Modelling Growth Scenarios for Biofuels in South Africa's Transport Sector

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in Collaboration with UNU-WIDER

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Outline

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2. Methodology of Preliminary Assessment
3. Key Assumptions
4. Scenarios
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1. Background - Rationale

- Southern Africa has considerable biofuels potential with resources of land and labour in Mozambique, Malawi and Zimbabwe in particular. Zimbabwe already has significant uptake.
- The market, certainly in the medium term is in South Africa which has considerably greater agricultural constraints.
- South Africa is completing construction of two of the largest coal power plants in the world with coal IPP procurement now underway – the grid is not going to decarbonise any time soon.
- Purpose of this preliminary work for UNU-WIDER:
  - Estimate the range of potential demand for biofuels in transport in South Africa till 2050
- To be extended to:
  - Implementation of biofuels supply chain in South African TIMES model (only in 1st stages now)
  - A regional assessment of potential biofuels production, trade and consumption

1. Background – Biofuels Policy Landscape

- Official targets were set in 2007 - Biofuels Industrial Strategy - along with incentives: a 50% rebate on general fuel levy and accelerated depreciation of plant but failed to stimulate significant production
- The Mandatory Biofuels Blending Regulation (R671 of 2012) gasoline and diesel targets between E2 and E10 for bio-ethanol and B5 for biodiesel.
- Promulgated to come into effect 1 October 2015 (R719 of 2013)
- Draft Position Paper on the South African Biofuels Regulatory Framework, sets the pricing and subsidy mechanism - January 15, 2014
  - Guaranteed 15% Return on Assets
  - Sorghum and soya as model crops for reference plant in subsidy calculation
  - 4 Bioethanol plants with capacity of 392 million litres licensed using sorghum, sugar beet and sugar cane
  - 3 Biodiesel plants with capacity of 470 million litres licensed using soya, canola and waste oil
  - Of these, construction has only commenced on one waste oil plant of 12 million litres capacity
- Final Position Paper and thus final subsidy scheme is not released so developers won't risk capital. Construction times are around 2 years so deadline will be missed.

1. IEA 2nd Generation Potential Study

Biofuel option	Production				Number of plants			
	Actual material flow		Unused residues		Actual material flow		Unused residues	
	million l_{ge}/yr*	PJ/yr	million l_{ge}/yr*	PJ/yr	Small scale**	Large scale**	small scale**	Large scale**
Based on primary residues								
Bio-SNG	4 680	156.8	375	12.6	252	34	20	3
BTL	3 297	110.4	264	8.9	30	8	2	1
Bioethanol	3 251	108.9	261	8.7	244	20	20	2
Based on secondary residues								
Bio-SNG	2 209	74.0	225	7.5	119	16	12	2
BTL	1 556	52.1	158	5.3	14	4	1	0
Bioethanol	1 534	51.4	156	5.2	115	9	12	1

Remark: Biofuel options are calculated using 100% of actual material flow and 100% of unused residues for each option.

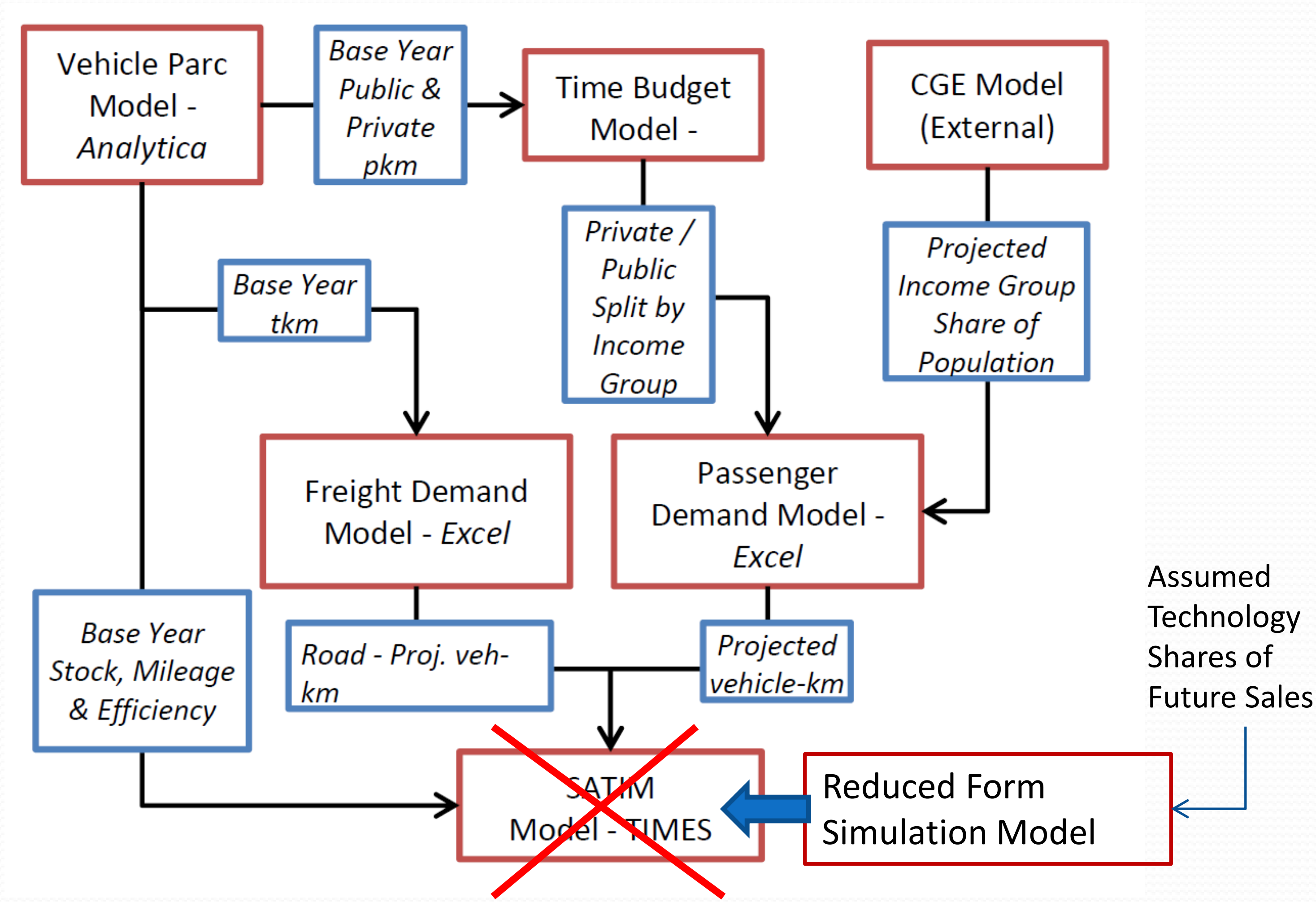
* Assumed conversion factors – BTL: 217 lge/t_{DM}; ethanol: 214 lge/t_{DM}; bio-SNG: 307 lge/t_{DM}

**Based on typical plant sizes – Bio-SNG: 23-170 $MW_{biofuel}$; BTL: 130-500 $MW_{biofuel}$; bioethanol: 15-185 $MW_{biofuel}$ (DBFZ, 2008)

From Eisentraut, A. (2010). Sustainable Production of Second-Generation Biofuels Potential and perspectives i major economies and developing countries. Paris, France: International Energy Agency (IEA)

BTL – Biomass to Liquid Diesel

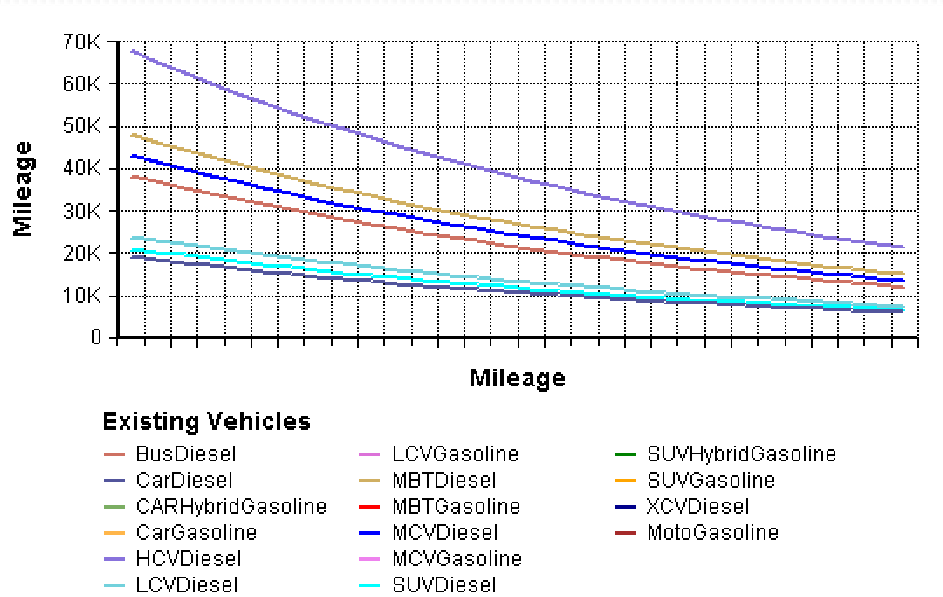
2. Methodology – Adaptation of SATIM

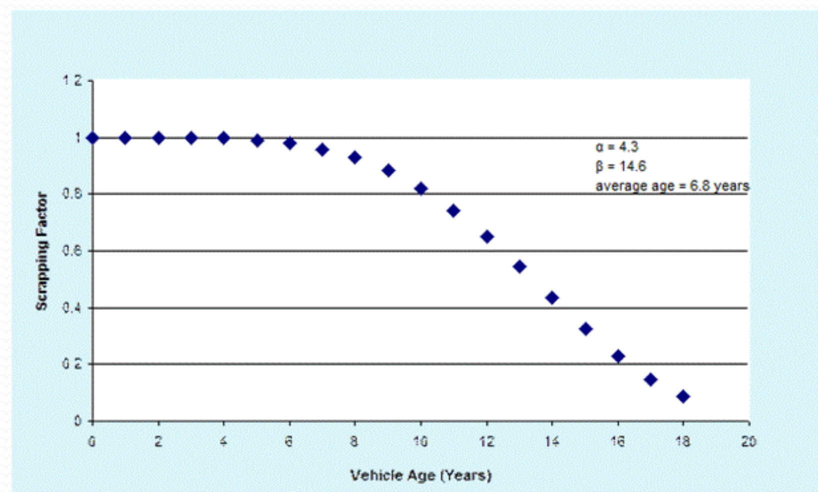


- See - Merven, B., Stone, A., Hughes, A., & Cohen, B. (2012). Quantifying the energy needs of the transport sector for South Africa: A bottom-up model. ERC Working Paper. Energy Research Centre (ERC), University of Cape Town.

2. Methodology – Features in Reduced Form Model

- Includes scrapping factors using weibull distribution and annual mileage decay curves with age.
- These assumptions are calibrated over 6 years in the Analytica based vehicle parc model (backward looking)
- The reduced form model (forward looking) is excel based and compacted to 5 year bins but retains all these features.
- Additionally fuel economy can be deteriorated with age.
- Growth in Energy demand is driven by the exogenous demand for vehicle km as determined by the time budget model which takes assumptions from the CGE model.
- The model “sells cars” (in 5 year blocks) to meet this demand and assumptions around the share of sales of new technologies drive the demand for energy carriers.





2. Methodology – Compacting the Parc Model

If we condense our time horizon into bins of size s and;

- $N_{t,k,j}$ = 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 km from service provided by technology segment t at end year of bin j
- $\lambda_{t,n}$ =The scrapping coefficient technology segment t of age n
- $M_{t,n}$ = The annual mileage of vehicles in technology segment t of age n

then:

$$N_{t,k,j} = \frac{VKM_{t,j} - \sum_{[i=1\ to\, j-1]}(N_{t,i}\bar{M}_{t,i})}{\sum_{[n=1\ to\, s]}(\lambda_{t,n}M_{t,n})} \times \sum_{n=[s(k-j+1)-1]to\ s(k-j)]} \lambda_{t,n}$$

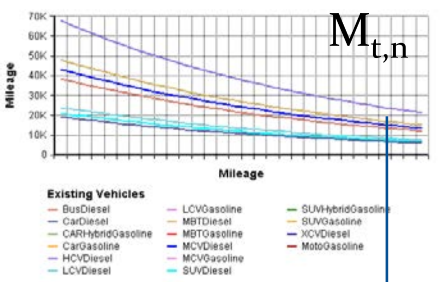
Without mode switching, VKM is driven by household income and population for passenger travel and by GDP with an elasticity of 0.8 for freight

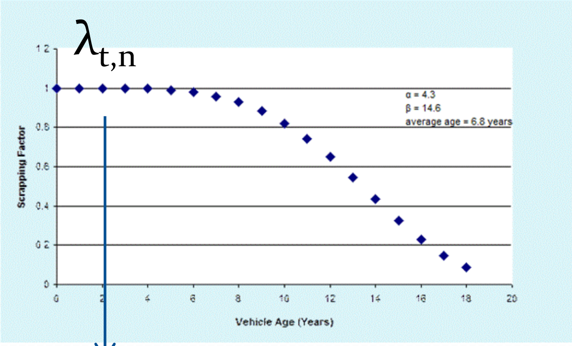
2. Methodology – Compacting the Parc Model

Service Demand from Other Models including CGE Model

Exogenous Demand for Road Transport (billion Vehicle km) by the Population - Aggregated by Type - Mid-Growth Scenario (4.1% Transport GDP Growth)										
	2006	2010	2015	2020	2025	2030	2035	2040	2045	2050
Car	73.33	80.8	95.3	109.8	124.1	138.4	150.0	161.7	172.8	184.0
SUV	9.75	10.7	12.7	14.6	16.5	18.4	19.9	21.5	23.0	24.5
Motorbike	1.75	1.9	2.3	2.6	3.0	3.3	3.6	3.9	4.1	4.4
Bus & BRT	0.62	0.63	0.8	0.87	1.04	1.21	1.4	1.65	1.9	2.06
Minibus	8.28	8.4	8.4	8.4	8.4	8.5	8.5	8.6	8.7	8.7
TOTAL	**93.7**	**102.5**	**119.4**	**136.3**	**153.1**	**169.8**	**183.5**	**197.3**	**210.4**	**223.6**

VKM





So just a spreadsheet model but compact and transparent – useful for quick assessments, validating the TIMES system model and distribution of methods

Data for Cars											
Years between which Vehicles were		**No of Cars in Vintage Group by Year**									
First Year	**Last Year**	**2006**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
All pre-2006	2006	4488815	3750073	2934997	1903219	1304844	706469	447035	187601	111869	36137
2006	2010		1177766	1077467	896481	673669	454935	276616	152944	77681	36302
2010	2015			1823492	1653236	1362668	1014138	678455	409091	224587	113323
2015	2020				2226879	2018959	1664113	1238482	828540	499589	274269
2020	2025					2307166	2091750	1724110	1283134	858412	517601
2025	2030						2627001	2381722	1963117	1461010	977411
2030	2035							2685092	2434389	2006528	1493318
2035	2040								2926078	2652875	2186613
2040	2045									3077302	2789979
2045	2050										3273285
	TOTAL	4 488 815	4 927 839	5 835 955	6 679 815	7 667 306	8 558 404	9 431 511	10 184 895	10 969 852	11 698 237

4. Scenarios - Technology Pathways

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) as per R671
- Conventional diesel internal combustion (IC) and hybrid technology fuelled by a blend of diesel with 5% biodiesel (B5) as per R671
- 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.

3. Assumptions Around Fuel Economy

- The gasoline/E85 fuel economies of 87 flex-fuel models compared - EPA 2015 *Fuel Economy Datafile*
- On average, the specific fuel economy (MJ/km) of flex-fuel cars operating on E85 is nearly 4% better than when operating on gasoline
- 87% of models have better fuel economy on E85 with the comparisons ranging between 4% worse and 13% better
- Caveat – average cc is 4.2 litres but smaller cc's in dbase are consistent

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%[1]

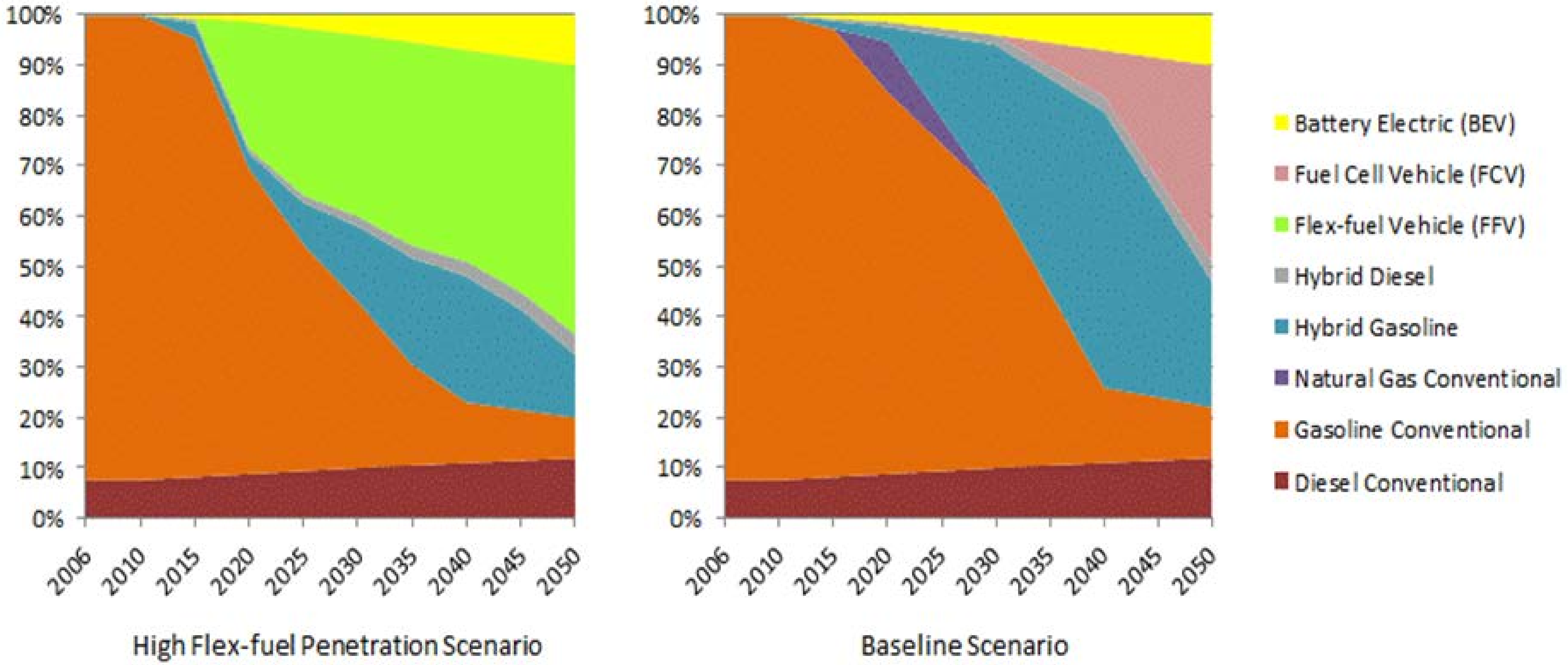
1: Relative to natural gas, not gasoline.

3. Assumed Blend Penetration Rates of Biofuels into Gasoline, Diesel & Kerosene

Blend	2006	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%

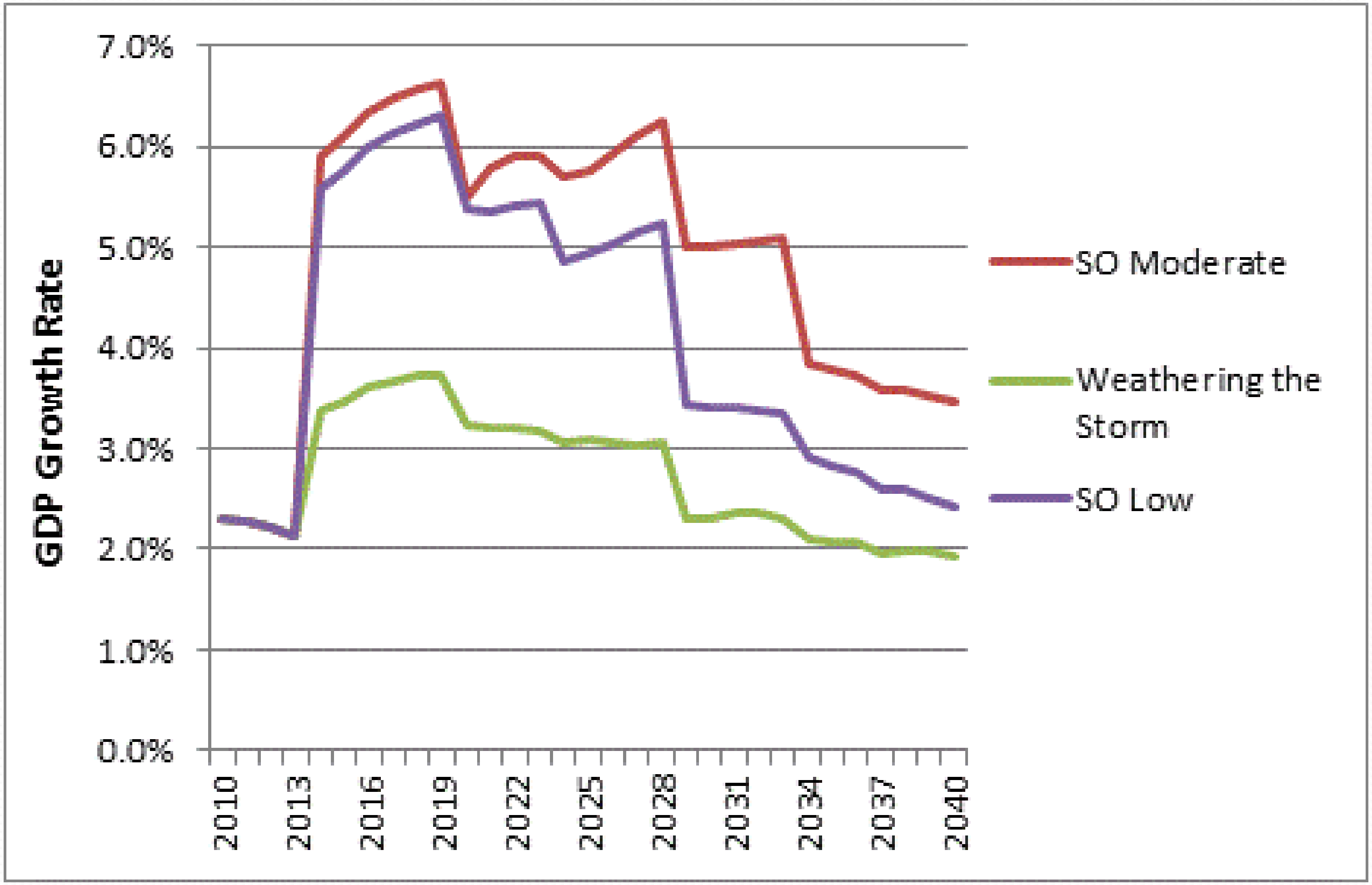
[1] The base year of SATIM is 2006, which was when the last reliable energy balance for South Africa was published. The energy balance for 2010 is expected to be published this year, which will serve as an updated baseline for SATIM.

4. Scenarios – Technology Penetration (% of Sales)



Assumed Evolution of Passenger Car Technologies for High Flex-Fuel Penetration and Baseline Scenarios

4. Scenarios – Economic Growth



- Adopted from the national electricity expansion plan the Integrated Resource Plan (IRP).

4. Scenarios – Matrix

High Flex Fuel (FF) Penetration Scenario

- FF is 25% pass. car sales by 2020
- FF is 40% pass. car sales by 2035
- FF (E85) displaces electromobility technologies and conventional
- E10 & B5 in conventional

'IRP Weathering the Storm'
2.7% GDP Growth

'IRP SO Low'
4.0% GDP Growth

'IRP SO Moderate'
4.7% GDP Growth

Baseline Scenario

- Only E10 & B5 in conventional
- No Flex-fuel (E85)
- Electromobility technologies dominate sales after 2035

'IRP Weathering the Storm'
2.7% GDP Growth

'IRP SO Low'
4.0% GDP Growth

'IRP SO Moderate'
4.7% GDP Growth

'Low Ambition' Scenario

- Only E2 & B5 in conventional
- No Flex-fuel (E85)
- Electromobility technologies dominate sales after 2035

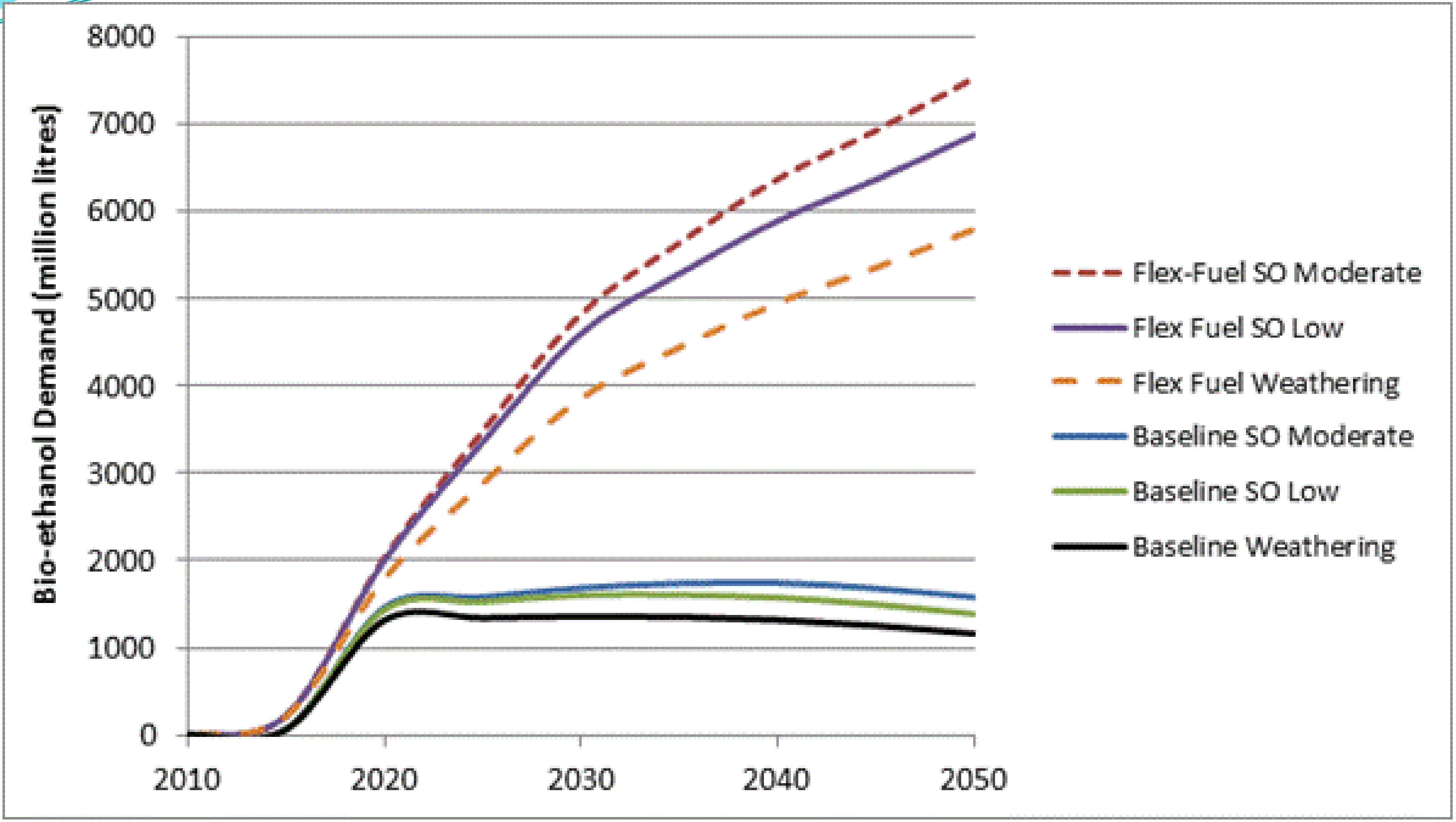
'IRP Weathering the Storm'
2.7% GDP Growth

'IRP SO Low'
4.0% GDP Growth

'IRP SO Moderate'
4.7% GDP Growth

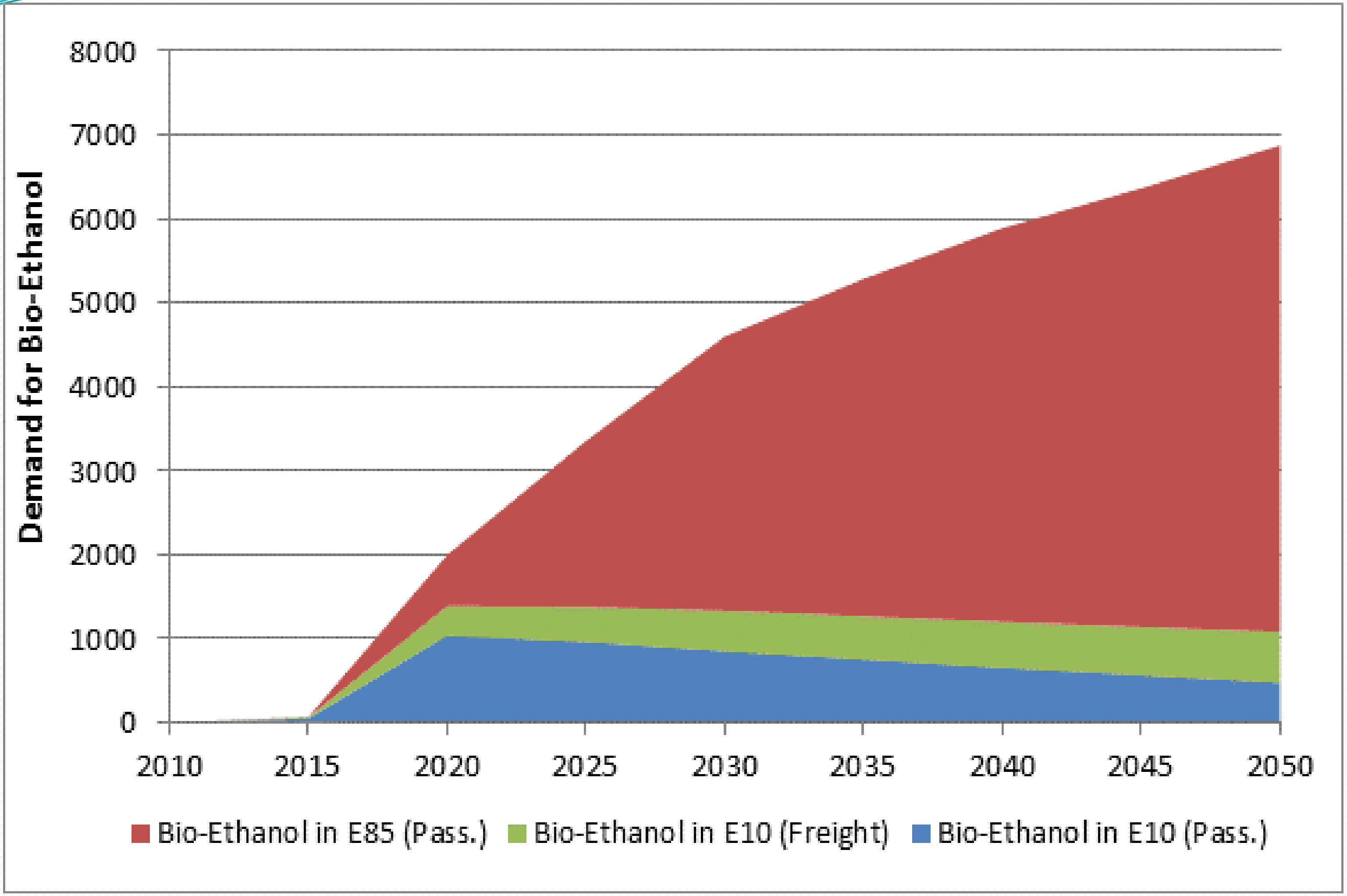
- Adopted from the national electricity expansion plan the Integrated Resource Plan (IRP).

5. Results – High Flex Fuel Bioethanol vs REF



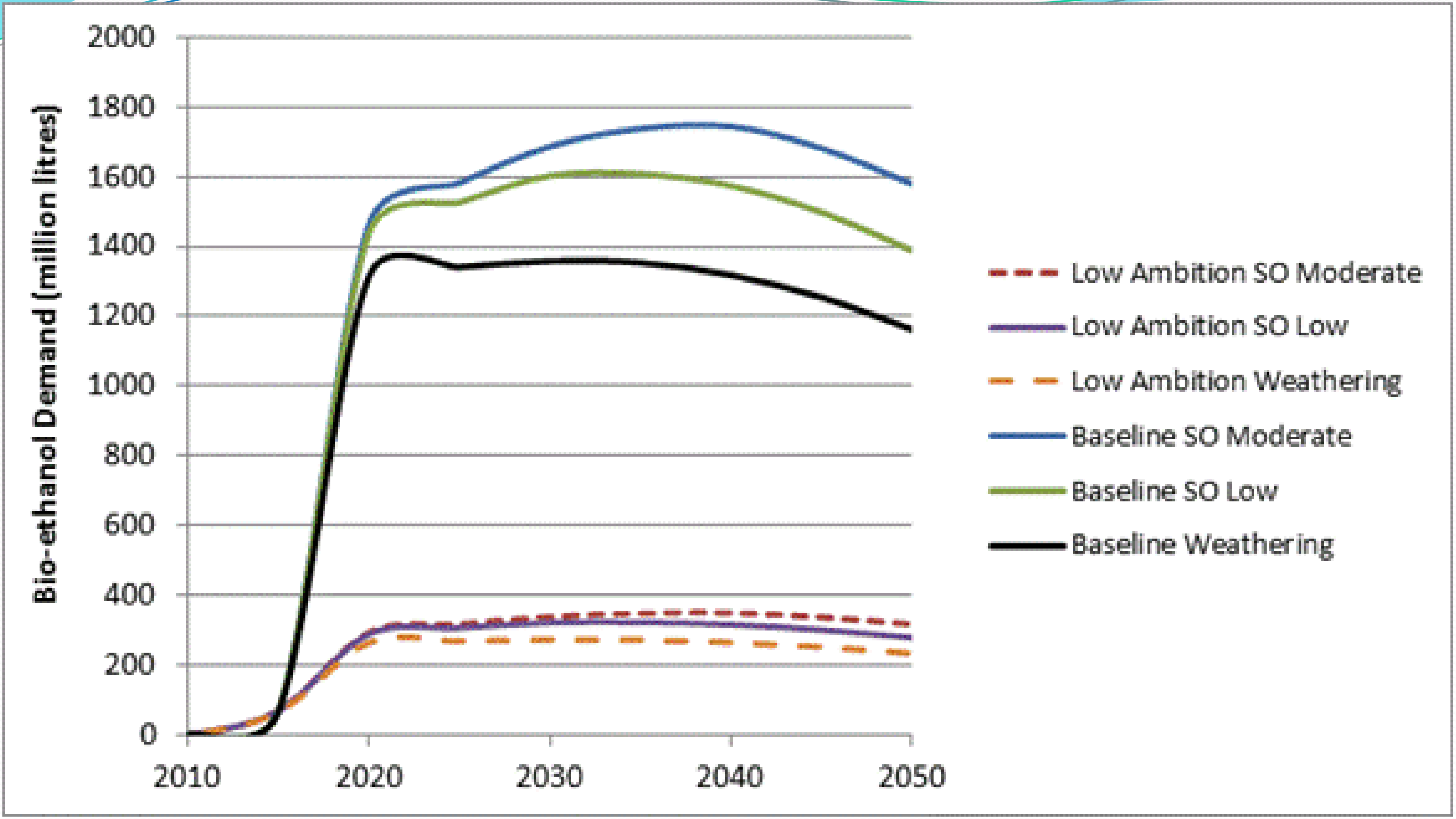
- Estimated demand for bio-ethanol from Road Passenger and Freight modes for the High Flex-fuel Penetration Scenario (E85 & E10) compared to the Baseline Scenario (E10) for three economic growth scenarios

5. Results – High Flex Fuel Bioethanol by Mode



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

5. Results – Low Ambition Bioethanol vs REF



- 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

5. Results – Limited Biodiesel & BioKerosene

Demand for Biodiesel Resulting from B5 uptake in Road and Rail Freight and Road Passenger Modes for the SO Low Economic Growth Scenario (million litres)

Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
Freight	0	37	424	453	483	487	491	496	501
Passenger	0	7	91	107	122	132	142	151	159
TOTAL	0	44	515	560	604	619	633	647	660

**For freight this is just a proportion of SATIM Outputs but for runs with high natural gas uptake so could be substantially higher*

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

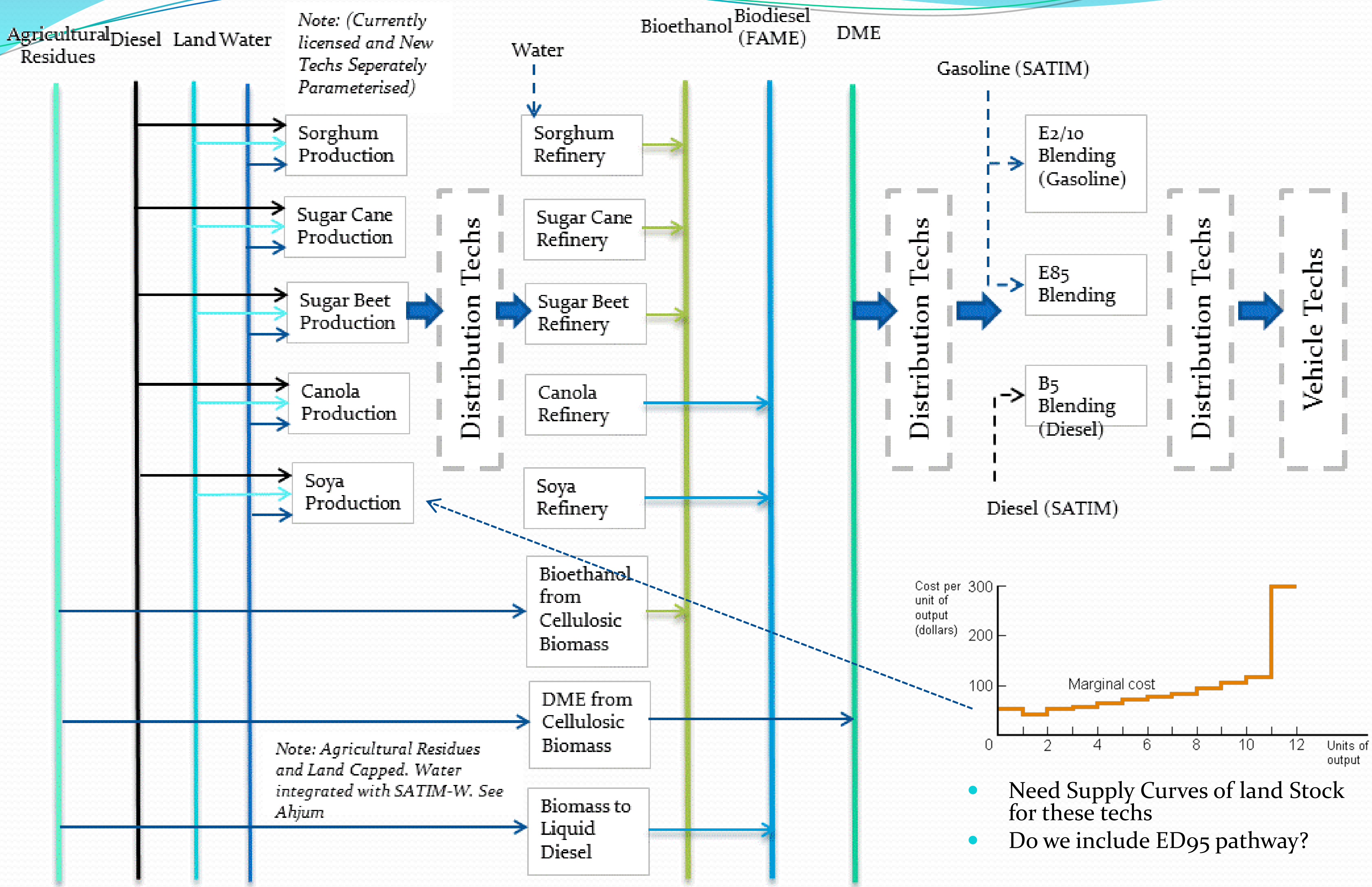
**This is still a final energy demand model so this is overstated*

6. Conclusions – Land Implications of Scenarios

- Land Implications of Bioethanol Results for different yield assumptions are shown below
- Context - At present, the area under sugarcane production in South Africa is 378,985 ha
- The Biofuels Industrial Strategy is more conservative assuming 300,000 hectares or 1.4% of arable land is required for an E2 policy
- Biodiesel and Biokerosene projections likely to require a **further 500,000 ha each**
- Significant flex fuel uptake will likely require imports from the region but the 14% of arable land lying fallow could potentially be utilised for 1st gen biofuels

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

7. Proposed TIMES Implementation (extend SATIM)



- Need Supply Curves of land Stock for these techs
- Do we include ED95 pathway?

7. Moving Ahead

- Debug reduced form model and distribute as a handy tool
- Busy with data collection to parameterise RES
- Proper bottom-up technology rich air transport representation
- Implement biofuels in national energy system representation
- Introduce regional producers as regions in TIMES model
- Assess the potential contribution of biofuels to decarbonising the transport sector at different time scales including an endogenous cost of water (SATIM-W)