System Modelling Approach in Transitioning Coal-based Energy Production to Sustainable Renewable Energy

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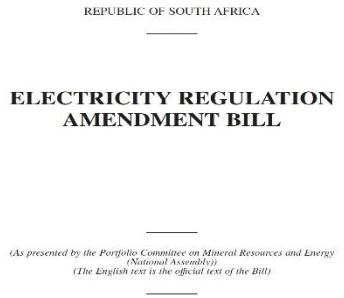
Introduction

- South African municipalities are facing a growing electricity demand, thus, putting a significant strain on the Eskom grid.
- Potential of renewable clean energy in alleviating the grid pressure, aligning with the Electricity regulation amendment bill [signed 16 Aug 2024]
- Improve the environmental outcomes through the reduction of emissions from coal-fired power stations.
- Introduction of Independent Power Producers (IPPs) to households and industries energy supply.
- Influence of power transmission, such as weather conditions, illegal connections, maintenance breakdowns, and cable theft.

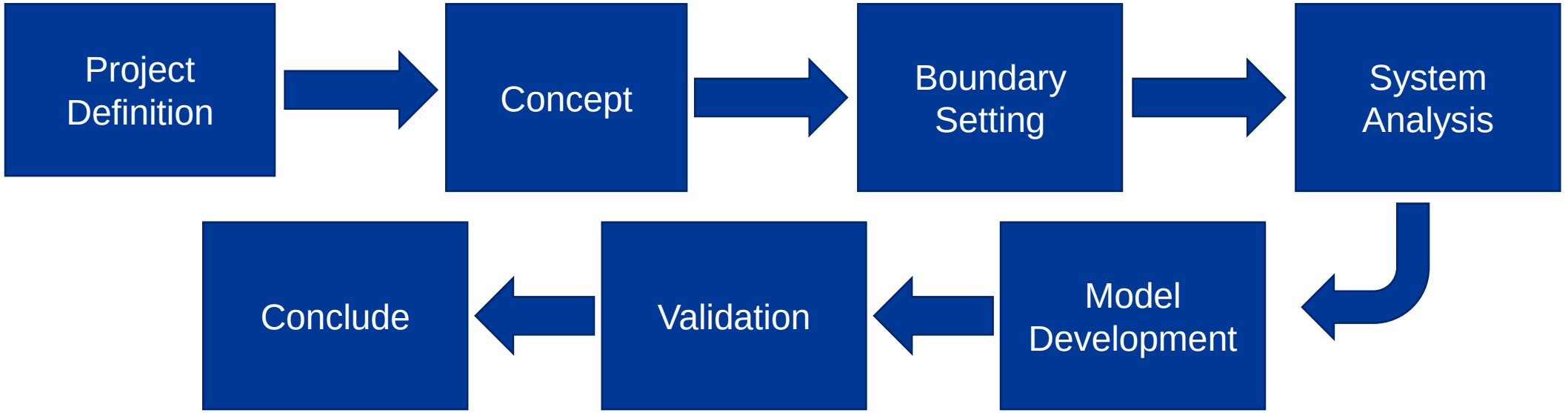

REPUBLIC OF SOUTH AFRICA

ELECTRICITY REGULATION AMENDMENT BILL

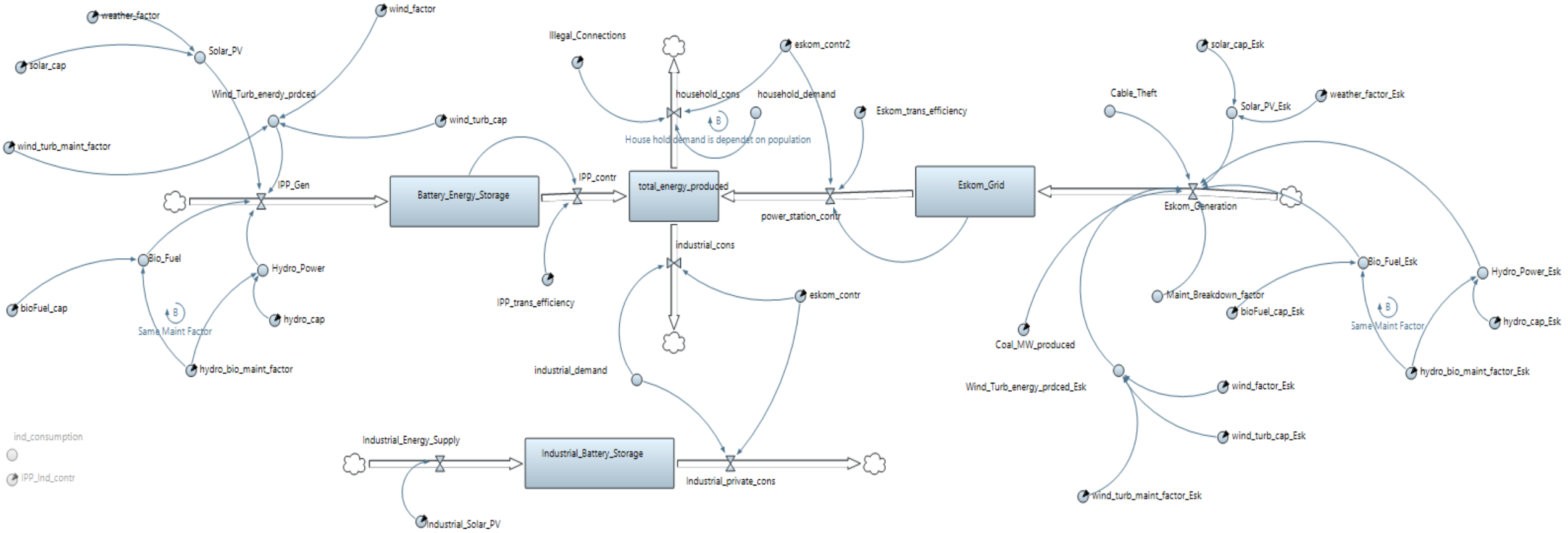
(As presented by the Portfolio Committee on Mineral Resources and Energy (National Assembly))
(The English text is the official text of the Bill)

Methodology

- By utilizing a system dynamics modelling approach in AnyLogic, we develop a comprehensive mode that incorporates stocks and flows to represent energy distribution from the grid and Independent Power Producers (IPPs) to households and industries



Model Development: Stock & Flow Diagram



Validation

The battery energy storage model receives renewable energy from different sources namely solar PV Plant, Biofuel Plants, Wind Turbine Plants, and Hydro-Electrical Plants. To determine the Wind turbine capacity, the production must be determined with the following formula.

$$P_{Wind\_Turbine} = (\eta_T X \eta_G) X C_p X \frac{1}{2} (\rho_{air} X A_{blades} v^3)$$

The efficiency of generation and transmission is denoted as η_G and η_T respectively, the power coefficient denoted as C_p, the density of air denoted as ρ_{air}, the velocity of the turbine denoted as v^3 and the blade area denoted as A_{blades}.

The energy produced by the hydro-electric plant was determined using the gravitational force formula:

$$P_{Hydro-Electric} = mgh(\eta_T X \eta_G)$$

Additionally, the mass of water, denoted as m, is determined using the expression:

$$m = \rho_{water} X v$$

Validation

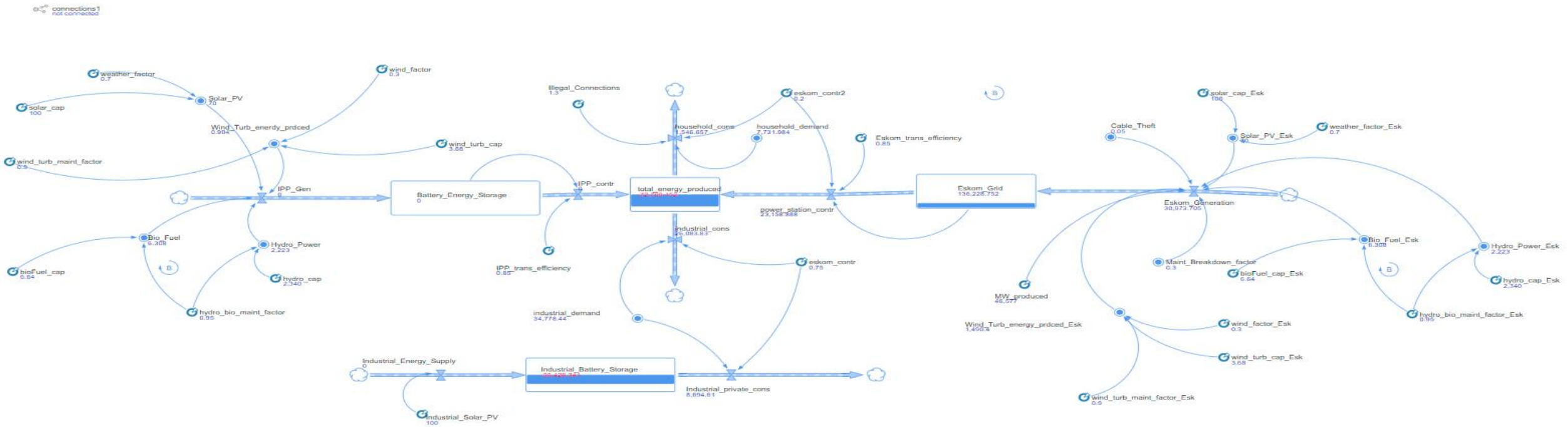
- To determine the energy produced by a plant that uses solid biomass to produce MW, the production was determined by using the following formula.

- $$P\_Output_{MWh} = ft \leq \frac{m\,(kg)\ X\ Energy\ Content\left(\frac{J}{Kg}\right) X\ \eta_{Plant}}{\leq} ft\ (Conversion\ Factor)$$

- Efficiency denoted as η_{Plant} is the steam plant efficiency. Additionally, the mass, denoted as m, is determined using the expression.

- $$m = Crops\ per\ Hectare\ X\ Area\ processed$$

Model Development: Consumption with Eskom being the sole producer of Energy



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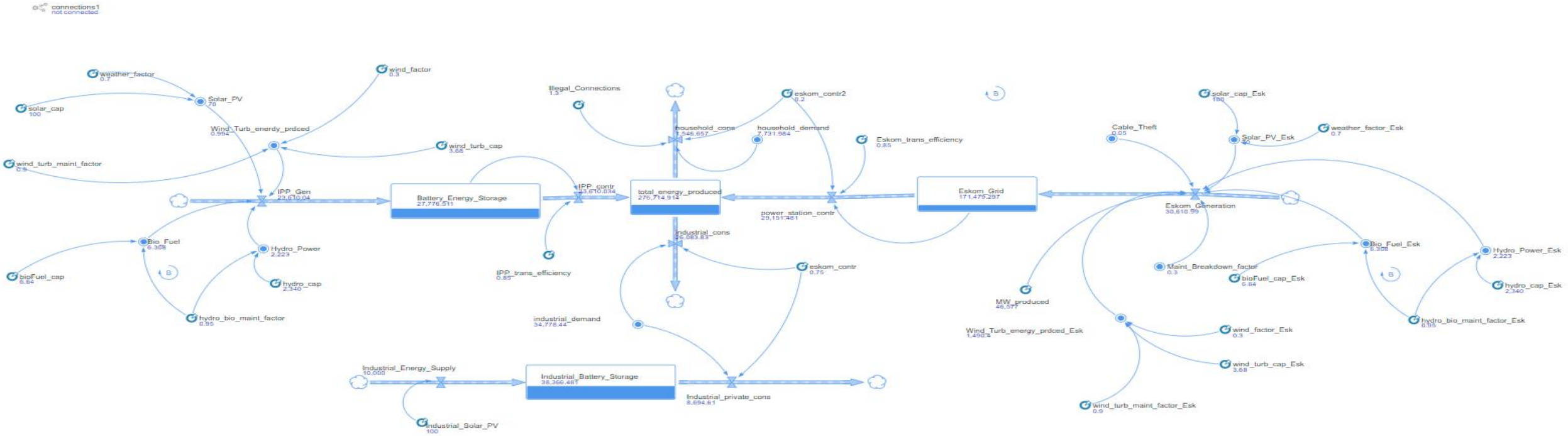

Discussion

- The simulation indicates a significant energy demand in the absence of independent power producer (IPP),
- industries consume more energy compared to households. From the model, several iterations were conducted with different outcomes.
- South Africa's energy of 20% to households and 80% to industrial, agriculture, transport, and others from a total energy of 46577MW generated by Eskom coal production.
- The system indicates a shortage of **1 746.99MW** to industries and households taking into consideration illegal connection, population, maintenance breakdown factor and transmission losses.
- This system shows that coal energy production alone is unable to supply South Africa without backup from IPP as shown in slide 8

- **Scenario 2: Slide 9, highlights a scenario when IPP's energy is proposed to supply both household and industrial and Clean Energy from Eskom and from IPP,**
- Recommendation to industrial sector to also install backup energy was proposed.
- IPPs produce a total of 23 610.04MW which 20% goes to households and 75% goes to industrial with an extra 10000MW industrial energy for its production and Eskom renewables generate 30 610. 04MW.
- The system with additional renewable energy is stable with surplus energy, which will accommodate population growth

Conclusion

The findings of the study highlighted the critical role of renewable energy and the percentage of contribution to the stocks. It was also discovered that industrial demand is higher than that of households, therefore more renewable energy must be prioritized in the industries rather than households. If South African IPPs can produce a total of 23 610.04MW, 20% will go to households and 75% will go to industrial with an extra 10000MW industrial energy for its production. Eskom is expected to produce 23 610.04 MW of clean energy that supplies 50% to industry and 20% to households. The system with additional renewable energy will be stable with surplus energy of 9391.03MW with Eskom grid only producing clean energy and 0MW supply from coal energy during off-peak hours.

Acknowledgment

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Thank You