SOUTH AFRICAN INTEGRATED LNG SUPPLY CHAIN MODEL

MODEL METHODOLOGY BRIEF

DRAFT 1.0

BUSINESS UNITY SOUTH AFRICA

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1) Disclaimer

This analysis contains assumptions, estimates, calculations, and projections which may or may not prove to be correct. No representation or warranty is made as to the accuracy of these assumptions, estimates, calculations, and/or projections. This analysis does not constitute an offer or recommendations by Business Unity South Africa ("**BUSA**") or any of its affiliates.

The analysis and supporting material are not intended to be used for presenting any definitive tariff or financial performance calculations. Certain assumptions have been made in this analysis which may require further validation.

2) Introduction

The South African Integrated LNG Supply Chain Model ("**Model**") was created to assist key stakeholders in analysing the impact of future gas infrastructure investment. The Model intends to provide an impartial assessment of the economics of different gas import and distribution scenarios. Where available, the Model relies on inputs from reputable publicly available sources to ensure unbiased model outputs. The Model has been developed and reviewed jointly with several local and international private sector stakeholders.

3) Approach

The BUSA Gas Working Group was established in October 2019 to play a constructive role in the development of a gas economy within the broader energy strategy of the country, and to motivate the development of a sustainable environment in which business can thrive. In this context, one of the objectives of the Working Group was to develop an evidence base for the role of gas in South Africa towards enhancing well-being, fostering economic growth, and generating sustainable employment opportunities. Another objective was to validate the value for gas in the broader economy.

Accordingly, the Working Group set out on an extensive education and information gathering work plan, engaging with multiple stakeholders and subject matter experts. In the course of work, the South African Integrated LNG Supply Chain Model was conceived and developed.

4) Methodology

The Model utilises quantitative analysis to derive key outputs needed to better understand LNG supply chains. The Model relies on the accuracy of the inputs which include *inter alia* costing and sizing of the different elements of the value chain. The quantitative analysis was undertaken with Microsoft Excel. Given the multiple factors at play in determining "the optimal LNG solution for the country", including; economic development, regional economic impact, gas price, electricity price, investment, job creation and local content maximisation, the Model does not undertake any form of algorithm-based optimisation. The Model is purely scenario driven and allows a user to test possible outcomes for different predefined value chain scenarios with due consideration of both quantitative and qualitative aspects impacting economic and social development.

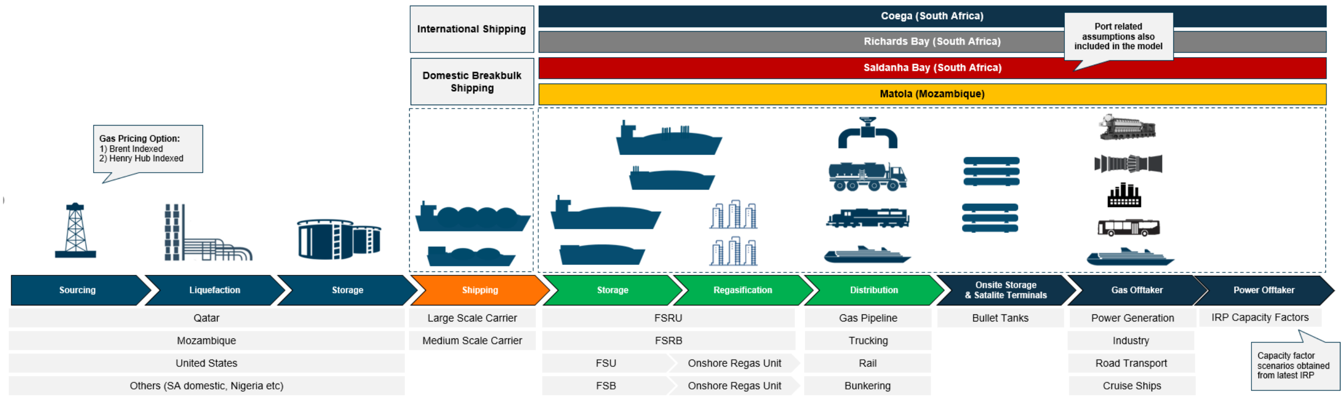
5) Scope

The scope of the Model includes the entire LNG value chain including:

- Gas sourcing – international and regional sources.
- Molecule pricing - Brent Indexed and Henry Hub Indexed pricing.
- Liquefaction
- Shipping options – Large and small/medium sized carriers
- Port options for LNG importation – Coega, Richards Bay, Saldanha Bay and Matola
- Storage – FSRUs, FSUs, FSRBs and FSBs
- LNG/Gas Distribution – Pipeline, trucking, rail freight and bunkering
- Onsite storage and satellite terminals

A graphical representation of the Model scope and structure can be seen in Figure 1 below.

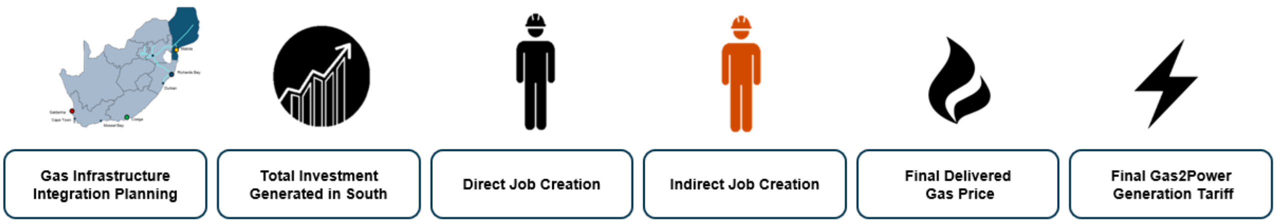
Figure 1:LNG Supply Chain Model Scope and Structure



6) Outputs

The objective of the Model is to allow for a better understanding of the potential impact of gas infrastructure and integration planning. The key outputs to this end include investment generated, direct job creation, indirect job creation, final delivered gas price, final gas-to-power generation tariffs and diesel cost savings (see Figure 2)

Figure 2:Key Model Outputs



7) Quantitative Analysis

The following section outlines some of the key calculations and formulas used in the Model.

Gas Demand

$$\delta_{t,l,total} = \sum_{o}^{O} \sum_{m}^{M} \delta_{t,l,m,o}$$

$\delta_{t,l,total}$	Total gas demand in GJ in period *t* in location *l*
$\delta_{t,l,m,o}$	Gas demand in GJ in period *t* in location *l* through distribution method *m* to offtaker *o*

Power Generation Gas Demand

$$\delta_{t,l,power} = \sum_{g}^{G} \sum_{m}^{M} \delta_{t,l,m,g}$$

$\delta_{t,l,power}$	Total gas demand from power generation in GJ in period *t* in location *l*
$\delta_{t,l,m,g}$	Gas demand delivered in GJ in period *t* in location *t* delivered through distribution method *m* to power generation offtaker *g*

$Where$

$$\delta_{t,l,m,g} = H_{l,g} \times MW_{t,l,m,g} \times \theta_{t,l,g} \times Hours_t$$

$H_{l,g}$	Heat rate as GJ/MWh in location *l* for power generation offtaker *g*
$MW_{t,l,m,g}$	Total capacity installed in MW in period *t* in location *l* delivered through distribution method *m* to power generation offtaker *g*
$\theta_{t,l,g}$	Capacity factor in % in period *t* in location *l* for power generation offtaker *g*
$Hours_t$	Total number of hours in period *t*

Final Delivered Gas Price

$$\beta_{t,l,m,final} = \beta_{t,l,molecule} + \beta_{t,l,liquefaction} + \beta_{l,s,shipping} + \beta_{t,l,port} + \beta_{t,l,bulk} + \beta_{t,l,m,dist}$$

$\beta_{t,l,m,final}$	Final delivered gas price in USD or ZAR per GJ in period t in location *l* with gas delivered through method *m*
$\beta_{t,l,molecule}$	Gas molecule cost charge in USD or ZAR per GJ in period *t* in location *l*
$\beta_{t,l,liquefaction}$	Liquefaction cost charge in USD or ZAR per GJ in period *t* in location *l*
$\beta_{l,s,shipping}$	Shipping cost charge in USD or ZAR per GJ in location *l* with gas imported from source *s*
$\beta_{t,l,port}$	Port cost charge in USD or ZAR per GJ in period *t* in location *l* with gas delivered through method *m*
$\beta_{t,l,bulk}$	Bulk storage/Break bulk cost charge in USD or ZAR per GJ in period *t* in location *l*
$\beta_{t,l,m,dist}$	Distribution cost charge in USD or ZAR per GJ in period *t* in location *l* with gas delivered through method *m*

Molecule Sourcing

$$\beta_{t,l,molecule} = \beta_{t,l,Brent} \text{ } or \text{ } \beta_{t,l,HH}$$

$\beta_{t,l,Brent}$	Gas molecule cost charge in USD or ZAR per GJ linked to Brent Crude price in period t in location *l*
$\beta_{t,l,HH}$	Gas molecule cost charge in USD or ZAR per GJ linked to Henry Hub price in period t in location *l*

$Where$

Option 1: Brent Crude Linked

$$\beta_{t,l,Brent} = \alpha_{BC,S}(BC_t)$$

$\alpha_{BC,S}$	Price index figure for Brent Crude from source s
BC_t	International brent crude price in USD or ZAR per barrel in period t

$Where$

Option 2: Henry Hub Linked

$$\beta_{t,l,HH} = \alpha_{HH\ S}(HH_t)$$

$\alpha_{BC,S}$	Price index figure for Henry Hub from source s
HH_t	Henry Hub price in USD or ZAR per GJ in period t

LNG Shipping Vessel

$$\beta_{l,s,shipping} = \frac{\mu_v \times Days_{l,s,v}}{\emptyset_v}$$

$\beta_{l,s,shipping}$ Shipping vessel charge in USD or ZAR per GJ in location *l* from source *s*

μ_v Shipping vessel charter rate per day for vessel type *v*

$Days_{l,s,v}$ Round trip shipping time in days to location *l* from source s with vessel *v*

$\emptyset_v$ Cargo size in GJ of shipping vessel *v*

LNG Port Infrastructure

$$\beta_{t,l,port} = \frac{\gamma_{t,l,port}}{\delta_{Total,t,l}}$$

$\beta_{t,l,port}$ Port charge in USD or ZAR per GJ in period t in location *l*

$\gamma_{t,l,port}$ Total port related cost in USD or ZAR in period *t* in location *l*

$Where$

$$\gamma_{t,l,port} = \gamma_{t,l,port,capex} + \gamma_{t,l,port,fixed} + (\gamma_{t,l,port,variable} \times \delta_{Total,t,l})$$

$\gamma_{t,l,port,capex}$ Total port capital cost amortisation in USD or ZAR in period t in location *l*

$\gamma_{t,l,port,fixed}$ Total port fixed operating cost in USD or ZAR in period t in location *l*

$\gamma_{t,l,port,variable}$ Total port variable cost in USD or ZAR in period t in location *l*

$Where$

$$\gamma_{t,l,port,capex} = \gamma_{t,l,port,invest} * \frac{R}{1-(1+R)^{-T}}$$

$\gamma_{l,port,invest}$ Total port related capital investment in location *l*

R *Average financing cost of capital investment for period t*

T *Total number of periods*

LNG Bulk Storage

$$\beta_{t,l,bulk} = \frac{\gamma_{t,l,bulk}}{\delta_{Total,t,l}}$$

$\beta_{t,l,bulk}$ Bulk storage charge in USD or ZAR per GJ in period *t* location *l*

$\gamma_{t,l,bulk}$ Total bulk storage related cost in USD or ZAR in period *t* in location *l*

$Where$

$$\gamma_{t,l,bulk} = \gamma_{t,l,bulk,capex} + \gamma_{t,l,bulk,fixed} + (\gamma_{t,l,bulk,variable} \times \delta_{Total,t,l})$$

$\gamma_{t,l,bulk,capex}$ Total port capital cost amortisation in USD or ZAR in period t in location *l*

$\gamma_{t,l,bulk,fixed}$ Total port fixed operating cost in USD or ZAR in period t in location *l*

$\gamma_{t,l,bulk,variable}$ Total port variable cost in USD or ZAR in period t in location *l*

$Where$

$$\gamma_{t,l,bulk,capex} = \gamma_{t,l,bulk,invest} \times \frac{R}{1-(1+R)^{-T}}$$

$\gamma_{l,port,invest}$ Total bulk storage/break bulk related capital investment in location *l*

R *Average financing cost of capital investment for period t*

T *Total number of periods*

Gas/LNG Distribution

$$\beta_{t,l,m,,dist} = \frac{\gamma_{t,l,m,dist}}{\delta_{t,l,m,total}}$$

$\gamma_{t,l,m,dist}$ Total gas distribution related cost in USD or ZAR in period *t* in location *l* for distribution method m

$\delta_{t,l,m,total}$ Total gas demand in GJ in period *t* in location *l* for distribution method *m*

Gas Pipeline Storage

$$\beta_{t,l,pipeline} = \frac{\gamma_{t,l,pipeline}}{\delta_{t,l,pipeline}}$$

$\beta_{t,l,pipeline}$	Pipeline charge in USD or ZAR per GJ in period *t* location *l*
$\gamma_{t,l,pipeline}$	Total gas pipeline related cost in USD or ZAR in period *t* in location *l*
$\delta_{t,l,pipeline}$	Total gas pipeline demand in GJ in period *t* in location *l*

$Where$

$$\gamma_{t,l,pipeline} = \gamma_{t,l,pipeline,capex} + \gamma_{t,l,pipeline,fixed} + (\gamma_{t,l,pipeline,variable} \times \delta_{pipeline,t,l})$$

$\gamma_{t,l,pipeline,capex}$	Total pipeline capital cost amortisation in USD or ZAR in period t in location *l*
$\gamma_{t,l,pipeline,fixed}$	Total pipeline fixed operating cost in USD or ZAR in period t in location *l*
$\gamma_{t,l,pipeline,variable}$	Total pipeline variable cost in USD or ZAR in period t in location *l*

$Where$

$$\gamma_{t,l,pipeline,capex} = \gamma_{t,l,pipeline,invest} \times \frac{R}{1-(1+R)^{-T}}$$

$\gamma_{l,pipeline,invest}$	Total pipeline related capital investment in location *l*
R	*Average financing cost of capital investment for period t*
T	*Total number of periods*

LNG Trucking

$$\beta_{t,l,truck} = \frac{\gamma_{t,l,truck}}{\delta_{t,l,truck}}$$

$\gamma_{t,l,truck}$	Total LNG trucking related cost in USD or ZAR in period *t* in location *l*
$\delta_{t,l,truck}$	Total LNG trucking demand in period *t* in location *l*

$Where$

$$\gamma_{t,l,pipeline} = \gamma_{t,l,truck,capex} + \gamma_{t,l,truck,fixed} + (\gamma_{t,l,truck,variable} \times \delta_{truck,t,l})$$

$\gamma_{t,l,truck,capex}$	Total trucking related capital cost amortisation in USD or ZAR in period t in location *l*
$\gamma_{t,l,truck,fixed}$	Total trucking fixed operating cost in USD or ZAR in period t in location *l*
$\gamma_{t,l,truck,variable}$	Total trucking variable cost in USD or ZAR in period t in location *l*

$Where$

$$\gamma_{t,l,truck,capex} = \gamma_{t,l,truck,invest} \times \frac{R}{1-(1+R)^{-T}}$$

$\gamma_{l,truck,invest}$	Total pipeline related capital investment in location *l*
R	*Average financing cost of capital investment for period t*
T	*Total number of periods*

LNG Rail Freight

$$\beta_{t,l,rail} = \frac{\gamma_{t,l,rail}}{\delta_{rail,t,l}}$$

$\beta_{t,l,rail}$	LNG rail cost charge in USD or ZAR per GJ in period *t* location *l*
$\gamma_{t,l,rail}$	Total LNG rail related cost in USD or ZAR in period *t* in location *l*
$\delta_{rail,t,l}$	Total LNG rail demand in period *t* in location *l*

$Where$

$$\gamma_{t,l,rail} = \gamma_{t,l,rail,capex} + \gamma_{t,l,rail,fixed} + (\gamma_{t,l,rail,variable} \times \delta_{t,l,rail})$$

$\gamma_{t,l,rail,capex}$	Total rail capital cost amortisation in USD or ZAR in period t in location *l*
$\gamma_{t,l,railfixed}$	Total rail fixed operating cost in USD or ZAR in period t in location *l*
$\gamma_{t,l,rail,variable}$	Total rail variable cost in USD or ZAR in period t in location *l*

$Where$

$$\gamma_{t,l,truck,capex} = \gamma_{t,l,rail,invest} \times \frac{R}{1-(1+R)^{-T}}$$

$\gamma_{l,rail,invest}$	Total rail related capital investment in location *l*
R	*Average financing cost of capital investment for period t*
T	*Total number of periods*

Onsite LNG Storage

$$\beta_{t,l,onsite} = \frac{\gamma_{t,l,onsite}}{\delta_{Truck,t,l} + \delta_{Rail,t,l}}$$

$Where$

$$\gamma_{t,l,onsite} = \gamma_{t,l,onsite,capex} + \gamma_{t,l,onsite,fixed} + (\gamma_{t,l,onsite,variable} \times (\delta_{Truck,t,l} + \delta_{Rail,t,l}))$$

$\gamma_{t,l,onsite,capex}$	Total onsite storage capital cost amortisation in USD or ZAR in period t in location *l*
$\gamma_{t,l,onsite,fixed}$	Total onsite storage fixed operating cost in USD or ZAR in period t in location *l*
$\gamma_{t,l,onsite,variable}$	Total onsite storage variable cost in USD or ZAR in period t in location *l*

$Where$

$$\gamma_{t,l,onsite,capex} = \gamma_{t,l,onsite,invest} \times \frac{R}{1-(1+R)^{-T}}$$

$\gamma_{l,onsite,invest}$	Total onsite related capital investment in location *l*
R	*Average financing cost of capital investment for period t*
T	*Total number of periods*

LNG Bunkering

$$\beta_{t,l,bunker} = \frac{\gamma_{t,l,bunker}}{\delta_{bunker,t,l}}$$

$\beta_{t,l,bunker}$	LNG bunker cost charge in USD or ZAR per GJ in period *t* location *l*
$\gamma_{t,l,bunker}$	Total LNG bunker related cost in USD or ZAR in period *t* in location *l*
$\delta_{bunker,t,l}$	Total LNG bunker demand in period *t* in location *l*
	$Where$

$$\gamma_{t,l,bunker} = \gamma_{t,l,bunker,capex} + \gamma_{t,l,bunker,fixed} + (\gamma_{t,l,bunker,variable} \times \delta_{bunker,t,l})$$

$\gamma_{t,l,bunker,capex}$	Total bunker capital cost amortisation in USD or ZAR in period t in location *l*
$\gamma_{t,l,bunker,fixed}$	Total bunker fixed operating cost in USD or ZAR in period t in location *l*
$\gamma_{t,l,bunker,variable}$	Total bunker variable cost in USD or ZAR in period t in location *l*
	$Where$

$$\gamma_{t,l,bunker,capex} = \gamma_{t,l,bunker,invest} \times \frac{R}{1-(1+R)^{-T}}$$

$\gamma_{l,onsite,invest}$	Total bunkering related capital investment in location *l*
R	Average financing cost of capital investment for period t
T	Total number of periods

Electricity Generation Price

$$\alpha_{t,l,g,power} = \frac{\gamma_{t,l,g,power}}{\varphi_{t,l,g}}$$

$\alpha_{t,l,g,power}$ Gas-to-power generation tariff in USD or ZAR per MWh in period *t* in location *l* of power generator *g*

$\gamma_{t,l,g,power}$ Total Gas-to-power generation cost in USD or ZAR in period *t* in location *l* of power generator *g*

$\varphi_{t,l,g}$ Total power generation in MWh in period *t* in location l of power generator *g*

$Where$

$$\gamma_{t,l,g,power} = \gamma_{t,l,g,power,capex} + \gamma_{t,l,g,power,fixed} + \left(\gamma_{t,l,g,power,variable} \times \varphi_{t,l,g}\right) + \gamma_{t,l,g,power,fuel}$$

$\gamma_{t,l,g,power,capex}$ Total power generation capital cost amortisation in USD or ZAR in period t in location *l* for power generator *g*

$\gamma_{t,l,g,power,fixed}$ Total power generation fixed operating cost in USD or ZAR in period t in location *l* for power generator *g*

$\gamma_{t,l,g,power,variable}$ Total power generation variable cost in USD or ZAR in period t in location *l* for power generator *g*

$\gamma_{t,l,g,power,fuel}$ Total power generation variable cost in USD or ZAR in period t in location *l* for power generator *g*

$Where$

$$\gamma_{t,l,g,power,capex} = \gamma_{l,g,power,invest} \times \frac{R}{1-(1+R)^{-T}}$$

$\gamma_{l,g,power,invest}$ Total power generation related capital investment in location *l* for power generator *g*

R Average financing cost of capital investment for period t

T Total number of periods

$Where$

$$\gamma_{t,l,g,power,fuel} = (\varphi_{t,l,g} \times H_{l,g} \times \beta_{t,l,g,final})$$

$\beta_{t,l,g,final}$ Final delivered gas price in USD or ZAR in GJ in period t in location *l* for power generator *g*

$H_{l,g}$ Heat rate in GJ/MWh t in location *l* for power generator *g*

Direct Job Creation

$$\in_{l,direct\ jobs} = \sum_{c}^{C} \in_{l,c,direct\ jobs}$$

$\in_{l,direct\ jobs}$ Total direct jobs created from LNG supply chain and power generation in location *l*

$\in_{l,c,direct\ jobs}$ Total direct jobs created from component c of the LNG supply chain and power generation in location *l*

$Where$

$$\in_{l,direct\ jobs} \sum_{l}^{L} \in_{l,direct\ jobs}$$

$\in_{direct\ jobs}$ Total direct jobs created from LNG supply chain and power generation across all locations

Total Investment

$$\gamma_{,l,total,invest} = \gamma_{l,port,invest} + \gamma_{l,bulk,invest} + \gamma_{l,pipeline,invest} + \gamma_{l,truck,invest} + \gamma_{l,rail,invest} + \gamma_{l,onsite,invest} + \gamma_{l,bunker,invest} + \sum_{g}^{G} \gamma_{l,g,power,invest}$$

$\gamma_{l,total\ ,invest}$ Total LNG supply chain and power generation related capital investment in location *l* for power generator *g*

$$\gamma_{,total\ ,invest} = \sum_{l}^{L} \gamma_{,total\ ,invest}$$

$\gamma_{,total\ ,invest}$ Total LNG supply chain and power generation related capital investment in all locations

Indirect Job Creation

$$\in_{l,indirect\ jobs} = \frac{\gamma_{,l,total,invest} \times \tau}{\varphi}$$

$\in_{l,indirect\ jobs}$	Total indirect jobs created from LNG supply chain and power generation in location l
τ	Investment multiplier
φ	GDP/Employment elasticity measured in USD or ZAR per job