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AN OPTIMAL ENERGY AND GREENHOUSE GAS MITIGATION PATH FOR SOUTH AFRICA IN THE SHORT TO MEDIUM TERM

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ABSTRACT

Following a description of the South African energy system, this paper discusses the results using the national Integrated Energy Planning (IEP) model and discusses why better management of existing energy resources provides and economic option for the country. Not only does this result in a more economic system and reduced energy demand, but also has the effect of reducing carbon dioxide emissions. The paper goes on to reference local case studies, carried out by the Energy Research Institute , with local industry, which clearly illustrate the potential benefits of energy management on a micro level.

INTRODUCTION

It is commonly considered the case that forcing an economy to reduce emissions levels to below current 'baseline' levels will increase system costs. This is an underlying principal to economic equilibrium modelling. It has, however, been argued by some that economies can still be optimised, to 'new production frontiers'. This is illustrated graphically in figure 1.

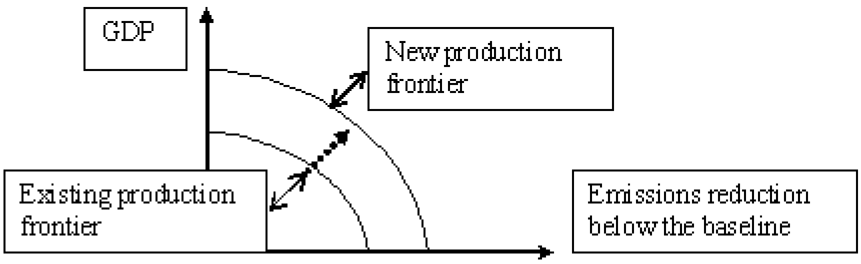


Figure 1: Production frontiers, Laitner 2002 [1]

It is the thesis of this paper that greenhouse gas emissions from the energy sector can be reduced at a profit to the South African economy. Further, it is argued that this can be done while maintaining its heavy reliance on coal.

THE SOUTH AFRICAN ENERGY SECTOR AT A GLANCE

The South African economy is energy intensive, using a large amount of energy for every Rand of value added. South African energy is dominated by coal, which contributes 70% of primary energy, the economy is therefore also carbon dioxide intensive. It is cheap and this results in low energy costs, particularly for electricity, which is the cheapest in the world. South Africa has little oil most of her crude is imported. She obtains useful amounts of energy from biomass and nuclear power, with smaller amounts from hydropower, natural gas, solar and wind. Much of the primary energy is transformed into final energy, such as electricity and liquid fuels. South Africa's final energy demand in 2000 was 3054 PJ (including marine bunkers and non-energy fuel use), consisting of electricity (20%), coal (32%), liquid fuels (31%), biomass (13%), crude oil (1.7%), other fuels (2%), and with natural gas and renewables less than 1%.

The following figure illustrates the energy flows through the South African energy-economy, from supply to the end use of energy. The system of energy flows and processes have been mathematically described with the aid of computer based models.

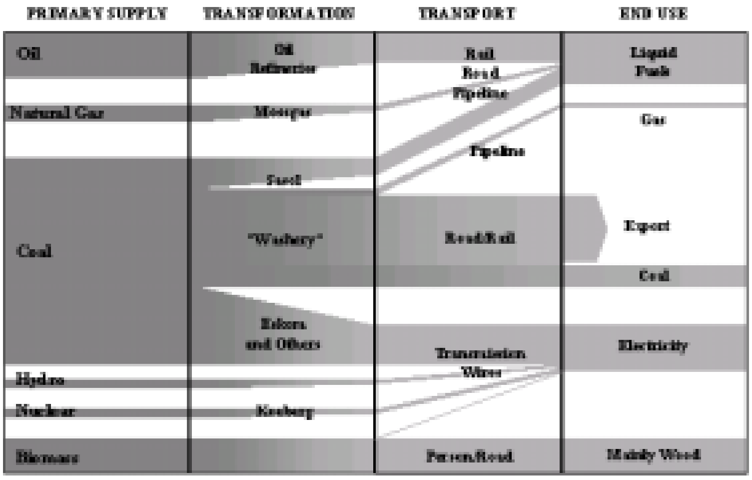


Figure 4: The South African energy system, (source: Surridge et al. [2])

For each process involved, life-cycle costs, emissions and efficiencies have been estimated. From this a matrix is developed for the energy economy in the MARKAL (Market Allocation) model developed by the International Energy Agency. Useful energy or energy service demands are projected into the future based on knowledge of the economy, and the least cost mix of processes (labelled 'technologies' in the MARKAL model) can then be calculated. Useful energy projections were calculated in the LEAP (Long range Energy Alternatives) Planning tool of the Stockholm Environmental Institute, Boston.

The choice of market share and change of these processes, which is reported on and modelled in this work, is dependant on the scenario chosen.

THE BASELINE SCENARIO

The scenario chosen for this work represents 'business as usual' and is as per the baseline scenario for South Africa as per the National Integrated Energy Plan (IEP).

The national IEP was produced by the Energy Research Institute with ESKOM (the national utility) and the National Department of Minerals and Energy (DME), and was also sponsored by ESKOM and the DME. The work was developed using variants of two scenarios for the energy sector in South Africa. One based on 'business as usual' (baseline) practice which focused on current least cost practice by sector, derived from an integrated resource approach (IRP), and another which was biased against coal. The business as usual scenario was called the 'baseline simulated' scenario, and, much like current greenhouse gas mitigation studies, focused on each fuel (or resource) and sector individually. These 'Least cost sector futures' (which involved stakeholder feedback) were then reconciled into a single scenario.

Two important, and false assumptions that are often made while doing this are that: the 'sum' of each least-cost resource plan would then constitute the least cost overall plan, and that mitigation studies can be done with each sector in isolation.

An important point about the all of the assumptions, relating to the technology database, is that they were realisable and represented an economically viable future scenario, with relatively little policy intervention. These were then used to structure the computer program based models.

THE MODEL STRUCTURE

Of the two programs used, the LEAP model was designed to project and then meet a range of useful energy or energy service demands, according to a preconceived, or simulated, future. The MARKAL model was designed to meet the same energy demand. The model could be run in both simulated and optimised mode. When optimising, this was done on the basis of 'least cost', subject to a range of constraints, for the energy system. These constraints were developed in order to keep the solution both realisable and therefore also of use in and for policy formulation.

Least cost optimisation

When run in optimised mode, the model can choose, what device to use to meet the useful energy demand, or, as it is also referred to, the energy service that is required by the growing economy and population. To do this the model calculates the fuel used by the device. The fuel use is termed the final energy demand. The choice of device is dependant on the cost of the production (in turn dependant on production technologies, resource and import costs) of the fuel that is used and cost of the demand device.

The MARKAL model was allowed to choose from a range of supply and demand options that were limited to projects and technology penetration rates, which represent conventional practice. This included options based on coal. Currently over 90% of South African electricity is produced by coal at the lowest cost in the world, similarly over 35% over petrol demand is produced by the liquefaction of coal, and much final energy demand is also met by coal. Coal is the cheapest option for the economy but is also carbon dioxide intensive.

RESULTS: GHG EMISSIONS, ENERGY MANAGEMENT AND A LEAST COST PATHWAY

Greenhouse gas emissions inventories for the South African energy sector have been carried out for the Department of Environment Affairs and Tourism (DEAT) by Howells & Solomon [3]. The same data sets were used to develop the inventory in the IEP model. Figure 5, below shows the progression of emissions that would be anticipated were the baseline, simulated case to be realised over the next twenty years.

Using the IEP energy models demand-supply effects can be captured simultaneously. For example, if power production were to shift from coal to nuclear, electricity would have lower carbon dioxide intensity than projected. This may make an electrical energy efficiency option, for CO_2 mitigation, less attractive than originally thought. This work represents the first significant attempt to do this in South Africa.

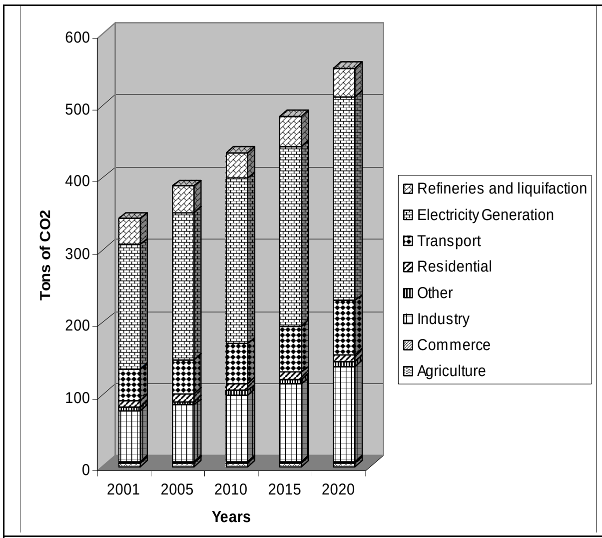


Figure 5: Carbon Dioxide emissions from the Baseline

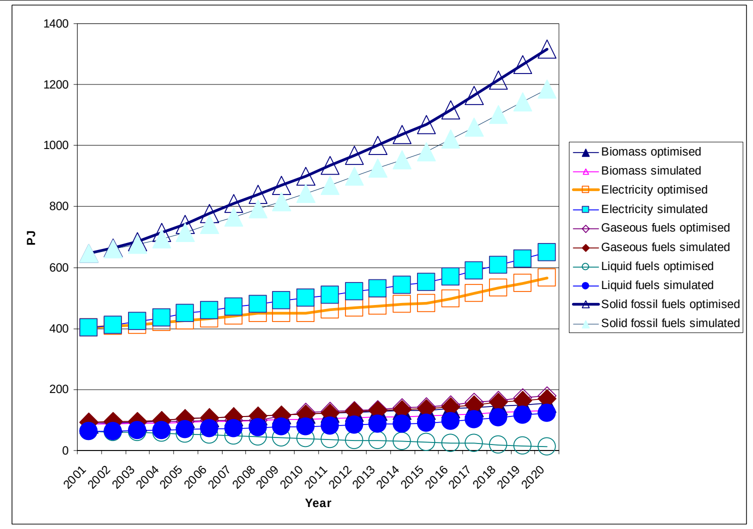


Figure 6: Energy use in the industrial sector

In the optimised scenario, energy use patterns change in order to reduce costs. This is particularly well illustrated by the fuel use patterns in the industrial sector. As Figure 6 shows, there is a general shifting to coal used and burned directly to produce process heat at the point of need. This displaces some coal that would have been used to generate electricity, which is displaced. Other important trends include the decreasing use of liquid fuels (and electricity) for thermal purposes and an increased uptake of energy efficient practice and technologies.

The uptake of energy efficient technologies is again well illustrated in the industrial sector. As the marginal cost of electricity increases, due to capacity shortages, several energy efficient options become viable, and are taken up, further reducing the demand for electricity.

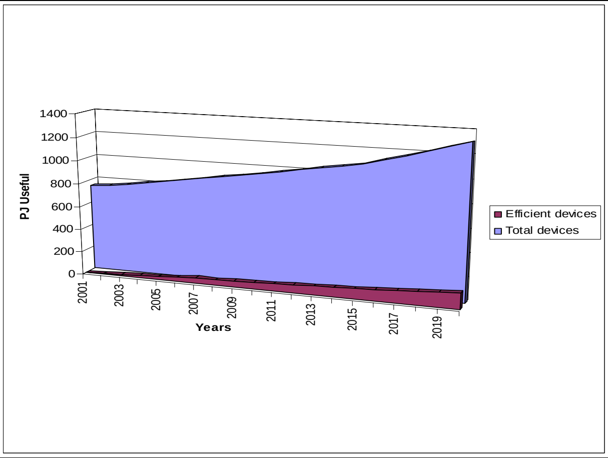
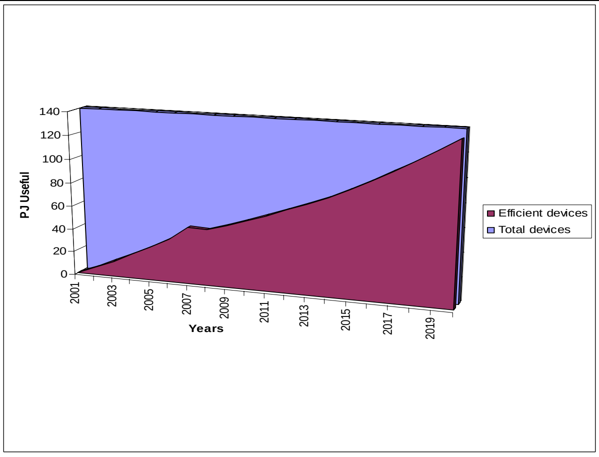
Overall uptake	Close-up view
	

Figure 7: Energy efficiency uptake in the industrial sector

The effect of decreasing electricity consumption thereby delaying the building of new power stations and using fuel more efficiently has the two fold effect of decreasing the system costs and lowering emissions.

The costs are discounted with a real rate of 11%, and are illustrated as a time series in the Figure 8 below.

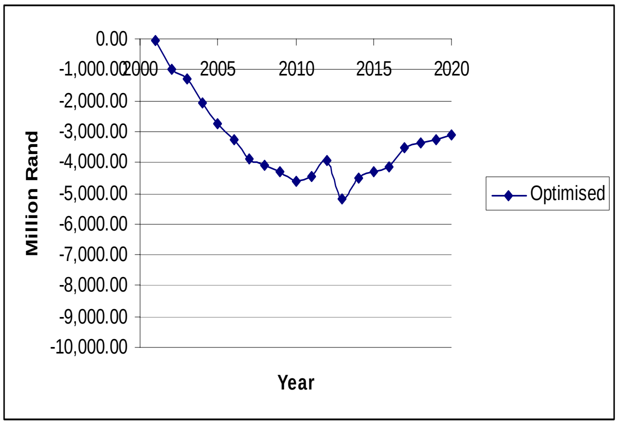


Figure 8: The discounted cost of the relative cost of the Optimised scenario compared to the Baseline scenario

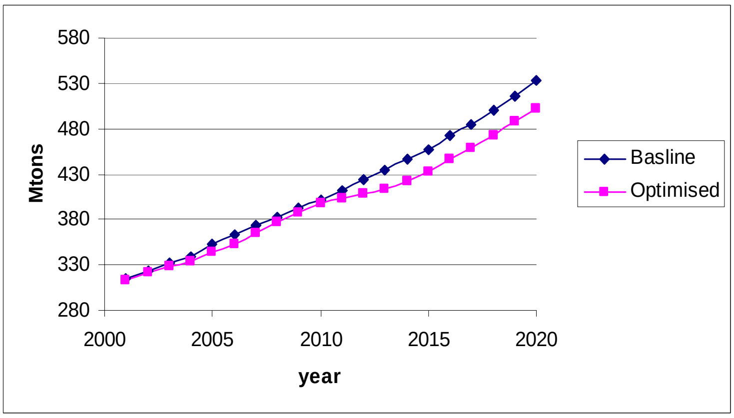


Figure 9: The carbon dioxide emissions of the Baseline and Optimised scenario

The peaky nature of figure 8 is due in part to the delay of large investment in base load power plant in the middle of the Baseline period. This has a direct effect on the CO_2 emissions during the same period, as can bee seen on the following Figure, figure 9.

Figure 9 Indicates millions of tons of CO_2 emissions, over time, for the scenario period for the Baseline scenario and the Optimised scenario. Emissions levels drop as energy efficiency measures and fuel switching occurs. A significant reason for this is to delay relatively costly power station investment.

Interestingly, the conclusion is reached that, emissions from the energy system can be reduced while at the same time the cost is lowered, and coal is still the dominant energy carrier to fuel South Africa.

If one wished to focus more carefully on reducing emissions from the system, and supply the same energy service at increasing cost relative to the optimised scenario, approximately 1400 million tons of CO_2 could be mitigated with an energy sector that costs the same for the period as the Baseline case. This is well illustrated by running the MARKAL model to meet emissions targets at a least cost. The results are shown in the Figure 10, and indicate that the current energy system is could be moved to a ‘new production frontier’.

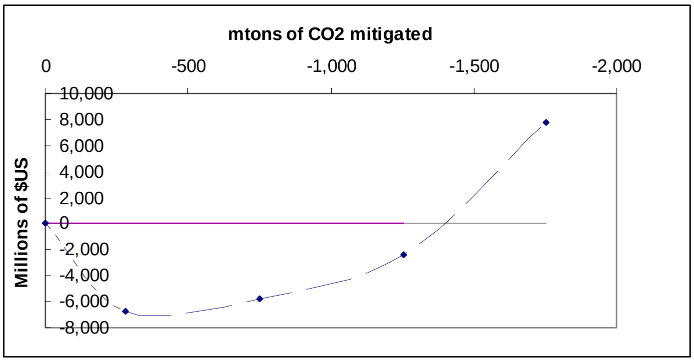


Figure 10: Cost of CO_2 mitigation for the energy system relative to the Baseline

Figure 10 shows the cost change necessary to mitigate CO_2 from the energy system. The negative cost values indicate where CO_2 could be removed from the system at a profit. Note that as one moves away from the baseline simulated case (origin), the cost of mitigation is negative. As we impose emissions restrictions on the optimised case, the cost associated with meeting more stringent targets increases. As about 1400Mtons of CO_2 is mitigated, the cost rises above that of the Baseline. This implies, that to no extra cost to the energy system significant CO_2 savings are possible.

DISCUSSION OF RESULTS

Essentially the thesis that the energy sector can be run at a lower cost and reduce CO_2 emissions, while still based on coal has been proved.

There are implications that will be briefly discussed in terms of application to South Africa, and these are mitigation and: bulk renewable energy, development needs, and liberalised markets.

Bulk renewable energy

It is interesting that bulk renewable energy generation options such as wind were not needed in order to reduce significant quantities of CO_2. These options are relatively expensive. When the system is constrained to meet emissions limits, new power large station investment is required only at the end of the period. This negates the use of such renewables, and indeed, much new electricity generation. There may, however, be a case for such renewables at higher cost CO_2 regimes, where electricity with low CO_2 intensity be come a 'mitigation fuel'.

Greenhouse gas mitigation in a developing country context

In terms of national and local considerations greenhouse gas mitigation needs to be seen in the context of development. As is the case of South Africa, developing country governments and organisations are faced with an array of other pressing objectives, and as a result, greenhouse gas mitigation is very often not a goal in itself. Therefore, if goals are met other than simply greenhouse gas mitigation the potential for intervention is greater. There are at least two levels, which should be considered, from a national and a local perspective. For example, in terms of local issues, low smoke or 'clean coal' technologies should be encouraged to limit local environmental damage, by burning more coal at the point of demand. If not carefully managed, local environmental damage may be unacceptably effected. This and other considerations are shown in the figure.

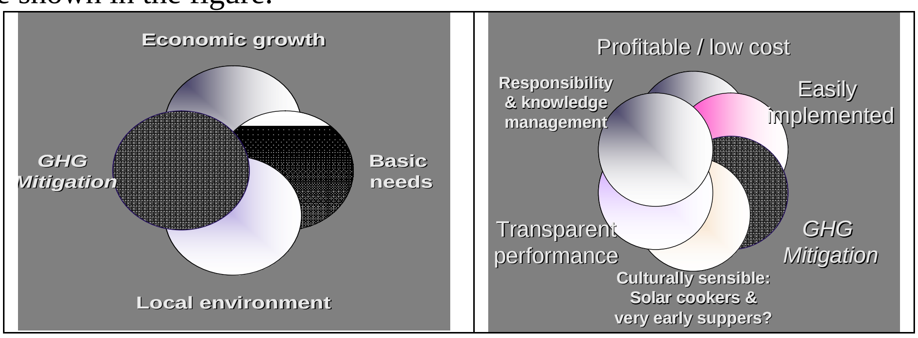


Figure 11: Greenhouse gas mitigation in the South African context

Mitigation in the context of energy liberalised market

Energy markets in many countries, including South Africa are deregulating. The use of market based instruments needs to be carefully considered, and may need to be engineered to help realise the optimization of the energy system. Emphasis needs to be placed on increasing the incentives to effectively remove market failures, especially where the promotion of 'integrated measures' are concerned.

SOME CASE STUDIES AND CONCLUSION

The central theme of this work is that energy management holds the potential to unlock profitable CO_2 mitigation for the energy system. There is clear potential for this profit to be realised for the end-user, especially in industry, which is profit driven. In this context the industrial sector has been a focus are of much recent work, which, it is hoped will meet several of the objectives illustrated earlier in figure 11.

The table below shows the results of several recent case studies carried out by the ERI, in partnership with government, and leading local industry, to illustrate this point. The case studies are from leading local industries who have kindly agreed to allow their dissemination, in order to help take the energy management further.

Industry	**Payback on investment**	***Annual* cost savings**	**Approx CO_2 Savings**
Car manufacture	10 months	R6.5m ($650 000)	33 000 tons/ps
Paper and Pulp	7 months	R5.5m ($550 000)	40 000 tons/pa
Gold mining	8 months	R 2m ($200 000)	13 000 tons/pa

Source: the 3E strategy program [4]

These and other case studies, training courses, and the South African Energy Management Association (SEMA) have been launched by the ERI as well as the '3E strategy' drive. The 3E's standing for energy, efficiency and earnings.

References

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