UNU-WIDER | 30 YEARS OF RESEARCH FOR DEVELOPMENT

WIDER Working Paper 2015/148

Modelling growth scenarios for biofuels in South Africa's transport sector

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December 2015

United Nations University World Institute for Development Economics Research

wider.unu.edu

Abstract: South Africa has a nascent biofuels industry and emerging regulatory framework, and although water scarcity limits local supply potential, that of the southern African region appears substantial. This paper describes the results and modelling approach of an assessment of potential biofuel demand from South Africa's transport sector to 2050 that may respond to this supply under a number of scenarios. Findings suggest implementing biofuel mandates will require significant additional areas of land for local supply, but that the bulk of potential demand is highly dependent on the evolution of transport technology, particularly the penetration of flex-fuel passenger cars.

Keywords: biofuels, transport, demand projection, South Africa
JEL classification: O13, N77, Q21, Q42, Q47

Acknowledgements: A version of this paper was presented at the 34th International Energy Workshop (IEW 2015) in Abu Dhabi and support from (UNU-WIDER) and the South African National Research Foundation (NRF) is acknowledged. The authors also gratefully acknowledge the support of the Department of Science and Technology (DST) of the Republic of South Africa and the South African National Energy Development Institute (SANEDI).

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This study has been prepared within the UNU-WIDER project 'Regional Growth and Development in Southern Africa'.

ISSN 1798-7237 ISBN 978-92-9256-037-9 https://doi.org/10.35188/UNU-WIDER/2015/037-9

Typescript prepared by Ayesha Chari for UNU-WIDER.

UNU-WIDER gratefully acknowledges the financial contributions to the research programme from the governments of Denmark, Finland, Sweden, and the United Kingdom.

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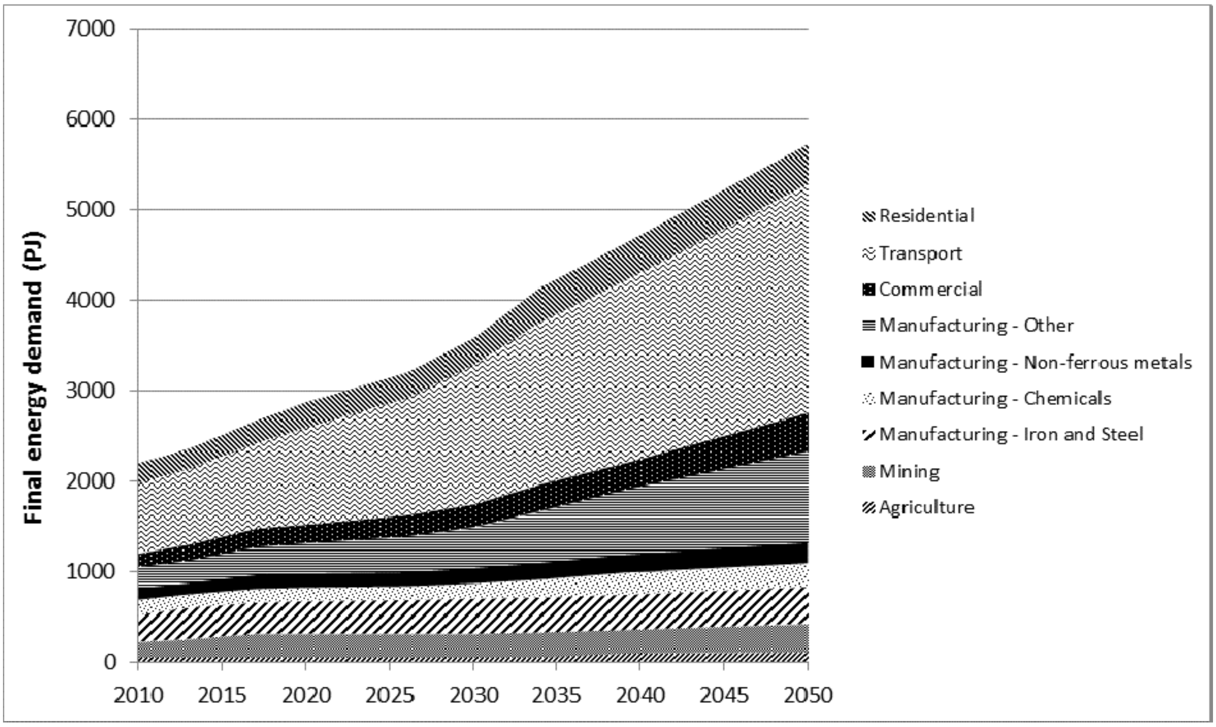
1 Introduction

1.1 Energy demand in South Africa's transport sector

Transport is a major consumer of energy in South Africa, consuming 28 per cent of final energy (Merven et al. 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 2013a).

Figure 1: Long-term (2010–50) projected growth in energy demand by sector for South Africa



Source: South Africa Integrated Energy Planning Report 2012 (DoE 2013a).

While this projected increase in energy demand is expected to lead to rising non-renewable liquid fuel consumption, a number of variables are expected to moderate the rate of growth. One of the most important factors is to what degree alternative sources of energy, including biofuels, might 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. However, biofuels production was not explicitly represented in the model because at the time firm policy decisions on biofuels blending had not been made (DoE 2013a). An earlier version of the South Africa Times Model (SATIM) framework 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 stabilization by 2050 (Merven et al. 2012). However, these measures excluded biofuels 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 compared to the other measures considered in the study such as shifting from road to rail, natural gas vehicles and electro-mobility technologies. For road and rail transport fuels, a maximum potential of locally sourced biofuels of 27 per cent by 2050 was assumed, and for aviation biokerosene was assumed to contribute 5 per cent of fuel requirements in 2050. This premise was based on first-generation biofuels supplying demand in the early years shifting later to second-generation biofuels derived from agricultural residues. The potential of second-generation biofuels was assessed from an International Energy Agency study (Eisentraut 2010), although this study seems to indicate that most agricultural residues produced in South Africa have existing uses, for instance, as fuel for co-generation, mulch, or compost.

Given the promulgation of mandatory blending regulations in South Africa and growing interest in biofuel production in the region, 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 on mitigating emissions from the transport sector.

1.2 Biofuel policy in South Africa

At present, despite regulations stipulating mandatory blending with gasoline and diesel by 1 October 2015 (DoE 2012; DoE 2013c), 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.[1] Although South Africa produced and consumed significant volumes of biofuels in its fuel mix in the middle of the twentieth 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).[2] 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 the industry was not compelled to act (USDA 2013). As well as a mechanism to enforce blending mandates, a licencing mechanism and an appropriate pricing framework were missing from the policy framework.
- *Conflicting policy aims*: Another interpretation sees the government's attempt to use biofuels policy as a means to achieve more equitable growth as a challenge to, if not incompatible with, swift industry growth (Köster 2012). The government's aim to empower poor parts of country that were underserved by infrastructure and promote strategies that maximized job creation inevitably made attracting private investment

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[1] 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 and inks and in the pharmaceutical industry (UNCTAD 2014).

[2] Tongaat Hulett estimate that constructing 5 to 6 bioethanol plants to be linked to 14 sugar mills involves substantial investment, estimated at more than R10 billion (Tongaat Hulett 2013).

difficult. It also led to prolonged discussions about which crops policy should be included and promoted through targeted support. The South African Biofuels Industrial Strategy ruled out the use of maize owing to concerns that this would raise maize prices and reduce availability in domestic and regional markets, especially at times of shortages. Both sorghum and sugarcane are eligible feedstocks for fuel ethanol, but which of these crops the government should prioritize for support continues to be debated. An initial study reported on by the South Africa's Department of Energy indicated production from sorghum would be significantly cheaper (DoE 2013a).

1.3 Recent adjustments to biofuels policy

Between 2011 and 2013, the government revised its policies, releasing a draft position paper in late 2013 to address some gaps in the existing policy framework (DoE 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 incentivize blending of biofuels with fuel. Blending targets are set at between E2 and E10 for bioethanol and B5 for biodiesel (DoE 2012).[3]

At present, some parts of the policy require further elaboration[4] and investors are still analysing whether 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 (DoE 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 2010; Henley 2014).

The draft position paper proposes a biofuels pricing framework that aims to provide a subsidy scheme with a return on assets of 15 per cent with sorghum (bioethanol) and soya (biodiesel) as model crops. Furthermore, licence applications have been processed for four bioethanol plants with a capacity of 392 million litres licenced using sorghum, sugar beet, and sugar cane as feedstock and three biodiesel plants with a capacity of 470 million litres with soya, canola, and waste oil feedstock (DoE 2014). Of these, construction has only commenced on one waste oil plant with a capacity of 12 million litres, with developers unwilling to risk capital until the final position paper outlining the final subsidy scheme is agreed to and released. Given the 18–24 month construction time of the licenced plants, at the time of writing it is assumed that the blending deadline of October 2015 will likely be missed by some margin (Greve 2015).

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 the production of biofuels for future supply (Boeing 2015; Kumwenda-Mtambo 2014; Lufthansa, n.d.).

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[3] In other words, the targeted blending ratio for fuel ethanol in petrol is between 2 and 10 per cent. The targeted blending ratio for biodiesel in diesel is 5 per cent.

[4] For example, transportation and tax issues need to be resolved.

1.4 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 the scale of production needed to supply 2 per cent of 20 billion litres, the size of South Africa's fuel pool in 2013 (DoE 2014). Although useful for understanding the potential size of the current market, this does not given insights into the scope for future growth and the market size in the medium term. It is therefore difficult to determine whether South Africa can 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 be an economically efficient way to increase liquid biofuel consumption in South Africa's transport sector and may contribute to economic development in neighbouring countries.[5]

To address this gap, we develop models 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 (DoE 2013; Merven et al. 2012). We also include preliminary estimates for biofuels uptake in the aviation sector to reflect growing interest from aviation companies seeking to reduce their emissions.

2 Methodology

2.1 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 SATIM framework for energy systems modelling in a simple, transparent, and distributable spreadsheet, making use of 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 vintage 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, 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 framework is presented in the study by Merven et al. (2012). 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 Equation (1). The technology segment fuel demands were summed to yield the vehicle parc demand and compared to historical fuel sales for calibration purposes.

$$D_{f,k} = \sum_{j=Y1}^{j=k} \sum_{i=1}^{i=c} N_{i,j} \times FC_{i,j} \times VKT_{i,j} \,. \tag{1}$$

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[5] 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.

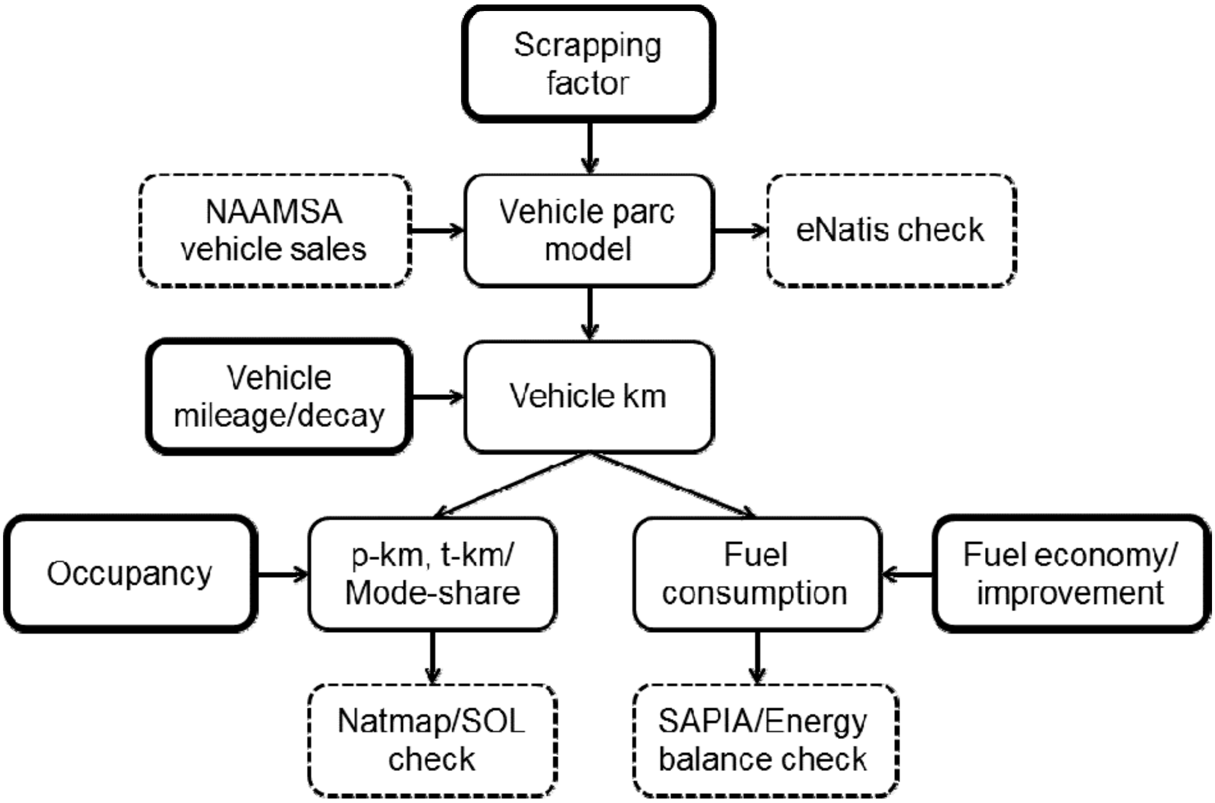
Here, $D_{f,k}$ represents the demand for fuel f in year k; $N_{i,j}$, the number of vehicles in technology segment i with model year j ($Y1$ being the first model year), where technologies numbered 1 to C all use fuel f; $FC_{i,j}$, the estimated fuel consumption for technology segment i with model year j; and $VKT_{i,j}$, 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 assumptions are as follows:

- A vintage profile derived from realistic scrapping curves that enabled vehicle stock to be estimated from sales of historical vehicles disaggregated by vehicle type; the curves were calibrated so that the stock estimate closely matched a vehicle registration database.
- An assessment of annual vehicle mileage for each vehicle class and the rate at which this decays as the vehicle ages.
- 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 (bold boxes) and validations against local data sources (dashed boxes)



Note: p-km, transport demand in passenger-km; t-km, freight demand in ton-km.

Source: Authors' compilation.

The reduced form of the model developed for this study reduces the size of arrays by condensing the 40-year time horizon of the model into 5-year bins so that calculations can be comfortably handled in a spreadsheet simulation model using Equation (2) for bins of size *s* years:

$$N_{t,k,j} = \left\{ \frac{VKM_{t,j} - \sum_{[i=1 \text{ to } j-1]} \left(N_{t,i} M_{t,i} \right)}{\sum_{[n=1 \text{ to } s]} \left(\lambda_{t,n} M_{t,n} \right)} \right\} \times \sum_{n=[s(k-j)+1] \text{ to } [s(k-j+1)]} \lambda_{t,n} . \qquad (2)$$

Here, $N_{t,k,j}$ represents the number of vehicles in technology segment *t* of vintage bin *j* still operating at the end year of bin *k*; $VKM_{t,j}$, the demand for vehicle kilometres from service provided by technology segment *t* at end year of bin *j*; $\lambda_{t,n}$, the scrapping coefficient of technology segment *t* of age *n* years; and $M_{t,n}$, the annual mileage of vehicles in technology segment *t* of age *n* years. Essentially, the model is driven by the demand for vehicle kilometres of technology segment *t* ($VKM_{t,j}$) which could be projected econometrically or, in the case of this study, by a time budget model described in Merven et al. (2012) where an increasing demand for private passenger kilometres is essentially driven by increasing household income driving access to private vehicles. The first part of Equation (2) in curly brackets estimates the number of vehicles in bin *j* required to meet projected demand in the end year of bin *j* not met by other bins, and the second part simply reduces this with increments of the applicable scrapping curve of *s* years wide that get smaller as bin *k* gets further from bin *j*.

2.2 Scenario development

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

The SATIM framework includes a computable general equilibrium (CGE) model that generates household income data and sector growth rates required for the energy model. This CGE model is 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. Behavioural change in terms of consumers choosing public modes of transport over private ones when they have the means for private transport was not considered for this paper, and passenger car use increases with increased household income in the version of the model used in this study.

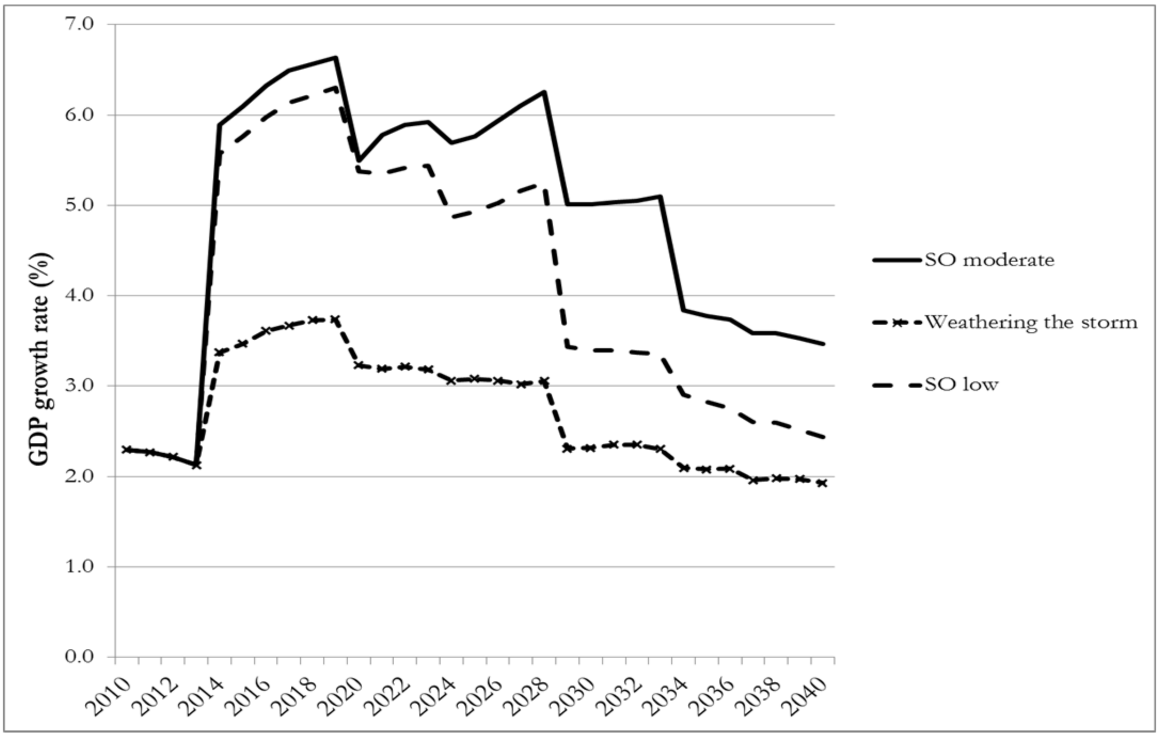
Table 1: Summary data for economic growth scenarios

IRP scenario	2040 Growth (%)	2007–2040 Average growth (%)
SO moderate	3.5	4.7
SO low	2.4	4.0
Weathering the storm	1.9	2.7

Note: IRP, integrated resource plan; SO, system operator.

Source: Authors' compilation (DoE 2013b).

Figure 3: Assumed GDP growth rates for economic growth scenarios



Note: SO, system operator.

Source: Authors' compilation based on DoE 2013b.

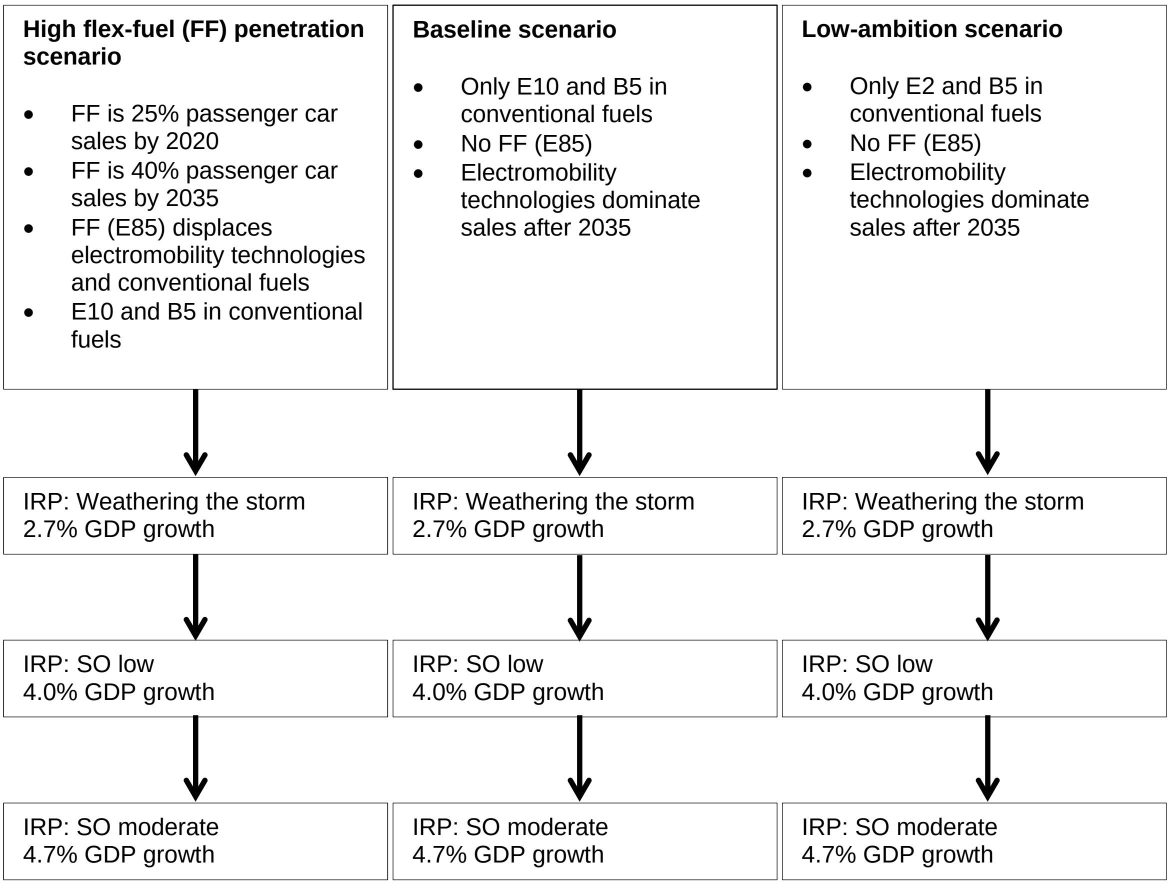
The technology pathways that were considered for biofuels to supply transport energy services were as follows:

- Conventional gasoline internal combustion and hybrid technology fuelled by a blend of gasoline and between 2 per cent bioethanol (E2) and 10 per cent bioethanol (E10) according to the Mandatory Blending Regulation.
- Conventional diesel internal combustion and hybrid technology fuelled by a blend of diesel with 5 per cent biodiesel (B5) according to the Mandatory Blending Regulation.
- So-called flex-fuel internal combustion technology fuelled by a blend of gasoline and 85 per cent 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 per cent of a blend with conventional aviation kerosene.

A bioethanol pathway to supply heavy-duty freight using ED95, which is 95 per cent ethanol blended with 5 per cent of an additive containing ignition improver, lubricant, and corrosion protection (SEKAB, n.d.), was not considered in any of the scenarios but may be significant. Scania (Strömberg 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 per cent and 25 per cent of the total fuel cost in different markets but with a projected operating cost per kilometre 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 summarized in Figure 4. Three economic scenarios are fed into each of the technology scenarios resulting in nine scenarios in total.

Figure 4: Modelling scenarios for the preliminary assessment of biofuels demand



Source: Authors' compilation based on study scenarios adopted.

2.3 Modelling assumptions

Owing 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 for biofuels from freight (see Table 7), given that the 5 per cent blending ratio for biodiesel in diesel as per the Mandatory Blending Regulation is applied.

However, the passenger mode is represented in some detail. Assumptions for the penetration rates of technologies and blending 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 2.

Table 2: Assumed baseline penetration rates of passenger car technologies

Technology	Fuel	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Conventional diesel	Diesel	7.6	7.6	8.2	9.0	9.4	10	10.5	11	11.5	12
Conventional gasoline	Gasoline	92	92.3	84.1	76	64.9	54	34.5	15	12.5	10
Conventional natural gas	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
Flex-fuel vehicle (FFV)[a]	E85	0	0.0	0.0	0	0.0	0	0.0	0	0.0	0
Fuel cell vehicle (FCV)	Hydrogen	0	0.0	0.0	0	0.0	0	4.6	9	24.1	39
Battery electric vehicle (BEV)[b]	Electricity	0	0.0	0.7	1	2.7	4	5.5	7	8.5	10
Total		100	100	100	100	100	100	100	100	100	100

Note: All values represent the per cent of new vehicle sales. A similar table was also developed for the other passenger modes: sport utility vehicles (SUVs), motorcycles, minibus taxis, and buses. Tables for these passenger modes are available in a spreadsheet model. [a]Baseline for FFV assumes no penetration of E85 using technologies in South Africa. [b]In this run of the South Africa Times Model (SATIM), the assumptions favoured a hydrogen supply chain and FCVs over BEVs but this could well shift given higher learning rates for BEVs and higher production and distribution costs for hydrogen. This aspect was not explored in this study as it has no bearing on the scenario modelling to assess the demand potential for biofuels as both BEVs and hydrogen technologies act to displace liquid fuels.

Source: Authors' compilation based on scenarios adopted.

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 (Table 3). These displace much of the growth in sales of electromobility technologies assumed in the baseline. The minibus taxi and bus modes are not assumed to adopt flex-fuel technology although heavy-duty solutions for bioethanol exist currently.

Table 3: Assumed penetration rates for high flex-fuel penetration scenario

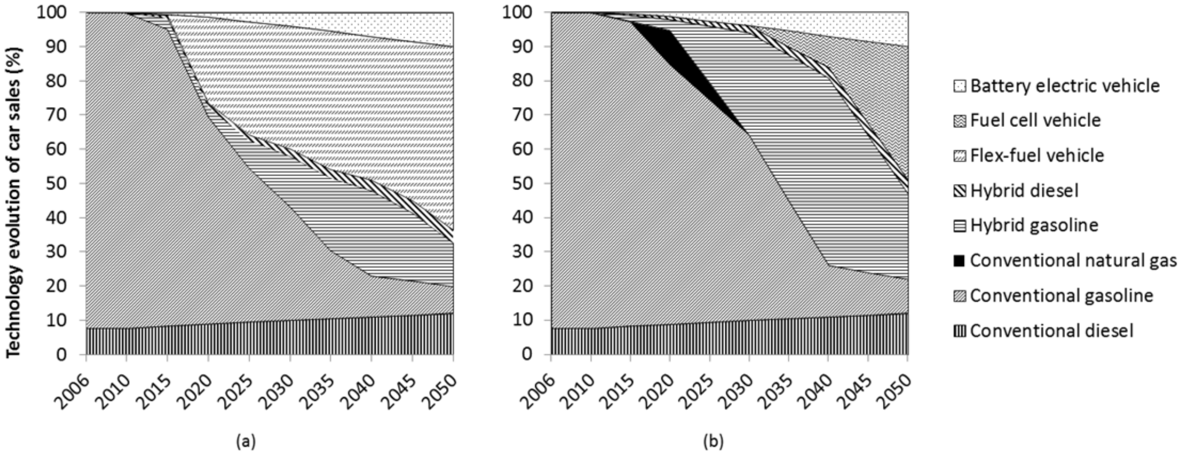
Mode	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Passenger cars	0	0	0.1	25	33	36	40	42	47	53
SUVs	0	0	0.1	25	50	49	49	50	51	52

Note: All values represent the per cent of new vehicle sales.

Source: Authors' compilation based on scenarios adopted.

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 in Figure 5.

Figure 5: Assumed evolution of passenger car technology sales for (a) high flex-fuel penetration and (b) baseline scenarios



Source: Authors' compilation based on scenarios adopted.

The fuel economy of flex-fuel cars using E85 relative to conventional gasoline technology was estimated from a comparative analysis of fuel economy data for 87 flex-fuel models considering both gasoline and E85 fuelling options as published in the EPA 'Fuel Economy Guide Datafile' (EPA 2014). On average, the specific fuel economy (megajoule per kilometre) of flex-fuel cars operating on E85 is nearly 4 per cent better than when operating on gasoline, with 87 per cent of models having better fuel economy when operating on E85 and with the comparisons ranging between 4 per cent worse and 13 per cent 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 suitable data for South Africa, it is appropriate to use data from the United States for the purpose of a preliminary demand estimate. The key assumptions in the model regarding fuel economy are presented in Table 4.

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[a]

Note: [a]Relative to natural gas, not gasoline.

Source: Authors' compilation based on Merven et al (2012), EPA (2014), and authors' assumptions.

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 (DoE 2012) by 2020, remaining there till 2050 as shown in Table 5.

Table 5: Assumed blend penetration rates of biofuels into gasoline, diesel, and kerosene

Blend	2006[a]	2010	2015	2020	2025	2030	2035	2040	2045	2050
Bioethanol 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
Biokerosene in aviation kerosene	0.0	0.0	0.1	10	10	10	10	10	10	10

Note: All figures in per cent. [a]The base year of SATIM is 2006, which was when the last reliable energy balance for South Africa was published. A revised energy balance for 2010 is expected to be published soon, which will serve as an updated baseline for SATIM.

Source: Authors' compilation based on scenarios adopted.

2.4 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 gross domestic product (GDP), rising in proportion linked by an assumed elasticity. In the absence of historical assessment, this is currently set to '1'. This leads to quite divergent outcomes for the economic scenarios as shown in Table 6.

Table 6: SATIM final demand projection of jet kerosene for economic scenarios

Scenario	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Weathering the storm	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

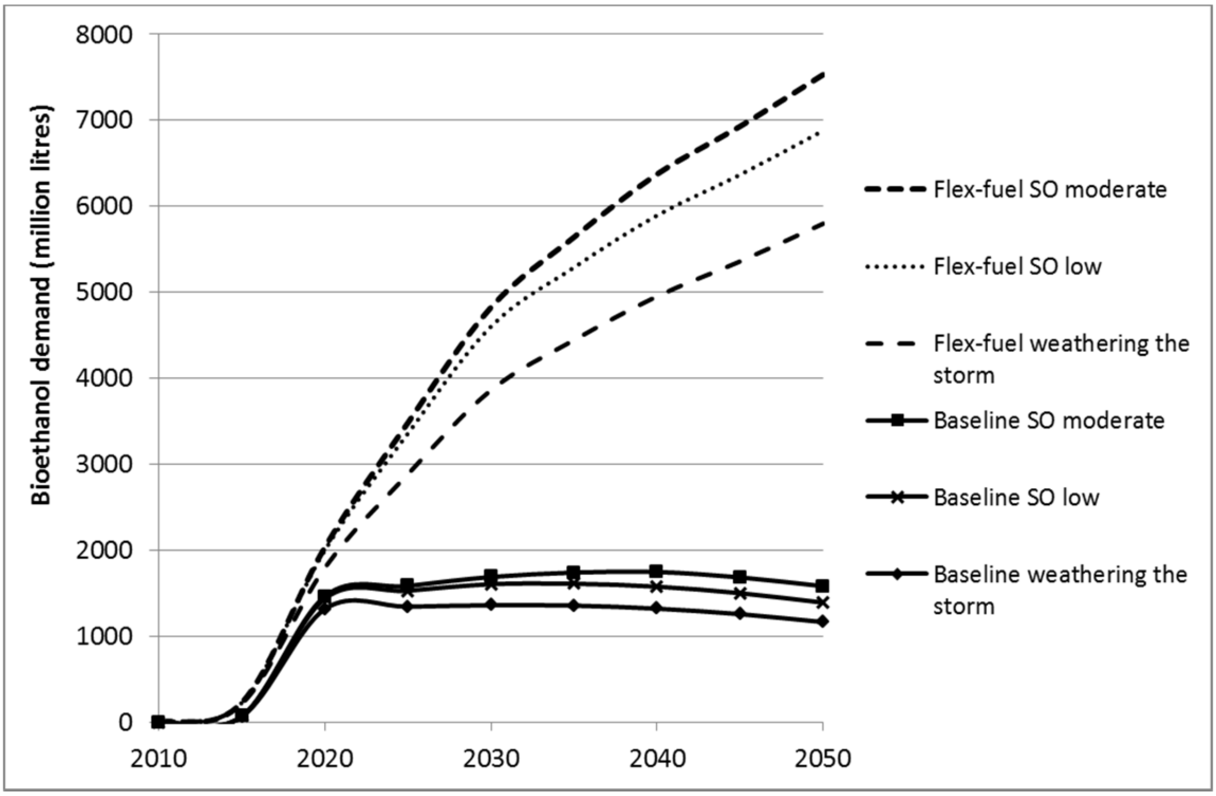
Note: All figures in petajoule.

Source: Authors' compilation based on outputs from SATIM model.

3 Results

Preliminary results for the assessment of future potential demand for biofuels by transport are presented in Figure 6. As discussed in the previous section, demand from road passenger modes of transport was assessed in the most detail with a vehicle parc model whereas demand from aviation and freight was estimated using previous runs of SATIM.

Figure 6: Estimated demand for bioethanol from road passenger and freight modes for the high flex-fuel penetration scenario (E85 and E10) compared to the baseline scenario (E10) for three economic growth scenarios

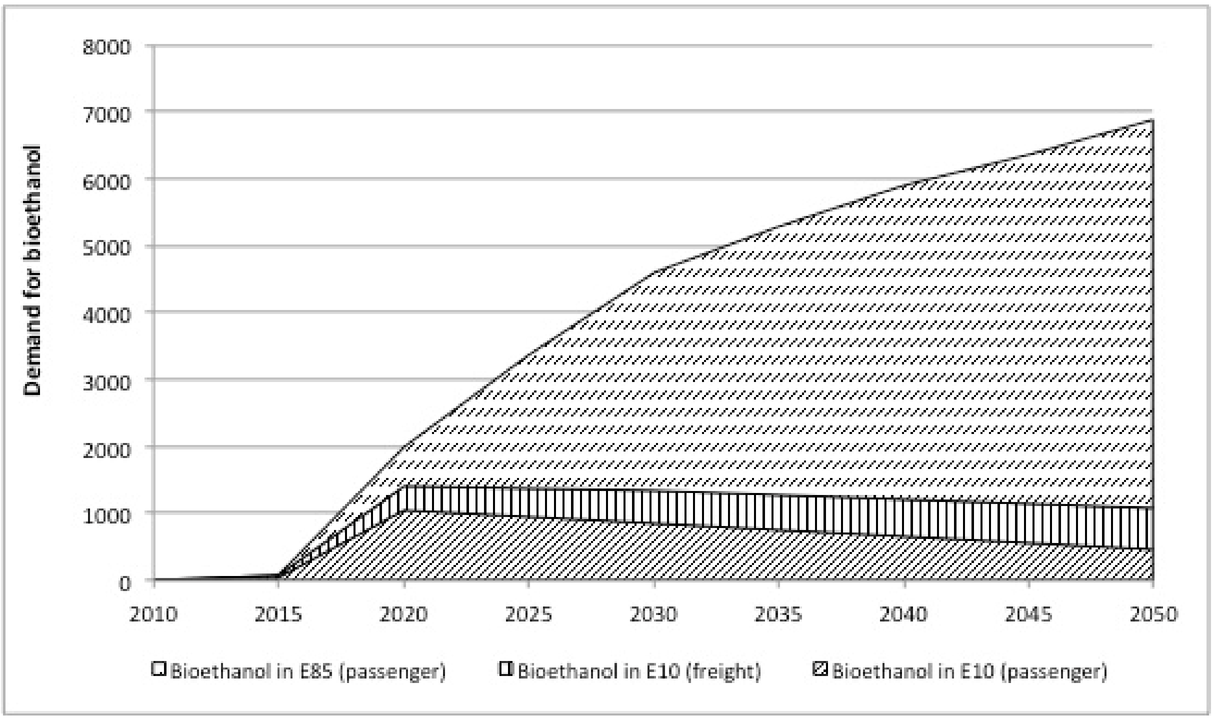


Source: Authors' compilation based on model results.

3.1 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 because of growth in competing electromobility 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

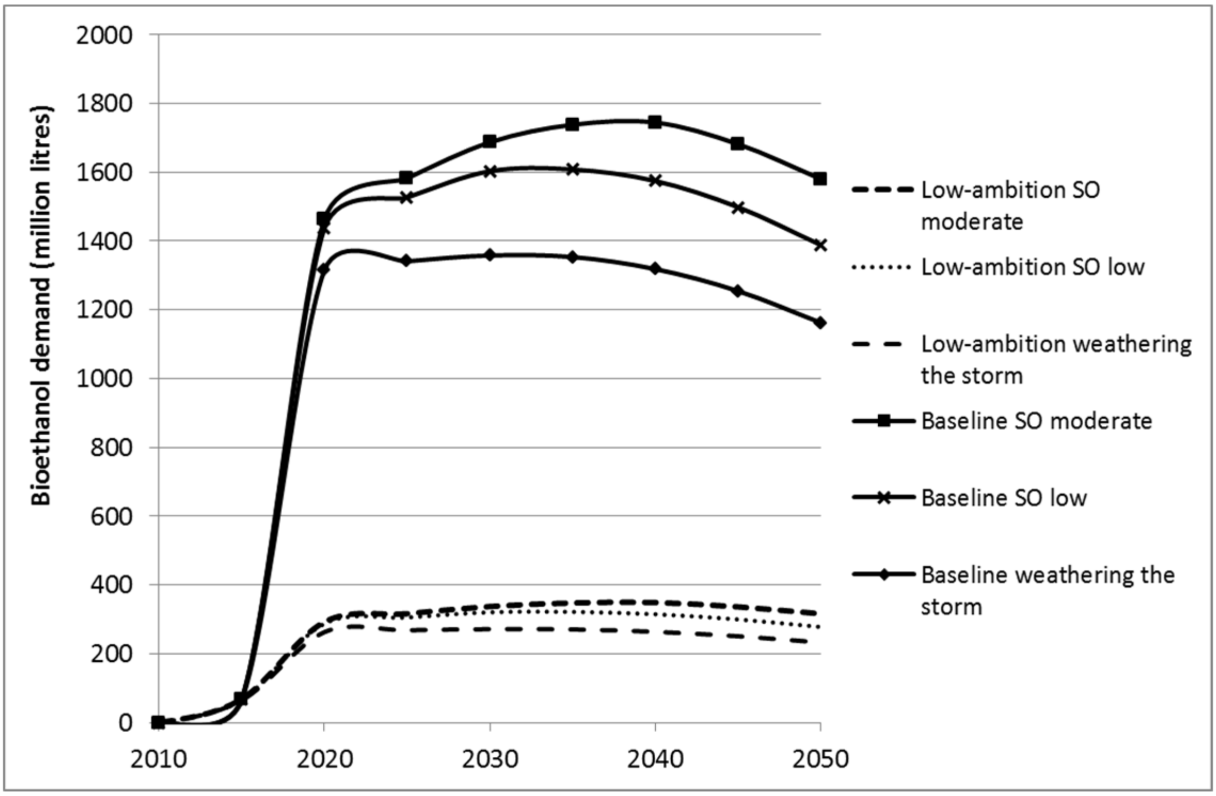


Source: Authors' compilation based on model results.

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

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

Figure 8: Estimated demand for bioethanol from road passenger and freight modes for the baseline scenario (E10) compared to the low-ambition scenario (E2) for three economic growth scenarios



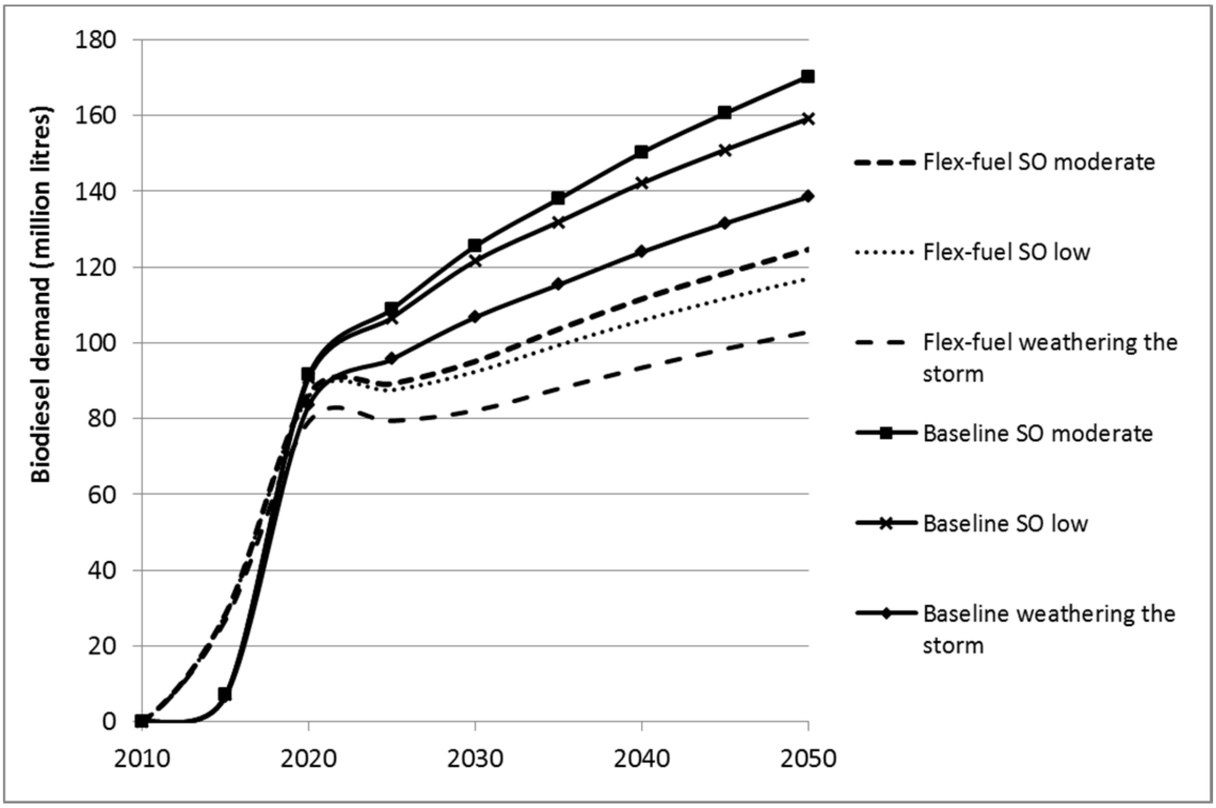
Source: Authors' compilation based on model results.

3.2 Biodiesel

Owing to time constraints, the demand for biodiesel in all six scenarios was estimated only for the passenger mode whereas demand from freight was projected from previous SATIM runs for the SO low scenario only. Results are plotted in Figure 9. This demand results solely from blending biodiesel into conventional diesel (B5). The flex-fuel scenario has lower biodiesel uptake because a major share of light commercial vehicle consumption is diverted away from biodiesel blend (B5) fuelled conventional technology to bioethanol (E85) fuelled flex-fuel technology.

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. Results are presented in Table 7.

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 three economic growth scenarios



Source: Authors' compilation based on model results.

Table 7: Demand for biodiesel resulting from B5 uptake in road and rail freight for the SO low economic growth scenario

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[a]

Note: All figures in million litres. [a]This will be much higher if natural gas does not emerge as a significant road freight fuel.

Source: Authors' compilation based on previous SATIM runs.

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.

Owing to time constraints and uncertainty regarding whether biokerosene would be used straight or as a blend, demand for this biofuel was only assessed for a 10 per cent blend under the SO low economic growth scenario. The projected penetration is presented in Table 8.

Table 8: Demand for biokerosene aviation given a 10 per cent blend with conventional kerosene for the SO low economic growth scenario

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

Note: All figures in million litres.

Source: Authors' compilation based on previous SATIM runs.

4 Discussion and conclusion

These results provide the following insights:

- In scenarios that see zero E85, consumption of biofuels is moderate, peaking at only 3.5 per cent (E2), that is, 6.5 per cent (E10) of all fuel consumption in terms of energy 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 is seen to expand rapidly. However, it is highly unlikely that flex-fuel cars will be introduced at this pace in the absence of policies to incentivize 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.
- In all scenarios used in the modelling exercise, the scale of biofuels demand has 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 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 hectares would be needed (for ethanol) in 2035 as shown in Table 9. 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 et al. 2014). If so, meeting an E10 blend by 2035 may require 174,000 hectares. If flex-fuel technology comes on stream, the area of land needed would increase proportionately to between 520,000 and 740,000 hectares, depending on yields. Of course, if yields are lower, more land will be required.

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

	Weathering the storm	SO low	SO moderate
Low yield (7000 litres per hectare)			
Zero E85; E10 mandatory blend	193,286	228,571	248,286
High penetration of E85	634,429	742,857	805,571
High yield (10,000 litres per hectare)			
Zero E85; E10 mandatory blend	135,300	160,000	173,800
High penetration of E85	444,100	520,000	563,900

Note: Land area figures in hectares.

Source: Authors’ compilation based on authors’ calculations.

- Although demand for biodiesel is projected to be lower than for bioethanol in almost all scenarios, lower expected yields (of around 1000 litres per hectare) mean proportionally more land is needed. The demand for 487 million litres to satisfy a B5 mandate in a low growth scenario will require 486,000 hectares of land. A 10 per cent blend of jet fuel derived from biofuels will also require a similar area (491,000 hectares).
- At present, the area under sugarcane production in South Africa is 378,985 hectares. Meeting bioethanol demand needed for a zero E85 scenario will require a major shift in orientation of sugar production to biofuels, or, more likely, some feedstock will need to be sourced from abroad. Imports will be essential if flex-fuel cars are introduced.

Several areas require further analysis:

- If the biofuels supply chain and its cost is fully represented in SATIM with likely import prices of imported regional biofuel, whether the model will select biofuels as optimal cost for the supply of energy services under carbon dioxide constraints.
- 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 in the modelling.
- Additives are needed when manufacturing biofuels. For example, ED95 contains ignition improvers, denaturants, lubricants, and anticorrosive additives (SEKAB, n.d.). It is unclear whether the costs of these additives used when refining biofuels adds significantly to forecourt price. The current model does not include a cost factor and inclusion of ED95 will require an assessment of this. Clearly, the penetration of other biofuels in the model assumes at least cost parity with conventional fuels.

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