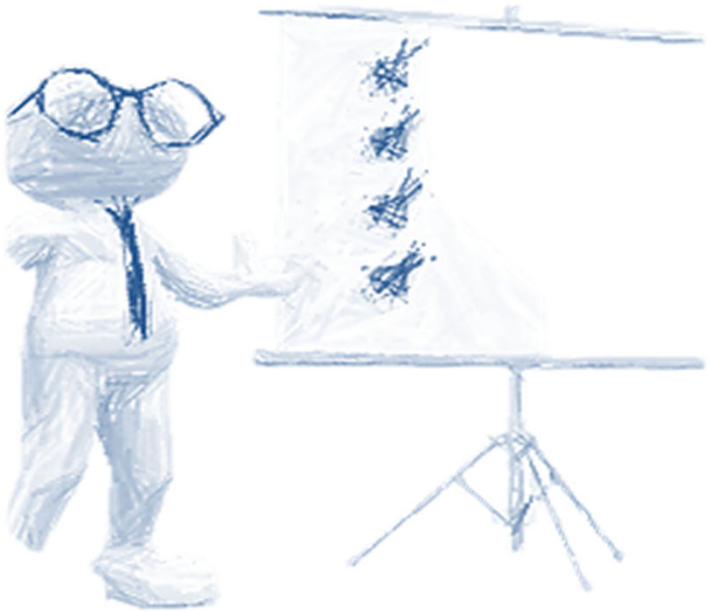
OPTIMIZATION MODEL FOR CRUDE OIL ALLOCATION IN NIGERIA UNDER GLOBAL ENERGY TRANSITION DYNAMICS

By
Kaase Gbakon
Joseph Ajienka
Omowunmi Iledare
Joshua Gogo

Presented at the
43rd IAEE International Conference, Tokyo, Japan
July 31 –August 4, 2022

Theme: Mapping the Energy Future -Voyage in Uncharted Territory

TABLE OF CONTENTS



INTRODUCTION – OVERVIEW OF STUDY

- Oil production deployed to several end uses – domestic refining, export, swap for products
- However, question remains on what is optimal deployment given upstream supply capacity, refining capacity, fuels demand and climate change imperative
- Identify expected features of the energy transition from the IPCC report, the IEA NZE2050 and contextualize them to Nigeria

- Imperative for this paper is driven by:
  - Need to optimize allocation of oil production to meet fossil fuel demand
  - Estimate the objective function under Energy Transition

AIM & OBJECTIVES

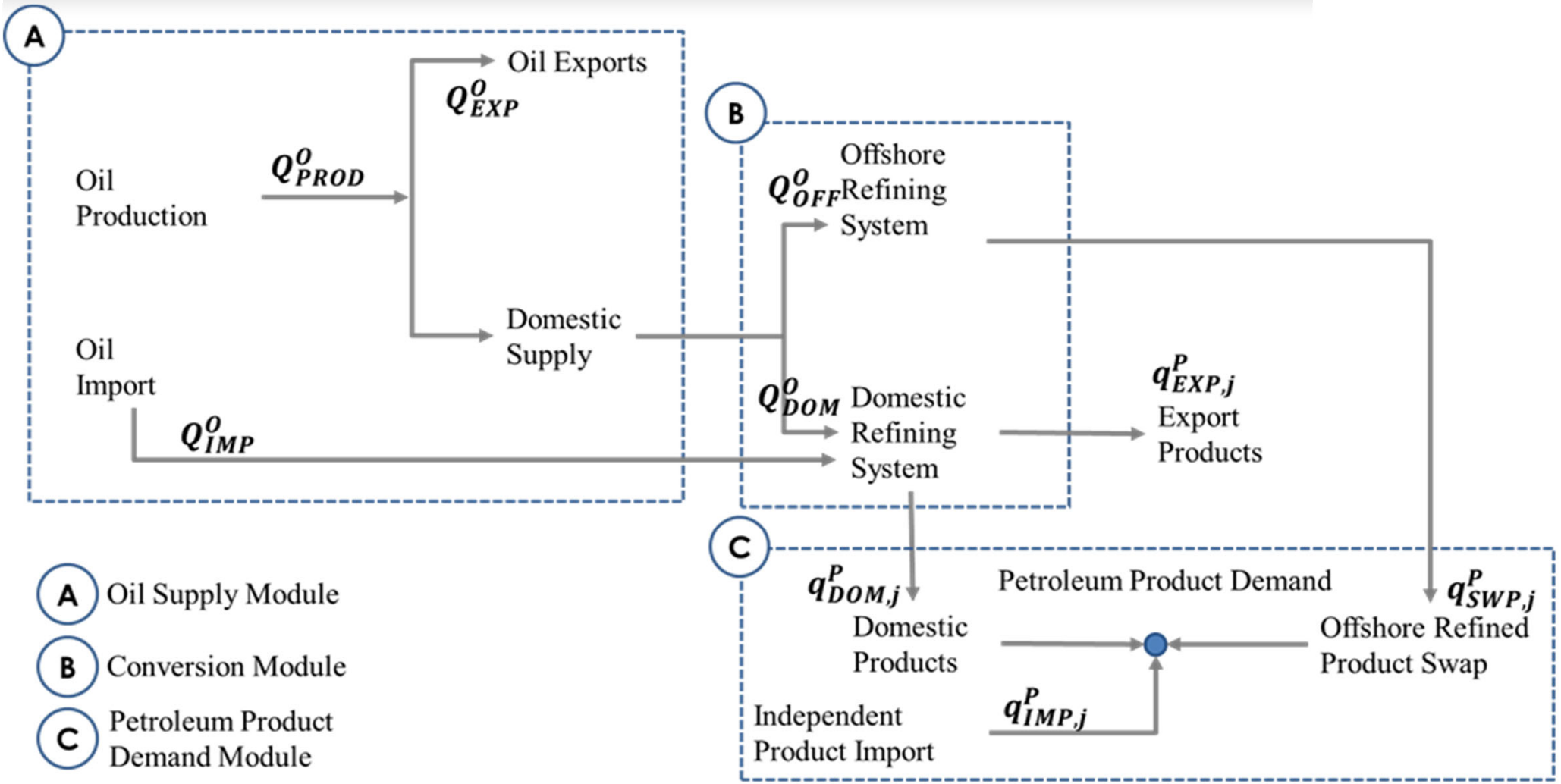
AIM

Utilize a mathematical program to determine optimal allocation of oil production, refined petroleum products to satisfy demand, under the dictates of the energy transition dynamics

OBJECTIVES

- Develop a Reference Energy System for crude oil utilization through a network of possible end-uses
- Formulate a mathematical programme with system-net-benefits maximization objective
- Use Oil Export/Production ratio, and Refined Product Import/Demand ratio metrics to characterize the optimal pathway under ET.

METHODOLOGY – Nigeria Reference Energy System (Oil Utilization)



METHODOLOGY – Optimization Framework

Objective Function

$$
\begin{aligned}
Z &= Q^{O}_{EXP}\left[P^{O} - C^{O}_{PROD} - C^{O}_{LOSS}\right] \\
&+ Q^{O}_{OFF}\left[-C^{O}_{DT} - C^{O}_{OREF} - C^{O}_{PROD} - C^{O}_{LOSS}\right] + Q^{O}_{DOM}\left[P^{O}\right. \\
&\left. - C^{O}_{DIST} - C^{O}_{DREF} - C^{O}_{PROD} - C^{O}_{LOSS}\right] \\
&+ Q^{O}_{IMP}\left[-P^{O} - \Delta P^{O} - C^{O}_{DIST} - C^{O}_{DREF} - C^{O}_{LOSS}\right] \\
&+ \sum_{j=1}^{5} q^{P}_{SWP,j}\left[P^{P}_{DOM,j} - C^{P}_{CT,j} - C^{P}_{DIST,j} - C^{P}_{LOSS,j}\right] \\
&+ \sum_{j=1}^{5} q^{P}_{IMP,j}\left[P^{P}_{DOM,j} - P^{P}_{IMP,j} - C^{P}_{CT,j} - C^{P}_{DIST,j} - C^{P}_{LOSS,j}\right] \\
&+ \sum_{j=1}^{5} q^{P}_{DOM,j}\left[P^{P}_{DOM,j} - C^{P}_{DIST,j} - C^{P}_{LOSS,j}\right] \\
&+ \sum_{j=1}^{5} q^{P}_{EXP,j}\left[P^{P}_{EXP,j} - C^{P}_{LOSS,j}\right] - FC_{DREF} - FC_{DIST}
\end{aligned}
$$

j = 1 … 5 is the subscript representation for the five (5) different petroleum products – Naphtha, Gasoline, Diesel, Kerosene, and Fuel Oil.

Functional Constraints

$$Q^{O}_{EXP} + Q^{O}_{DOM} + Q^{O}_{OFF} = Q^{O}_{PROD}$$

Upstream production constraint

$$\sum_{j=1}^{5} q^{P}_{DOM,j} + \sum_{j=1}^{5} q^{P}_{EXP,j} = Q^{O}_{IMP} + Q^{O}_{DOM}$$

Domestic refining production constraint

$$Q^{O}_{IMP} + Q^{O}_{DOM} \leq TDRC$$

Domestic refining capacity constraint

$$\sum_{j=1}^{5} q^{P}_{SWP,j}\left[P^{P}_{IMP,j} + F^{P}_{SWP,j}\right] = Q^{O}_{OFF}\left[P^{O} - C^{O}_{OREF}\right]$$

Offshore refining production constraint

$$\sum_{j=1}^{5} q^{P}_{DOM,j} + \sum_{j=1}^{5} q^{P}_{IMP,j} + \sum_{j=1}^{5} q^{P}_{SWP,j} = \sum_{j=1}^{5} q^{P}_{DEM,j}$$

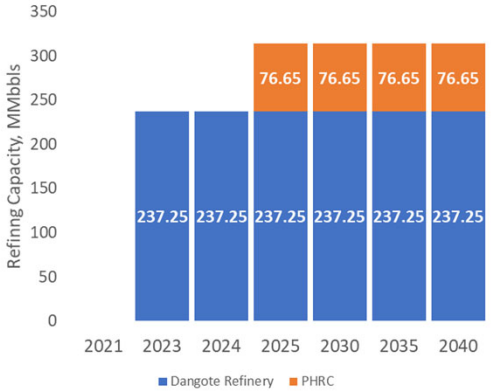
Domestic product demand constraint

$$LB_j \leq \frac{q^{P}_{DOM,j} + q^{P}_{EXP,j}}{Q^{O}_{IMP} + Q^{O}_{DOM}} \leq UB_j$$

Domestic refinery yield constraints

METHODOLOGY – Energy Transition & Data Sources

S/N	Dimension	Scenario: Energy Transition
1	Oil Production	Production decline by 3.30% pa as per the IEA NZE2050
2	Oil Price Profile	Oil price (RT2019) declines as per IEA NZE2050 scenario from $37/bbl (2021) to $29/bbl (2040)
3	PMS price subsidy	No subsidy from 2024
4	Domestic Refining Capacity Build-up	DORC (start 2023) + PHRC (start 2025)



Nigeria's Expected Refinery Capacity Build-up under Energy Transition

	Oil Price $/bbl (RT2019)	Oil Production (MMbbls)
2021	37.27	623.04
2025	35.55	545.99
2030	33.40	462.94
2035	31.25	392.53
2040	29.10	332.82

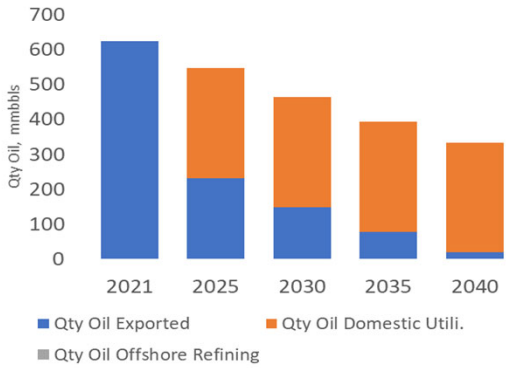
Oil Price and Production (Nigeria) under Energy Transition

S/N	Parameters	Data Source
1	Oil price, P^O	IEA NZE2050 scenario
2	Oil production, Q^O_{PROD}	IEA NZE2050 scenario
3	Cost of upstream oil production, C^O_{PROD}	model (Gbakon, *et. al.* 2021)
4	Dirty Tanker Freight, C^O_{DT}	Argus Media
5	Oil pipeline distribution costs, C^O_{DIST}	Sayne *et. al.* 2015
6	Price differential of imported oil, ΔP^O	Argus Media
7	Variable cost of domestic refining, C^O_{DREF}	Sayne *et. al.* 2015
8	Fixed cost domestic refining, FC_{DREF}	NNPC F&O reports, Reuters
9	Offshore refining processing fee, C^O_{OREF}	Sayne *et. al.* 2015
10	Clean Tanker Freight, C^P_{CT}	Argus Media
11	Domestic demand of refined products, $q^P_{DEM,j}$	Woodmac
12	Product yields: domestic refineries LB_j, UB_j	NNPC ASB, EIA Dangote refinery
13	Domestic prices of refined products, $P^P_{DOM,j}$	PPPRA, Platts

	Gasoline (MMbbls)	DPK (MMbbls)	AGO (MMbbls)	Fuel Oil (MMbbls)	Total (MMbbls)
2021	118.24	23.66	31.79	8.06	181.75
2025	135.13	25.01	35.39	6.71	202.24
2030	153.06	27.19	42.93	7.03	230.21
2035	171.59	28.69	50.59	6.77	257.64
2040	188.89	30.73	60.53	6.82	286.97

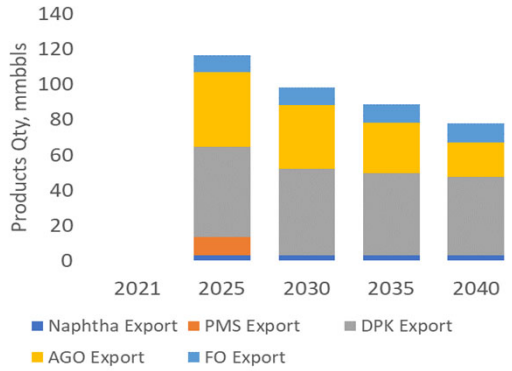
Nigeria Petroleum Product Demand Forecast (Woodmac)

RESULT – Oil exports decline, DPK and AGO drive product exports and 84% product demand met by domestic supply in 2040



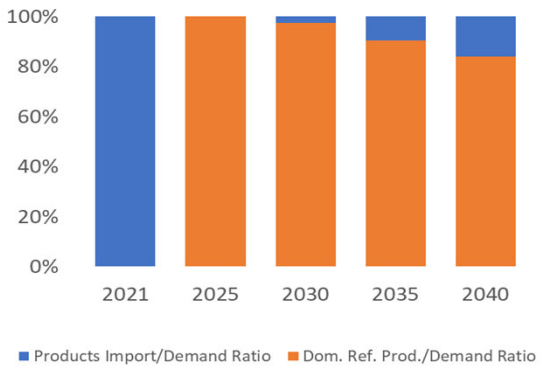
Optimal Allocation of Nigeria's Oil Production under Energy Transition

- **crude oil exports decline from 623 MMbbls in 2022 to ~ 19 MMbbls in 2040**
- **domestic utilization of crude oil production stays constant at 314 MMbbls 2025 to 2040.**
- **no oil dedicated to offshore refining.**
- **optimally, the export ratio declines from 100% (in 2021) to 6% (in 2040).**



Optimal Petroleum Product Export Profile

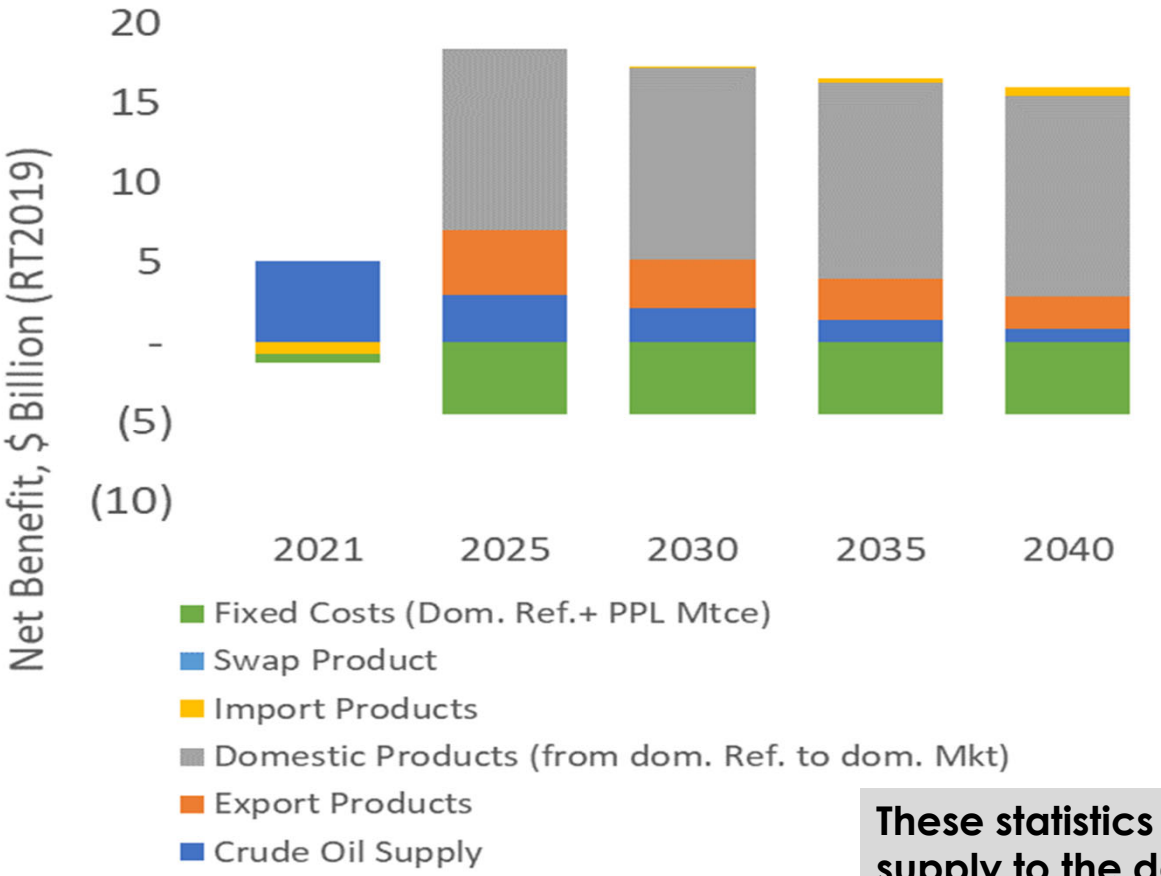
- **product exports start in 2023 at 67 MMbbls, rise to 117 MMbbls 2025 but declines to ~78 MMbbls by 2040**
- **DPK and AGO constitute the bulk of exported products. PMS is minimally exported at 10.4 MMbbls in 2025 and from 2030 onwards, no PMS is exported.**
- **ratio of refined products exported in 2025 at 37%, The ratio declines to 25% in 2040.**



Optimal Mix of Petroleum Products Supply to Domestic Market

- **In 2025, domestic demand is 100% fulfilled by domestic refining production.**
- **this declines to 84% in 2040.**
- **2030 marks the first-time products are imported and this is comprised only of PMS.**
- **PMS imported increases from ~ 6 MMbbls in 2030 to ~45 MMbbls**
- **Zero products imports between 2025 and 2029.**

RESULT – Net benefits 2021 – 2040 amounts to $228 billion.



Distribution of Optimal Net Benefits

- **Net benefit rises from $3.76Bn in 2021 to a peak of $13.81Bn in 2025 and then declines to $11.45Bn in 2040.**
- **Greatest contribution to the net benefits from domestic sales of products from the domestic refineries.**
- **Between $11.4Bn and $12.5Bn is attributable to product supply to the domestic market from the domestic refining system.**
- **Net value contribution from product exports declines from $4 billion (2025) to $2.1 billion (2040).**
- **The net value from crude oil sales (both to export and to domestic refineries) declines from $2.9 billion (2025) to $0.81 billion (2040).**

These statistics highlight the importance of product supply to the domestic market from domestic refining and the diminishing import of the value from oil supply (both to export and domestic refining system).

KEY CONCLUDING POINTS

- Characteristics of energy transition scenario with respect to Nigeria is established, in terms of declining oil production, fuel subsidy phase out, limited refinery capacity growth, and declining crude oil price.

- Oil exports decline – from 43% of oil production in 2025 to 6% in 2040 – while domestic demand is satisfied wholly from domestic refining from 2025 to 2030, beyond which gasoline imports are specifically required to augment domestic production.

- Refined petroleum exports increase from 67 MMbbls in 2023 to a peak of 117 MMbbls in 2025 and decline to 78 MMbbls in 2040. Refined products exports are driven by jet (DPK) and diesel (AGO).

- Net benefit driven by products supplied to the domestic market from dom. Refining and refined product exports

KEY CONCLUDING POINTS

- Oil supply diminishes in importance as a driver of net benefits. However, optimal allocation of oil and refined products under energy transition scenario sees a shift of value to the domestic market, and products exports market

- Investment decisions and strategic policy choices need to consider likelihood of a future consistent with the energy transition scenario.

- This consideration especially so for Sub-Sahara Africa energy systems and calls for energy modelling that employs stochastic analysis to address energy trilemma challenges.

END