An Expansion of the Long Term Impact of Renewable Wind Technology Implementation in South Africa

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Author Biography

Naledi Memela holds a BSc in Chemical Engineering from the University of KwaZulu-Natal, South Africa. Naledi was first introduced to System Dynamics (SD) in 2013 and officially joined the Energy utility, Eskom, under the Research division, in the System Dynamics Centre of Expertise. He has since submitted and presented numerous papers at the South African System Dynamics conference. Naledi has also facilitated on Systems and Modelling as well as Systems Thinking at SD courses given to the Universities in South Africa as well as corporate stakeholders. Naledi has applied the SD methodology for the development of operational and strategic decision support models for various areas within Eskom, such as Demin Water Production Planning tools for 4 coal-fired power stations, a Organizational key performance indicator simulator and a strategic renewable energy penetration model. He is representing Eskom and South Africa at the International System Dynamics Conference in Reykjavik, Iceland.

Introduction

- Rapid growth in renewable energy market has made an impact on the South African energy supply and generation mix
- Renewable energy consists of various technologies, this paper and presentation focuses on the potential long term impact wind energy could have on South African energy supply.
- System Dynamics approach has been used to assess this impact & interrogate numerous scenarios
- The expansion of this model has included land availability and plant spatial requirement dynamics
- The application of the methodology has produced a capable planning tool for the energy sector

Background

- The wind capacity roll out schedule is based on the IRP 2016. The model enables the IRP base case scenario to be interrogated in terms of high level feasibility
- Electricity production projections are generating by considering the proposed new build regions and respective weather conditions, wind turbine design type options and land availability
- The expansion has included land availability dynamics by taking exclusion zones into account and finite spatial availability
- Potential regions for new build were refined by a feedback stock flow structure to redistribute new wind build based on spatial availability within each region

Land Exclusion Criteria & New Build Regions

Table 1: Site Exclusion Criteria (Eskom Holdings, 2013)

Exclusion	Layer	Exclusion Buffers
Social	Urban edge	1km
	Major towns	5-15km
	Rural settlements	1km
	Suburbs Boundaries	1km
Infrastructure	Rail	250m
	National Roads	1km
	Provincial/Main Roads	500m
	Hv/Tx Line	400m
	Airports	30km
	Airfields	15km
	Military sites	15km
Environment	Wetlands	500m
	Dams	500m
	Rivers/Mainstreams	500m
	Agricultural land potential	Perimeter exclusion
	Nature reserves	2km
	National Parks	2km
		2km
	World Heritage sites	2km
	Forestry (Indigenous forest)	1km
Technical	Slope	<15°
	Square Kilometre Array (SKA)	Perimeter exclusion

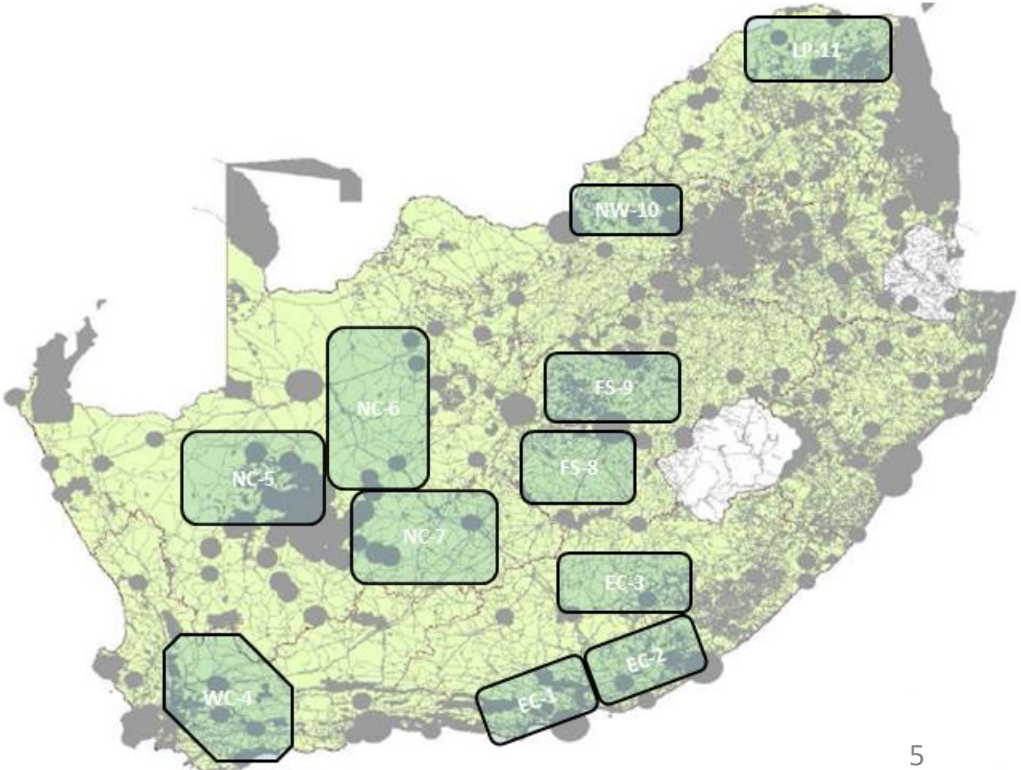

Fig1:Wind Energy Location Index with Exclusion Zones (Eskom Holdings, 2013)

Causal Loop Diagram

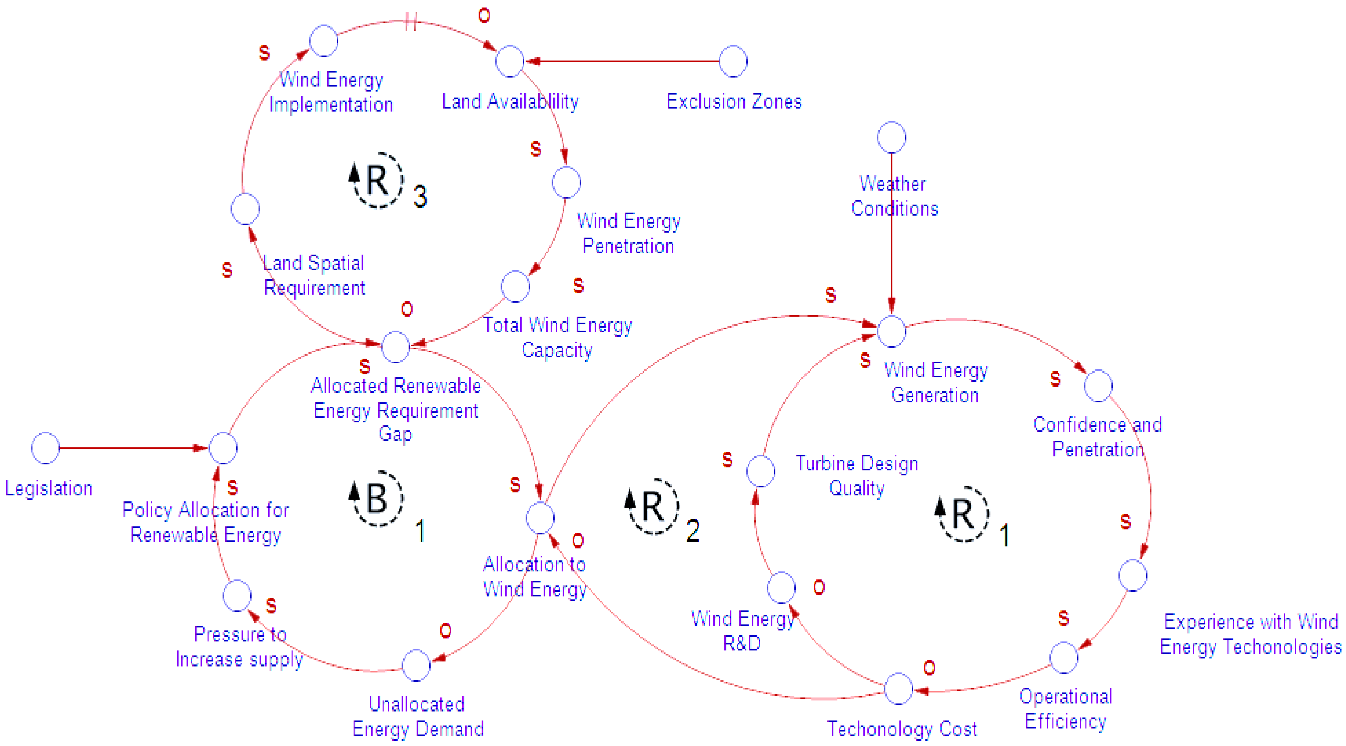

Fig 2:Wind Energy Casual Loop Diagram

Model Boundary Chart

Table 2: Model Boundary Chart

Endogenous	Exogenous	Excluded
Power Generated (MW)	Weather Data (Wind Speed)	Wind direction
New Build Capacity Factor	Turbine design options	Plant degradation
Energy Generated (MWh)	Existing build Capacity Factor	
Spatial Requirements (km^2)	IRP Base Case	

https://www.cnbc.com/2016/10/07/these-are-the-top-10-countries-leading-the-way-in-energy.html

Stock-Flow Structures

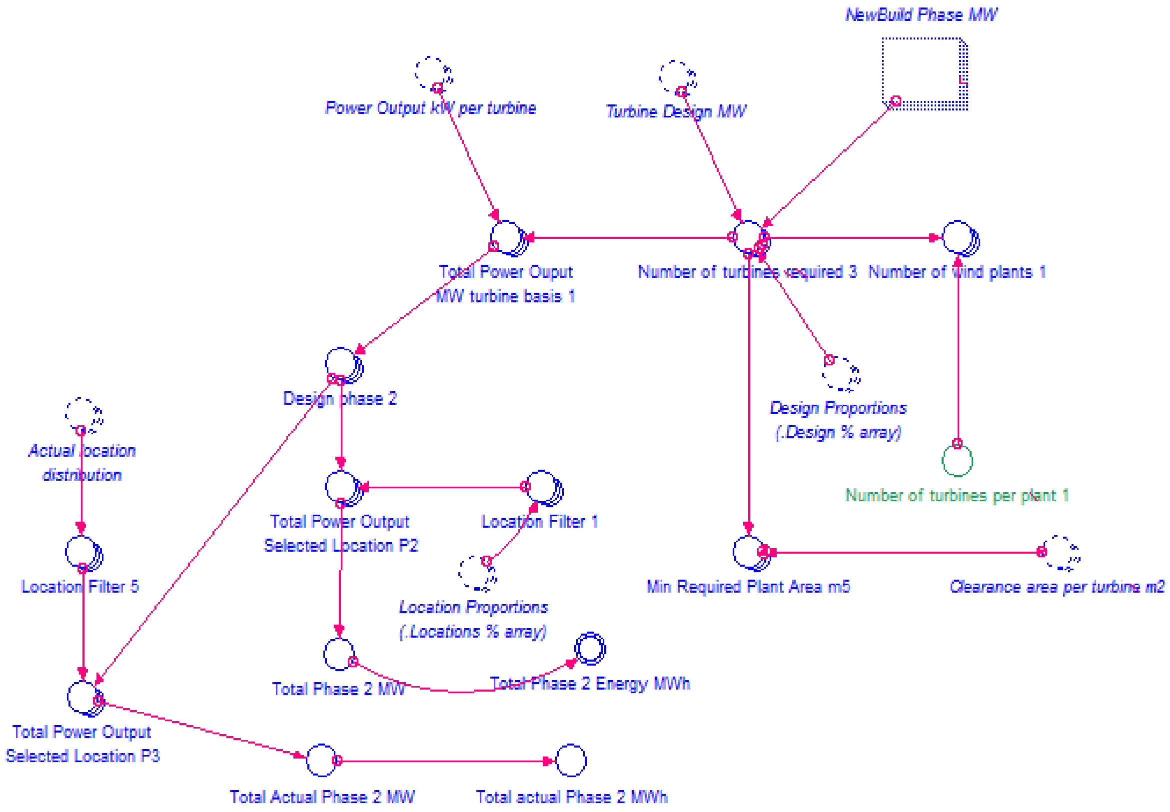

Fig 4: Energy Projection Structure

Stock-Flow Structures

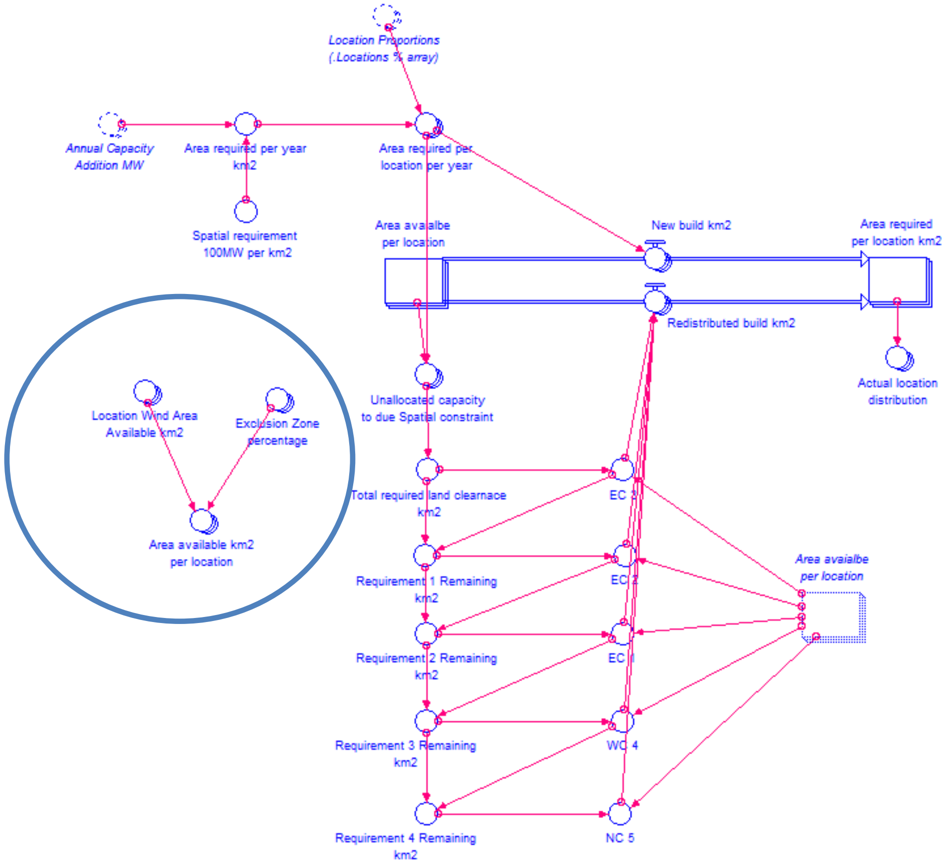

Fig 5:Land Allocation Structure

Model Results

Land availability scenario

The scenario shown below allocates 90% of new build to the Eastern Cape, which has favourable high wind speeds. Fig 6 shows the land availability in location EC3 depletes in the year 2040. This was due to the large new build allocation

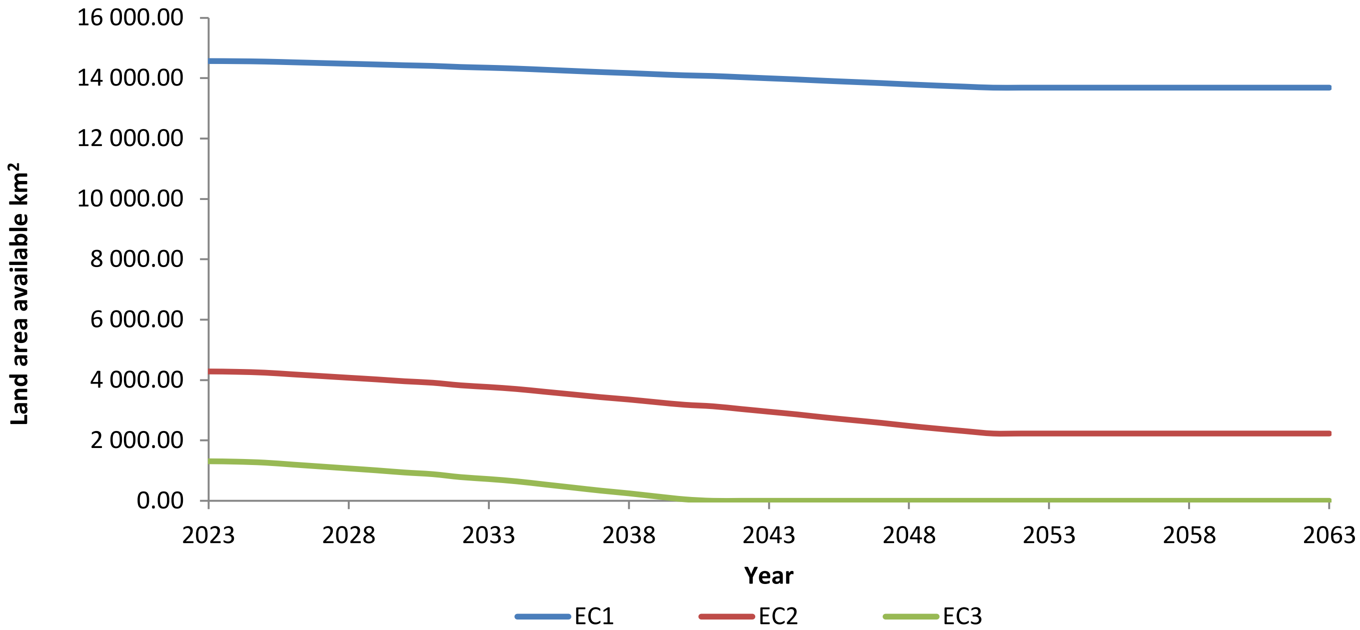

Fig 6 :Land area availability per location

Model Results

Land availability scenario

The model then redistributed the allocation proportions to the next favorable region EC2, the proportion can be seen to increase post 2040, in Fig 7

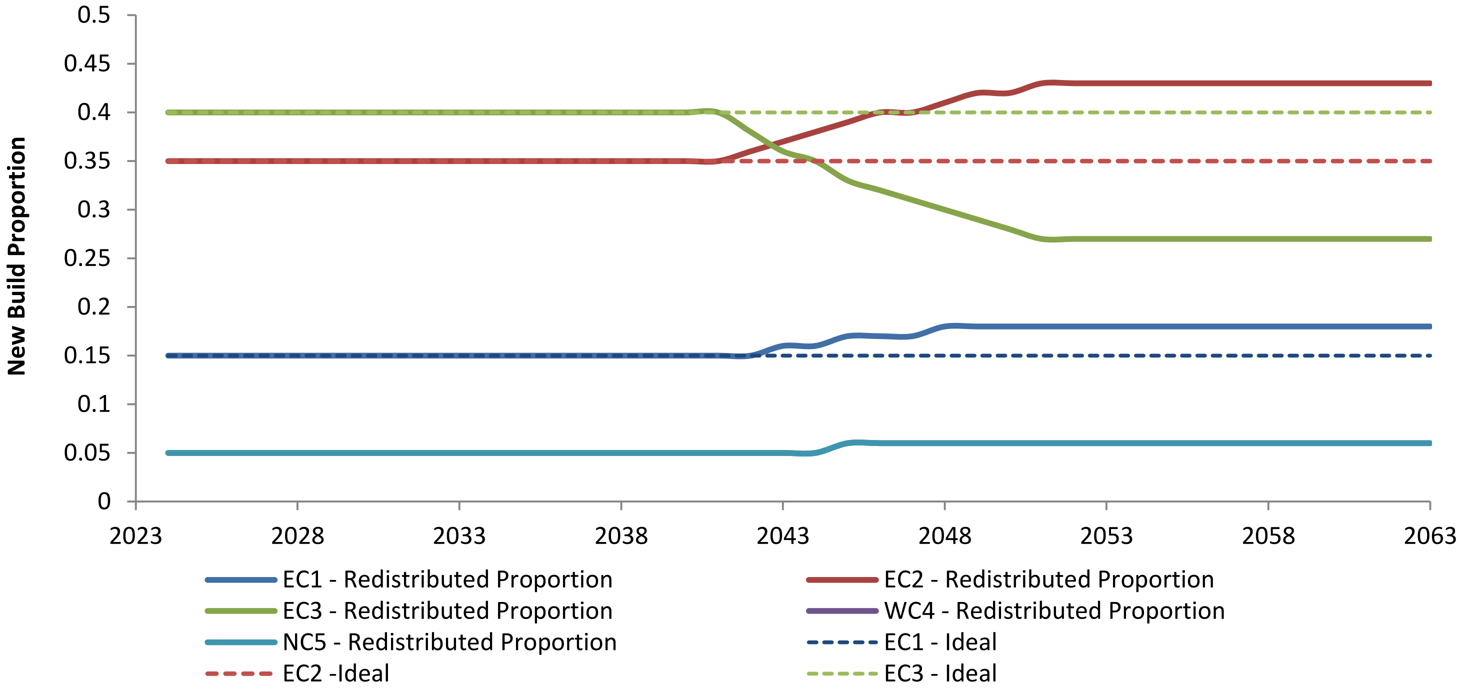

Fig 7 Ideal vs redistributed new build proportions

Model Results

Land availability scenario

The redistribution will cause a change in the energy yield projection due the average wind speeds in the regions are not the same. The redistributed energy projection curve shows a resultant 15.13% reduction in energy output

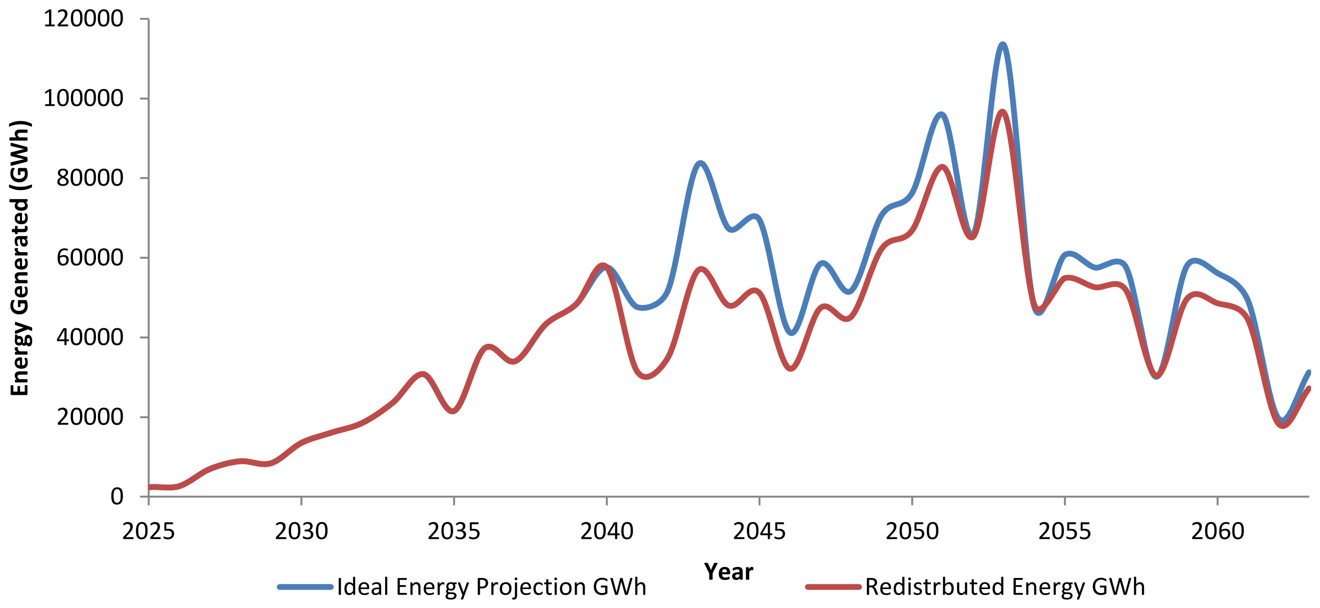

Fig 8 Ideal vs redistributed new build proportions

Model Results

Plant decommission versus Plant non-decommission scenario

This scenario speaks to the possibility of wind energy plants being refurbished post the 20 year plant life. The difference in energy yield translates to a 55.18% increase in energy yield from the year 2034 to 2063. decommissioning plants 5.70% loss in total energy production. This may present a cost trade off for energy planners and producers.

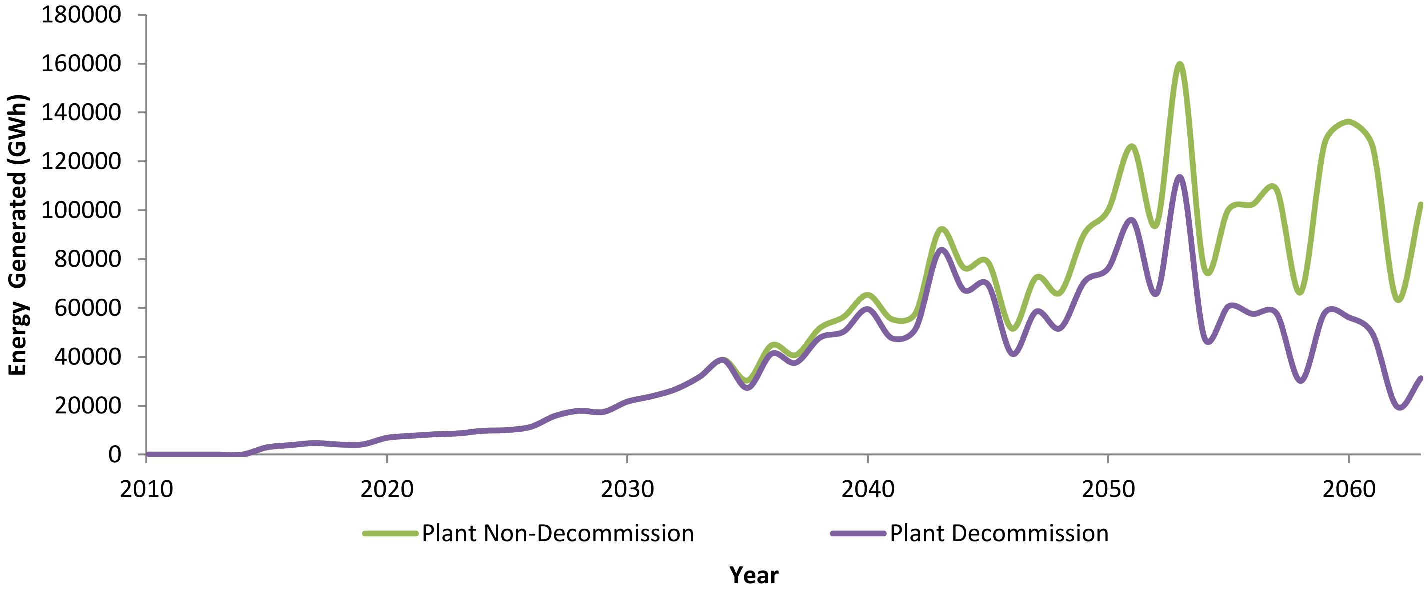

Fig 9 Plant decommission versus Plant non-decommission scenario

Conclusion

- System dynamics methodology combined with the use of iSee STELLA has produced a model capable of providing valuable insights into the future of wind energy in South Africa.

- The expansion has included spatial factors and land availability constraints to improve the feasibility of the generated scenarios

- The model has shown the energy yield difference in plant decommission and non-decommissioning scenarios

- The model is able to interrogate energy production targets for wind energy and provide decision support to energy planners with the functionality and factors included in the study

- The results of the model are to be benchmarked against other tools such as the System Advisor Model (SAM) developed by NREL for validation