M A P S

Mitigation Action Plans & Scenarios

REGIONAL TRADE CONSIDERATIONS

in the LTMS

October 2012

TECHNICAL // Regional Trade

Authors: Adrian Stone, Alison Hughes

Purpose

To discuss regional trade opportunities available to South Africa, the way these opportunities were modelled in the Long Term Mitigation Scenarios and the reasons behind the approach taken. The briefing paper discusses alternative ways of including regional trade in bottom up energy economic models such as MARKAL or MESSAGE and explores general opportunities for including regional trade in modelling exercises.

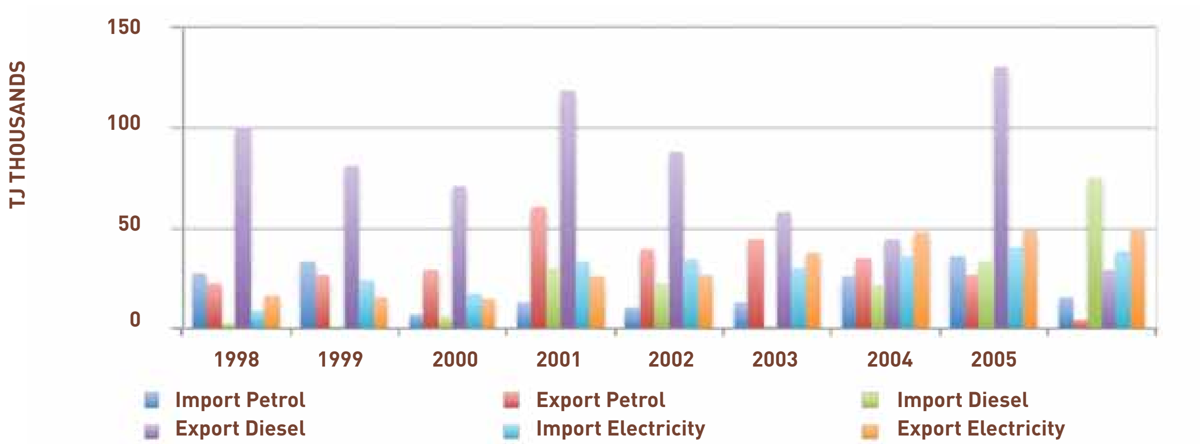
Background

Southern Africa has large renewable energy and fossil fuel resources and opportunities to develop regional trade in primary and secondary energy are abundant in the region. Within Southern Africa, South Africa has large refining and electricity generating capacity compared to other countries in the region and has been a net exporter of liquid fuels to the region, whilst imports and exports of electricity have occurred in roughly the same quantity (see Figure 1). Currently however liquid fuel imports are increasing and the reserve margin for electricity generation is very low. Existing plants will begin to retire over the coming decade and as economic growth continues to drive demand, further generation, refining capacity or imports are needed to meet the growing

FIGURE 1:

IMPORTS AND EXPORTS OF PETROL, DIESEL, AND ELECTRICITY IN SOUTH AFRICA

Source: DOE energy balances



needs of the economy. South Africa therefore faces two questions, whether to build further refining capacity or import liquid fuels, and whether to import electricity or rely on locally built plants.

Historically coal has been the most economical way to produce base load electricity in South Africa, and over 90% of local generating capacity lies in coal fired power plants. Due to the large reliance on coal for electricity generation, thermal industrial needs and liquid fuels production, South Africa has a relatively high greenhouse gas (GHG) footprint both in per capita and in economic terms. Electricity generation accounts for around 40% of the GHG emissions. Importing electricity from hydro plants in the region, as well as other renewable energy (RE) could greatly reduce South Africa's carbon footprint. South Africa could also benefit economically if trade allows a reduction in the cost of mitigation, or the cost of energy for the economy. There are many opportunities for imported hydro from the region, shown in Table 1, many of these options have levelised costs below that of South African coal fired power plants and are therefore attractive.

There is also opportunity to import electricity from future coal and gas plants in the region. Regional trade of electricity is however only possible through a large interconnected grid. In Southern Africa this grid has linkages in South Africa, parts of Botswana and Zimbabwe and it extends in the west to Walvis Bay in Namibia and Ruacana in Angola, in the north to Inga in the DRC and to Mozambique in the east. Trade in other fuels can take place via the road and rail network, pipelines and ports.

1. Consideration of regional trade in the South African LTMS

Countries within the Southern African geographical region have very different climates and topography which results in a range in the potential for renewable energy between countries within the region. Whilst there would be opportunity to import electricity generated by wind, solar and hydro, South Africa already has large solar and wind resources, and electricity from wind and solar resources outside South Africa were not included explicitly in the LTMS model as there was no cost advantage to doing so.

South Africa is a relatively arid water-scarce country compared to its neighbours and has limited hydropower potential. Imports of electricity from hydropower plants in the region were included explicitly in the model for

TABLE 1:
HYDRO POTENTIAL IN SOUTHERN AFRICA

	EXISTING HYDRO			IDENTIFIED HYDRO PROJECTS		
COUNTRY	CAPACITY	AVERAGE GENERATION	DRY YEAR GENERATION	CAPACITY	AVERAGE GENERATION	DRY YEAR GENERATION
	MW	GWh	GWh	MW	GWh	GWh
Angola	474	2 595	1 713	3 580	2 063	1 362
Botswana	-	-	-	-	-	-
Democratic Republic of Congo	2 333	14 259	11 183	40 384	331 663	279 403
Lesotho	73	414	274	190	500	330
Malawi	278	1 391	919	614	4 885	3 224
Mozambique	2 122	15 604	12 107	2 552	12 678	7 680
Namibia	240	1 395	921	360	1 724	1 138
South Africa	665	878	583	2 832	-	-
Swaziland	62	202	134	-	77	51
Tanzania	561	1 525	1 161	1 972	2 825	1 865
Zambia	1 752	10 043	7 778	1 484	11 836	9 067
Zimbabwe	750	4 000	3 137	1 100	7 280	5 710
Total	9 310	52 306	39 910	55 068	375 531	309 830

Mepanda Uncua and Cohora Bassa in Mozambique. Imports from Inga were considered but not included due to the percieved risk of instability in the Democratic Republic of Congo at the time. When Inga is included, it is a preferred option; therefore the exclusion of Inga was based on a scenario building team (SBT) directive.

At the time of modelling the LTMS a large coal-fired power station was being planned in Botswana. 70% of the electricity that could have been generated by the plant was available as an import to South Africa and was therefore included as a supply option. Gas fields in neighbouring countries offer opportunities to either import gas for combined cycle gas turbines (CCGT's) or import electricity from CCGT's. The LTMS model included imported gas fired electricity from Namibia, supplied from the Kudu gas fields, as a power sector option.

All imported electricity was assigned the levelised cost of generating electricity from the plant which differs between plants and therefore each plant is included explicity in the model. Transmission losses were taken into account but did not exceed transmission losses of plants located in South Africa. All costs attached to imported electricity were discussed in the SBT meetings and agreed to by the stakeholders. This was not an easy process, and required several meetings, as well as the creation of a smaller technical group which finally agreed on the costs.

A critical decision in setting up the LTMS model was whether to include or exclude the emissions from fossil fuel fired stations in neighbouring countries. Through the SBT it was decided that any electricity generated in neighbouring countries would not have emissions allocated to it following the methodology for accounting for emissions developed by the IPCC (2006). Electricity from plants located outside South Africa's borders were therefore free of carbon taxes in the carbon tax scenario. The exclusion of emissions from plants located outside South Africa avoids double counting where both suppler and buyer count carbon in their national accounts. However it introduces the possibility of 'carbon leakage' whereby one country buys electricity from another country with low national emissions and thereby appears to have a low carbon intensity economy.

A model optimised on emission and cost criteria may therefore maximise imported coal-fired electricity. Carbon leakage is discussed in more detail below in Section 2.1.

1.1 Limits to regional trade

There are no official policies in South Africa which directly restrict the trade of electricity. However due to energy security concerns imported electricity was capped at 15% of total national supply in the LTMS model.

Infrastructure requirements are clearly a limit to fuel and electricity trade. Infrastructure caps were not directly modeled, as the LTMS model treated South Africa as a single node, accounting for the cost of transmission and distribution in a single generic technology.

South Africa became a signatory to the Kyoto Protocol in mid-2002. As an Annex 3 country, there is no emissions target for South Africa, and therefore no emissions trading is considered although South Africa can sell Clean Development Mechanism (CDM) credits.

1.2 Modelling regional trade

The LTMS used a single region model which included the regional trade of electricity and other fuels as imports and exports only and thus did not account for increasing demand in neighbouring countries, and the consequent impact on tradable electricity in the region. This can be done with a multi-region model where capacity in each region and demand in each region is modeled explicitly and imports to South Africa would be competing with demand in other countries. In the Southern African context this is very significant because many countries import energy in the form of electricity, refined liquid fuels and coal from South Africa. Many of these countries are growing fast, albeit from a small base, and utilities and industries in South Africa could well expand to meet this demand as well as demand within South Africa.

2 Beyond the LTMS: future considerations in modelling regional trade

Since the time of the LTMS, the modelling and development of climate change mitigation actions have taken new directions, and some of these have dealt specifically with regional and global trade aspects, particularly the issues of carbon leakage, embodied emissions and trade in carbon smart goods. These are briefly discussed below and are broadly applicable to analyses and models that aim to expand their scope beyond purely territorial emissions.

2.1 Carbon leakage

Carbon leakage has been defined generally by the IEA as follows:

"Carbon leakage is defined as the increase in emissions outside a region as a direct result of the policy to cap emissions in this region", (Reinaud, 2008)

and more mathematically by the Intergovernmental Panel on Climate Change as follows,

> *"Carbon leakage is defined as the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the reduction in the emissions of these countries.", (IPCC, 2007)*

Fundamentally this amounts to the law of unintended consequences in action and is probably an inevitable outcome of the wide-ranging, integrated and complex policies and interventions necessary to mitigate climate change across the economies of the globe.

The primary reason for carbon leakage is that given the difficulties in reaching consensus in climate change negotiations and the diverse stages of development of the world's economies, countries have different climate change mitigation commitments and some have none at all. Thus a rise in fossil fuel prices caused by mitigation actions in a country with ambitious targets may, for instance, quickly displace production to a country with less stringent regulations, leaking the carbon to that country. The new producer may be less efficient and transport emissions may rise and so net GHG emissions per unit consumption may increase. Similarly, it's been surmised that if widespread mitigation is initially successful and demand for fossil fuel from developed countries drops then a drop in price will likely drive up consumption in developing economies (IPCC, 2007).

Following the adoption of the Kyoto Protocol a number of modelling studies estimated probable carbon leakage from developed nations of 10 - 20% while the results for one study ranged as high as 130% implying a net increase in emissions. The counter argument has been that a mitigation strategy leading to high carbon leakage would necessarily target energy intensive industries that are mobile, e.g. smelters for instance, instead of less mobile sectors such as power production or domestic consumption. It has been argued that in practice such a policy would be unlikely and that most countries have and will act to adjust policy to limit carbon leakage (IPCC, 2007).

In the event it appears difficult to tease out the historical effects of climate change mitigation on production displacement as shown by an IEA analysis of the impact of emissions trading schemes (ETS) on the European aluminium industry (Reinaud, 2008). It is reported that at this time 85% of the EU's aluminium supply came from 8 outside countries including Russia, Mozambique, Brazil and South Africa. Furthermore that there was no new production capacity being planned and some smelters had closed. Indications were however that this situation was already unfolding in 1999 before the existence of emissions caps, due to high European power prices and high labour costs. There are of course many drivers of shifts in the site of production and as found by Reinaud, this complicates carbon leakage analysis.

> *"The study of the impacts of the EU ETS on competitiveness is, and will remain plagued by the difficulty to establish the counterfactual, i.e., what would have happened in the absence of a CO_2 cost: how does one detect, in the rapid industrial production growth outside the EU, the actual effect of an ambitious climate policy in the EU?", (Reinaud, 2008)*

Notwithstanding this, policy to reduce carbon leakage from the EU in energy intensive industries has been mooted in two forms:

- **'free allocations'** of uncapped electricity for industries where electricity constitutes a high proportion of production costs.
- **'carbon equalisation system'** for imports which would equal the carbon playing field for energy intensive imports.

Hence probably the most useful role of modelling in understanding the carbon leakage issue is to highlight the possible ill effects of proposed policies that do not take the possibility of carbon leakage into account, for instance the crude 'shotgun' policy approach targeting all sectors and industries with punitive taxes.

In the South African situation carbon leakage scenarios are easy to envision, Southern Africa being a cluster of developing economies with South Africa a relatively highly industrialised kingpin and many of its neighbours growing rapidly from a low base. Smelters in particular could move to neighbouring countries and make the long term supply contracts critical to this industry with exactly the same utility, Eskom, who is the dominant supplier in the region. The wealth of gas reserves in Mozambique make it a particularly attractive site for energy intensive industries. Botswana's coal reserves would be increasingly attractive to the synthetic fuel and chemicals giant Sasol should an unfavourable regulatory environment unfold for them. Indeed, as discussed above, these reserves formed the basis of the planned Mmamabula project to build a 1200 MW coal-fired power station to supply South Africa at the time of the LTMS, illustrating that in a regional context carbon leakage from the power sector is quite possible. In the end energy security issues may however well have militated against this project and the argument that electrical power supply is largely immobile is perhaps demonstrated by this case.

Given the growing attention to carbon leakage and carbon trade flows it seems reasonable that the original LTMS decision not to account for emissions from imported power would be reviewed in current scenario modelling exercises. As will be discussed below a literature is emerging that advocates a calculation of 'consumption' emissions as a complement to 'production' emissions so that the linkages between regions is better understood from the published country data.

2.2 Consumption versus production calculation of GHG emissions

The most commonly used method for CO_2 accounting called production-based or territorial accounting develops an inventory of the CO_2 emitted within a country. This is the standard method advocated by the IPCC. It has been argued that while this method can be used to estimate the environmental impacts of the production and consumption activities within a specific country, it cannot easily be used to examine the effect of changing global production, trade and consumption patterns on the environment. Neither is it possible to use this method to analyse carbon leakage or the impact of the structure of trade relations between developing and industrialised coutries on the issue of equitable responsibility for emissions (Bruckner, Polzin, & Giljum, 2010).

A study published in the Proceedings of the National Academy of Sciences (Peters, Minx, Weber, & Edenhofer, 2011) indicates that, "a significant and growing share of global emissions are from the production of internationally traded goods and services". These were estimated to have increased from 4.3 Gt CO_2 in 1990 (20% of global emissions) to 7.8 Gt CO_2 in 2008 (26%). Thus the net emission transfers via international trade from developing to developed countries was estimated to have increased from 0.4 Gt CO_2 in 1990 to 1.6 Gt CO_2 in 2008, exceeding the Kyoto Protocol emission reductions. The authors note that by virtue of the IPCC reporting standard specifying strictly territorial emissions, many developed countries have reported their emissions to have stabilised. Their results however indicated that the net emissions associated with consumption in many developed countries have rather increased with a large share of the emissions originating in developing countries. This is evident from Figure 2 below which shows the results of one analysis.

The countries at the two extremes in this analysis reflect the effect of the carbon intensity of the power sector in those countries, France being low and South Africa high. China by virtue of its enormous exports would also be expected to show a large difference in production and consumption based calculation of CO_2. At present these studies are being used to show that the net CO_2 emissions associated with consumption in some developed countries claiming to have reduced emissions, have rather increased. Why such analyses are of interest to a developing country like South Africa is due to the possible emergence of 'carbon equalisation' systems for imports to the EU, as alluded to in the section above, which would equal the carbon playing field for energy intensive imports. South Africa's ranking as an exporter of carbon in its goods may vary in the literature but will feature prominently in any comparative study because of heavily coal reliant power production. The popularisation of consumption based accounting and the natural progression to policy influenced by it is therefore a highly significant phenomenon for South Africa and countries like it and should form part of the broader climate change initiatives there.

The emissions arising from the production of a good that is imported or exported are known as the "emissions embodied in trade" or "embodied emissions". A 'consumption' based calculation of GHG emissions would, in simple terms, take these into account as follows (Boitier, 2012):

GHGcons = GHGdcons - GHGexp + GHGimp

GHGcons:	*National GHG emissions*
GHGdcons:	*GHG emissions from domestic final consumption*
GHGimp:	*GHG emissions embodied in imports*
GHGexp:	*GHG embodied in exports*

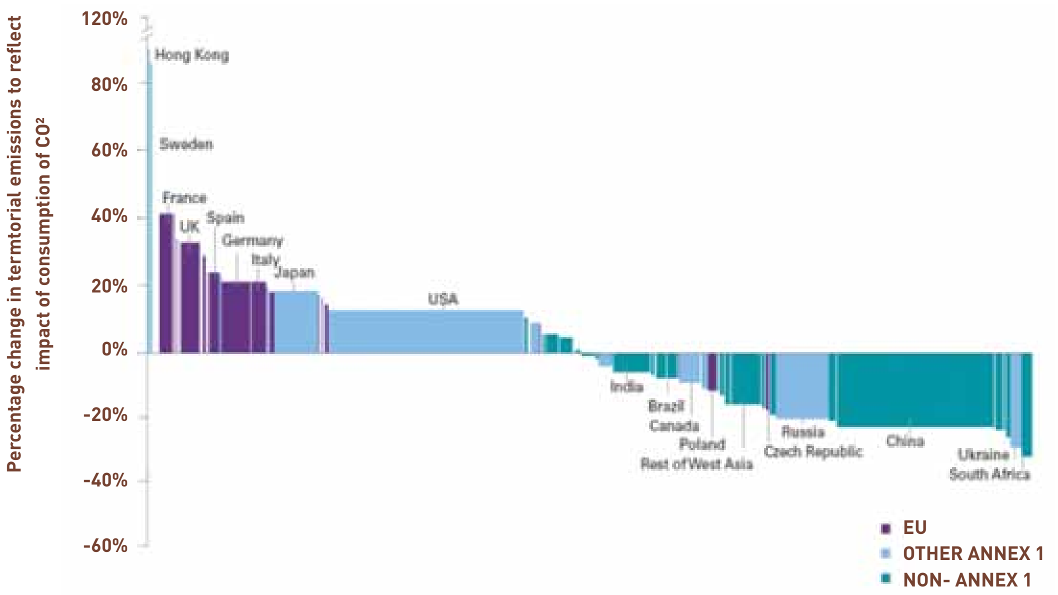
Determining these aggregate quantities is however challenging because this requires the modeller to profile inter-industry and inter-country trade relationships (Bruckner, Polzin, & Giljum, 2010). The most common methodology for accomplishing this is the analysis of so-called input output (IO) tables which express the structure of an economy in terms of its inputs, its various sectors and the nature of the outputs from those sectors (Bruckner, Polzin, & Giljum, 2010). The analysis tracks all financial transactions between industrial sectors and consumers within an economy. It is possible to assign an environmental impact to these financial transactions by adding environmental information, such as greenhouse gas emissions to each sector which is termed an environmentally extended input-output model. This tracks the flow of environmental impacts along supply and production chains. Input and output models have been developed along three basic designs as follows (Sato, 2012):

Single-Region Input-Output (SRIO) models calculate the emissions associated with the total demand (including household, government and capital investment) in a single country, accounting for the embodied carbon in trade with the rest of the world. This model aggregates the rest of the world into one region and so assumes that the same technology is applied to production both home and abroad.

Bilateral Trade Input-Output (BTIO) models also consider the emissions associated with the total demand of one country, but decompose trade by trading partner and apply country specific emission factors.

Multi-Regional Input-Output (MRIO) models discriminate between imports which are directed towards 'final consumption' and those directed towards 'intermediate consumption' (i.e. for the

FIGURE 2:
EFFECT (%) ON THE TOTAL NATIONAL EMISSIONS OF SELECTED COUNTRIES OF A CONSUMPTION BASED CALCULATION (THE CARBON TRUST, 2011)



Note 1: Includes CO_2 emissions from production, process, transport and houshold sources only (27Gt in 2004); excludes non-CO_2 emisions due to land-use-change.

Note 2: Based on an MRIO (multi-region input/output) model allocating emissions to regions of consumption.
Source: Carbon Trust Analysis; CICERO/SEI/CMU GTAP7 MRIO Model (2004).

production of export goods). The intention is to capture re-exports and thus the analysis is in theory truly multi-regional, allocating imported and exported carbon to all trading partners.

Computational General Equilibrium (CGE) models have also been used to model emissions on a consumption basis (Sato, 2012). Multi-regional Input Output (MRIO) models seem to be emerging as the favoured approach with input output modelling in general becoming more widespread since the development of the World Input Output Database (http://www.wiod.org) by the European Commission which to some extent ameliorates the data challenges implicit in these models. The WIOD databases provide detailed data on trade and GHG emissions for 41 countries and 35 economic sectors (Bruckner, Polzin, & Giljum, 2010).

While advances have been made on the data challenges MRIO has been described as a "minefield for practitioners desiring fairly accurate numbers". Problems cited include data and computational requirements, the lack of transparency, as well as the numerous sources of uncertainty involved in MRIO analysis (Sato, 2012). Given these difficulties it has generally been proposed by those active in the field that consumption based calculations are a complementary method to standard IPCC production based accounting and not a substitute.

2.3 GHG implications of trade in carbon smart technologies

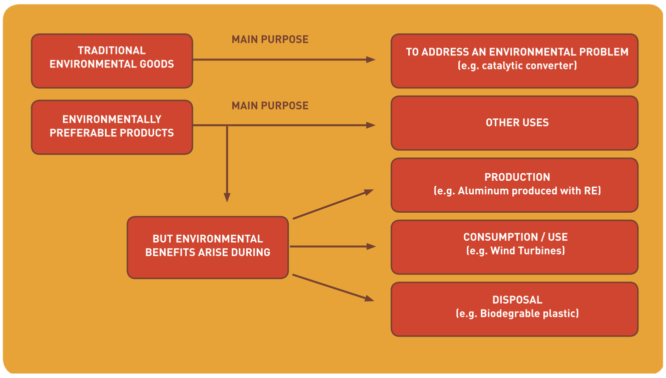
The above discussion suggests that emerging concerns about embodied emissions might cause climate change mitigation to radically reverse the growth in global trade. Indeed, transport emissions can be a substantial, even dominant portion of the carbon footprint of a good. Trade can however assist mitigation as follows:

- Imported goods can have a lower carbon footprint than what could be manufactured locally even if accounting for transport emissions particularly if the local power pool is energy intensive.
- Trade in so-called 'carbon smart' technologies is a necessary feature of mitigation strategies. A very basic example of such a technology would be wind turbines but there are many examples across sectors, of technologies that are either offer relative efficiency or produce power with low GHG emissions.

The detailed modelling of the outcomes of policy that takes these two factors into account, for instance tariff exemptions, would tend to be very data intensive as specific data for many products would be required. The implementation of policy amounts to the selective liberalising of trade, but is itself problematic as shown in Figure 3 below (Cho, 2010), the environmental benefits from such goods arising in either their production, consumption, disposal or a combination of these thus requiring sophisticated assessment systems.

Clearly, South Africa with its carbon intensive power pool would stand to gain more in terms of GHG mitigation from carbon smart technologies than most countries. Likewise import substitution would likely have a dilute or GHG increasing effect and so protectionism would be unlikely to have mitigation potential. Given these circumstances, future studies aiming to inform policy would likely attempt to model potential benefits and the economic trade-offs.

FIGURE 3:
CHALLENGES TO POLICY – THE DIVERSE NATURE OF CARBON-SMART GOODS (CHO, 2010)



2.4 Considerations in the trade of biofuels

Many countries have adopted biofuel targets as mitigation strategies. The case of Brazil has illustrated that sustained market penetration of, for example, ethanol as a blend or option with fossil fuel gasoline is feasible. Clearly when plant oils or plant derived alcohols are used as fuel in a combustion engine, CO_2 is emitted but this is in a sense recycled by the next crop that absorbs an equivalent mass of carbon from the atmosphere. The process is therefore approximately carbon neutral. When fossil fuel is combusted on the other hand, the carbon from the great Carboniferous forests or bodies of ancient marine animals sequestered for millennia in oil deposits is released.

The prevailing criticism of biofuel policies is the extent to which the supply will derive from existing pasture or involve a so-called 'land use change' particularly involving deforestation. The latter results not only in the loss of a CO_2 sink but also releases the carbon sequestered in forest biomass, above and below ground which will unlikely be offset by the biofuel crop as well as carbon in the soil. The mitigation potential of biofuel over time is therefore highly sensitive to the land use situation. Policy regulating local mitigation by biofuel production should obviously take this into account but the situation regarding the possible import of biofuels is less clear.

The potential extent of land use on mitigation outcomes is demonstrated by a World Bank CGE modelling study that estimated the effect of implementing the biofuels targets of 40 countries on global GHG emissions to 2040 (Timilsina & Mevel, 2011). The results for this study indicated that the short term increases due to deforestation are very high and can take decades to offset by continued substitution for fossil fuels from that land. The model projected that where deforestation occurs as part of biofuels production, emissions from land use change exceed the emissions reductions from the fuel use nearly ten-fold in the short term until 2020. Even 20 years later this was not offset by cumulative emissions reductions and net emissions were projected to show a net substantial increase by 2040. Even where deforestation does not occur it was projected that net emissions would show a marginal increase until 2020 only showing significant benefits in the longer term.

Liquid fuel distribution infrastructure is expensive and therefore biofuel import and export over very long distances seems unlikely to be viable. This does not preclude regional trade in biofuels however where circumstances are favourable. South Africa for instance has limited arable land and is a water scarce country. Neighbours like Zimbabwe however have a more favourable climate for agriculture and a large land commitment to tobacco which while still finding markets in the developed world is likely to become a less and less attractive crop. Given a restoration of political equilibrium the prospects for biofuels trade in the region are not far-fetched in the medium to long term.

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MAPS Programme
Tel: +27 21 461 2881
Email: info@mapsprogramme.org
Twitter: MAPSProgramme
www.mapsprogramme.org