

# Long Abstract - Modelling Growth Scenarios for Biofuels in South Africa's Transport Sector

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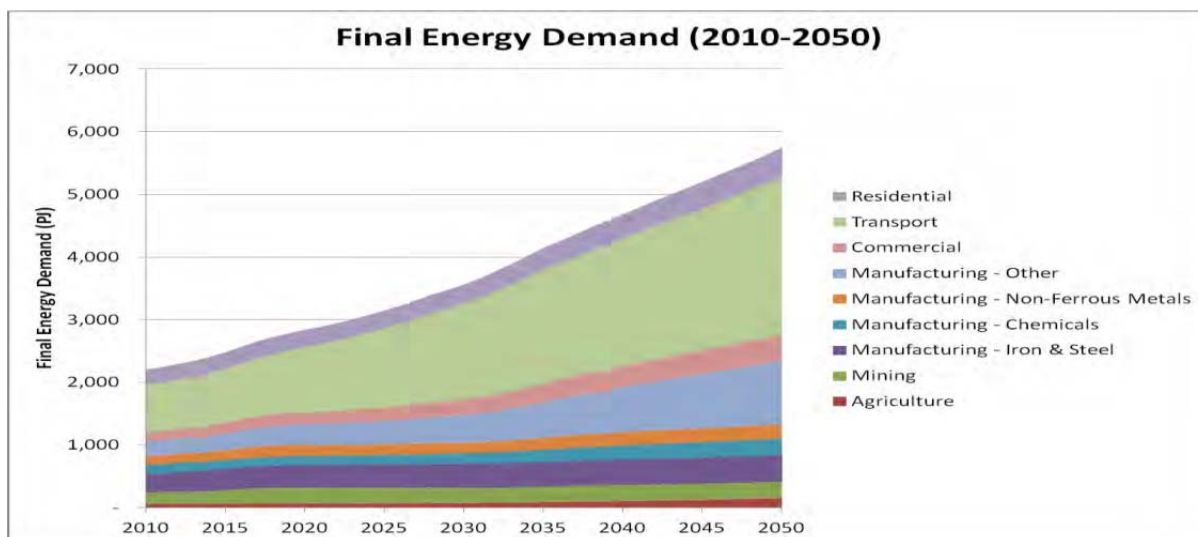
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**Abstract:** This paper describes the preliminary results and modelling approach of an assessment of the potential for biofuel demand in South Africa with supply modelling to be included by the time of the IEW conference. In 2014, the Government of South Africa issued regulations aimed at raising consumption of biofuels in the transport sector. These introduce compulsory blending mandates for fuel ethanol to reach between 2 - 10% by volume of all petroleum usage and biodiesel to meet 5% of diesel demand by volume. South Africa has a nascent biofuels industry with a number of commercial projects at the feasibility stage but stalled until it becomes clear when the start date for mandatory blending will be. South Africa's water scarcity limits local supply potential but that of the Southern African region appears far greater. While there is some understanding then of how much the biofuel industry can supply, how much South Africa's transport sector can consume and whether a biofuels chain will be cost competitive is less clear. Applying the South African TIMES model (SATIM) and dataset to model energy needs in South Africa's transport sector, this paper estimates potential demand for biofuels up to 2050. Findings suggest implementing biofuel mandates will require significant additional areas of land for local supply, although how much exactly is highly dependent on the evolution on transport technology, especially whether or not flex-fuel cars are introduced and become an attractive choice for consumers in South Africa. The range of mandated blend ratios of 2% to 10% ethanol in gasoline, imply a five-fold variation in the possible volumes consumed by the future vehicle parc. It seems likely that the 2% blend would be implemented early on and the price of ethanol locally and in the region relative to oil would drive higher blends. A sustained high oil price would therefore have further implications for land and water or open up potential for biofuel imports from the region given the scarcity of both in South Africa.

## Introduction

### Energy demand in South Africa's transport sector

Transport is a major consumer of energy in South Africa, consuming 28% of final energy (Merven, Stone, Hughes, & Cohen, 2012). This is projected to grow in absolute and relative terms to 2050 (Figure 1) as population growth and increasing prosperity lead to growth in the vehicle fleet and the numbers of journeys South Africans take (DoE, 2013).



**Figure 1: Long Term Projected Growth in Energy Demand by Sector for South Africa**

**Source:** *South Africa Integrated Energy Planning Report 2012*, (DoE, 2013)

While this projected increase in energy demand is expected to lead to rising non-renewable liquid fuel consumption, a number of variables will moderate the rate of growth. One of the most important factors is to what degree alternative sources of energy, including biofuels, displace fossil fuels. A few studies have modelled potential pathways for future liquid energy demand in the transport sector, including biofuels to a greater or lesser extent.

The Integrated Energy Plan which modelled energy demand across sectors to 2050 discussed biofuels as an option for South Africa in some detail noting for instance that substantial forestry residues remain unused in paper industry plantations. Biofuels production was not however explicitly represented in the model because at the time firm policy decisions on biofuels blending had not been made (DoE, 2013). An earlier version of the SATIM model applied in this study was used to project national transport energy demand to 2050 for a base case and a scenario that included a raft of energy efficiency measures that shifted demand from a high rate of increase to near stabilisation by 2050 (Merven, Stone, Hughes, & Cohen, 2012). These measures excluded biofuels however as at the time significant biofuels uptake seemed unlikely given land and water constraints. In contrast, The Mitigation Potential Analysis (DEA, 2014) found that some of the most important measures to mitigate greenhouse gas emissions were in the transport sector. Within this sector, biofuels had the single largest mitigation potential while falling in the mid-range of cost effectiveness of measures. A maximum potential of locally sourced biofuels within road and rail transport fuels of 27% by 2050 was assumed and for aviation biokerosene was assumed to contribute 5% of fuel requirements in 2050. This was premised on 1<sup>st</sup> generation biofuels supplying demand in the early years shifting to 2<sup>nd</sup> generation biofuels derived from agricultural residues later. The potential of 2<sup>nd</sup> generation biofuels was assessed from an International Energy Agency (IEA) study (Eisentraut, 2010) although this study seems to indicate that most agricultural residues produced in South Africa have found use, for instance, as fuel for co-gen, mulch or compost.

Given the promulgation of mandatory blending regulations in South Africa and growing interest in biofuel production in the region however, the assumptions for biofuels used in these studies warrant review, as they have not considered potential growth pathways for biofuels. Consequently, they do

not reliably indicate what role increased consumption of biofuels may have on shifting energy demand, or mitigating emissions from the transport sector.

## **Biofuel policy in South Africa**

At present, consumption of biofuels in South Africa is limited to a small number of test projects: none of the bioethanol South Africa currently produces is used for liquid fuel.<sup>1</sup> Although South Africa produced and consumed significant volumes of biofuels in its fuel mix in the middle of the 20th Century, a subsequent period of cheap oil undermined the industry's economic viability (UNCTAD, 2014). The government renewed its interest in promoting biofuels in the early 2000s, but industrial strategies released in 2005, including targets for biofuels consumption, did little to stimulate the sector and no large-scale producer of either fuel ethanol or biodiesel emerged during this period (DOE, 2014). The available literature identifies several reasons for this:

- *Lack of financial viability:* Biofuels development was not financially attractive for investors given the high capital requirements needed to upgrade existing facilities and low prevailing prices (DOE, 2014).<sup>2</sup> For oil crop producers and processors, higher margins for the production of cooking oil meant producers were unwilling to switch to producing biodiesel.
- *Incomplete policies:* The lack of key policies or the government's reluctance to implement these — especially the blending mandates — meant industry was not compelled to act (USDA, 2013). As well as a mechanism to enforce blending mandates, missing from the policy framework were a licencing mechanism and an appropriate pricing framework.
- *Conflicting policy aims:* Another interpretation sees the government's attempt to use biofuels policy as a means to achieve more equitable growth was challenging to, if not incompatible with, swift industry growth (Köster, 2012). The government's aim to privilege poor parts of country that were underserved by infrastructure and promote strategies that maximised job creation inevitably made attracting private investment difficult. It also led to prolonged discussions over which crops policy should include and promote through targeted support. The Biofuels Industrial Strategy ruled out the use of maize due to concerns that this would raise maize prices and reduce availability on domestic and regional markets, especially at times of shortages. Both sorghum and sugarcane are eligible feedstocks for fuel ethanol, but which of these crops government should prioritise for support continues to be debated. An initial study reported on by the Department of Energy indicated production from sorghum would be significantly cheaper (DoE, 2013).

## **Recent adjustments to biofuels policy**

Between 2011 and 2013, the government revised its policies, releasing a new position paper in late 2013 that addresses some gaps in the existing policy framework (Department of Energy 2014). These policies attempt to overcome financial barriers by introducing a subsidy programme and offer more clarity on rules and pricing. In addition to setting out guidance for production and conditions for government support, the position paper introduces a Mandatory Blending Regulation that compels licenced fuel manufacturers (and their wholesaling arms) to buy and blend biofuels from licenced biofuel manufacturers. The Mandatory Blending Regulation is the main legal tool to incentivise

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<sup>1</sup> Although international statistics show small quantities of bioethanol being produced and traded, this is not used in fuel but rather as potable alcohol, and solvent in paints, inks and in the pharmaceutical industry (UNCTAD 2014).

<sup>2</sup> Converting sugar mills to manufacture ethanol involves substantial investment, estimated at R20 billion (Business Day Live 2014).

blending of biofuels with fuel. Blending targets are set at between E2 and E10 for bio-ethanol and B5 for biodiesel (DoE, 2012).<sup>3</sup>

At present, some parts of the policy require further elaboration<sup>4</sup> and investors are still analysing if incentives are sufficient to merit further investment. This is especially so for fuel ethanol manufacturers using sugarcane, who in 2012 had signalled reluctance to invest if subsidies were not calculated based on prices in sugar markets (Department of Energy 2014). As the government's position paper establishes a preference for domestically-produced biofuels, there is limited scope to source biofuels from outside South Africa (Cartwright 2007, Henley 2014).

In addition to policy-led expanding demand for road transport, aviation companies are increasingly seeking to reduce carbon emissions by substituting some of their petroleum-based jet kerosene with biofuels. In recent months, South African Airways, Boeing and Lufthansa have all expressed intentions to invest in producing biofuels in coming (Lufthansa) (Kumwenda-Mtambo, 2014) (Boeing, 2015).

## **Forecasting demand for biofuel**

So far, the main estimate of potential biofuel demand, which comes from the 2007 Biofuels Industrial Strategy is for 400 million litres per year for the year 2013. This is derived from calculating what scale of production would be needed to supply 2% of 20 billion litres, which was the size of South Africa's fuel pool in 2013 (Department of Energy 2014). While useful for understanding the potential size of the current market, this does not give insights into the scope for future growth and the market size in the medium term. It is therefore difficult to determine if South Africa could continue to rely on domestic production to meet its future needs, as current policy suggests. If this appears unrealistic, sourcing biofuels from neighbouring countries may both be an economically efficient way to increase liquid biofuel consumption in South Africa's transport sector and contribute to economic development in neighbouring countries.<sup>5</sup>

To address this gap, we develop a model to estimate the potential size of the market under different future scenarios. This exercise builds on existing work to quantify energy needs in the transport sector ( (Merven, Stone, Hughes, & Cohen, 2012); (DoE, 2013)).

We also include preliminary estimates for biofuels uptake in the aviation sector to reflect growing interest from aviation companies seeking to reduce their emissions.

## **Methodology**

### **Modelling approach**

We develop basic models to estimate future biofuels demand in two sectors: road transport and aviation. These models are a reduced form of the South Africa Times Model (SATIM) framework for energy systems modelling in a simple, transparent and distributable spreadsheet, making use of

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<sup>3</sup> In other words, the targeted blending ratio for fuel ethanol in petrol is between 2% and 10%. The targeted blending ratio for biodiesel in diesel is 5%.

<sup>4</sup> For example, transportation and tax issues need to be resolved.

<sup>5</sup> Exploring the implications of enlarging regional production and trade of biofuels forms the focus of UNU WIDER's forthcoming research project on Biofuels in Southern Africa.

many of the same assumptions and inputs. The most relevant features of the models include the following:

- Bottom-up technology rich vehicle parc model with vintaged stock of modes and technologies within modes
- Calibration of the base year assumptions in a supporting Analytica™ based model against six years of historical fuel sales data from 2003 to 2009.
- Penetration of new technology into the fleet, for example flex-fuel vehicles fuelled by E85, is driven by scenarios of the share of new vehicle sales in each future year.
- Time horizon from 2006 to 2050.

A full description of the handling of transport in the SATIM modelling framework is presented in Merven, Stone, Hughes, & Cohen, 2012 but essentially in both SATIM and the reduced form model used for this paper, fuel demand was calculated by multiplying the kilometres travelled, the vehicle technology fuel efficiency and the number of vehicles in the vehicle technology segment as shown in the equation below. The technology segment fuel demands were summed to yield the vehicle parc demand and compared to historical fuel sales for calibration purposes.

$$D_{f,k} = \sum_{j=Y1}^{j=k} \sum_{i=1}^{i=C} N_{i,j} \times FC_{i,j} \times VKT_{i,j} \quad \text{Equation 1}$$

- $D_{f,k}$  = Demand for fuel f in year k
- $N_{i,j}$  = The number of vehicles in technology segment i with model year j (Y1 being the first model year), where technologies numbered 1 to C all use fuel f.
- $FC_{i,j}$  = Estimated fuel consumption for technology segment i with model year j
- $VKT_{i,j}$  = Vehicle kilometres travelled per vehicle in technology segment i with model year j

The fuel demand calculation and model calibration process therefore required a number of assumptions to populate the three variables in Equation 1: N the number of vehicles; VKT, their mileage and FC their fuel economy. These are:

1. A vintage profile derived from realistic scrapping curves that enabled vehicle stock to be estimated from historical vehicles sales disaggregated by vehicle type. The curves were calibrated so that the stock estimate closely matched a vehicle registration database.
2. An assessment of annual vehicle mileage for each vehicle class and the rate at which this decays as the vehicle ages.
3. Estimates of the fuel economy of each vehicle class and how this will change over time.

The fuel demand is calibrated to match the known fuel sales data by first iterating till approximate agreement by means of scaling the kilometres travelled per vehicle and then fine tuning with

adjustments to the fuel economy assumptions. A schematic representation of the vehicle parc model and its data inputs and validations is shown in Figure 2.

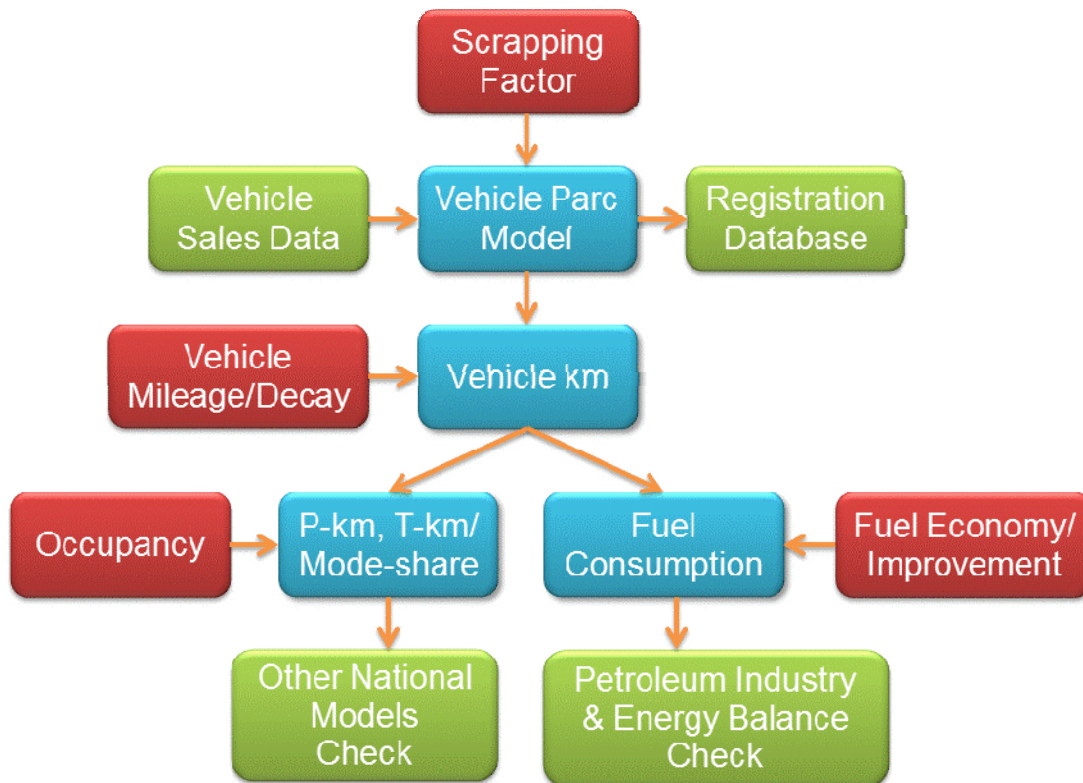


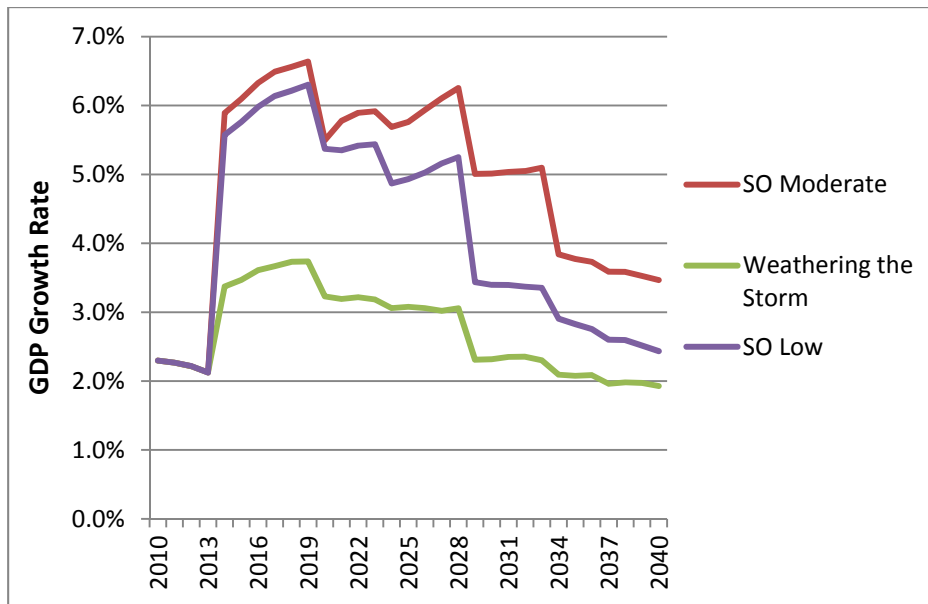
Figure 2: Schematic representation of the vehicle parc model and its data inputs (red) and validations (green)

### Scenario development

We adopted three economic growth scenarios from the Integrated Resource Plan (IRP) (DOE, 2013) as shown in Table 1 below. The economic trajectories are presented in Figure 3 below.

Table 1: Summary Data for Economic Growth Scenarios

<i>IRP Scenario</i>	<b>2040 growth</b>	<b>Avg. growth 2007 - 2040</b>
SO_Moderate	3.5%	4.7%
SO_Low	2.4%	4.0%
Weathering_The_Storm	1.9%	2.7%



**Figure 3: Assumed GDP Growth Rates for Economic Growth Scenarios**

The SATIM framework includes a CGE model that generates the household income data and sector growth rates required for the energy model and this CGE model has been adjusted to broadly match the aggregate growth of the IRP scenarios. In SATIM, demand for passenger transport in particular is driven by the income estimated for household deciles and a lower growth scenario will result in slower growth of access to private transport. Behaviour change in terms of consumers choosing public modes over private when they have the means was not considered for this paper and passenger cars use increases with household income.

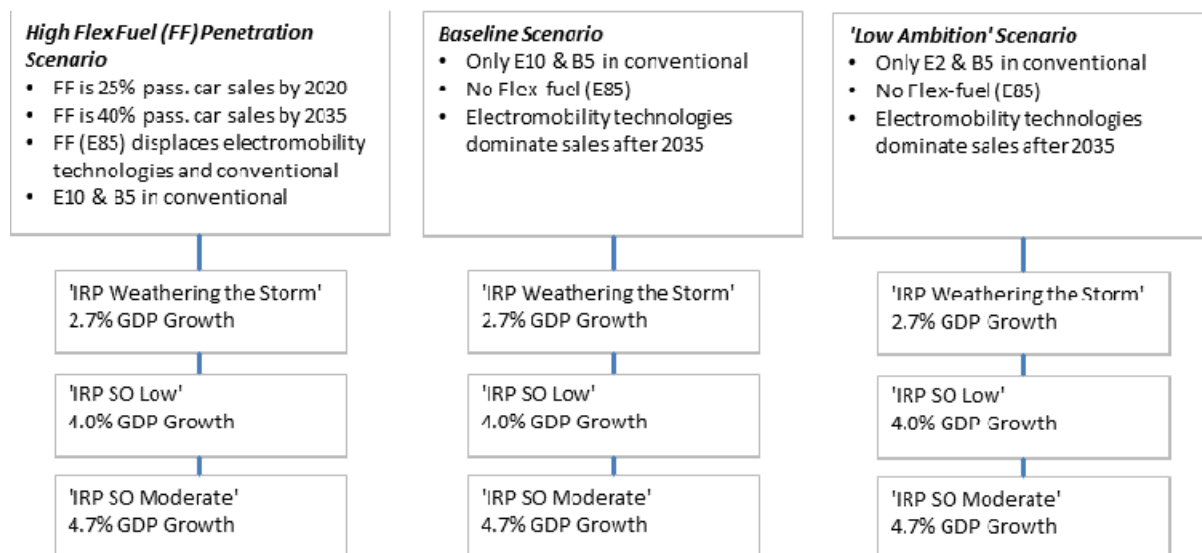
The technology pathways that were considered for biofuels to supply transport energy services were as follows:

- Conventional gasoline internal combustion (IC) and hybrid technology fuelled by a blend of gasoline and between 2% bioethanol (E2) and 10% bioethanol (E10) according to the Mandatory Biofuels Blending Regulation;
- Conventional diesel internal combustion (IC) and hybrid technology fuelled by a blend of diesel with 5% biodiesel (B5) according to the Mandatory Biofuels Blending Regulation .
- So-called flex-fuel internal combustion (IC) technology fuelled by a blend of gasoline and 85% bioethanol (E85). These vehicles can operate on conventional gasoline and a range of ethanol gasoline blends but were assumed to use E85 exclusively.
- Aviation biokerosene making up 10% of a blend with conventional aviation kerosene.

A bio-ethanol pathway to supply heavy-duty freight using ED95 which is 95% ethanol blended with 5% of an additive containing ignition improver, lubricant and corrosion protection (SEKAB) was not considered in any of the scenarios but may be significant. Scania (Strömberg, Conference Presentation - Bioethanol in heavy duty transport, 2013) has developed commercially available heavy-duty engines that have comparable fuel efficiency but far better emissions (ignoring aldehydes) than the equivalent diesel fuelled variant. A limiting factor may be the price of the additive which is reported by Scania to vary between 5% and 25% of the total fuel cost in different

markets but with a projected operating cost per km for South Africa equal to diesel operation (Strömberg, 2014).

The scenarios explored for a preliminary assessment of biofuels demand by transport in South Africa are summarised below. Three economic scenarios are input to each of the technology scenarios resulting in nine scenarios in total.



**Figure 4:** Modelling Scenarios for the Preliminary Assessment of Biofuels Demand

## Modelling assumptions

Due to time limits, we do not represent freight in the revised projected vehicle parc model but have used previous runs of SATIM to estimate the demand of biofuels from freight, given that the 5% blending ratio for biodiesel in diesel of the mandatory biofuels regulation is applied. This will be addressed for the final conference version of the paper.

The passenger mode however is represented in some detail. Assumptions for the penetration rates of technologies and blend ratios of biofuels with conventional fuels are critical to the results. The assumed penetration rates of new technologies for the baseline are presented in Table 3.

**Table 2:** Assumed Baseline Penetration Rates of Passenger Car Technologies (% of new vehicle sales)<sup>1</sup>

Technology	Fuel	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Diesel Conventional	Diesel	7.6%	7.6%	8.2%	9%	9.4%	10%	10.5%	11%	11.5%	12%
Gasoline Conventional	Gasoline	92%	92.3%	84.1%	76%	64.9%	54%	34.5%	15%	12.5%	10%
Natural Gas Conventional	Natural Gas	0%	0.0%	5.0%	10%	5.0%	0%	0.0%	0%	0.0%	0%
Hybrid Gasoline	Gasoline	0%	0.1%	1.6%	3%	16.5%	30%	42.4%	55%	39.9%	25%
Hybrid Diesel	Diesel	0%	0.0%	0.5%	1%	1.5%	2%	2.5%	3%	3.5%	4%
<b>Flex-fuel Vehicle (FFV)<sup>2</sup></b>	<b>E85</b>	<b>0%</b>	<b>0.0%</b>	<b>0.0%</b>	<b>0%</b>	<b>0.0%</b>	<b>0%</b>	<b>0.0%</b>	<b>0%</b>	<b>0.0%</b>	<b>0%</b>



Fuel Cell Vehicle (FCV)	Hydrogen	0%	0.0%	0.0%	0%	0.0%	0%	4.6%	9%	24.1%	39%
Battery Electric (BEV) <sup>3</sup>	Electricity	0%	0.0%	0.7%	1%	2.7%	4%	5.5%	7%	8.5%	10%
SUM		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

1: A similar table was also developed for the other passenger modes: SUV, motorcycles, minibus taxis and buses and tables for these passenger modes are available in a spreadsheet model.

2: Baseline assumes no penetration of E85 using technologies in South Africa

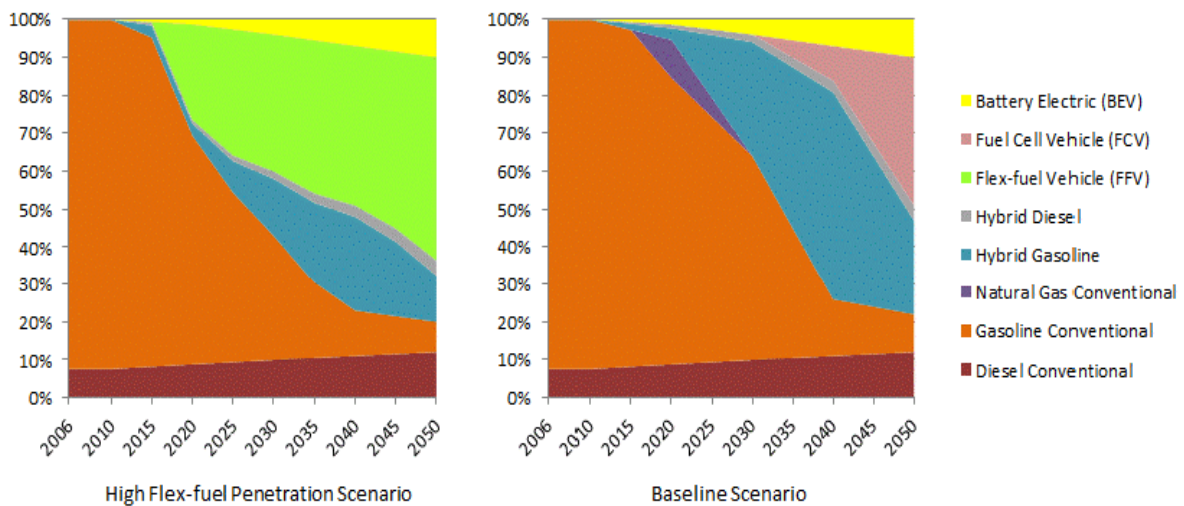
3: In this run of SATIM, the assumptions favoured a hydrogen supply chain and fuel cell vehicles over battery electric vehicles but this could well shift given higher learning rates for BEV and higher production and distribution costs for hydrogen. This was not explored for this paper as it has no bearing on the scenario modelling to assess biofuels demand potential as both BEV and hydrogen technologies act to displace liquid fuels.

For the high flex-fuel penetration scenario it was assumed that flex-fuel technology would only penetrate the passenger car and SUV modes but at quite high rates of penetration. These displace much of the growth in sales of electro-mobility technologies assumed in the baseline. The minibus taxi and bus modes are not assumed to adopt flex-fuel technology although heavy-duty solutions for bio-ethanol exist currently.

**Table 3:** Assumed Penetration Rates for High Flex-fuel Penetration Scenario (% of Sales of New Vehicles)

Mode	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Passenger Cars	0%	0%	0.1%	25%	33%	36%	40%	42%	47%	53%
SUVs	0%	0%	0.1%	25%	50%	49%	49%	50%	51%	52%

The assumed evolution of passenger car technologies over the time horizon of the model for the High Flex-Fuel Penetration and Baseline scenarios is shown below in **Figure 5**.



**Figure 5:** Assumed Evolution of Passenger Car Technologies for High Flex-Fuel Penetration and Baseline Scenarios

The fuel economy of flex-fuel cars using E85 relative to conventional gasoline technology was estimated from EPA data of models sold in the United States. The fuel economies of 87 flex-fuel models for both gasoline and E85 fuelling options were compared using the EPA 2015 *Fuel Economy*

*Datafile* (EPA, 2014). On average, the specific fuel economy (MJ/km) of flex-fuel cars operating on E85 is nearly 4% better than when operating on gasoline with 87% of models having better fuel economy on E85 and with the comparisons ranging between 4% worse and 13% better. Although the average engine displacement of 4.2 litres for all cars in the database is not representative of light passenger vehicles in South Africa, data for cars with smaller displacement within the dataset is consistent with the average results. In the absence of South African data, it is therefore appropriate to use this US data for the purpose of a preliminary demand estimate. The key assumptions in the model regarding fuel economy are presented in Table 5.

**Table 4:** Key Model Assumptions for Fuel Economy

Vehicle Category/Mode	Average Annual Fuel Economy Improvement of New Vehicles	Average Annual Fuel Economy Deterioration of Old Vehicles	Flex Fuel Energy Intensity Relative to Gasoline
Car	1%	0.05%	96.10%
SUV	1%	0.05%	96.10%
Motorcycle	0.5%	0.05%	96.10%
Minibus Taxi	1%	0.05%	96.10%
Bus	0.5%	0.05%	98.40% <sup>1</sup>

1: Relative to natural gas, not gasoline.

For the contribution of blends with fossil fuel gasoline, diesel and aviation kerosene to biofuel demand it was assumed that small amounts of blending start in 2015 and reach the upper ceiling of the mandatory blending regulations limits (DoE, 2012) by 2020, remaining there till 2050 as shown in Table 5 below.

**Table 5:** Assumed Blend Penetration Rates of Biofuels into Gasoline, Diesel & Kerosene

Blend	2006 <sup>6</sup>	2010	2015	2020	2025	2030	2035	2040	2045	2050
Bio-Ethanol in Gasoline	0%	0%	0.5%	10%	10%	10%	10%	10%	10%	10%
Biodiesel in Diesel	0%	0%	0.5%	5%	5%	5%	5%	5%	5%	5%
Bio-kerosene in Aviation Kerosene	0.0%	0.0%	0.1%	10%	10%	10%	10%	10%	10%	10%

## Representation of the aviation sector

SATIM does not currently represent stock of aircraft and demand is not projected as useful energy as is the case for road and rail transport. Final energy demand is projected by assuming that it is driven by GDP, rising in proportion linked by an assumed elasticity. In the absence of historical assessment,

<sup>6</sup> The base year of SATIM is 2006, which was when the last reliable energy balance for South Africa was published. The energy balance for 2010 is expected to be published this year, which will serve as an updated baseline for SATIM.

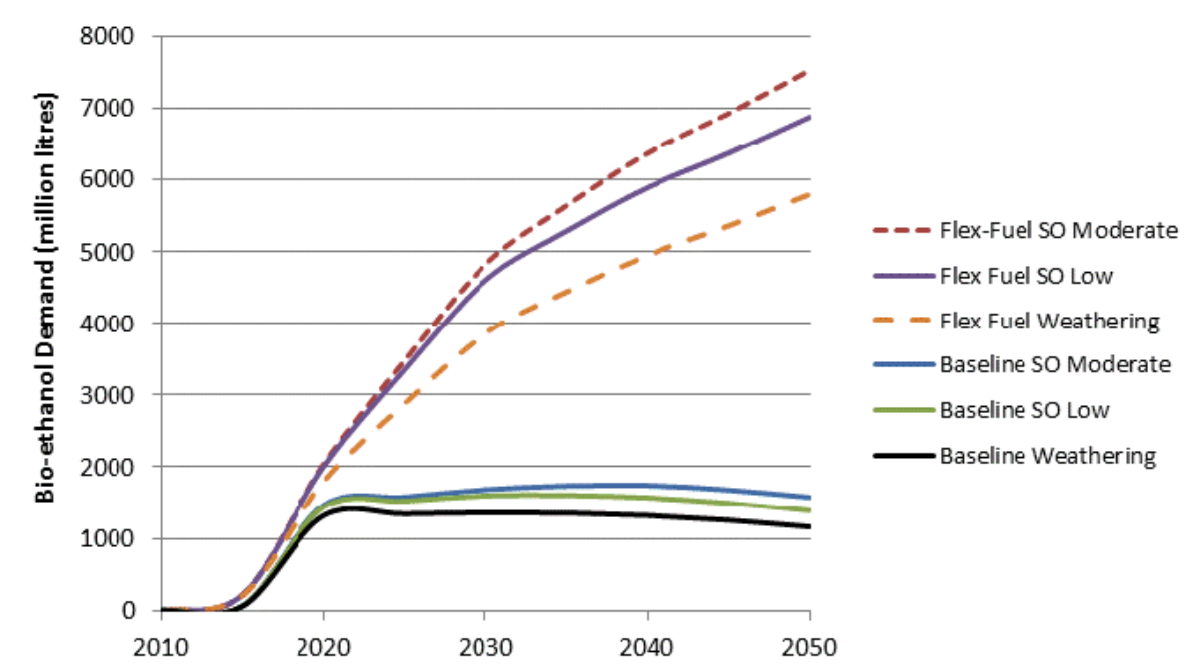
this is currently set to 1. This leads to quite divergent outcomes for the economic scenarios as shown in Table 6. The authors aim to address these issues in time for the final paper.

**Table 6: SATIM Final Demand Projection of Jet Kerosene for Economic Scenarios (PJ)**

Scenario	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Weathering	77.9	82.1	88.7	99.0	109.7	120.6	130.6	105.2	115.0	124.9
SO Low	77.9	82.1	96.0	110.0	132.5	155.0	167.0	179.1	191.1	203.1
SO Moderate	77.9	82.1	91.4	111.5	136.4	168.5	201.7	198.6	230.4	262.5

## Results

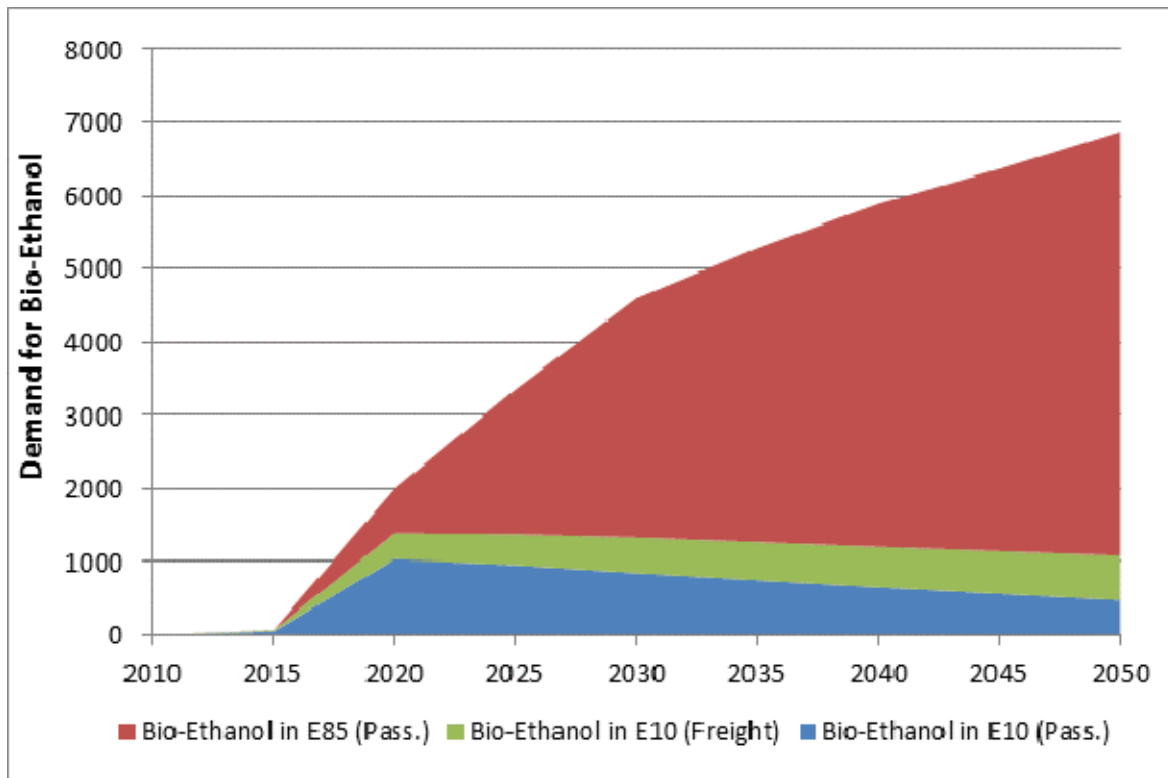
Preliminary results for the assessment of future potential demand for biofuels by transport are presented below. As discussed above, demand from road passenger modes was assessed in the most detail with a vehicle parc model while demand from aviation and freight was estimated using previous runs of SATIM.



**Figure 6:** Estimated demand for bio-ethanol from Road Passenger and Freight modes for the High Flex-fuel Penetration Scenario (E85 & E10) compared to the Baseline Scenario (E10) for three economic growth scenarios

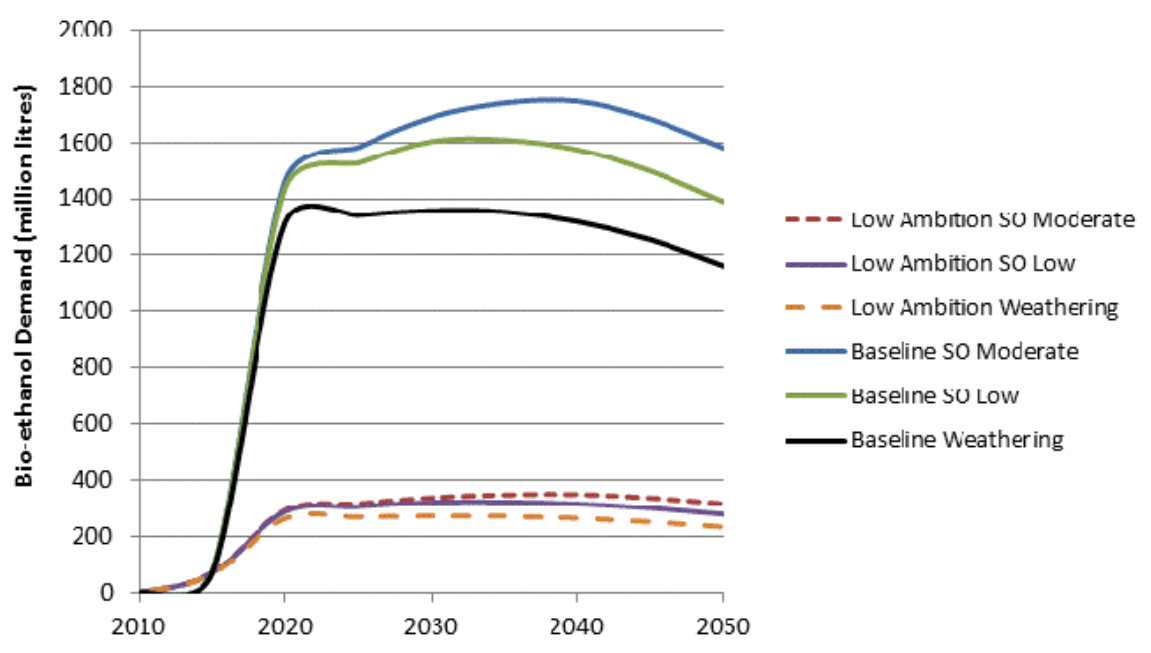
### Bioethanol

The impact of E85 uptake by high flex-fuel sales from 2020 onwards can be seen in a breakdown of sources of demand for the SO Low economic growth scenario presented in Figure 7. Demand for E10 from the passenger mode drops over the time horizon due to growth in competing electro-mobility technologies. The contribution from freight comes mainly from light commercial vehicles.



**Figure 7:** Demand for Bioethanol by Fuel Blend and Mode for the SO Low Economic Growth Case of the High Flex-Fuel Penetration Scenario

Assuming zero penetration of E85 and a mandatory blend ratio for gasoline of E10, by 2035 demand for bioethanol is between 1353 million litres and 1738 million litres, with the passenger car portion accounting for about 5% of energy demand in that mode. Assuming high penetration of E85 (flex-fuel scenario), by 2035 bioethanol demand is between 4441 million litres and 5639 million litres, the passenger car portion of this accounting for about 22% of energy demand in that mode.

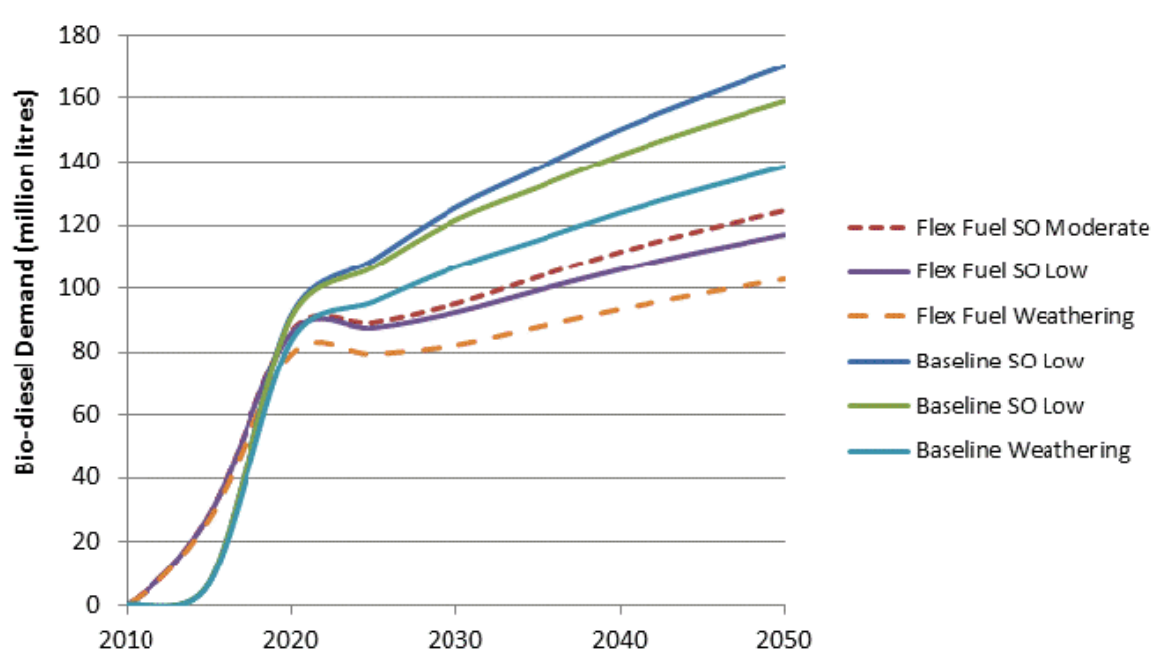


**Figure 8:** Estimated Demand for Bio-ethanol from Road Passenger and Freight Modes for the baseline scenario (E10) compared to Low Ambition Scenario (E2) for 3 economic growth scenarios

As can be seen in Figure 8 assuming zero penetration of E85 and a low ambition mandatory blend ratio for gasoline of E2, by 2035 demand for bioethanol is between 270 million litres and 350 million litres. This suggests that the range of ethanol blending ratio provided by the regulation gives rise to considerable uncertainty of the future demand for bioethanol.

### Biodiesel

Due to time constraints, the demand for biodiesel in all six scenarios was estimated only for the passenger mode due to time constraints. This is presented in Figure 9. This demand results solely from blending bio-diesel into conventional diesel (B5).



**Figure 9:** Estimated Demand for Biodiesel from Road Passenger Mode only for a high flex-fuel penetration scenario compared to a no flex-fuel baseline for 3 economic growth scenarios

The demand for biodiesel from the freight mode was assessed from previous SATIM runs for the SO Low scenario. These runs resulted in high penetration of natural gas in freight in the long term, which limited biodiesel penetration. These results are presented in Table 7 below:

**Table 7:** Demand for Biodiesel Resulting from B5 uptake in Road and Rail Freight for the SO Low Economic Growth Scenario (million litres)

2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
0.0	0.0	37.0	424.2	453.4	482.6	486.8	491.0	496.1	501.2 <sup>1</sup>

*1: This will be much higher if natural gas does not emerge as a significant road freight fuel*

This preliminary assessment suggests that if the mandatory blending regulations are implemented over the next five years, demand for biodiesel will likely reach 500 million litres by 2020 for all transport modes. How much demand rises thereafter will depend on whether or not natural gas emerges as a significant fuel for freight transport.

Due to time constraints and uncertainty regarding whether bio-kerosene would be used straight or as a blend, demand for this biofuel was only assessed for a 10% blend under the SO Low economic growth scenario. The projected penetration is presented in Table 8.

**Table 8:** Demand for Bio-kerosene Aviation given a 10% blend with conventional kerosene for the SO Low Economic Growth Scenario (million litres)

2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
0	0	2.8	323.4	389.6	455.8	491.2	526.6	562.1	597.5

## Discussion and Conclusion

These results provide the following insights:

- Under scenarios that see zero E85, consumption of biofuels is moderate, peaking at only 3.5% (E2) – 6.5% (E10) of all fuel consumption in energy terms between 2020 and 2030 because of the relatively low energy density of ethanol. However, if we assume flex fuel cars are introduced fairly aggressively, biofuel consumption expands rapidly. However, it is highly unlikely that flex-fuel cars will be introduced at this pace in the absence of policies to incentivise uptake. This could include policies that have been used to influence consumer car purchasing choices, including tax rebates, as well as new policies such as rebates related to carbon emissions.
- Under all scenarios used in the modelling exercise, the scale of biofuels demand will have important implications on land use. However, the amount of land needed is heavily influenced by the yields of feedstock crops, and how efficiently these can be converted into fuel. If South African bioethanol feedstock growers producers can achieve similar yields to those in Brazil (around 7000 litres per hectare), under low GDP growth and with a full E10 mandate but no flex-fuel cars, around 228,000 has would be needed (for ethanol) in 2035. Demand may be met using less land if production comes from higher yielding crops, such as sugar beet currently being trialled in one South African farm (Cradock), where yields of at least 10,000 litres per hectare are expected (Nasterlack, von Blottnitz, & Wynberg, 2014). If so, meeting an E10 blend by 2035 may require 174,000 has. If flex-fuel technology comes on stream, the area of land needed would increase proportionately to between 520,000 to 740,000 has, depending on yields. Of course, if yields are lower, more land would be required.

**Table 9: Demand for land to meet bioethanol demand in 2035 under different yield and growth assumptions**

Area of land (has) under different economic scenarios in 2035			
	Weathering	So Low	SO Moderate
<b>Low yield (7000l/ha)</b>			
Zero E85; E10 mandatory blend	193,286	228,571	248,286
High penetration of E85	634,429	742,857	805,571
<b>High yield (10,000l/ha)</b>			
Zero E85; E10 mandatory blend	135,300	160,000	173,800
High penetration of E85	444,100	520,000	563,900

- Although demand for biodiesel is projected to be lower than bioethanol in almost all scenarios, lower expected yields (of around 1000 litres/ hectare) mean proportionally more land is needed. The demand for 487 million litres to satisfy a B5 mandate in a low growth scenario would require 486,000 has of land. A 10% blend of jet fuel derived from biofuels would similarly call for a similar area (491,000 has).

- At present, the area under sugarcane production in South Africa is 378,985 has. Meeting bioethanol demand needed for zero E85 scenarios would therefore require a major shift in orientation of sugar production to biofuels, or more likely, some feedstock would need to be sourced from abroad. Imports would be essential if flex-fuel cars were introduced.

Several areas require further analysis which will be included for the final IEW paper:

- Whether, if the biofuels supply chain and its cost is fully represented in SATIM with likely import prices of imported regional biofuel, the model will select biofuels as cost optimal for the supply of energy services under CO<sub>2</sub> constraint.
- Development of scenarios of the likely cost of biofuels imported from the region and the effect on the least cost penetration of biofuels in the South African market.
- Improvements in the demand side representation of road freight and air travel.
- Additives are needed when manufacturing biofuels. For example, ED95 contains ignition improvers, denaturants, lubricants and anticorrosive additives (SEKAB 2013). It is unclear if the costs of these additives used when refining biofuels adds significant costs to forecourt price. The current model does not include a cost factor and inclusion of ED95 would require an assessment of this. Clearly the penetration of the other biofuels in the model assumes at least cost parity with conventional fuels.

## References

- Boeing. (2015, January 14). *Boeing, Embraer open aviation biofuel research center in Brazil*. Retrieved from Biomass Magazine: <http://biomassmagazine.com/articles/11431/boeing-embraer-open-aviation-biofuel-research-center-in-brazil>
- Cartwright, A. (2007). *Biofuels trade and sustainable development: An analysis of South African bioethanol*. London: International Institute of Environment and Development.
- DEA. (2014). *South Africa's Greenhouse Gas (GHG) Mitigation Potential Analysis*. Pretoria, South Africa: Department of Environmental Affairs Mitigation Potential Analysis.
- DoE. (2012, August 23). Petroleum Products Act, 1977: Regulations Regarding the Mandatory Blending of Biofuels with Petrol and Diesel - No. R. 671. *Government Gazette No. 35623, 566*. Department of Energy, Republic of South Africa.
- DoE. (2013). *DRAFT 2012 INTEGRATED ENERGY PLANNING REPORT*. Pretoria: Department of Energy, Republic of South Africa.
- DOE. (2013, November 21). Integrated Resource Plan for Electricity (IRP) 2010 - 2030 Update Report 2013. Pretoria: Department of Energy, Republic of South Africa.
- DOE. (2014, January 15). Draft Position Paper on the South African Biofuels Regulatory Framework - The First Phase of the Implementation of the Biofuels Industrial Strategy. *Government Gazette, Notice 24 of 2014(No. 37232)*. Department of Energy, Republic of South Africa.



- Eisentraut, A. (2010). *Sustainable Production of Second-Generation Biofuels Potential and perspectives i major economies and developing countries*. Paris, France: International Energy Agency (IEA).
- EPA. (2014). *Download Fuel Economy Data*. Retrieved from US Environmental Protection Agency (EPA) - [www.fueleconomy.gov](http://www.fueleconomy.gov): <http://www.fueleconomy.gov/feg/download.shtml>
- Henley, G. (2014). *Markets for Biofuel Producers in southern Africa: Do recent changes to legislation in the region and EU bring new opportunities?* E. P. H. Request, ODI.
- Köster, H. (2012, April). Biofuels in South Africa--where do we stand. *AllAboutFeed magazine*.
- Kretschmer, B., Allen, B., Kieve, D., & Smith, C. (2013). *The Sustainability of Advanced Biofuels in the EU: Assessing the sustainability of a list of wastes, residues and other feedstocks set out in the European Commission's proposal on Indirect Land Use Change (ILUC)*. London: Institute for European Environmental Policy (IEEP).
- Kumwenda-Mtambo, O. (2014, August 7). *SAA to develop tobacco biofuel with Boeing*. Retrieved from Business Day Live: <http://www.bdlive.co.za/business/transport/2014/08/07/saa-to-develop-tobacco-biofuel-with-boeing>
- Lufthansa. (n.d.). *Sustainable alternative fuels*. Retrieved January 2015, from <http://www.lufthansagroup.com>: <http://www.lufthansagroup.com/en/responsibility/climate-and-environmental-responsibility/keroseneandemissions/biofuel-at-lufthansa.html>
- Merven, B., Stone, A., Hughes, A., & Cohen, B. (2012). Quantifying the energy needs of the transport sector for South Africa: A bottom-up model. *ERC Working Paper*. Energy Research Centre (ERC), University of Cape Town.
- Nasterlack, T., von Blottnitz, H., & Wynberg, R. (2014). Are biofuel concerns globally relevant? Prospects for a pioneer bioethanol project in South Africa. *Energy for Sustainable Development, 23*, 1-14.
- SEKAB. (n.d.). *ED95 – THE GREEN BIOFUEL FOR HEAVY TRANSPORT*. Retrieved 2014, from <http://www.sekab.com/biofuel/ed95>
- Strömberg, J. (2013, March 25 – 27). Conference Presentation - Bioethanol in heavy duty transport. 20th International Symposium on Alcohol Fuels. (ISAF).
- Strömberg, J. (2014, December 22). Personal Communication on the Cost of the Additive to ED95 Fuel. Södertälje, Sweden: Director Sustainable Solutions, Scania CV AB.
- UNCTAD. (2014). *The State of the Biofuels Market: Regulatory, Trade and Development Perspectives*. Geneva: United Nations Conference on Trade and Development.
- USDA. (2013). *South Africa Looks to Develop Domestic Biofuels Production*. Pretoria, South Africa: United States Department of Agriculture Foreign Agriculture Service.

