionnaire interviewed households that could be reached by road. Later trends relating LPG consumption to accessibility were revealed (Jonsson and Käck, 2005). This means that the extrapolation of this 'random' survey may have led to overstating the benefits associated with LPG, as it was not associated with negative distribution problems.


**Fig. 1.** Nkweletsheni.

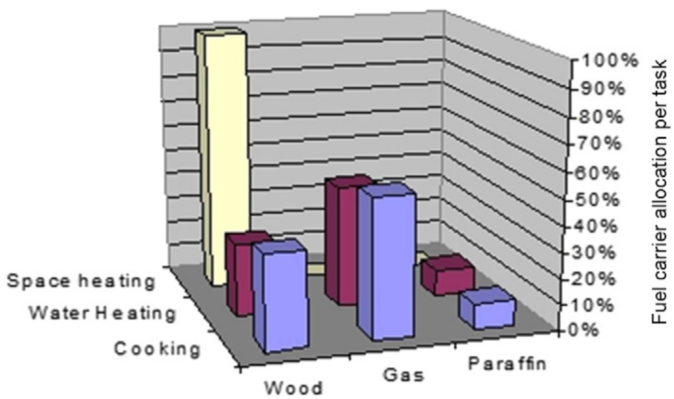


**Fig. 2.** Fuels used per activity post-intervention (Howells and Dick, 2003).

time. 90 installations were eventually installed under the program.

There were advantages and disadvantages associated with conducting the second survey relatively soon after the intervention. A disadvantage was that people's behavior may still have been affected by things such as the novelty value of their new systems, and therefore their responses were not representative of their long term usage patterns. On the other hand, an advantage was that effects of the recent displacement of old fuel and usage patterns were easily recalled. For example households were still aware of how many hours they used to spend collecting wood and how this had changed since they started using LPG.[11]

The results of the survey were striking, and we focus on the effects of LPG[12] uptake. All of the households questioned were using LPG, and less wood, for cooking and water heating in particular, as reported in Fig. 2. Less efficient (and more polluting) paraffin was also displaced.

It was estimated that if all 90 households were to partially displace wood collection at the rate observed during this survey, for 16 years between 1.0 and 1.7 thousand tons of $CO_{2equivalent}$ would be mitigated (Howells and Dick, 2003). Further, were this project to be replicated, this would be at a cost of between 7$ and 12$ per ton.[13] This is well within the estimated externality cost range associated with $CO_2$ emissions (Blignaut and King, 2002), and market prices of emissions bought through the CDM. Further estimates of health cost savings (supposing the treatment was sought and paid[14] for) were significant.[15] Much of these costs would simply be borne in terms of poor health by household members – under "normal" circumstances.

## 10. Household response months after the intervention

Implementation took place over the period November 2002–November 2003, and the maintenance of the PV systems as well as LPG supply was ongoing. The transition from fuel-wood use to increased LPG usage is of interest. In particular for households who paid[16] their monthly contribution for the energy package and their LPG collection habits.[17]

Fig. 3 gives the percentage of eligible households who did not collect their LPG refills. The figure clearly shows a significant increase in the non-collection of LPG. After conducting several interviews with the Switch On team and with a limited number of consumers (Jonsson and Käck (2005)) the following reasons were given for increased non-collection (both instances of market-related-failure, however this time due to poor incentive structures within the Switch On business and poor understanding of the

[11] This data was used to confirm the baseline initially estimated.

[12] We note however that the uptake of the PV systems was a clear example of an energy transition according to the definition adopted earlier. Unlike the LPG contracts, the Switch on Team were obliged (at no extra cost) to provide maintenance on the PV systems once they had been put in place – and this should be limited at the start of the program, as the systems were new. Further, once in place there were obviously no effort or costs associated with delivering their fuel. Both factors distinguish the PV from the LPG systems, and in part, account for its success.

[13] Much of the initial cost involved scoping, international project promotion and initial research. Were all costs to be included, the total cost of $CO_2$ mitigated would be between $65 and $111 per ton. Further, in Howells and Dick (2003) emphasis was placed on the fact that these estimates were based on survey rather than scientifically monitored data.

[14] These costs could be borne either by government through rural clinics or by households directly.

[15] Howells and Dick (2003) estimate a saving of over $500 per household per annum. This is based on reduction of indoor air emissions as a result of increased LPG to wood-fuel burning. 'Low-end' externality costs relate tons of emissions to treatment costs. These cost data were based on project data estimating indoor air emissions, The Royal Society (1995), Sarkar and Wolter (1998), Van Horen, 1996 and others.

[16] Due to the sporadic income of many in the case study at some stage or another most have been in debt to the Switch On business. This observation implies that methods such as flexible "micro-finance" may play an important role in this context.

[17] Note that variation in heating degree days was not factored into the planned deliveries. This may be a useful future exercise that should be done with care. In this instance, LPG is used predominantly for heating water or cooking, when heat is not required at the same time (Howells et al., 2005). In that instance, it is likely that LPG may be more demanded in Summer. In winter wood is used to supply both space heating as well as water and cooking heat.

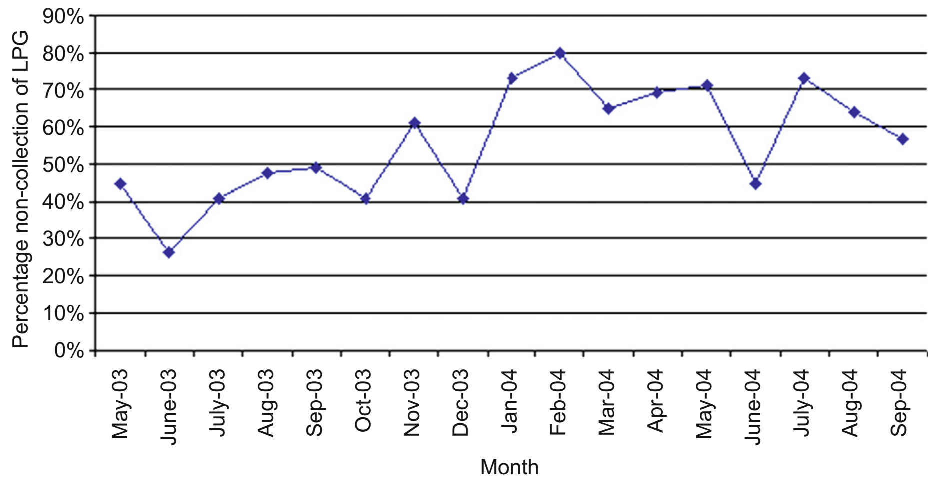


**Fig. 3.** LPG 'non-collection' for eligible households (Jonsson and Käck, 2005).

consumers needs):

- The Switch-On team limited the number of LPG deliveries, as this extra effort (and cost) was not rewarded, neither was this a key performance indicator (KPI). This represented a failure in the incentive structure of the Switch On business. At the onset of the project, LPG deliveries were carried out during the maintenance cycle for the PV systems.
- Many of the LPG appliances provided were inappropriate. These were essentially small stoves that were not suitable for large pots used for long cooking periods. In this case, customary food is a maize-based starch dish, which is typically cooked for long periods in heavy pots which damaged the stoves (Households on average reported cooking over several hours per day.) This represented a failure in terms of the knowledge of the needs of local consumers.

## 11. Some considerations

Were there utility to be gained by transitioning from biomass, the informational market failures reported would likely have resulted in increased dependence on biomass. "Pre-intervention" these failures included: (the non-accounting for) the reduction of a carbon sink, poor consumer information of the long term health hazards of biomass smoke, poor land management, and exaggerated fears of the dangers of LPG. When measures were put in place to reduce non-accounting for the carbon sink, a partial transition to a 'cleaner' energy package (LPG and PV) was observed. One of the changes associated with this transition tackled by the implementers was improving consumer knowledge of the relative safety of LPG.

Many of the reasons limiting a more complete transition to LPG might be attributed to some extent to yet other "failures". These include: poor knowledge of local needs, manifest in the provision of inappropriate appliances, as well as poor KPI selection and incentive schemes set up in the Switch On business.

It is difficult to attribute the relative importance of the specific market failure and their effect on the fuel transition – assuming that a transition from biomass as the only significant heat providing fuel would increase utility. However, there was market failure reduction and there was a partial fuel transition away from biomass to LPG.

## 12. Conclusions

In this paper an energy transition is defined and three drivers are identified. The primary (and independent) driver for energy transitions is the increase in utility that the new appliance or service brings. Other drivers relate to the circumstance and information that the energy users have at hand. Various failures and their role in energy transitions were discussed. These relate to imperfect information, poor land management, barter economics, erosion of the global commons, externalities, the abuse of monopoly power and others. In all cases chosen, there is a propensity for these market failures to suppress the uptake of new fuels–appliance use and encourage traditional biomass usage – where we to assume that there is greater utility to be had from moving to so-called modern fuels. (The trend of moving away from traditional biomass use is common to most now modern economies.)

The result of these failures would tend to retard both the potential economic growth effect to be gained by and uptake of new fuels – especially where gains are to be obtained by new technology in the case of the producer.

Were transitions to new fuel use patterns to be hastened this work implies conditions under which energy transitions may be more likely to take place. A case study examined some of these elements and shows that the design and implementation of an intervention are critical for its success. This particular case study and its finding were presented in its entirety for the first time in this paper and it illustrates an instance where correcting for market failure encouraged a transition away from biomass. The market failure in question related to climate damage. However, the full effect of this transition is probably not realized due to poor supplier information and certain institutional arrangements associated with the implementation of the corrective intervention.

Increased economic growth, improved market efficiency and removal of market failure are axiomatic.[18] Studies show a relationship between growth and the fuel transition away from traditional use of biomass. However, it is not clear how much of this transition could be due to reduced market-related-failure and how much due to increased efficiency of markets. In this paper it

[18] Removing market failure results in a more efficient economy. In the context of a growing economy, this means it will grow faster.

has been indicated that the casual effects may be associated with the efficiency of the market, and certain types of market failure.

## 13. Recommendations

Much of what is cited is location and situation specific. It is therefore risky to generalize, moving away from inferring that a relationship is likely. A detailed inventory of case studies, and drivers should be examined in the context of transitions and market failure. Where possible, it would also be useful to try and quantify 'changes in utility' during transitions: An easier task to undertake for micro-producers than consumers, perhaps.

Efforts should focus on the following, amongst others things:

- Careful study of the needs of energy users, and the economics of their energy use.
- Systematic study of the role of institutions and energy transitions.
- Market situation of producers before and after electrification, testing for market failure and developing (and if possible quantifying) a database of 'success factors'.
- Changes in energy consumption during transitions to more monetised economies.
- The effects of more economically efficient subsidies versus less sensible subsidies with the same aim.

Further a weakness in the study is the estimation of "un-sustainability" of biomass harvesting where perhaps changes in lifestyle or population growth or other reasons have accelerated this trend. This warrants further study into appropriate methods and estimates of data accuracy.

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