Appendix D: Refinery Technologies

Crude Oil Refineries

This sector supplies liquid fuels such as diesel and gasoline to the South African economy. Conventionally these products would be derived from crude oil but South Africa has a large so-called synthetic fuel industry that produces liquid fuels from gas and coal feedstocks. This industry, which includes a Coal-to-Liquids (CTL) and a Gas-to-Liquids (GTL) refinery complicates the modelling of this sector somewhat because these plants add a number of input commodities to the energy chain.

The refinery slate data for existing crude oil refineries are derived from Lloyd (2001) which is now quite an old study but the only large scale changes to South Africa's refineries since then has been the increase in capacity of Enref in 2003 from 100,000 barrels/day to 125,000 barrels/day. Table D-1 lists the output commodities from refineries in SATIM and Table D-2 describes the relative share of each commodity.

Table D-1: SATIM refinery outputs

Commodity	SATIM code
Aviation Gasoline	OAG
Diesel Oil	ODS
Gasoline	OGS
Methane Rich Gas	GIM
Kerosene	OLK
Liquified Petroleum Gas	OLP
Other Oil-derived Products	OTH

Table D-2: Assumed upper bounds on output commodity shares for refinery technologies

Output Product	Crude Coastal Existing	Crude Inland Existing	GTL Existing	GTL New	CTL Existing	CTL New	Crude New
Av Gasoline	0%	0%	0%	0%	0%	0%	0%
Diesel	33%	39%	6%	29%	24%	73%	36%
Gasoline	29%	32%	53%	50%	54%	24%	36%
HFO	23%	4%	0%	0%	0%	0%	0%
Kerosene	11%	21%	11%	12%	4%	0%	20%
LPG	2%	0%	8%	4%	1%	4%	3%
Other	2%	4%	18%	5%	7%	0%	5%
Methane Rich Gas	0%	0%	0%	0%	8%	0%	0%
TOTAL	100%	100%	100%	100%	100%	100%	100%

Table D-3 presents a summary of the assumptions regarding refinery technology characteristics and costs as used in SATIM currently.

Table D-3: Summary of Refinery Technology Characteristics

		Existing Technologies				New Technologies		
	Units	Sasol CTL	Inland Crude Existing	Coastal Crude Existing	PetroSA GTL	New GTL[1]	New CTL[2]	New Crude[3]
Capacity	bbl/day	150 000	108 000	405 000	45 000			
Capacity in terms of outputs	PJ/annum	246	212	874	59			
Overall Efficiency	%	44%	93%	95%	70%	73%	49%	97%
Availability	%	96%	96%	96%	96%	96%	96%	96%
Plant Life	Yrs					50	50	50
Running Costs per unit of output	mR/PJ	30	11	11	25	14.25	30	11
Investment Cost[3]	mR/[PJ/ annum]	0	0	0	0	130	305	66
CO_2 emissions	(kt/PJ)	119	6.87	2.90	28	28	119	6.2
CH_4 emissions	(kt/PJ)	1.49	0.00	0.00	0.0045	0.0045	1.49	0.00

1: Based on the Integrated Energy Plan Technical Report (DoE,2013) 2: Based on data for the proposed Mthombo project; 3: Based on data for proposed Mafutha project

Characterisation of CTL technology

In brief, the CTL refinery is characterised as described below.

1. Required for constraints on output shares:
   - The product slate is derived from Lloyd (2001), and
   - The Methane Rich Gas output is determined from Sasol's financial statements as published in the "Analyst Book Dec 2006" (SASOL, 2007).

2. Required for constraints on input shares:
   - The total coal use by SASOL is determined from SASOL's financial statements as published in the "Analyst Book Dec 2006" (SASOL, 2007);
   - The coal for material use for the base year (feedstock excl. steam generation) is published in the Sasol Sustainability Report (2009) expressed in kton dry ash free (DAF);
   - The dry ash free (DAF) coal to run of mine coal (ROM) ratio used to convert this number is 0.65 as per personal communication with Sasol;
   - The total coal for energy use (TJ) is published in the Sasol Sustainability report 2009 (SASOL, 2009), and
   - The Energy content of steam used in the Sasol process of 2,627 MJ/ton comes from a personal communication with SASOL.

Modelling the supply of ancillary steam input services to refineries

Refineries have various commodity inputs which can include crude oil, coal, gas, methane rich refinery gas and steam, all of which complicates costing the energy chain. Steam is modelled as an ancillary input service to the refinery by creating boiler technologies that output steam with an energy commodity as an input.

The modelling of steam as an ancillary input service allows the model to potentially optimise the most cost effective fuel (coal vs gas) and technology (e.g. existing vs new and more efficient boiler vs CHP) to provide the steam needed for process heat, as well as for feedstock in CTL plants. This latter use is much greater per unit of refinery output than process heat requirements. Steam is also consumed by crude refineries and GTL plants but further data is required for the characterization and therefore this consumption is not currently reflected in SATIM. The steam consumption of crude and GTL refineries is however significantly lower and so the absence of this detail is assumed to not have a very significant impact on the overall results. While the framework for optimising refinery steam production is in place, the current version of SATIM has only the following tow technologies implemented.

Table D-4: Current Refinery Steam Boiler Technologies Implemented in SATIM

Boiler Technology	Input Commodity	Output Commodity	Efficiency
Refinery CTL Boiler Existing	Coal Existing	Steam Existing	72%
Refinery CTL Boiler New	Coal New	Steam New	77%