INDUSTRIAL ENGINEERING
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Fostering Sustainable Energy Transitions for South Africa's Electricity Sector

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SUSTAINABLE ENERGY TRANSITIONS

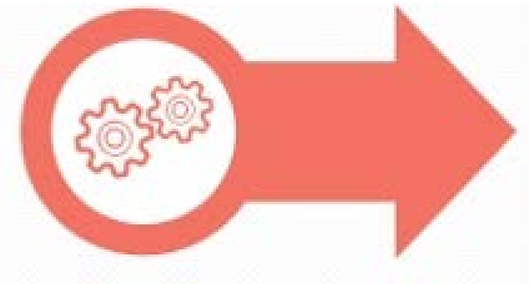
The Research Process

Problem Definition

Understand the South African Context and define the Research Question

Literature Survey

Conduct a Literature Search on Scientific Database, attend Lectures and Search Campus Library



System Dynamics Modelling

Understand Real Life Context and determine Model Boundaries, Develop Causal Loop Diagram and Construct Dynamic Model

Scenario Development

Perform Various Scenario Interventions and Test Possible Futures

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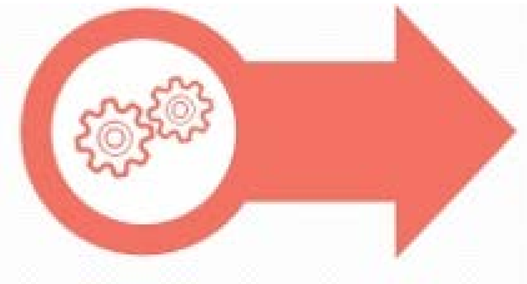

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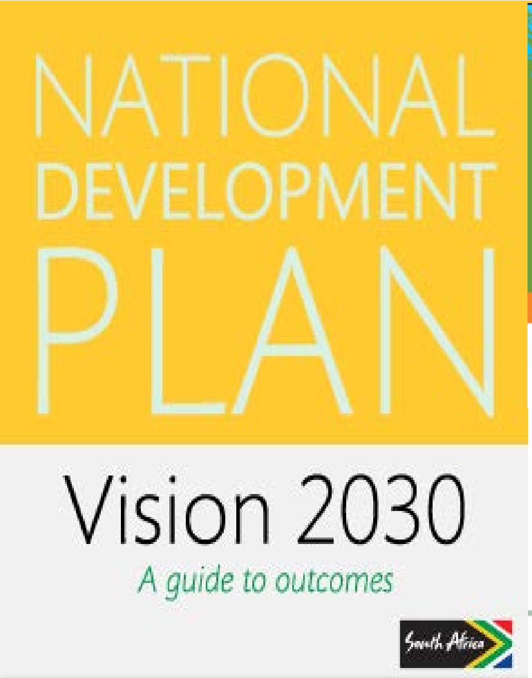
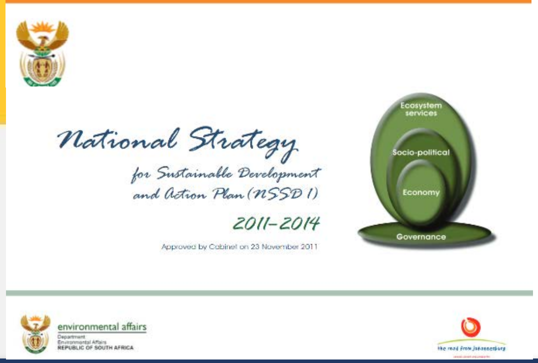
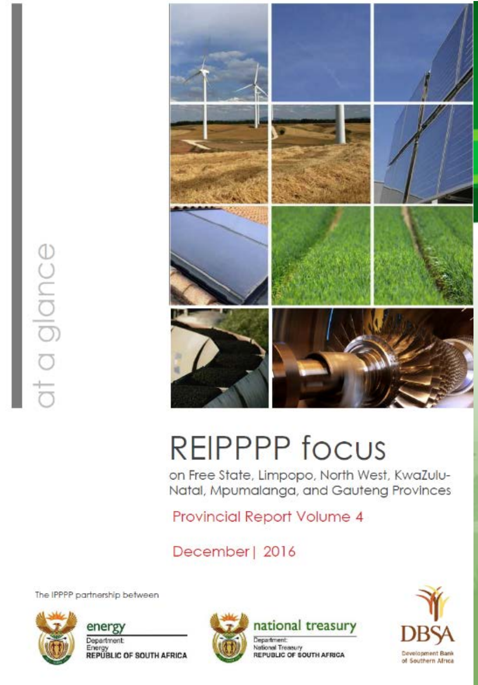
South Africa's Key Policies







Is South Africa's Fostering a Sustainable Energy Transition?

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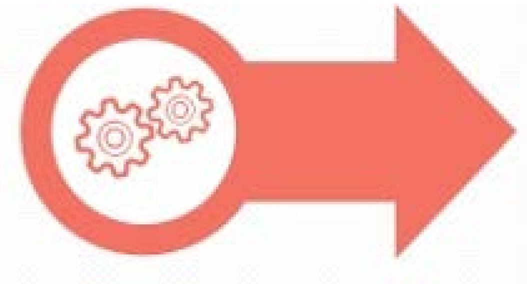
Literature Survey

Conduct a Literature Search, Define a Set of Criteria for Electricity Sector's SET



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Energy transitions research: Insights and cautionary tales, Grubler (2012)

Socio-Technical Perspective

Insight 1: The importance of energy end-use in driving energy transitions

Insight 2: Rates of change are slow, but not always

Insight 3: There are distinct patterns in the successful scaling up of technology systems

- Economic competitiveness
- Supply Security and Generation
- Innovation and Technology
- Politics and Public Acceptance

Energy and the Economy: Five Propositions, Heun (2016)

1. Energy and the Economy are Linked
2. The Fundamentals of Energy Supply/Demand and Prices are different now
3. Society uses the easily accessible resources first
4. They Dynamics of Energy and the Economy Nexus are an *Interdisciplinary* Grand Challenge
5. Unstable Economies are deterrent for sustainable transition investment

- Energy Efficiency
- Economic Competitiveness
- Supply Security and Generation

Sustainable Energy Transitions: Principles, Dynamics and Implications, Csala and Sgouridis (2014)

1. Rate of Emissions < Ecosystems Carrying Capacity
2. Renewable Energy Generation < Ecosystems Carrying Capacity
3. Energy Demands are Adequately Satisfied
4. Sufficient Investment in Renewable Energy Before Fossil Fuel Depletion
5. Future Consumption is coupled to Availability of Energy in the Future

- Energy Efficiency
- CO_2 Emission Reduction
- Economic Competitiveness
- Supply Security and Generation

Literature Survey

The Future of Energy Use, O'Keefe et al. (2010)

Bridging the Energy Gap through Technology Transfer

Energy Poverty should be approached via a bottom up approach

Suggests Features for Sustainable Energy Systems : Appropriate, Exploits Indigenous Renewable Energy Resources, Capacity Enhancing, Adaptable, Easy to Repair and Maintain, Upgradeable

- Supply Security and Generation
- Resilience
- Innovation and Technology

A participatory multi-criteria approach for power generation and transmission planning, Bertsch and Fichtner (2015)

Socio-political Perspective

Involvement of end consumers which may become producers in the future.

Suggests a Multi-Criteria Approach which considers:

- *Public Acceptance*
- Economic Competitiveness
- Environmental Sustainability
- Security of Supply

- CO_2 Emission Reduction
- Economic Competitiveness
- Supply Security and Generation
- Politics and Public Acceptance

Energy, Economic Growth and Environmental Sustainability: Five Propositions, Sorrell (2010)

1. Energy Efficiency has rebound effects on energy consumption and economic growth
2. Energy has improved productivity and economic growth
3. Sustainability requires both improved efficiency and a principle of —sufficiency.
4. Sustainability cannot be achieved with increased economic growth in rich countries
5. A zero-growth economy is incompatible with a fractional reserve banking system.

- Energy Efficiency
- Economic Competitiveness

Measures of Success for South Africa's Electricity Sector SET

1. **Energy Efficiency**
2. **Emission Reduction**
3. **Economic Competitiveness**
4. **Supply Security and Generation**
5. **Resilience**
6. **Innovation and Technology**
7. **Politics and Public Acceptance**

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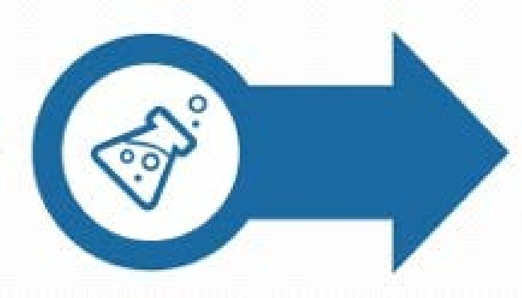

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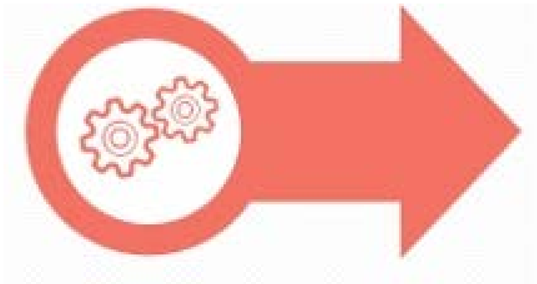

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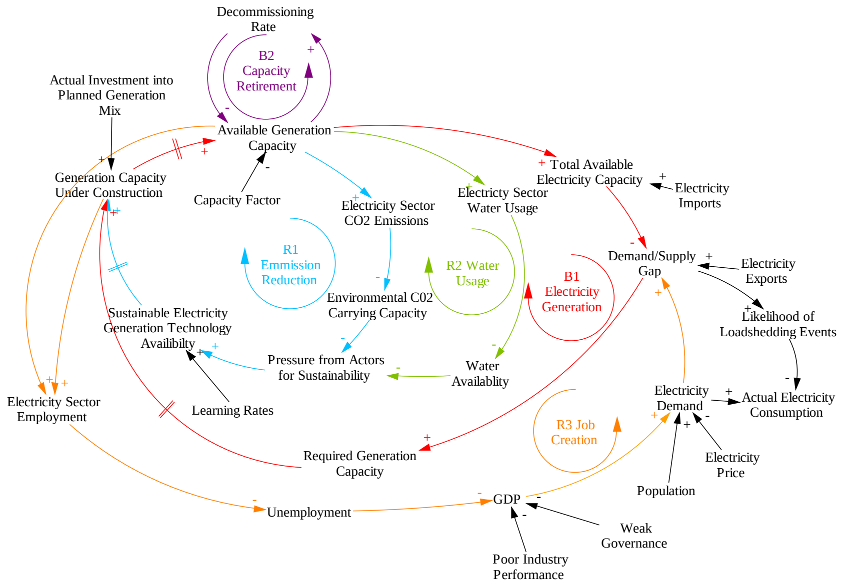
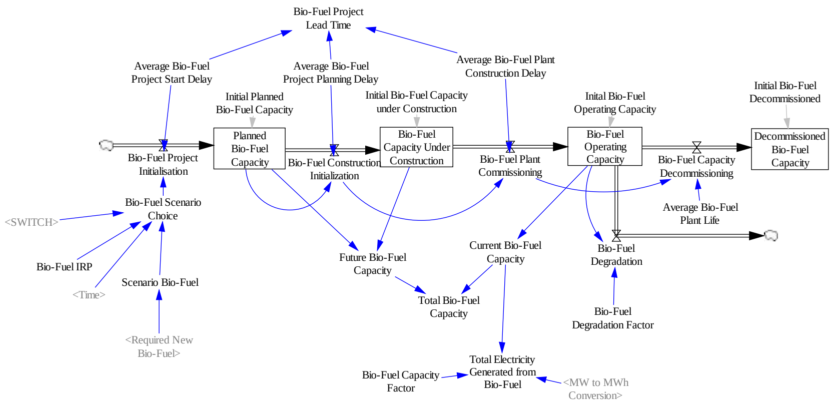
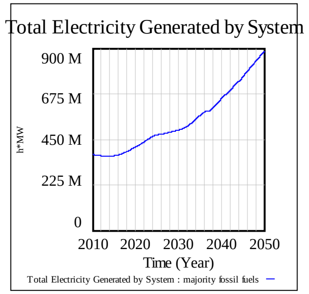
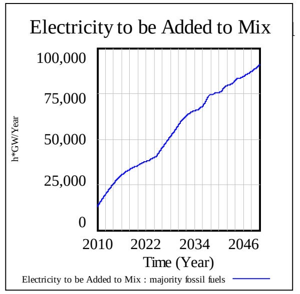
What is System Dynamics?

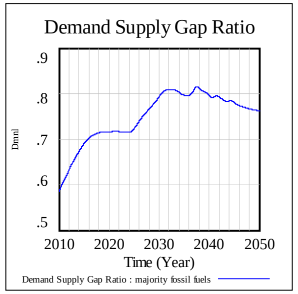
The Big Picture

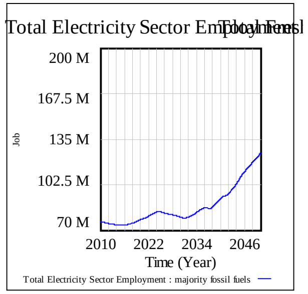






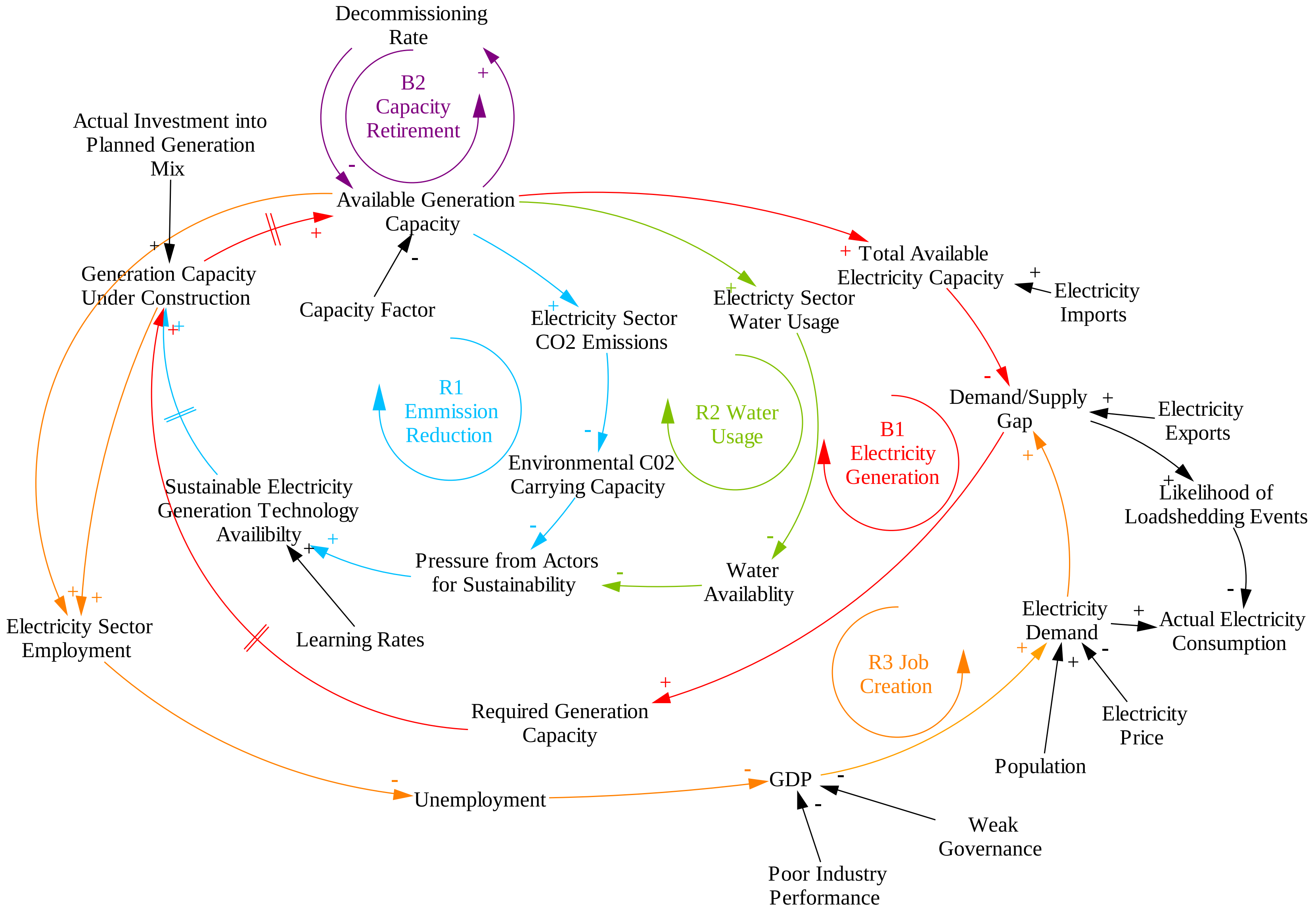




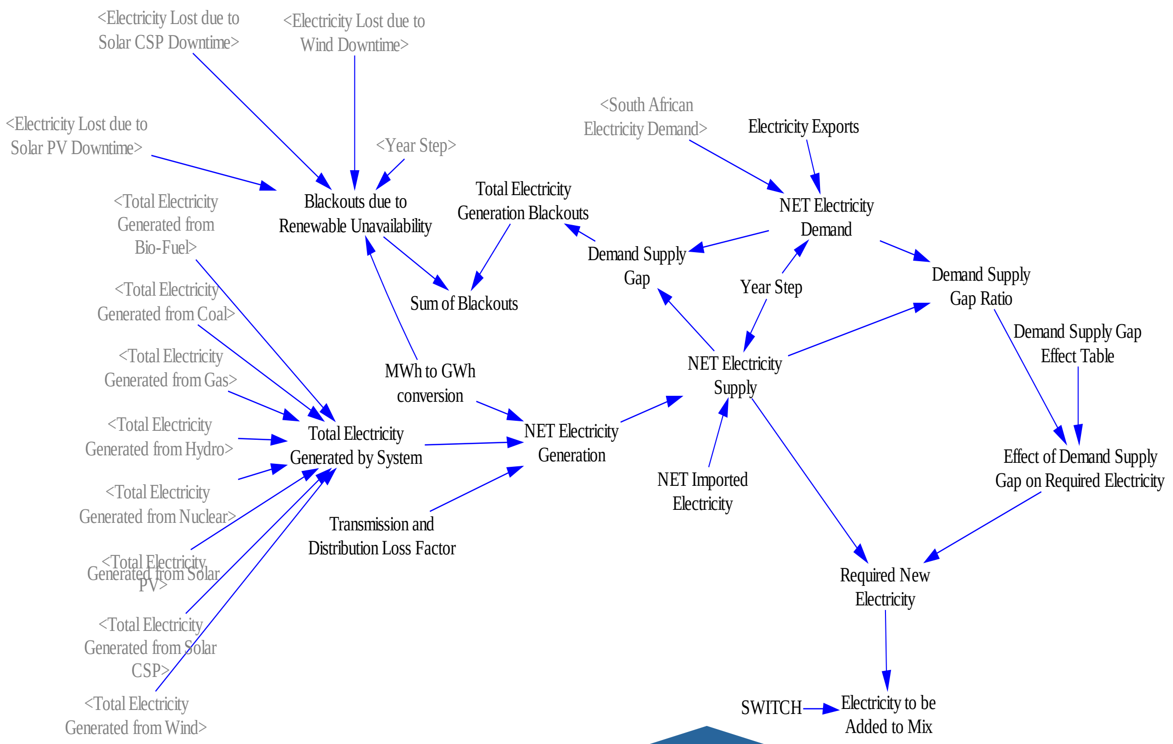


System Dynamics Modelling is often used to generate possible futures and predict a system's likely evolution under varying circumstances; with the aim of initiating discussions between varying audiences from technical and non-technical backgrounds.

System Dynamics – Causal Loop Diagram

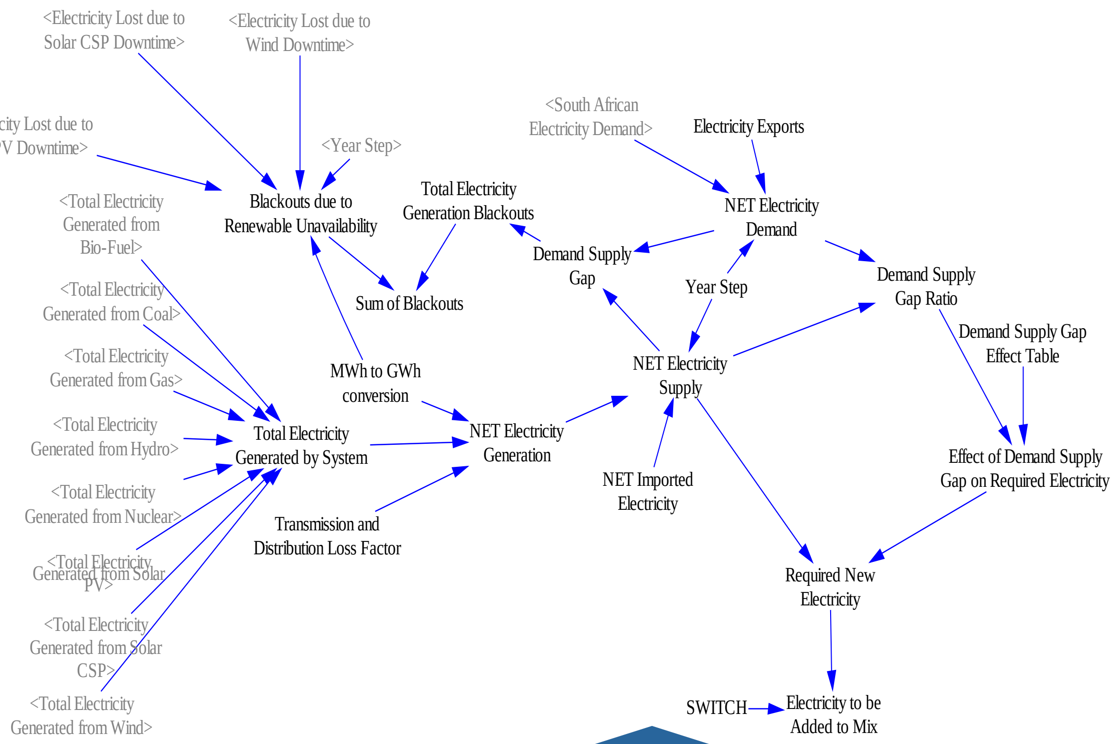


How does it work?



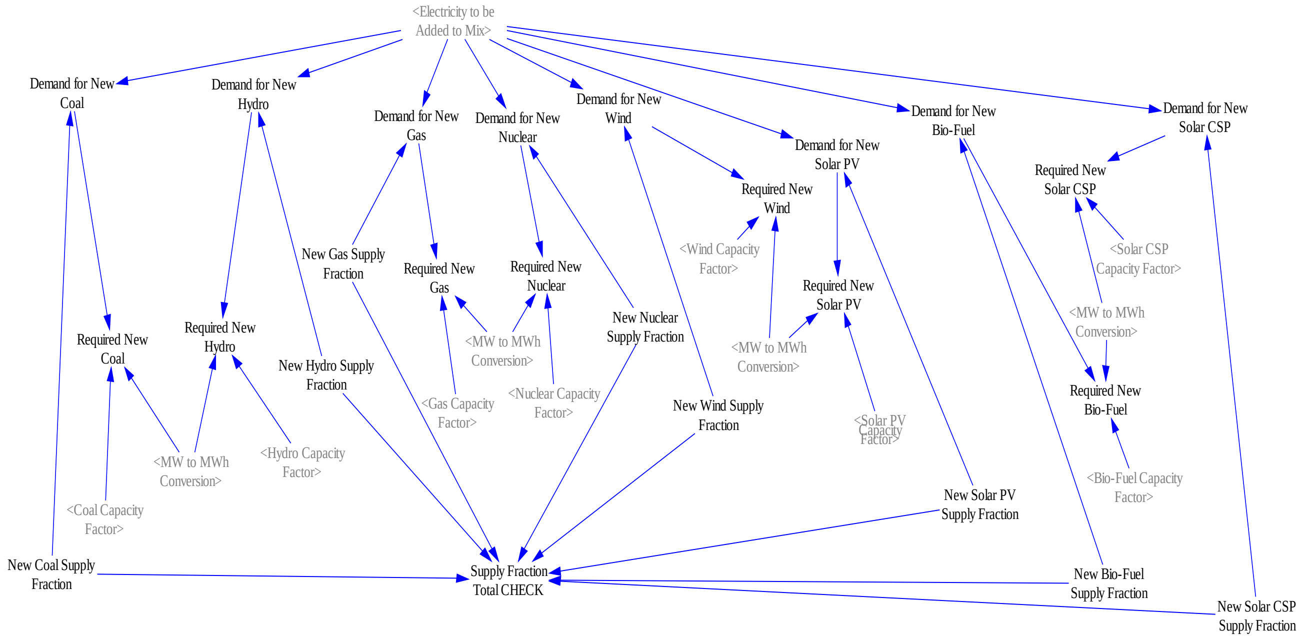
Driver: Satisfy Demand by adding New Capacity

How does it work?



Driver: Satisfy Demand by adding New Capacity

Input: Supply Fraction



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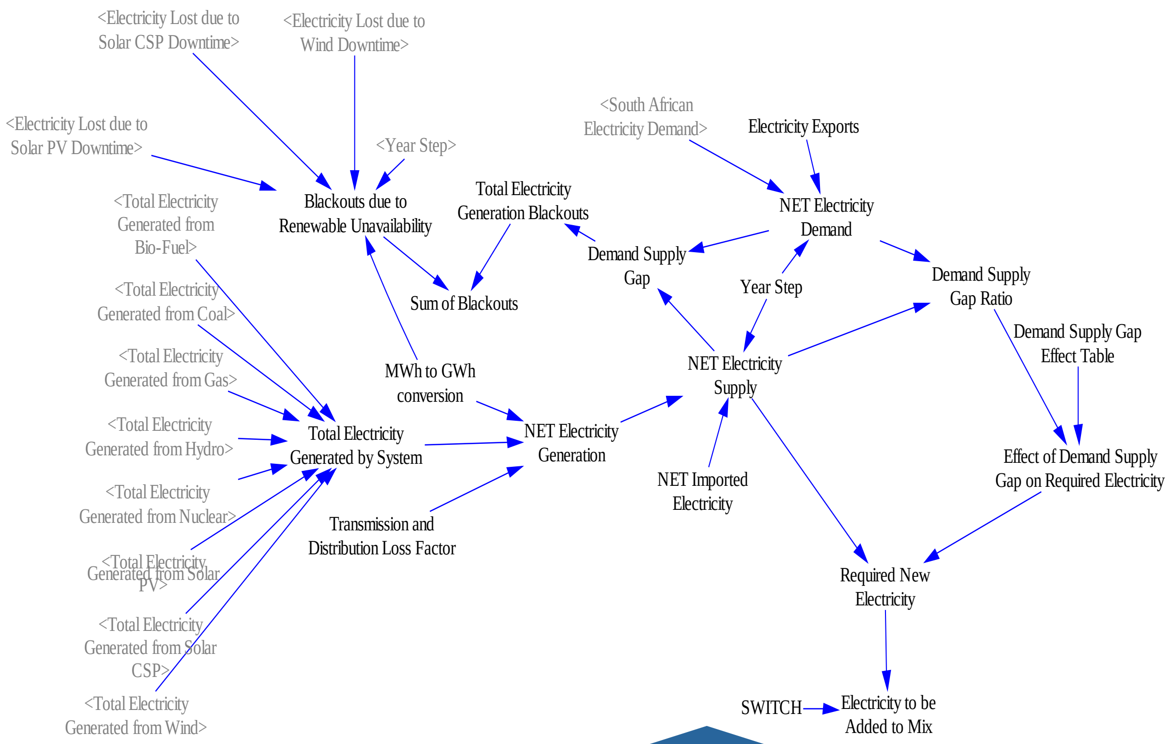
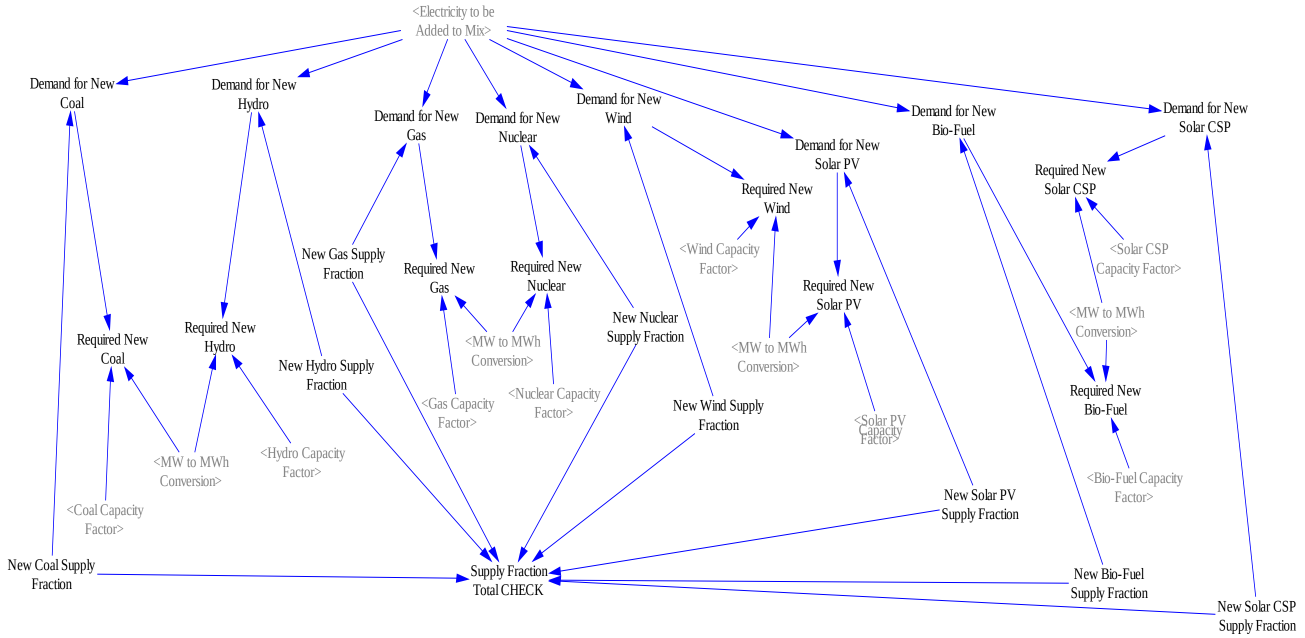
Input: Supply Fraction





Driver: Satisfy Demand by adding New Capacity

Output: Determine the impact on employment, water usage, land usage, cost and emissions…
Sustainable?

System Dynamics – Model Outputs

Addressed Criteria	Preliminary Model Outputs
CO_2 Emission Reduction	Emissions for CO_2, NO_x, SO_x (kg/MWh)
Economic Competitiveness	Unserved Energy (R/MWh) Levelised Cost of Electricity (R/MWh)
Supply Security and Generation	Demand Supply Ratio: <1= Adequate Supply >1 = Inadequate Supply Blackouts (MWh/Year)
Resilience	Operations and Maintenance Jobs (Jobs/Year) Fuel Supply Jobs (Jobs/Year) Manufacturing Jobs (Jobs/Year) Construction Jobs (Jobs/Year) Water Usage (L/MWh) Land Usage (km^2/MWh)
Politics and Public Acceptance	Graphical output of IRP capacity specifications

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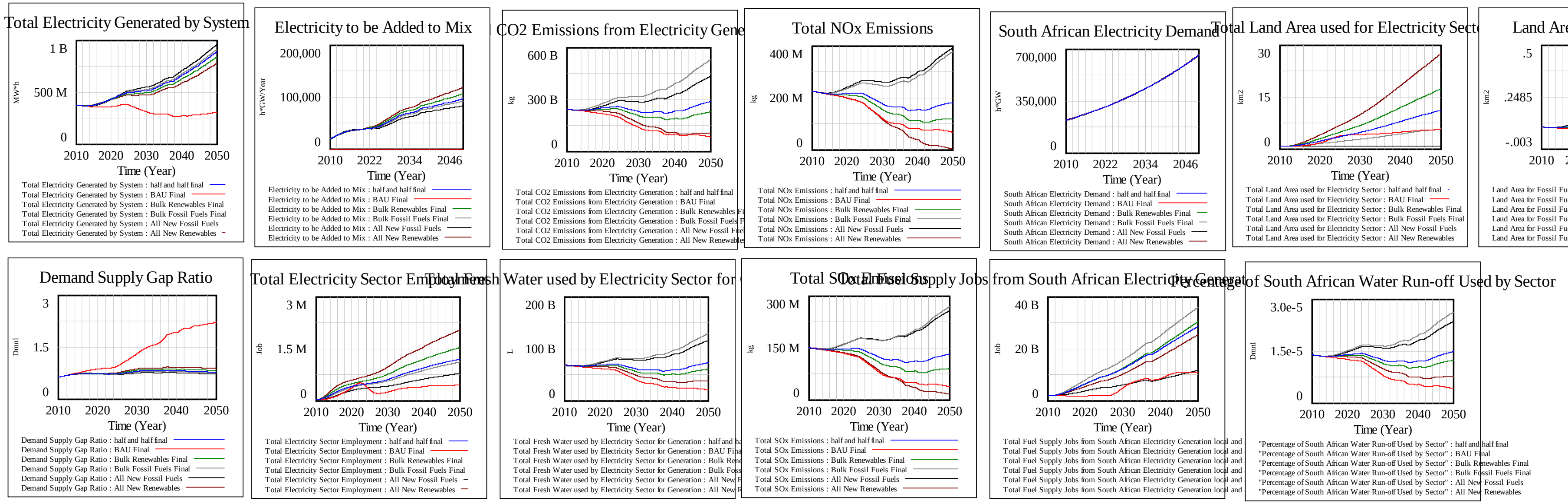
Scenario Breakdown

Scenario Name	Scenario Conditions	Electricity Mix Percentage Split (%)							
		Technology Type							
		Coal	Nuclear	Gas	Wind	Solar PV	Solar CSP	Hydro	Biofuel
Business as Usual	Input from IRP 2016	Input as specified in IRP2016 and inputted via lookup tables							
Bulk Fossil Fuels	70:30	55	10	5	10	7	3	3	7
All New Fossil Fuels	100:0	60	30	10	0	0	0	0	0
Half and Half (50/50)	50:50	25	20	5	20	12	8	5	5
Bulk Renewables	30:70	15	10	5	30	20	10	5	5
All New Renewables	0:100	0	0	0	45	30	15	5	5

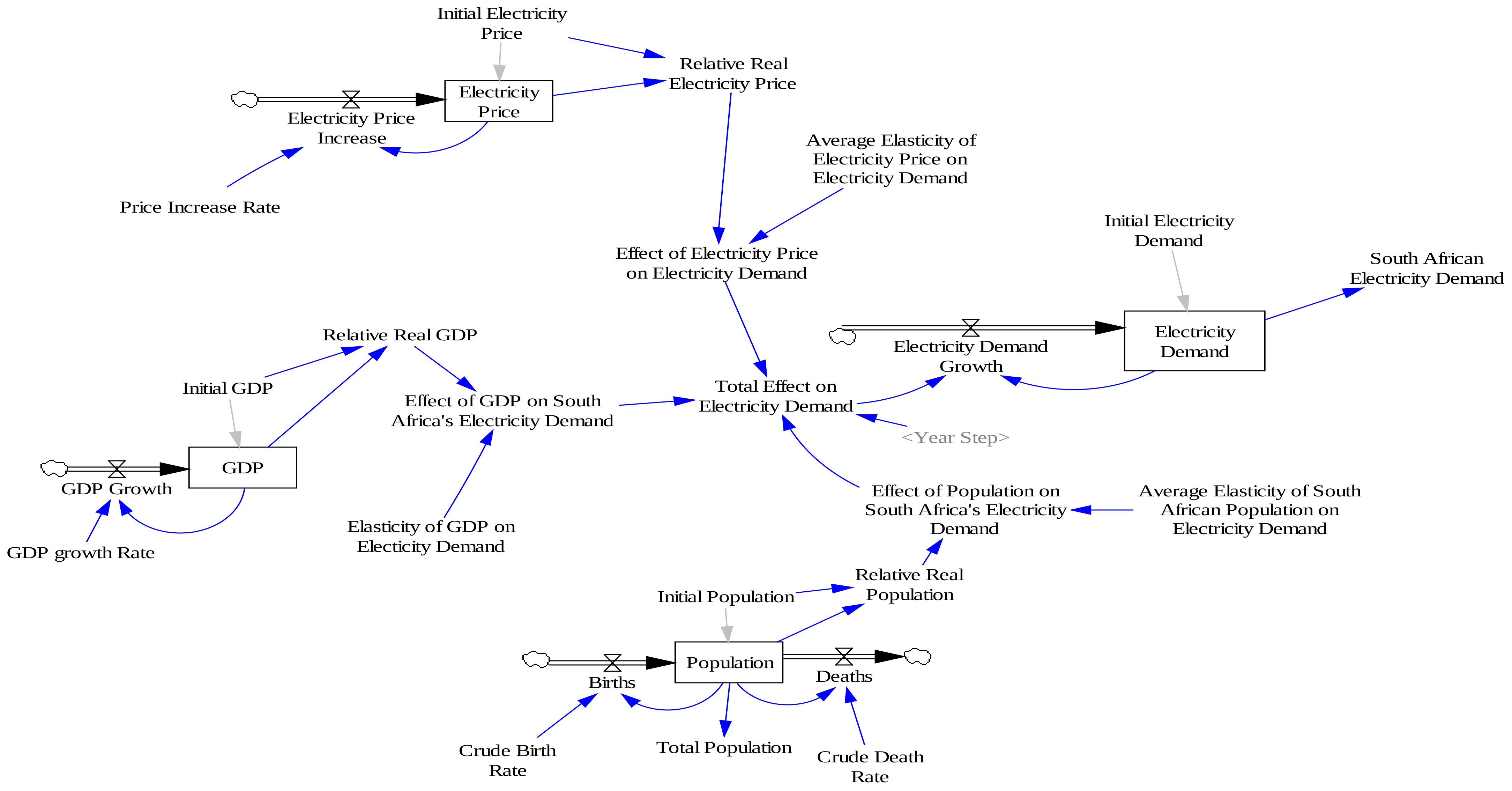
Next Step: Results Analysis



The insights gained from the model could possibly be used to develop and implement mechanisms to collectively transform the electricity sector to an SET, as well as stimulate the necessary discussions with stakeholders in various roles in government and private sector, in order to facilitate the changes necessary to drive the transition and meet the set of criteria.

THANK YOU

Stock and Flow Diagram: Electricity Demand



Stock and Flow Diagram: Capacity Generation