Problem Statement

The provision of diesel for energy security for the Abuja airport has been difficult to sustain and there is an increasing need for long term sustainable energy solution.

Literature Review

Sergio O. A and Mario M. (2016) analyzed the main behaviors and energy trends at airports in more recent research, starting with the description of the main energy sources and consumers, the application of energy conservation and energy efficiency measures, the establishment of energy indicators and benchmarking between airports, as well as energy modeling and simulation.
Heating, ventilation and air conditioning (HVAC), lighting, Information and communication technologies (ICT) are usually the most important energy consumers at airports (airside and landside). Electricity is the dominant energy source which usually comes from the commercial grid. However, during the last several years, it is possible to find in the scientific literature and at airports other kinds of energy sources such as combined heat and power plants (CHP) or renewable energy technologies. Nowadays energy consumption reduction is a priority for airport managers. Most important measures can be classified into the following categories: improvements in management systems and energy facilities, improvements in HVAC systems and lighting, and new operational management systems that help to improve and optimize airport energy efficiency. Likewise, modeling and simulation of energy consumption at airports can be an important factor in lowering consumption.

Qudrat-Ullah H. 2015 carried out an overview of modelling approaches and models and identification of their key challenges in the face of characterization of energy systems as complex, dynamic system with numerous uncertainties, non-linearities, time lags, and intertwined feedback loops. The traditional econometric and linear programming methods alone are not adequate to deal with the increasing liberalization and privatization, heightened emphasis on environmental issues including global warming and climate change, complexity of multi-dimensional and conflicting interests of stakeholders, and unprecedented technological disruptions added to the complexity of the task of the energy policy decision makers across the globe.

Vithayasrichareon P. 2012 presented a novel decision-support tool for assessing future generation portfolios in an increasingly uncertain electricity industry. The tool combines optimal generation mix concepts with Monte Carlo simulation and portfolio analysis techniques to determine expected overall industry costs, associated cost uncertainty, and expected CO_2 emissions for different generation portfolio mixes.
In this study, it highlighted the potential value of the tool, in facilitating generation investment and policy decision making as well as exploring a wide range of issues with regard to future electricity generation portfolios. The tool does, of course, have some limitations. For example, the work in this study assessed complete new-build generation portfolios without considering existing generation capacity. However, consideration of existing generation should only require a relatively straightforward extension of the tool. Also, and as noted earlier, the tool does not consider all the

issues associated with electricity industry operation; for example, unit commitment, ramp rate constraints and network constraints.

Table 1 The model boundary chart

Endogenous	Exogenous	Excluded
GDP	Emission	All ground equipment in the airside except ground power
Fuel price	Population	Terrorism, Pandemic, war etc.
Generator turn over	Energy capacity of the grid	
Airlines	Grid reliability	
Supply from the national grid	Energy capacity of renewable	
Revenue passenger kilometres	Building rate	
Airfare	Diesel shipments	
Flight frequency	Normal energy demand	
Diesel consumption		
Subsidy		
Employment		
Dwell time for turnaround		
Generator manufacturers		
Energy demand		
Energy supply		
Installed capacity		
Accidents		
Security		
Delay		
Carbon tax		
Fuel storage		
No of runways		

Federal aviation authority of Nigeria (FAAN)		
Routes		

3. Reference Mode

Figure 1 shows the historical behavior regarding electrical energy usage in the Nnamdi Azikiwe International Airport. We can see that energy demand was increasing slowly up until 2016 but is now is increasing rapidly. Also, we can see that the energy supplied by the grid was larger than the energy supplied by diesel generators up until 2017 but now is roughly the same.

Figure 2 shows two possible scenarios for the future usage of diesel-generated electrical energy.
The hoped scenario is that energy efficiency measures will be introduced and renewable energy sources with come online in the near future which will create a reduction in the dependence on diesel-generated electricity and diesel fuel usage over time. The feared scenario is the demand for diesel-generated electricity will grow exponentially along with the diesel fuel usage.

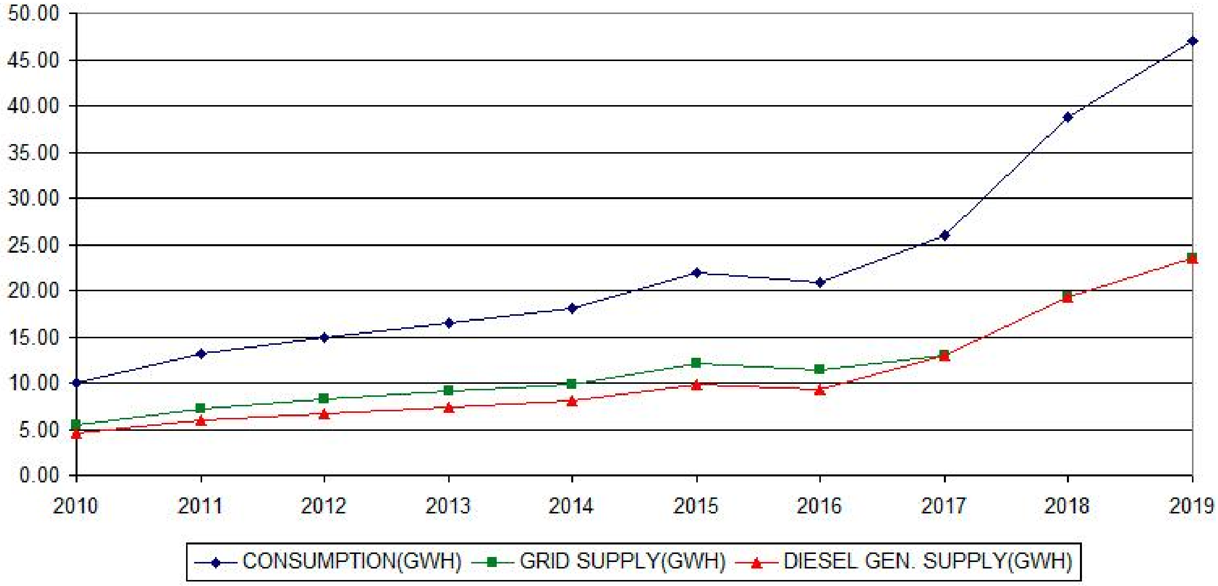

Figure 1: Historical data on electricity usage in Nnamdi Azikiwe International Airport

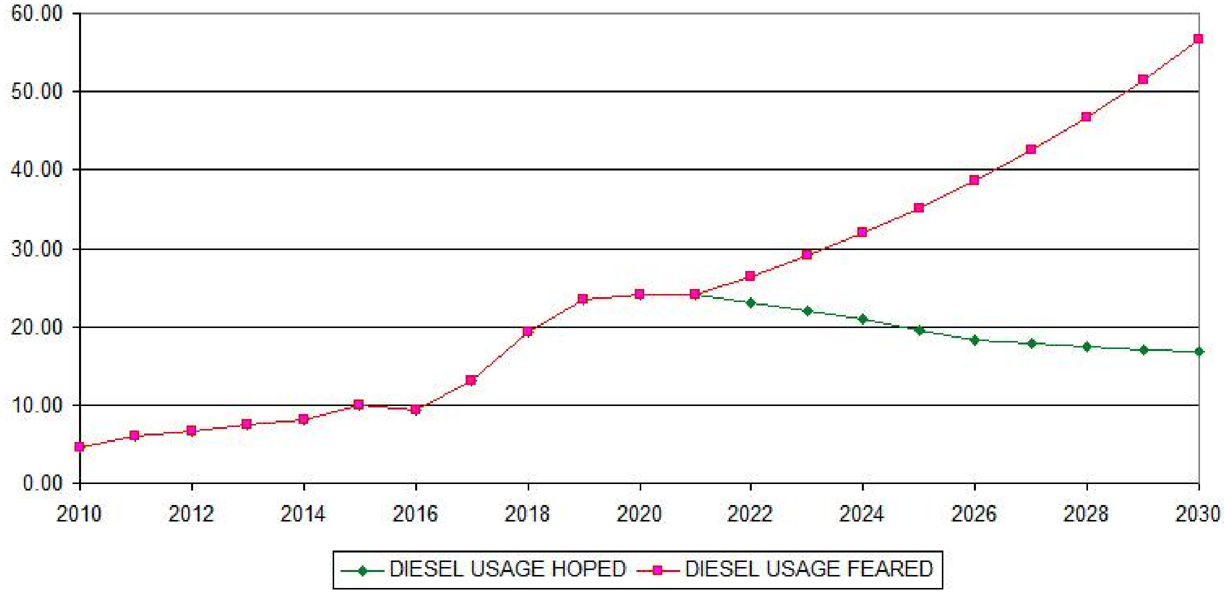

Figure 2: Hoped and feared scenarios for future diesel usage

3. Dynamic Hypothesis

Figure 3 shows the dynamic hypothesis. Economic growth is increasing the amount of travel which is increasing the amount of airport use which is increasing the amount of energy use (diesel-generated R1, grid-generated R2, and in the future renewables-generated R3) which is increasing the amount of energy security which is increasing the amount of economic growth which is increasing the number of travelers' which is increasing the airport usage. This results in three reinforcing loops. R1 would lead to the feared projected behavior of exponentially growing diesel usage. R2, R3 or both could lead to the hoped-for future.

However, with grid reliability, the electricity supplied by the grid will increase and the amount of energy supplied by diesel will decrease and the energy security will decrease, and the economic growth will decrease, the number of travelers will decrease, and the airport usage will decrease, and the amount o energy supplied by the grid will decrease which represents a balancing loop, B1. There is a similar balancing loop, B2 when renewable energy sources come online. Either or both of these balancing loops could lead to an equilibrium situation.

Thus, energy supplied by the grid and energy supplied by renewables limits the growth in energy supplied by diesel generators and diesel usage. Energy efficiency policies will also limit the growth in energy supplied by diesel, energy supplied by the grid, and energy supplied by renewables which will limit the growth in diesel usage.

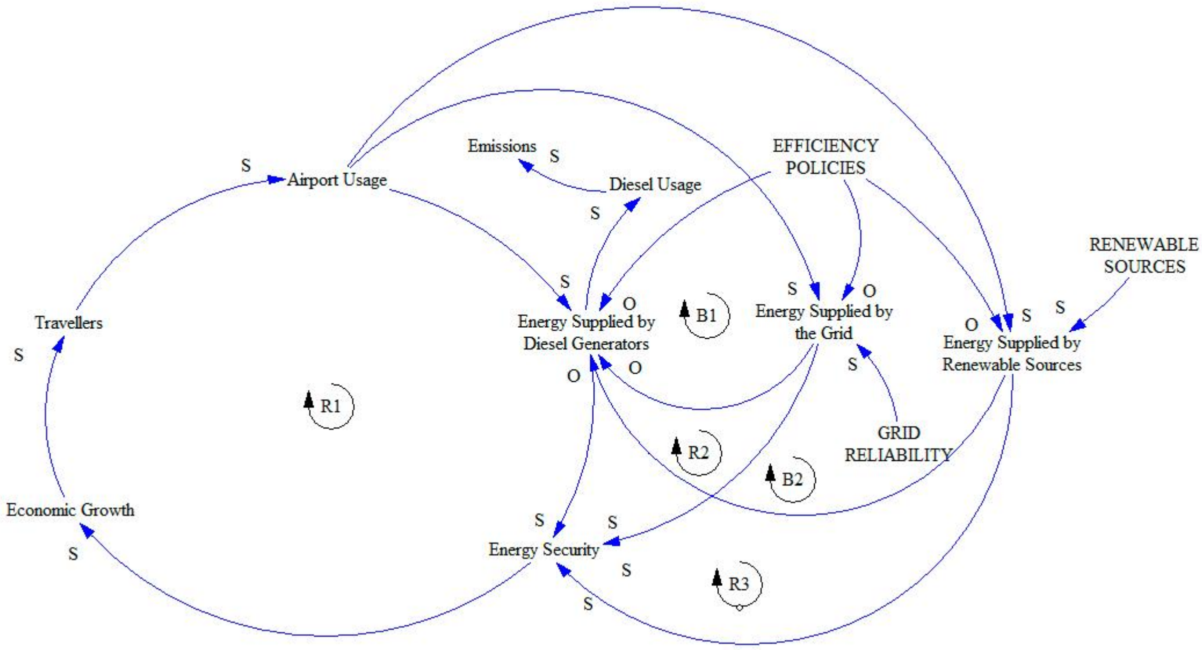

Figure 3. Dynamic Hypothesis

4. Stock and Flow Diagram

Figure 4 shows a preliminary stock and flow diagram of our planned System Dynamics model. There are three stocks: Energy Demand, Diesel in Storage, and Renewables Available.

Diesel in Storage has an inflow of diesel supply which depends on the Diesel in Storage and an outflow of diesel consumption which depends on electricity produced per liter of diesel and on energy demand from diesel. The energy demand from diesel depends on total energy demand and the energy from the grid and renewables. The energy supplied by the grid depends on grid reliability and grid capacity. The energy supplied by renewables depends on renewables available and renewables capacity.

Renewables Available has an Inflow called building which depends on the build rate and an outflow called demolishing which depends on the lifespan of the renewable sources and Renewables Available

Energy Demand has a bi-flow called the change in demand which depends on desired energy demand and current Energy Demand and the adjustment time. The desired energy demand depends on the effect of energy security on desired demand and this depends on energy security. Energy security depends on energy demand and energy supply. Energy supply depends on energy from the grid and renewables and energy from diesel and normal energy demand. Normal energy demand will depend on airport usage but this is not shown in Figure 4.

Finally, there is the auxiliary variable emissions which depends on diesel consumption and emissions per liter of diesel consumed

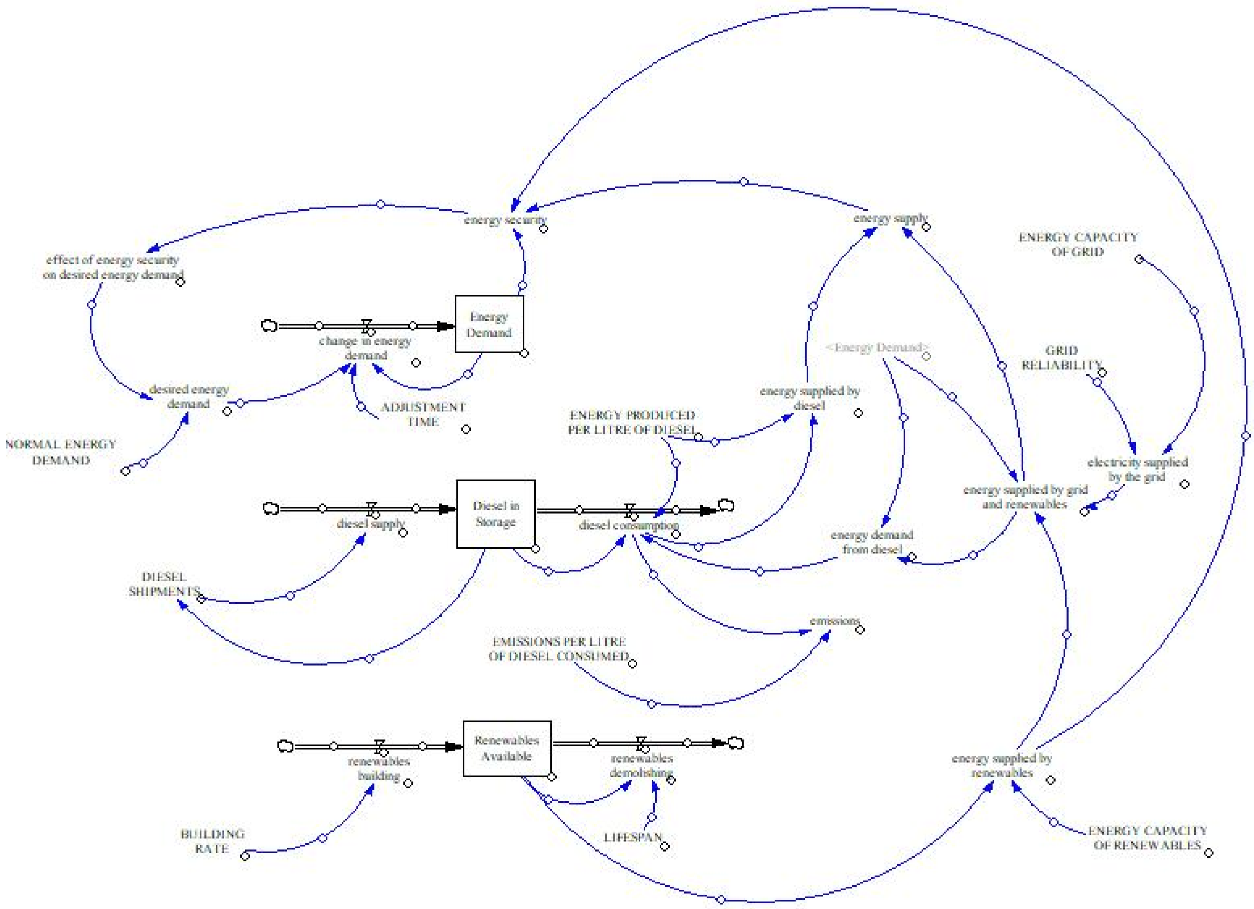

Figure 4: Stock and Flow Diagram

Future Work

We will calibrate the model using available time-series data. Finally, we will conduct scenario analysis to look at new technologies and their return on investment using the 3E framework that considers; energy security, the economy, and the environment.