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GREEN economy

Modelling Report of South Africa

Focus on Natural Resource Management, Agriculture, Transport and Energy Sectors

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South African Green Economy Modelling Report (SAGEM)

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List of acronyms

ASPO-USA	Association for the Study of Peak Oil and Gas
BAU	Baseline scenario (business-as-usual)
BAU2%	Business-as-usual 2% scenario
CGE	Computable General Equilibrium
CRSES	Centre for Renewable and Sustainable Energy Studies
CSP	Concentrating Solar Power
DBSA	Development Bank of Southern Africa
DC	Disaggregated Consistency
DEA	Department of Environmental Affairs
DME	Department of Minerals and Energy
DoE	Department of Energy
DTI	Department of Trade and Industry
EIA	Energy Information Administration
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GE1%	Green Economy 1% scenario
GE2%	Green Economy 2% scenario
GER	Green Economy Report
GETS	Green Economy Target Specific scenario
GGND	Global Green New Deal
GHG	Greenhouse gas
GW	Gigawatt
GWh	Gigawatt hours
HA	Hectare
IEA	International Energy Agency
IRP	Integrated Resource Plan
kW	Kilowatt
kWh	Kilowatt hour
ME	Macro-Econometric
MFLE	Male female life expectancy
MI	Millennium Institute
MIT	Massachusetts Institute of Technology
MW	Megawatt
MWh	Megawatt hour
NDP	National Development Plan
NERSA	National Energy Regulator of South Africa
NRM	Natural Resource Management
NT	National Treasury
OECD	Organisation for Economic Co-operation and Development
PC	Per capita
PGM	Platinum Group Metals
PV	Photovoltaic
RSA	Republic of South Africa
SAGEM	South African Green Economy Modelling report
SAM	Social Accounting Matrix
SAPS	South African Police Service
SARi	South Africa Renewables initiative
SD	System Dynamics
SI	Sustainability Institute
STATS SA	Statistics South Africa
TJ	Terajoules
T21	Threshold 21
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
WEF	World Economic Forum
WfW	Working for Water
WPP	World Population Prospects
ZAR	South African Rand

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Foreword

In the past decade, natural resources, environmental risks and ecological scarcities have come to the centre of international attention, as it has become increasingly clear that these issues are of fundamental importance for achieving inclusive growth and enhancing social equity. The environmental crises that occur in different regions of the world represent not only a significant and historic challenge to our generation, but also an opportunity for change.

South Africa confronted the world financial and economic crisis of 2008 by launching a US$7.5 billion stimulus package, of which about 11 per cent, or US$0.8 billion, was allocated to environment-related themes, such as railways, energy-efficient buildings, and water and waste management. Furthermore, in May 2010, the South African government hosted a Green Economy Summit to set the stage for the formulation of a Green Economy Plan. More recently, in November 2011, the country announced a Green Economy Accord – a social pact between government, labour unions, private sector and civil society – to advance the country's New Growth Path with the aim to create 300,000 new green jobs by 2020. These initiatives demonstrate a strong political will and government commitment to foster a transition to a more inclusive and sustainable path of growth and development.

The present study was undertaken at the request of South's Africa Department of Environmental Affairs to assess potential opportunities and options to promote a green economy, with a focus on key economic sectors set out by South Africa's National Development Plan – Vision 2030. Commissioned by UNEP, the assessment was led by Stellenbosch University and the Sustainability Institute of South Africa, in cooperation with the Millennium Institute. It presents a modelling exercise that compares a scenario of investments directed to "business-as-usual" (BAU) with scenarios of investments allocated to four critical sectors for a transition to a green economy in South Africa, namely: natural resource management, agriculture, transport and energy.

The findings from this assessment using the parameters of economic growth, poverty, employment, resource efficiency and climate change, show that the strengthening of natural resource management and environmental protection is fundamental for sustained economic growth and well-being.

We hope that this report will be a useful contribution to supporting the vision and leadership of South Africa in paving the way towards a green and inclusive economy in the context of sustainable development and poverty eradication in South Africa.

Ms Sylvie Lemmet
Director
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Foreword

South Africa has set its short, medium and long-term vision for contribution towards an environmentally sustainable, climate-change resilient, low-carbon economy and just society. The vision is outlined in the Cabinet endorsed National Strategy for Sustainable Development and Action plan (2014), New Growth Path (2020) and National Development Plan (2030) supported by various sector policies and strategies including the integrated resource plan, industrial policy action plan, environment sector green economy implementation plan, national biodiversity strategy and action plan and the national climate change response white paper.

The first national green economy summit of 2010 committed the country to working together to pursue and explore the opportunities "towards a resource efficient, low carbon and pro-employment growth path". This South African Green Economy Modelling (SAGEM) report contributes to building knowledge and understanding of the South African context. The cases within four sectors were selected to initiate the modelling exercise, based on the existing country commitments and targets. Firstly the natural resource management with the specific focus on Government's working for water programme. Secondly the agriculture crop production and differentiates between production utilising conventional and organic fertilizer. Thirdly transport sector categorised into roads infrastructure and transport. Lastly the energy sector was categorised into energy production and energy demand.

The global economic crisis, depletion of natural resources, changing climate and high unemployment provide key signals that economic growth has to be redesigned in an integrated systems approach to sustainability. By adopting an integrated approach focus on the interaction of stocks and flows across sectors, the South African green economy modelling process examined the hypothesis that a correct management of natural resources does not necessarily imply accepting lower economic growth going forward. Instead, it explored the question of whether equal or higher growth could be attained with a more sustainable, equitable and resilient economy, in which natural resources would be preserved through more efficient use. By way of contrast, the green economy approach supports both growth and low-carbon development, by reducing emissions and conserving stocks in the short-term to profit from their healthier state in the future.

I would like to thank all the stakeholders for contribution that made this SAGEM report possible. I look forward to your continued support as we generate knowledge for national green economy in the context of sustainable development and poverty alleviation.

Ms Nosipho Ngcaba
Director General
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Key messages

The South African Green Economy Model (SAGEM), which is based on a system dynamics modelling approach, is primarily aimed at assessing the impacts of green economy investments in selected sectors pertaining to the South African economy. Based on planned targets and expenditures and/or costs of interventions, the model identifies the possible options and opportunities to achieving these targets. Four scenarios were defined: BAU, or business-as-usual; BAU2% representing a 2 per cent investment of gross domestic product in the BAU activities; GE2% representing an allocation of 2 per cent of gross domestic product in green economy sectors (natural resource management, agriculture, transport and energy); and GETS, which is a target-specific scenario aimed at identifying whether policy-makers can achieve the medium- to long-term targets following green economy interventions in the prioritised sectors.

Natural Resource Management (NRM)

Green economy contributes to natural resource management, while maintaining agricultural land size.
Investments in the green economy simulated in SAGEM will positively contribute to additional restored land without leading to a reduction in land requirements in the agriculture sector. The GE2% scenario reveals an additional 46.4 per cent restored land by 2030 and higher water availability.

Investments in NRM create jobs, while increasing water supply and making biomass available for power generation.
Employment in the NRM sector occurs both in the restoration of the water ecosystem services and in the utilization of the biomass for energy. Most of the employment, however, arises from the alien species elimination. With the GETS scenario, employment is created for 701,000 people in 2030, while the GE2% scenario is projected to create jobs for 737,000 people – higher than BAU (568,000) and BAU2% (569,000) scenarios, respectively.

Agriculture

Investments allocated to the adoption of ecological agriculture practices (such as organic fertilizer use) provide a sustained increase of the yield per hectare, as opposed to the short-term gains from the use of conventional fertilisers.
With these green economy investments, crop yield is projected to increase by 5.5 per cent and 23.9 per cent by 2030 for the GETS and GE2% scenarios, respectively.

While the increase in the yield per hectare reduces land requirements for agricultural crop production, the effect of population growth on agricultural land requirements is higher, which results in a net increase in land requirements.
An additional benefit of avoided CO_2 emissions due to the use of organic fertilizer is observed in the GE2% scenario.

Transport

Green investment in the transport sector aims at improving energy efficiency, which in turn translates into reduced energy consumption in the sector.
In the GETS scenario, investments in transport efficiency are not enough to reduce the energy demand by 9 per cent by 2015, as stipulated in the energy efficiency strategy of 2005.

The demand for energy in the transport sector is projected to grow because of the growth in GDP and population.
A more aggressive investment scenario, such as the GE2% scenario, contributes to reduced energy consumption in the transport sector. The efficiency improvement in the GE2% scenario reaches 5.5 per cent by 2030. As a result,

transport energy use in the GE2% scenario is expected to decline relative to the BAU scenario, as well as CO_2 emissions.

Energy demand and supply

A green economy contributes to energy efficiency and results in a reduction in energy demand and lowered investments in power supply.

A 2 per cent (of GDP) investment in the green economy, which is distributed equally among all the sectors, including energy efficiency, results in a reduction of energy demand. In the power sector, this translates into a very significant reduction of coal power generation capacity. The reduction that could be achieved is comparable to the capacity of the large coal power stations that are under construction in South Africa (e.g., Medupi). A reduction of energy consumption in the transport sector would also be realized.

A green economy contributes to electricity diversification mix.

With a green investment targeted to expand renewable electricity generation (GETS), the share of renewable energy would reach 24.4 per cent by 2030 in the GETS scenario and 16 per cent in the GE2% scenario. A more aggressive green economy investment intervention than GETS and GE2% would be required to achieve the stipulated target in the NDP (of 33 per cent by 2030).

National development

The green economy scenarios simulated in SAGEM reveal that a green economy stimulates economic growth.

All green investments stimulate the growth of GDP relative to a BAU scenario. Investments in a green economy could realize a further growth in real GDP of over 2 per cent by 2030 relative to 2012. While this also translates into an increase in per capita income over the years, the growth target, stipulated in the National Development Plan (NDP), will not be realized and will require higher investments than the amounts simulated.

A green economy creates jobs and the extent of the employment increase is dependent on the investment option chosen.

Overall, green economy investments simulated in SAGEM stimulate job creation relative to the BAU scenario. However, prioritizing investments in the energy sector will maximize the employment creation potential of a green economy (as simulated in the GETS scenario), due to the additional infrastructure requirements in this sector. If the investments are spread equally across all sectors, then the agriculture sector will deliver the highest employment creation potential.

Using the same assumption for additional investment spread equally across the four sectors, BAU2% appears to be comparable to GE2% in terms of economic output, but GE2% contributes to better environmental performance than BAU2%.

The BAU2% scenario yields fewer overall benefits across the sectors than the GE2% scenario. While comparable, the GE scenario supports the environment and creates employment in sectors that support production (e.g., water). The green economy simulated in SAGEM is therefore able to deliver as much as the BAU case, but in a more sustainable manner.

A green economy contributes to the reduction of GHG emissions.

A combined intervention in the energy sector to improve energy efficiency and diversify power supply with renewable energy, as well as other low carbon options in the various sectors, is projected to create relevant synergies in lowering GHG emissions.

1 Introduction

South Africa's Department of Environmental Affairs (DEA), in partnership with the United Nations Environment Programme (UNEP) and with support from United Nations Development Programme (UNDP), embarked on the development of a green economy for South Africa, with technical assistance from the Millennium Institute and the Sustainability Institute, in collaboration with the Centre for Renewable and Sustainable Energy Studies (CRSES) of Stellenbosch University. The need for this modelling work has its beginnings in the first national green economy summit that was held in May 2010, which was aimed at catalyzing efforts towards a resource efficient, low carbon and pro-employment growth path. Subsequent to the summit, a roundtable and workshop were held, which aimed at identifying a shared approach, programmes and initiatives in support of South Africa's transition to a green economy.

This report presents the modelling process and the results represented as the South African Green Economy Modelling (SAGEM) report that was developed to test national targets and the effects of investing in a green economy in South Africa. It affirms the current government's support for a green economy. SAGEM was developed on the same basis as the model that underpins the UNEP Green Economy Report (GER) (UNEP, 2011). In essence, SAGEM utilised the Threshold 21 (T21) framework developed by the Millennium Institute.[1] T21 provides a framework for integrating several sectoral models, which were customised for the South African context (see Appendix A). The modelling traces the effects of a proportion of GDP on four of the nine core sectors prioritized to support a green economy for South Africa, namely: natural resource management, agriculture, transport and energy. These sectors were identified during a stakeholder workshop held on 1 February 2012 (see Section 3.4).

The report is divided into nine sections. Section 2 presents the country profile, followed by a discussion of green economy, in general, and an in-depth understanding of its origin in the South Africa context. The features of the T21 framework, which was utilised for the study, are presented in Section 4. This is followed by a discussion of the characteristics of SAGEM in Section 5, and the process of defining the scenarios and their underlying assumptions are discussed in Section 6. The modelling results are presented in Section 7 consisting of: (i) two business-as-usual scenarios, or BAU – where there is no additional investment – and BAU2% per cent, which consist of a 2 per cent of GDP investment in the BAU; and (ii) two green economy scenarios, which entail additional investment interventions on selected green economy sectors or programmes. This is followed by a discussion that compares GER results with SAGEM in Section 8. Finally, the conclusions of the study are presented in Section 9.

2 Country profile

2.1 Economic and social profile

At the southern tip of Africa, with a population of around 51.8 million, the Republic of South Africa (RSA) is considered as an upper-middle income country, although there remain large disparities in income with a Gini coefficient of 0.70, ranked as being among the highest in the world. It is an emerging market with an abundant supply of natural resources ranking as the 3rd largest mega-diverse country in the world. Out of the 144 economies cited in the 2012 world competitiveness index (WEF, 2012), South Africa rankings include scores by sustainability indicators (52nd), financial market development (3rd) and judicial independence (27th). Although considered good by regional standards, infrastructure (63rd) and the quality of electricity supply (94th) requires upgrading. Health and primary education is ranked 132nd resulting from high rates of communicable diseases. On the other hand, South Africa does reasonably well in more complex areas such as business sophistication (38th) and innovation (42nd), benefitting from good scientific research institutions (34th) and strong collaboration between universities and the business sector in innovation (30th).

Growth was robust from 2004 to 2008 as South Africa reaped the benefits of macroeconomic stability and a global commodities boom. However, it began to slow in the second half of 2008 due to the impact of global financial crisis on commodity prices and demand.

At the end of 2007, South Africa went through a national electricity crisis because the state-owned electricity enterprise, Eskom, suffered supply problems with aged plants, necessitating "load-shedding" cuts

Box 1. Basic data on South Africa (Source: Grant Thornton, 2012)

Area	1.219 million km^2
Capitals	Cape Town (Legislative); Pretoria/Tshwane (Administrative); Bloemfontein (Judicial).
Form of government	Federal/unitary hybrid, comprising a central government and nine provincial governments.
Legal system	Based on Roman Dutch Law and the 1996 Constitution.
Legislative branch	Bicameral Parliament consisting of the National Council of Provinces and the National Assembly.
Judicial branch	Constitutional Court; Supreme Court of Appeals; High Courts; and Magistrate Courts.
Currency	ZAR 1 (South African Rand) = 100 cents USD 1 = approximately ZAR 8 (2012) EUR 1 = approximately ZAR 11 (2012)
Languages	There are eleven official languages: Afrikaans, English, IsiNdebele, IsiXhosa, IsiZulu, Sesotho, Northern Sotho, Setswana, SiSwati, Tshivenda and Xitsonga. English is the language of commerce, banking, government and official documentation.
Total GDP (2011)	Approximately ZAR 3 trillion or US$408 billion (World Bank)
GDP per capita (2011)	Approximately ZAR 60 000 or US$8 000 dollars (World Bank)
Real GDP growth (2011)	3.1 per cent
Exports	Minerals, diamonds, metals and metal products, chemicals, foods and automotive components
Imports	Machinery and transport equipment, manufactured goods, chemicals and oil
Main trading partners (in order of trade volume)	China, Germany, United States of America, Japan, India and the United Kingdom

to residents and businesses in the major cities. In addition, daunting social and economic challenges remain from the apartheid era, in particular poverty, youth unemployment, lack of economic empowerment among the disadvantaged groups and shortage of public transportation.

South Africa's economic policy is fiscally conservative but pragmatic, focusing on inflation targeting, maintaining a budget surplus and using state-owned enterprises to deliver basic services to low-income areas as a means to increase job growth and household income. The country's main long-term social and economic challenges include a high rate of unemployment at 25.5 per cent (StatsSA, 2012) and the total number of people living with HIV/AIDS estimated at approximately 5.38 million in 2011 (StatsSA, 2011). On the other hand, according to the South African Policy Service crime statistics overview (SAPS, 2012), the level of serious crime has been reduced by 31.8 per cent (4,852 to 3,609 crime ratio per 100,000 of the population) from 2004/5 to 2011/12.

2.2 Environmental profile

According to the 2006 South Environment Outlook report (DEA, 2006), the key trends in respect of the state of South Africa's natural resources include the following:

- South Africa has a relatively low annual rainfall and water is extracted from most of the country's 22 major rivers to supply the growing number of domestic, agricultural and industrial users. It is estimated that national water requirements will exceed availability by 2025. This is exacerbated by the fact that water quality has been seriously compromised in many areas.

- There is limited agricultural land in South Africa. Of the country's 122 million hectares total land surface, it is estimated that only 16 million hectares, or 7.5 per cent, can be used for crop production. Soil erosion and degradation of agricultural land through overexploitation and inappropriate and unsustainable farming methods pose a threat to the country's food security. Indeed, there are many issues that affect agricultural production, soil quality and erosion, as well as lack of infrastructure, but water is considered to be one of the most important.

- About 34 per cent of the country's terrestrial ecosystems, 82 per cent of its main river ecosystems and 65 per cent of its marine biozones are threatened, while 50 per cent of its wetlands have already been destroyed and living marine resources are either maximally or over-exploited.

- There are elevated levels of a variety of pollutants in the atmosphere that, among other things, are leading to a growing incidence of respiratory problems.

The well-being of South Africans, as well as its economic development, is heavily reliant on the services that ecosystems supply such as air, food, water, energy, medicines as well as recreational, spiritual and cultural benefits. But measures of environmental sustainability show that the country has exceeded its ecological carrying capacity. The World Wide Fund for Nature's Ecological Footprint for South Africa is 2.8 global hectares per person, compared to the world average of 2.2 global hectares per person, considering that the average for Africa is 1.2 hectares per person. In Africa, carbon represents the largest footprint component for five middle-income countries whose energy economies are dominated by fossil fuels, which accounts for over 50 per cent of South Africa's footprint (WWF and AfDB, 2012). According to Greenhouse Gas Inventory South Africa, which was compiled under the United Nations Framework Convention on Climate Change (UNFCCC) in May 2009, the country's emissions increased from 347 metric tons CO_2 equivalent (Mt CO_2e) in 1990 to 437 Mt CO_2e in 2000 (DEA, 2011).

3 Transformation to a green economy

3.1 Green economy – Origins and definitions

More than twenty years since the term "green economy" appeared in the "Blueprint for a Green Economy" (Pearce et al., 1989), interest in a green transition has evolved and intensified. As a result of the global market and financial crisis in 2008, calls were made in the global policy arena for a Global Green New Deal (GGND). This was the focus of a report commissioned by UNEP in 2009 (Barbier, 2010). The implementation of green economic action was described as a long-term strategy for moving national economies out of the crisis. The GGND set out three concrete objectives:

- Economic recovery;
- Poverty reduction; and
- Reduced carbon emissions and ecosystem degradation.

The document proposed a framework for green stimulus programmes as well as supportive domestic and international policies, including support to least developed countries.

Following the GGND study, the Green Economy Report (GER) was published by UNEP in 2011. This document develops the concept of green economy, analyses its key sectors and identifies global as well as sectoral recommendations for action. At the visionary level, UNEP (2011) considers a green economy as "an economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities".

At the operational level, a green economy is seen as one whose growth in income and employment is driven by investments that:

- reduce carbon emissions and pollution;
- enhance energy and resource efficiency; and
- prevent the loss of biodiversity and ecosystem services.

These include investments in human and social capital, recognizing the central position of human well-being and social equity as core goals promoted by income growth and increasing employment. This transition is guided by the economic analysis of current trends, risks and opportunities as well as by national experiences in applying more integrated policy tools effectively.

3.2 Key green economy interventions

A green economy aims to facilitate resilient, equitable and pro-employment development following a development path that reduces carbon dependency, promotes resource and energy efficiency and lessens environmental degradation. According to UNEP (2011), the priority areas for green policy-making could include:

- Addressing environmental externalities and existing market failures, where the production or consumption of goods and services has negative effects on third parties and the environment whereby the cost is not fully reflected in market prices;
- Limiting government spending in areas that deplete natural capital, such as subsidies that stimulate unsustainable production, resulting in the depletion of natural resource stocks and overexploitation;
- Promoting investment and spending in areas that stimulate a green economy, such as (a) innovation in new technologies and behaviours that are vital to green markets; (b) expansion of infrastructure that is required for certain green innovations to flourish; and (c) fostering infant green industries;

- Establishing a sound regulatory framework to channel investments into environmentally and socially valuable activities. A well-designed regulatory framework provides the legal basis on which government authorities can rely to monitor and enforce compliance, reduce regulatory and business risks and increase the confidence of investors and markets; and
- Strengthening international frameworks that regulate economic activity, including the international trading system, in driving a green economy.

Enabling conditions include the establishment of sound regulatory frameworks that would create rights and incentives that drive green economic activity, remove barriers to green investments, and regulate the most harmful forms of unsustainable behaviour, either by creating minimum standards, or by prohibiting certain activities entirely.

Furthermore, improved international governance is also a critical enabling condition. This can be enhanced through:

- Multilateral environmental agreements: regulating unsustainable economic activity with standards or prohibitions;
- International trade law enabling the flow of green goods, technologies and investments; and
- International investment frameworks: promoting sustainable over unsustainable investments.

Finally, a green economy greatly emphasises education and training as a means to meet the needs of a greener and more sustainable future, as providing relevant education and training opportunities for a new, green workforce will be critical to achieving a successful transition.

3.3 Understanding green economy in the South African context

According to the May 2010 Summit Report (DEA, 2010), South Africa views a green economy as a sustainable development path that is based on addressing the interdependence between economic growth, social protection and natural ecosystems. This view is in line with the country's vision on sustainable development, which states that:

South Africa aspires to be a sustainable, economically prosperous and self-reliant nation-state that safeguards its democracy by meeting the fundamental human needs of its people, by managing its limited ecological resources responsibly for current and future generations, and by advancing efficient and effective integrated planning and governance through national, regional and global collaboration.

Table 1. Focus sectors prioritised by workshop participants

Priority	Group		
	1	2	3
1	NRM*	Energy	Waste
2	Energy	Transport	Energy
3	Transport	Agriculture	Construction
4	Agriculture	NRM*	Transport

* Natural Resource Management refers to soil, water, ecosystems, etc., as well as extracted non-renewable (mineral and energy) resources.

Figure 1. Policy documents linked to green economy

National Development Plan, Vision 2030	New Growth Path, Green Economy Accord & Green Jobs Report	National Strategy for Sustainable Development and Action Plan (NSSD1)	2009 South African Framework for Responding to Economic Crisis
2009-2014 Medium Term Strategic Famework and 12 Outcomes	Industrial Policy Action Plan	National Climate Change Response Policy	National Green Economy Summit and Programmes' Reports
Integrated Resource Plan & Integrated Energy Plan	National Water Resource Strategy	Agriculture and Rural Development	Transport and Human Settlement
10-Year Innovation and Global Research Plan	Environmental Fiscal Instruments (e.g., carbon tax, green fund)	National Skills Development Strategy 3	National Skills Development Strategy 3

The 2011 Cabinet endorsed the National Strategy for Sustainable Development and Action Plan, which identified five strategic priorities:

1. Enhancing systems for integrated planning and implementation;
2. Sustaining our ecosystems and using natural resources efficiently;
3. Towards a green economy;
4. Building sustainable communities; and
5. Responding effectively to climate change.

The transition to a green economy in South Africa is linked to many policies, strategies and plans (see Figure 1).

3.4 Sector priorities

For the purpose of the green economy modelling for South Africa, an inception meeting between DEA and UNEP was held at the DEA offices in September 2011 in order to discuss, among others, the sectors and key issues to be included in the customization and modelling. The four sectors for the modelling were chosen from the broader nationally prioritised nine green economy programmes:

1. Resource conservation and management;
2. Sustainable waste management practices;
3. Water management;
4. Environmental sustainability: greening & legacy; major events & tourism, research, skills, financing and investments;
5. Green buildings and the built environment;
6. Sustainable transport and infrastructure;
7. Clean energy and energy efficiency;
8. Agriculture, food production and forestry; and
9. Sustainable consumption and production

Other issues that were discussed were the data requirements for the green economy modelling process and how the various stakeholders would provide support in data collection.

In order to refine and prioritise the modules for SAGEM, there was a need to interface with the policy-makers and stakeholders in other government departments, research institutions, civil society, and non-governmental institutions. This was achieved through a Green Economy Technical Workshop, which was organized by DEA, in partnership with UNEP, and facilitated by the Millennium Institute and the Sustainability Institute. Held on 1 February 2012 in Pretoria, the primary purposes of the workshop were to:

- Prioritise the areas of focus for SAGEM based on the eight prioritised sectors;
- Identify the South African specific targets for the green economy for the prioritised areas; and
- Identify the possible scenarios for consideration in the modelling.

The participants were organized in three groups to address the above objectives and reported their discussion in a feedback session.

Table 2. Medium- and long-term targets		
Sector	Medium-term (2020)	Long-term (2030)
Employment	• 5 million additional jobs by 2020, with a total workforce of 18 million • Direct green economy-related: 300 000 additional jobs, of which 80 000 in manufacturing and the rest in construction, operations and maintenance • In the agricultural sector: 300 000 households in smallholder schemes by 2020; 145 000 jobs in agro-processing 2020; upgraded employment on commercial farms (currently total of around 660 000)	• Increase employment from 13 million in 2010 to 19 million in 2020 and to a total workforce of 24 million by 2030 • Direct green economy-related: Over 400 000 jobs • Agriculture (rural): 643 000 direct and 326 000 indirect jobs
Education	• 1 million students in FET colleges by 2014; from the current around half-a-million in 2010 • 30 000 additional engineers by 2014 • 50 000 additional artisans by 2015	• Increase enrolment at university by at least 70 per cent by 2030, reaching a total enrolment of 1.62 million, as compared to 950 000 in 2010 • Produce 30 000 artisans per year
Economic growth	• Growth rate of GDP should rise to between 4 and 7 per cent a year	• GDP should increase by 2.7 times in real terms, requiring average annual GDP growth of 5.4 per cent over the period. GDP per capita should increase from about ZAR 50 000 per person in 2010 to ZAR 110 000 per person in 2030, in constant prices.
Trade	None stipulated	• Export (in volume terms) grow by 6 per cent per year up to 2030 with non-traditional export growing by 10 per cent
Carbon emissions	None stipulated	• Peak GHG emissions reached by 2025
Energy mix	• 33 per cent of new generation from renewables and 25 per cent from Nuclear; currently at around 0 per cent and 4 per cent respectively	• 20 000 MW of the total new generation (40 000 MW) from renewables
– energy demand	• 1 million solar water heaters by 2014	• 5 million solar water heaters by 2030
– energy access	None stipulated	• 90 per cent access to grid electricity, with the remainder meeting their energy needs from off-grid sources.
Transport	None stipulated	• Public transport will be user-friendly, less environmentally damaging, cheaper and integrated or seamless
Water access	None stipulated	• 100 per cent access to clean water • Water demand in urban areas, 15 per cent less than BAU

Given the time constraints and the availability of data for the modelling process, the participants agreed to focus the SAGEM on four areas (see Table 1).

The criteria used by the participants to prioritise the key areas mainly revolved around aspects of employment and localisation, addressing inclusivity and inequality, attracting funding and improving competitiveness as well as the availability of data to support the analysis of the respective sectors. Energy and transport featured in all the top four priority lists of the groups; natural resource management and agriculture featured in two groups. Thus, the four areas that were finally selected were: natural resource management (NRM), agriculture, transport and energy.

With respect to prioritising the targets, the participants generally felt that it was challenging to quantify the targets, particularly for non-experts. It was therefore decided that the medium- to 2020 and long-term to 2030 targets should be defined based on the New Growth Path and the National Development Plan (NDP). These are summarized in Table 2.

A number of stakeholders suggested that more aggressive targets by 2030 should be used, if green economy is to be realised. Some examples given include: (i) universal access to 12 years of education; (ii) a cap at 400 million tonnes of carbon per annum; (iii) 50 per cent of energy derived from renewable resources; (iv) more than 80 per cent of cargo transported by rail; (v) more than 15 per cent of the government's vehicle fleet should be electric cars; and (vi) more than 25 per cent improvement in energy intensity. Sensitivity analysis for some of the suggested targets was therefore taken into account, which is discussed in Section 5.

3.5 Intervention priorities

In terms of defining appropriate scenarios, there was limited time for the participants to explore all possible scenarios. There were, however, some indications of the scenarios to be investigated in the modelling effort, including, among others:

i) South African economy grows between 4 and 7 per cent on average per year by 2030;
ii) A global 'double-dip' recession, as experienced in 2008, between 2012 and 2017;
iii) Global warming of between 4° and 6°C; and
iv) Depletion of natural resources, specifically a 'peak oil' and 'peak coal' (for South Africa) by 2020.

Only two of the suggested scenarios above were taken into account in the modelling process. The first one is the global double dip scenario (ii), which was achieved through an exogenously determined effect of economic crisis on GDP. The depletion of coal reserves was incorporated into the modelling in order to account for (iv) as suggested by stakeholders.

Based on the outcomes of the stakeholder engagement workshop, it was clear that a green economy in the South African context refers to two inter-linked developmental outcomes for the South African economy, as stipulated in the Summit Report:

- Growing economic activity (which leads to investment, jobs and competitiveness) in the green industry sector; and
- A shift in the economy as a whole towards cleaner industries and sectors with a low environmental impact compared to its socio-economic impact.

4 Modelling a green economy for South Africa

4.1 Introduction

Development programs for national governments, particularly emerging and developing countries, primarily consist of large-scale public investments in infrastructure. In most cases, a standard cost-benefit analysis is used to assess the suitability of such investments. However, effects on the local society and environment are often not taken into account (Bassi, 2009).

To account for such effects, computer models have been used to perform integrated analysis of socio-economic-environmental systems.

4.2 Overview of modelling approaches

According to UNEP (2011), over the last 40 years, a variety of applied models and modelling methods have been developed to support national planning. Among those tools the most commonly used today include the following: Disaggregated Consistency (DC), Computable General Equilibrium (CGE), Macro-econometric (ME) and System Dynamics (SD) models. These models have proven useful in different degrees for various kinds of policy analyses, especially for mid-/short-term financial planning.

More specifically, CGE models are based on a matrix of flows concept, where actors in the economy interact according to a specified set of rules and under predetermined equilibrium conditions (Robinson et al., 1999). Initially conceived to analyse the economic impact of alternative public policies, e.g., those that work through price mechanism, such as taxes, subsidies, and tariffs, recent CGE models include social indicators (Bussolo and Medvedev, 2007) and environmental ones (OECD, 2008).

On the other hand, ME models are developed as combinations of macroeconomic identities and behavioural equations, estimated with econometric methods (Fair, 1993), which are largely used by national and international financial organisations to support short- and mid-term macroeconomic policy analysis, such as general fiscal and monetary policies.

DC models consist of a combination of spreadsheets representing the fundamental national macroeconomic accounts, and enforcing consistency among them. Well-known examples of this category of models include the World Bank's RMSM-X (Evaert et al., 1990) and the International Monetary Fund's FPF (Haque et al., 1990) that are mostly used to analyse the macroeconomic impact of adjustment programmes.

The three modelling methods described focus primarily on economic aspects and in general are not designed to support integrated, long-term planning exercises. However, recent global developments have stressed the importance of jointly addressing the economic, social, and environmental dimensions of development.

As a technique to analyse a variety of development issues (Saeed, 1998), including national policy analysis (Pedercini and Barney, 2010), the methodology of systems dynamics (SD), conceived in the late 1950s at the Massachusetts Institute of Technology (MIT), has greatly evolved over the last 60 years (see Forrester, 1961 and Forrester, 2007 for early and current examples on the use of this methodology). Specifically, the SD method has been adopted in various instances to analyse the relationship between structure and behaviour of complex, dynamic systems, where causal relationships are analysed, verified and formalised into models of differential equations (see Barlas, 1996), and their behaviour is simulated. The method uses a stock and flow representation of systems and is well-suited to jointly represent the economic, social and environmental aspects of the development process.

4.3 Characteristics of T21

Threshold 21 (T21) is a system dynamics national model that is specifically designed for planning and policy-making support (Bassi, 2009). It integrates economic, social, and environmental structures into one specialized tool. Thus, the model is organized into three macro sectors: society, environment and the economy.[3] The sectors interact with each other as shown in Figure 2. Each application of the model is built around a core model – a set of main structures representing features of the socioeconomic-environmental systems that can be generalized across many countries – to which additional modules can be added to better portray specific aspects of the country being analysed. The characteristics of T21, as outlined in Perdercini (undated; 2009), are explained in Sections 4.3.1 to 4.3.11 below.

4.3.1 Transparency

Transparency indicates the degree of clarity and explicitness of a model's structure and the related assumptions, which are fundamentally important for allowing civil society and the private sector to participate effectively in the analysis.

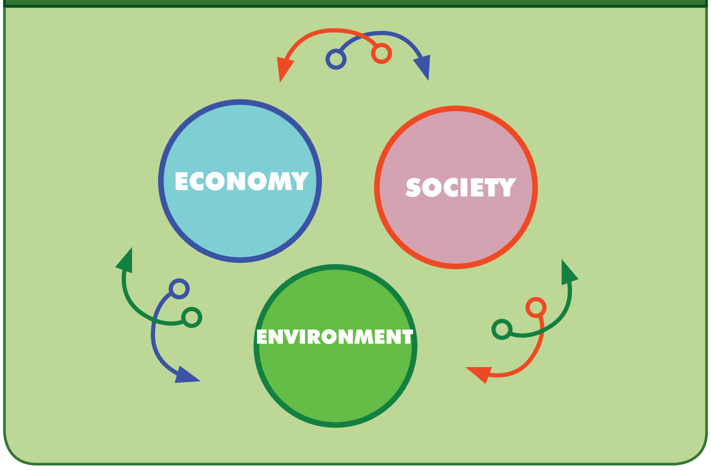
In T21, all variables constituting the structure of the model are accessible and generally well-documented. All the relationships between variables are evident since the structures of the different sectors are represented in stock and flow diagrams. Furthermore, the assumptions underlying the different modules are clearly stated, with the aim of stimulating the users' confidence in the model as much as possible.

4.3.2 Comprehensiveness

Comprehensiveness refers to a model's ability to represent the socioeconomic-environmental system of a region as a whole, by integrating in a single framework all the relevant aspects of development planning.

The T21 model was conceived explicitly to represent the social, economic and environmental system of a country as a whole. This goal has been achieved by utilising the complex structure that considers that any kind of human activity influences and is interdependent with the environment. Such perception, in turn, affects the economy and society in general. To have a rise in economic development, a country needs, for instance, an efficient workforce, which will need clean air and water to be healthy and productive. Conversely,

Figure 2. Structure of T21



intensive economic activities can pollute the environment, lowering the potential for further development.

4.3.3 Policymaking guidance

Policymaking guidance refers to a model's usefulness for guiding policymaking; that is, the extent to which it provides relevant cross-sector policy insights to support long-term development planning.

The T21 model can be seen as an organic whole of many parts, in which every element influences and is influenced by the others, in a close network of feedback relationships. This kind of structure implies that every action taken locally in one sector will somehow influence the behaviour of other sectors, with a certain delay. Whilst testing a policy based on T21, the user is able to observe both its direct effects on the target sector and its indirect effects on the rest of the system in the long-term. The Causal Tracing feature offered by the system dynamics software enables the users to determine which components of a specific development plan have caused a particular change in one variable or indicator. This allows identification of leverage points of the system, which is a necessary condition for designing effective policies.

4.3.4 Strategy comparison

Strategy comparison refers to the extent to which a model allows for an easy comparison of alternative development strategies and supports the assessment of the feasibility of implementing strategies, both fiscally and institutionally.

T21 allows for the testing of different policies in different sectors and can estimate the costs and benefits they generate, both locally and within the system as a whole. Alternative development plans can be compared on the basis of their contribution to the achievement of different targets. Given the economic, social, and environmental resources available, the feasibility of implementing the potential policies in the short-, medium-, and long-term can be assessed.

4.3.5 Long-term perspective

A long-term perspective indicates the extent to which a model enables both short-term analyses (one to three years) and long-term perspectives (up to 30 years) for national policy-making.

T21 allows to focus on short-, medium-, or long-term analysis by modifying the time horizon of the simulation. Past development of key variables that led to the current situation can be simulated, as well as the potential effect of any policy on future developments.

4.3.6 User-friendliness

User-friendliness refers mainly to the ability of a model's interface to give the users an access to the main functions while using simple commands, to clearly display the output, and to help operators to find the information they need.

T21 model can be formatted in a simple and well-structured environment as well as organised in different windows that can be easily navigated using simplified command buttons on every page.

After the simulation has been run, the results can be reported in different forms, depending on the user's needs. Generally, data relative to the national accounting system are presented in tables and the behaviour of most of the other indicators is reported on time graphs, which facilitates readability and comparison.

The Causal Tracing function can also be used to navigate the network of causal relationships between variables and to identify the effects of each policy on the system. The results of different simulation runs can be compared as this functionality is available in the system dynamics software.

4.3.7 Environmental analysis

Environmental analysis is the extent to which a model can calculate various environmental indicators for all scenarios and its usefulness for performing environmental impact assessments.

The environmental macro sector of T21 describes the mechanisms of pollution accumulation, the consumption of non-renewable resources and land use. Other sectors can be added to the core to better portray the specific situation of a country, including modules for analysing the dynamics of fossil fuel consumption, air pollution, water pollution and GHGs. The resulting model structure considers the effects of human activities on the environment, and produces a wide range of indicators that are useful in evaluating the environmental effects of different policies.

4.3.8 Partnership building

Partnership building indicates the extent to which a model is able to produce structured outputs in standard formats that can help coordinate the participation of development partners.

T21 produces all the outputs required for the United Nations Development Assistance Framework, including indicators for environment (e.g., emissions) and society (e.g., education and poverty), for every year in the simulated future and for every scenario that is defined by the users.

Such features make T21 the ideal tool to foster the participation and collaboration of International Financial Institutions and other partners in the development plans of any country.

4.3.9 National development indicators

National development indicators refer to the modelling ability to estimate and display national development indicators for each scenario projected. The T21 model produces a wide range of aggregated indicators that allow for the monitoring of the development process of the country.

4.3.10 Continuous time-series output

Continuous time-series output refers to the ability of the modelling to produce continuous time-series outputs for major variables, which are essential for the effective monitoring and evaluation of development programs.

To monitor and evaluate the state of the system in any moment of the simulation, T21 can produce time-series outputs for all variables of the model that users wish to control. The frequency at which each calculation is made and each value is reported can also be set to suit the specific demands and needs of a country.

4.3.11 Applications

Currently, more than 30 customized T21 models have been created and applied, both in developed and developing countries. The large size of the model implies a significant effort to customize the model for a specific country, particularly if, as suggested, local experts and policymakers are involved in the process. Once the structure is defined, the user needs to provide the necessary data inputs for the model. The additional modules can then be developed separately by different groups of experts, thus reducing the time required for customization.

5 Applying T21 to the South African Green Economy Modelling (SAGEM)

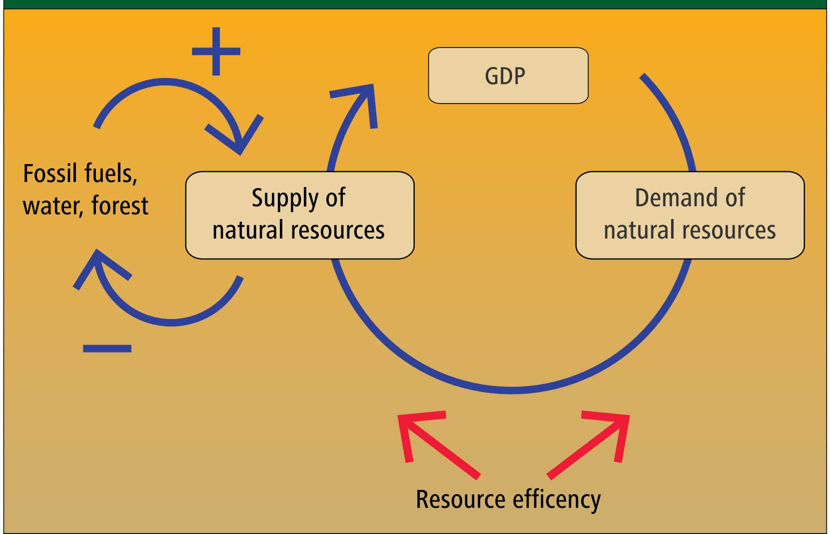
5.1 Introduction

T21 takes into account the stocks and flows of natural resources, which are the key drivers of a green economy, as well as the stocks and flows of capital and labour that are important in any long-term economic model. Stocks are accumulations of inflows and outflows (e.g., an area infested with invasive alien species is an accumulation of restoration and infestation). In a green economy, capital and labour are needed to develop and process natural resource stocks.

Three key factors transform natural resources into added economic value:

1. the availability of capital (which accumulates through investments and declines with depreciation);
2. labour (which follows the South African demographic evolution, especially the age structure, and labour force participation rates); and
3. stocks of natural resources (which accumulate with natural growth – when renewable – and decline with harvest or extraction).

Figure 3. The relationship between economic growth and natural resources



Some of the examples of a direct impact of natural resources on GDP are the availability of water in the production sectors (e.g., agriculture, industry and services) and the availability of fossil fuels to power the capital needed for the operations of these sectors. In this respect, T21 accounts for both monetary and physical variables representing each sector in a coherent and consistent manner. Water stress and energy prices, which are endogenously determined, are some of the factors that also affect GDP (see Figure 3).

The analysis that was carried out in this study focused on the transition towards a green economy in South Africa, which is characterised by high resource-efficiency and low-carbon intensity. It assessed the needs for a short- to medium-term transition and evaluated the impacts of a longer-term green economic development. An emphasis is therefore naturally put on stocks because they define the state of the system, as highlighted by projections of many key indicators for sustainability, which are categorised according to economic, social and environmental indicators. In concrete terms, the study aims at analysing the dynamic complexity of the social, economic, and environmental characteristics of the South African context with the goal of evaluating whether green investments can create synergies and help move the country toward green economy goals: resilient economic growth, job creation, low-carbon development and resource efficiency.

Longer-term sustainable growth is related to the sustainable management of natural resources, such as water, land and fossil fuels. Increasing the efficiency of use and curbing waste of such resources would reduce the decline of stocks, or even support their growth in certain cases. In this respect, understanding the relationship between stocks and flows is crucial (e.g., the concentration of emissions in the atmosphere may keep increasing, even if yearly emissions are kept constant or decline; or carbon concentrations will decline only if yearly emissions are below the natural sequestration capacities of forests and land).

The economic growth of recent decades, which profited from the contribution of natural resources, did not allow stocks to regenerate (as has been illustrated by the Millennium Ecosystem Assessment). For instance, according to EIA, oil production has reached its peak and is declining in most countries (EIA, 2009), and global peak oil, although much debated, is expected to take place within the next two or three decades (ASPO-USA, 2010; IEA, 2009). In addition, water is becoming scarce and water stress is projected to increase. Water supply would be satisfying only 60 per cent of world demand in 20 years, in a BAU scenario (McKinsey, 2009), which in turn will make significant changes in consumption (and demand) patterns necessary.

Agriculture has seen increasing yields, primarily owing to the use of chemical fertilisers (FAO, 2009), which reduced soil quality (Muller and Davis, 2009) by almost 10 per cent relative to the 1970 level. Agricultural intensification did not curb the growing trend of deforestation, which remains at 13 million hectares per year during the 1990-2005 period (FAO, 2009).

There has been a long-standing perception among both the general public and policymakers that the goals of economic growth, environmental protection and national energy security involve a complex set of trade-offs (Brown and Huntington, 2008; CNA 2007; Howarth and Monahan, 1996). By adopting an integrated approach focused on the interaction of stocks and flows across sectors, the South African green economy modelling process examined the hypothesis that a correct management of natural resources does not necessarily imply accepting lower economic growth going forward. Instead, it explored the question of whether equal or higher growth could be attained with a more sustainable, equitable and resilient economy, where natural resources would be preserved through more efficient use. This initial framework is in contrast with a variety of sectoral reports focused on energy and climate change mitigation scenarios. By way of contrast, a green economy approach supports both growth and low-carbon development by reducing emissions and conserving stocks in the short-term. As such, in the future, the country could profit from their improved state.

5.2 Developing a green economy for South Africa

Integrating the concept of a green economy into a formal model calls for a mathematical model that integrates economic and physical dimensions of the social, economic and environmental systems being analysed. This is due to the cross sectoral and dynamic nature of the green economy concept.

Within this context, SAGEM was developed to explore the transition to a green economy for South Africa, with special attention to its ability to meet low carbon growth, resource efficiency and pro-job development targets.

Accelerating environmental, economic, social and technological change challenges the decision and policymakers to learn at a faster rate, while at the same time the complexity of the environment in which we live continues to increase (Sterman, 2000). Many of the challenges that humanity faces today are related to unforeseen side effects arising from actions in the past. Effective development planning thus requires extending the current discourse of analysis by incorporating the dynamic complexity of the systems being studied and their interrelationships with other sub-systems.

This is the approach that was undertaken in the development of SAGEM, based on the T21 framework.

5.2.1 Boundary

The key variables that were considered essential in catalyzing the green economy agenda in South Africa were calculated endogenously in the model. These include, among others, the variables of the prioritized areas, that is, natural resource management, agriculture, energy and transport.

5.2.2 Time horizon

The South African green economy modelling (SAGEM) was developed to evaluate the impact of green economy investment on medium- to long-term environmental, economic and social development issues. Given the data availability at a national scale, the time horizon for modelling begins in 2001 and extends to 2030, which is in line with the current NDP time horizon. The simulation could also be easily extended further in the future if need be. The historical trends from 2001 to 2010 were utilised to ensure that the modelling replicates the characteristics of the behaviour of the issues investigated in SAGEM.

5.2.3 Scope

SAGEM represents the South African national environmental, social and economic spheres without disaggregation at provincial or cities level.

5.2.4 Modules

In a broad sense, SAGEM was divided into fourteen sectors (see Table 3) and 31 modules (see Table 4).

The sub-sectors represent the economy, society and environment interactions implicated by the green economy investment that was investigated for the South African context in the identified sectors: natural resource and management, agriculture, energy and transport.

A brief description of each of the sectors, sub-sectors and their respective modules for SAGEM is presented in the next section.

5.2.5 Data collection

Based on the outcome of the workshop, the Sustainability Institute and Millennium Institute collected data in consultation with, and assistance from, the Department of Environmental Affairs, National Treasury, Department of Trade and Industry, and Development Bank of Southern Africa, among others. The data that were collected covered the various sectors and were obtained from various sources (see Table 5).

In utilizing the data, the approach was to first use nationally available data, or to use expert-based documents in South Africa. In cases where these forms of information were not available, the internationally best available data, such as the World Development Indicators and data of the International Energy Agency, were utilised. Where data were entirely unavailable, assumptions were made based on the experience of the Millennium Institute pertaining to the GER; these assumptions are discussed in greater detail in Section 6.

The availability of data only allowed the simulation to start in 2001, and the modelling period was set to 2030.

Table 3. Green economy spheres and sectors

	Spheres		
	Environment	Society	Economy
Sectors	• Natural Resource Management • Land • Water • Energy • Emissions • Minerals	• Population • Education • Health • Employment • Public infrastructure	• Production • Investment and households • Government

Table 4. Modules of SAGEM

Environment sphere	Society sphere	Economy sphere
Natural Resource Management sector 1. Water quantity provision with WfW 2. Potential electricity generation from invasive species **Land sector** 3. Land **Water sector** 4. Water demand and supply 5. Water requirements in electricity generation **Energy sector** • ***Energy production*** 6. Electricity supply – coal 7. Electricity supply – nuclear 8. Electricity supply – hydro 9. Electricity supply- pumped storage 10. Electricity supply – solar 11. Electricity supply – wind 12. Electricity technology generation share 13. Electricity prices • ***Energy demand*** 14. Electricity demand 15. Oil demand 16. Gas demand **Emissions** 17. Emissions from different sectors - Power sector - Industry - Transport - Agriculture **Minerals** 18. Mining - Coal - Gold and uranium - PGM - Other	**Population sector** 19. Population **Education sector** 20. Education **Health sector** 21. Access to basic health **Employment sector** 22. Employment in different sectors - Industry employment - Agriculture employment - Services employment - Employment from NRM (invasive alien) 23. Power sector employment **Public infrastructure sector** 24. Transport 25. Access to roads	**Production sector** 26. Agriculture 27. Industry 28. Services 29. GDP **Households and investment sector** 30a) Household accounts 30b) Banks **Government sector** 31. Government accounts

5.3 Environment sphere

The environmental sphere of the SAGEM consists of six sectors and 18 modules (see Table 4) described below.

5.3.1 Natural resource management

The natural resource management represents the environmental and biodiversity protection programmes, with a specific focus on the WfW programme. The sector is classified into two modules: the first module calculates water quantity provision with the WfW programme[4] (see Annex 2.1), while the second one estimates the potential electricity generation from invasive species (see Annex 2.2). WfW is one of the country's strategic programmes aimed at reducing the area of land under invasive alien species, which is essential in maintaining the ecological integrity in terms of restoring the water flows. In addition, the programme has plans for value-added activities from invasive alien biomass, in particular electricity generation, which is the key value-added activity that was investigated in this module.

The variables in blue font are those that were extracted from other modules and used in the current modules.[5] The variables in red font are those that were determined in the current module and used in other modules.[6]

5.3.2 Land

The land module represents land use in South Africa and includes forest land, cropland, agricultural land, conservation land, land covered by invasive alien species. and other types of land (see Annex 2.3), and considers the land use changes for the different land types within the constraint of land availability.

5.3.3 Water

The water sector consists of two modules: water supply (see Annex 2.4) and water demand (see Annex 2.5). The water supply module represents the yearly water supply from renewable resources. It is utilised to estimate the water stress index, which influences the production sectors. Water demand from production sectors, as well as domestic and municipal demand,

is also estimated in this module. In the case of water demand, specific attention is given to the water requirement for electricity generation, including coal, wind, solar, nuclear and biomass energy.

5.3.4 Energy

The energy sector is categorised into energy production and energy demand.[7] Energy production consists of electricity supply (which is further categorised into coal, nuclear, wind, pumped storage, hydro and solar), electricity generation share and electricity prices. The electricity supply from coal (see Annex 2.6) represents the capacity of a coal electricity plant, the amount generated given the capacity factor and the potential for coal capacity reduction within given energy-efficiency measures. It was assumed that the required electricity generation from coal is the difference between the total electricity demand and the total electricity generation from other electricity technologies.

In a similar manner, other electricity supply modules, mainly nuclear, hydro, pumped storage, solar and wind (see Annex 2.7 to 2.11), represent the electricity generation from electricity technologies other than coal. Electricity production is influenced by investments (installed capital capacity). Electricity production is computed taking into account the demand and production capacities. Gross electricity demand is calculated by the sum of retail sales and distribution, distribution and transmission losses as well as electricity net exports. Subtracting the gross electricity demand from the electricity generation from renewables, nuclear, hydro and pumped storage yields the coal electricity demand for electricity production.

The technology share module estimates the proportion in which each electricity generation technology contributes to the total electricity supply (see Annex 2.12). In the case of electricity prices, this module (see Annex 2.13) describes the electricity prices, which are taken as exogenous. This assumption is reasonable for South Africa because the electricity prices are regulated by NERSA and projected exogenously based on assumptions for NERSA's determination on different electricity growth after 2013. They are considered as: (i) BAU – 10 per cent; (ii) average growth – 5 per cent; and (iii) slow growth – 2.5 per cent. Relative electricity prices have a major influence on production sectors, which in turn influence GDP and investments.

Energy demand, on the other hand, consists of electricity demand (see Annex 2.14), oil demand (see Annex 2.15) and gas demand (see Annex 2.16), representing the drivers of energy demand in the medium- and long-term. Electricity demand estimates future electricity dynamics by different electricity users, and is driven by GDP, population and electricity prices. Oil demand is influenced by an exogenously determined oil price since South Africa imports approximately 64 per cent of its oil consumption requirements.[8] At present, gas production and consumption still plays an insignificant role in the South African energy market. The gas demand module is therefore assumed to be influenced only by GDP.

5.3.5 Emissions

The air emission module estimates CO_2 emissions from the different sectors (see Annex 2.17) that comprise industry – which is categorised as electricity and non-electricity industry – as well as transport, agriculture, residential and services CO_2 emissions. The annual CO_2 emission is endogenously determined in the modelling.

5.3.6 Minerals

The mineral module represents the main mining activities, mainly coal, gold and PGM, and tracks both proven and unproven mineral reserves. The module further calculates the corresponding energy demand and employment generated from these sectors (see Annex 2.18 and 2.19).

5.4 Society sphere

The societal sphere of the SAGEM consists of five sectors and seven modules (see Table 4), which are discussed in the following sections.

5.4.1 Population

The population module represents the population of South Africa and was categorized according to sex (male and female) and age groups (see Annex 2.20). The module is generally used to dynamically estimate the factors that influence population (fertility rate and birth rate) and the way in which population influences environmental, social and economic indicators in other modules such as water demand, energy demand and GDP. For example, a growing population results in an increase in domestic water demand, which in turn increases total water demand. With an increasing total demand, the water stress index subsequently increases, implying a reduction in the water reserve margin relative to the demand. Consequently, a rising water stress index negatively influences the production sectors (agriculture, industry and services), which in turn influences the size of the country's GDP. Finally, GDP, in particular per capita income, has an influence on fertility rate and life expectancy, which in turn determines the level of population in the country (see Figure 4).

The main output of the sub-model is population, which was compared with the nationally available population data.

5.4.2 Education

The module (see Annex 2.21) represents the advancement of the population through the education system, from school age children (both primary and high school) to becoming a literate population. The module is categorised according to the South African educational system consisting of seven years in primary school and five years in high school. Government expenditure in education and per capital income is assumed as the main influences of entrance to school. Generally, the module is utilised to estimate the access to education and the literacy rate. These, in turn, are utilised to estimate the broader socio-economic factors such as availability of labour, population and GDP.

5.4.3 Health

The health module (see Annex 2.22) aims to represent the access of basic health care based on government expenditure on health. While access to health has an influence on fertility and life expectancy, the sparse data for this sector did not allow for the modelling to be linked to other modules.

5.4.4 Public infrastructure (access to roads and transport)

This sector is subdivided into two categories: roads infrastructure and transport. In the case of the roads module (see Annex 2.23), the process of road construction is estimated as influenced by government expenditure on transport and communication as well as the unit cost of roads construction. The process is aimed at providing an estimation of access to roads, which has an influence on the production sectors.

The transport module (see Annex 2.24), on the other hand, estimates the volume of roads, air and rail transport, which are categorised according to goods and passenger transport. The travel volumes are calculated by multiplying the initial value of 2001 to the effects of GDP and population. It is assumed that travel volumes increase as GDP and population increases. The associated emissions, employment and energy use from these transportation modes is also estimated. These are calculated based on the CO_2 emissions, employment and energy consumption factors for each of the transport modes, which are exogenously determined.

Figure 4. Casual loop of effect of population on water demand

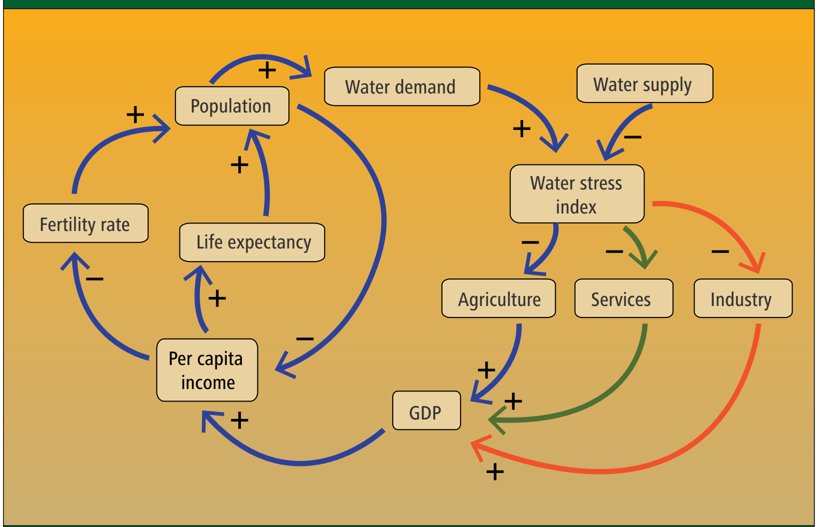
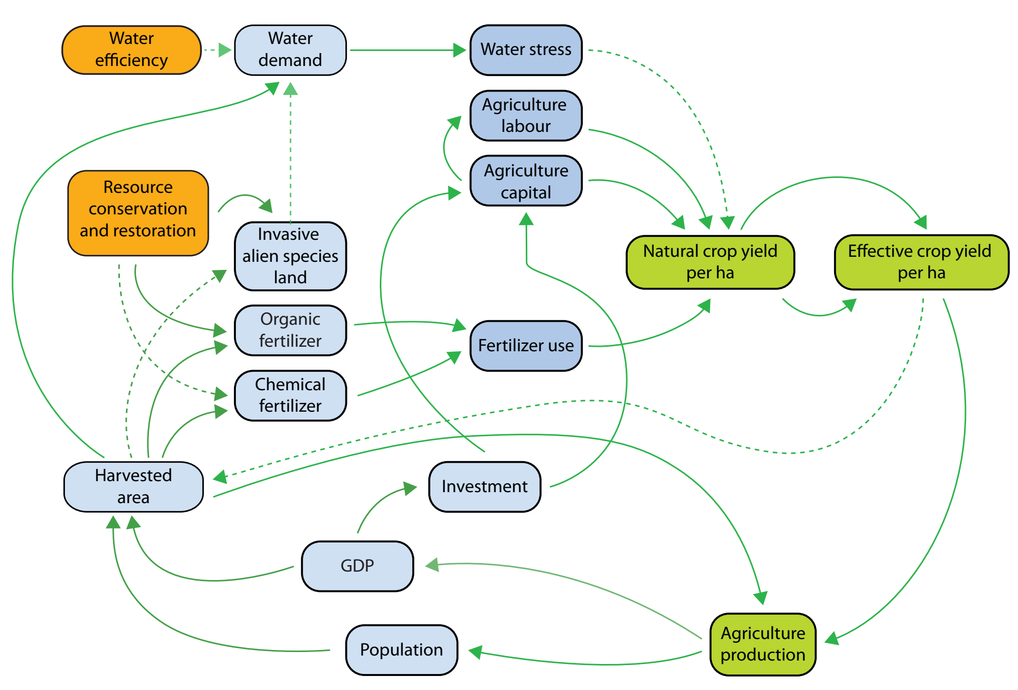


Figure 5. Causal loop diagram – Effects of green economy investment on agricultural production



5.4.5 Employment

This represents employment created throughout all economic activities (see Annex 2.25). The accumulation of capital in the main production sectors (agriculture, industry and services) is considered important in driving the growth in employment. The estimation of employment was disaggregated from other sectors. For instance, employment from ecosystems restoration, for NRM, with a specific focus on the WfW programme; and employment from mining, transport and power sectors (see Annex 2.26). Employment in all the sectors tends to adjust over time to the demand, whilst recognising that employment cannot be more than the supply of labour force.

5.5 Economy sphere

The economic sphere of the SAGEM consists of three sectors and six modules (see Table 4), which are discussed in the following sections.

5.5.1 Production (agriculture, services and industry)

This sub-sector represents the agriculture, services, and industry sectors that are utilised to calculate the gross domestic income.

The agriculture module (see Annex 2.27) includes crop production and differentiates between production utilising conventional and organic fertilizer. The agricultural production is based on the Cobb-Douglas production function, where land, labour and capital are the main factors of production, and are influenced by water availability, electricity prices, literacy rate and access to roads. Growth in the agriculture production is dependent on these factors of production.

Being a production sector, agriculture has an influence on macroeconomic indicators related to a green economy, as illustrated in the causal loop diagram in Figure 5 above. An investment in 'resource conservation' and 'agriculture capital', will lead to an increase in 'agricultural production' with a consequent increase in GDP with opportunities for further investments.

Table 5. Data sources for SAGEM modules

Sphere	Data source
Environment	
NRM- water quantity provision with WfW	Various documents from SA experts on Working for Water Programme
NRM – potential electricity generation from invasive alien species	Various documents from SA experts on Working for Water Programme
Land	STATS SA; World Bank Database (World Development Indicators); various documents on invasive alien land
Water (demand and supply)	Water stress index
Water requirements in electricity generation	DME / DoE Digest of Energy Statistics; Evans et al., 2009
Electricity supply- coal	STATS SA; DME / DoE Digest of Energy Statistics
Electricity supply- nuclear	STATS SA; DME / DoE Digest of Energy Statistics
Electricity supply- hydro	STATS SA; DME / DoE Digest of Energy Statistics
Electricity supply- pumped storage	STATS SA; DME / DoE Digest of Energy Statistics
Renewable energy – solar	DME/DoE Digest of Energy Statistics; IRP 2010; SARi documents; Information on Engineering News
Renewable energy – wind	DME / DoE Digest of Energy Statistics; IRP 2010; SARi documents; Information on Engineering News
Electricity technology generation share	STATS SA; DME / DoE Digest of Energy Statistics; IRP 2010
Electricity prices	DME / DoE Digest of Energy Statistics; NERSA
Electricity demand	STATS SA; DME / DoE Digest of Energy Statistics; World Bank Database (World Development Indicators); International Energy Agency
Oil demand	DME / DoE Digest of Energy Statistics
Gas demand	DME / DoE Digest of Energy Statistics
Air emissions	International Energy Statistics; World Bank Database (World Development Indicators)
Mining	STATS SA Minerals statistics; World Bank Database (World Development Indicators)
Society	
Population	STATS SA; World Bank Database (World Development Indicators)
Education	STATS SA; World Bank Database (World Development Indicators)
Health (access to basic health)	World Bank Database (World Development Indicators)
Roads (access to roads)	Various South Africa documents; World Bank Database (World Development Indicators)
Employment	STATS SA; World Bank Database (World Development Indicators); Green jobs report
Power employment	SARi documents; International Energy Agency
Economy	
Agriculture	STATS SA; World Bank Database (World Development Indicators)
Industry	STATS SA; World Bank Database (World Development Indicators)
Service	STATS SA; World Bank Database (World Development Indicators)
GDP	STATS SA; World Bank Database (World Development Indicators)
Investment and Household	STATS SA; South African Reserve Bank
Government	STATS SA; South African Reserve Bank
Transport	DME / DoE Digest of Energy Statistics; World Bank Database (World Development Indicators)

These investments may be in 'health and education', which will increase the 'population' and 'labour force', which can then also boost 'agricultural production'; or it can also increase 'education levels' that will improve 'labour productivity', as well as 'agricultural production'. Another option is to channel investments into 'pollution control', which can improve 'life expectancy' and associate benefits to the rest of the economy, or directly improve 'agricultural production'. Many other casual loops are possible for this and other sectors.

Similarly, the industry and services modules (see Annex 2.28 and 2.29) represent the industry and services production respectively, and employ the Cobb-Douglas production function. Their production is also influenced by water availability, electricity prices, access to roads and the education level.

The GDP module (see Annex 2.30) shows the accounting relationships in the calculation of the major income-related indicators. These include the real GDP, which is influenced by the production sectors and the per capita income among others. GDP is one of the main outputs of the economic sector and the simulation results were similarly compared with the historically available data.

5.5.2 Investment and households

This represents the accounts of how the flows from the various economic production sectors determine the investment in the country and the household income. The investment arises from both private and public sectors, which is then allocated to the various production sectors. On the other hand, the household income is divided into consumption and savings. The savings part eventually becomes part of the investment.

Annex 2.31 represents the accounts of how the flows from the various economic production sectors determine the investment in the country and the household income.

5.5.3 Government

The government module (see Annex 2.32) shows the various sources of government revenue including taxes, grants and interest, which are received both domestically and from abroad. The module also shows the government expenditure allocation to the various sectors.

6 Scenario definitions and challenges

SAGEM has been used to simulate green investment scenarios that aim to promote economic growth, job creation and a transition towards low carbon development and resource efficiency in comparison to the baseline scenario. The development of the scenarios was guided by the outcomes of the discussions of the workshop (see Section 3.4), which suggested the need to identify the scenarios based on the existing targets in the different South African documents that are supporting the green economy.

A combination of three criteria was used in the identification and selection of green economy scenarios, as follows:

1. The available targets in the existing policy and strategy documents were used (see Figure 1).
2. In cases where the targets were not available, the planned expenditure for projects that are being evaluated, or are already planned, was used.
3. Where targets or expenditure were not available, speculative assumptions on specific interventions were used.

There was enough information regarding the targets and investment costs for the energy sector, and this was used in the modelling. For instance, the IRP 2010 provides electricity capacity targets up to 2030; the South Africa Renewables initiative (SARi) has documents estimating employment in different energy technologies; and the International Energy Agency (IEA) provides the capital and operational costs for the different energy technologies. This was the same data that was used in setting the target-specific green economy investment.

For the case of transport, the IEA carbon abatement costs for the whole sector were used due to the unavailability of cost multipliers. For the agriculture sector, speculative assumptions were used on an intervention where the agricultural arable land is converted to ecological agriculture, which uses organic instead of chemical fertilizer. This target followed similar assumptions in the GER, which used estimations of cost interventions per hectare.

The NRM sector used estimates from the WfW programme regarding the costs of interventions. These include the costs of clearing the invasive alien species, establishing a biomass electricity generation plant, and the associated employment.

6.1 Scenario definitions

A particular interest in the analysis of the green economy for South Africa was the evaluation of the broader impacts of investments in the selected sectors and their respective indicators. It was therefore crucial to explore how such investments would be allocated in the South African context.

Two types of scenarios were thus developed for the SAGEM analysis (also refer to Box 2). The first one comprises the BAU scenarios, which assume a general continuation on the current investment in the economy in the areas of natural resource management, energy sectors, and agriculture and transport sector. These scenarios were defined as BAU and BAU2%. The BAU2% scenario allocates an additional 2 per cent of GDP investments to the business-as-usual activities.

The second type of scenario comprises the green economy scenarios, which assume an active government intervention in the identified four sectors in order to encourage shifts towards low carbon, resource-efficient and pro-employment development. Two green economy scenarios are defined as GETS and GE2%. These two green economy scenarios represent an additional investment of 2 per cent of the total real GDP, and a priority-driven investment respectively, in the four selected sectors.

The GE2% assumes that the investment is allocated equally across the four selected sectors. While a variety of additional investments equally distributed could be analysed,[9] the GE2% was considered more coherent and relevant.

GETS was developed based on the target expenditure and goals for the different sectors of interest. In this scenario, all the options are weighted differently based on their investment prioritisation and targets in various policy and strategy documents, for instance, in the NRM sector. The targets for clearing invasive alien species in the WfW programme were used; for the case of energy sector, the IRP 2010 electricity capacity targets were used; and for agriculture, the targets for increasing land based on the NDP were used, but it was assumed that this land would be used for organic instead of chemical fertiliser. For the transport sector, the targets for improving efficiency were used. Thus, the proportion of green investment varied over time, and differed across the sectors, with the allocation driven on the prioritisation of targets (see Table 6).

The process of scenario analysis began by first simulating a base scenario (BAU) and a BAU2%. This was followed by green economy scenarios which explored the effects of allocating a proportion of GDP to green economy sectors and provided the outcomes of such interventions. In order to ensure consistency in the comparison of the results, GETS was compared with BAU while GE2% was compared with BAU2%.

A comparison of the baseline and the green economy scenarios for the four prioritised areas are shown in Table 6.

Based on the suggestions from the stakeholder workshop, some additional scenarios and sensitivity analysis were also carried out. These included the analysis of:

- Invasive alien species clearance impacts due to uncertain cost of clearing invasive species; and
- Employment impacts with 90 per cent of manufactured components imported in the renewable power sector.

6.2 Challenges

The modelling process does not address the sources of funding for a green economy, but assumes an allocation of 2 per cent of the GDP is made. While sources of funding, such as the reallocation of funds, may be available in the medium- to long-term, in the short-term, the government needs to embark on strategies to provide resources for the green economy.

The specific responsibilities of the different agents in transitioning the green economy were also not explicitly addressed. However, the key contribution of SAGEM is its dynamic nature, cross-sectoral analysis and endogenous feedback loops (Roberts et al., 1983) within the various spheres, sectors and modules.

Table 6. Allocation of green investment across sectors in a green economy

Sector	Share of green investment GE2% (%)	Share of green investment GETS (%)
Natural resource management	20	0.32
Agriculture	20	0.15
Transport	20	4.70
Energy	20	94.30
Industry resource efficiency	20	0.47
Share of GDP	2	0.70

Table 7. Comparison of scenarios for the selected sectors			
Sector and objective	Baseline scenario BAU and BAU2%	Green economy scenario 2% (GE2%)	Green economy target specific scenario (GETS)
Natural resource management			
Decrease the land cover infested with invasive alien species	Less aggressive investment in restoration of land under invasive alien species	An equal allocation of investment in the clearing of the invasive alien species	Target specific on investment requirement to clear the invasive alien species in the WfW programme
Agriculture			
Increasing the yield and land under agricultural production	Extensive utilisation of chemical fertiliser	An equal allocation of investment to the use of organic fertiliser	Target specific to the amount of land using organic fertilisers. Assumes that the expansion of land as in the National Development Plan will use organic fertiliser
Transport			
Improving energy efficiency in transport sector	No investment in energy efficiency	An equal allocation of investment to improving transport sector efficiency	An aggressive investment in transport expansion and energy efficiency in the sector. This was equivalent to 16 per cent of energy efficiency by 2030
Energy			
Diversification of power energy mix	Investment in coal electricity, with minimal renewable energy. Investment in Kusile and Medupi included in the BAU. This also includes the committed renewable energy development (Wind, CSP and Solar PV)	Assumes equal allocation of investments to all the renewable energy specified in IRP 2010. This includes the new built plans to renewable energy development	This is a priority expansion of renewable power generation as specified in IRP 2010

7 Results of the simulation analyses

7.1 Baseline scenario (BAU) results

The baseline scenario replicates the historical trend over the period 2001-2010 and assumes no fundamental changes in the policy or external conditions in the years leading up to 2030. This scenario was set up and calibrated to reflect the baseline projections for the various existing sectoral models presented in Table 3.

The real GDP[10] is observed to grow over the simulation period (see Figure 6) due to the growth of the production sectors, namely: services, industry and agriculture. The result of the GDP simulation was compared with STATS SA data. For the past projections, the simulation results perform well compared with the STATS SA data, with an R-square of 94.8 per cent and an average point-to-point standard deviation of 0.21 per cent.

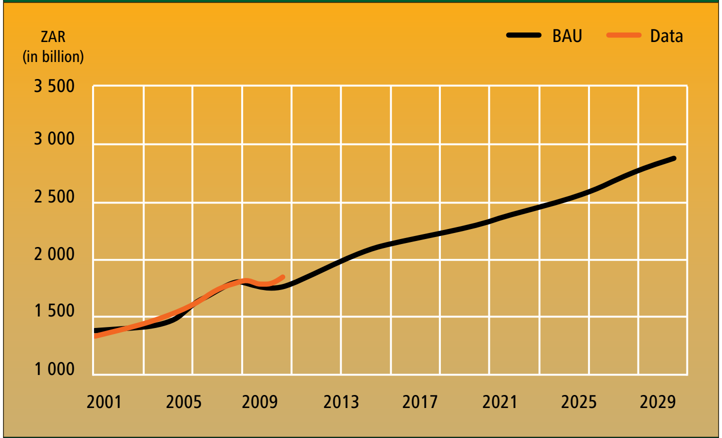
Between 2012 and 2030, the contribution for these production sectors to the GDP is expected to increase by 68 per cent for industry, 44 per cent for services and 14 per cent for agriculture. Overall, this represents an increase in real GDP of 50.2 per cent in 2030 relative to 2012.

The growth in the production sectors also corresponds to the employment opportunities that these sectors offer, with industry still providing much of the employment. BAU shows a 24 and 36 per cent increase in employment in the services and industry sectors, respectively. On the other hand, agriculture shows a drop in employment of about 14 per cent in 2030 relative to 2012.

Total employment covers all the sectors. This was disaggregated for the industry sector, which also provides employment in the mining and power sectors. Natural resource management is also contributing to employment, resulting from BAU allocation of some amount in the WfW programme. When considering the employment creation of the specific sectors, the transport sector shows an increase in employment by 2.3 times in 2030 relative to 2012 (see Figure 7).

Similarly, the population grows from 51.7 million in 2012 to 61.4 million in 2030 (see Figure 8). Simulation from 2001 to 2010 matches the historical data from STATS SA, with an R-square of 97.9 per cent and an average deviation of 0.09 per cent. While births are projected as declining, life expectancy is increasing.

Figure 6. Comparison of real GDP in BAU and data



Energy demand, including electricity, oil and gas, are projected to grow due to population and GDP growth. In 2030, demand is projected to reach 121,643 thousand TJ for oil, 112,783 TJ for gas and 232,644 GWh for electricity. Coal-generated electricity remains relatively high, only declining from 91.7 per cent in 2012 to 83.6 per cent in 2030 due to the introduction of renewable energy that is already committed in the BAU scenario. It should, however, be noted that the demand for electricity is unmet for some years in this scenario.

Figure 7. Employment in the key sectors in BAU scenario

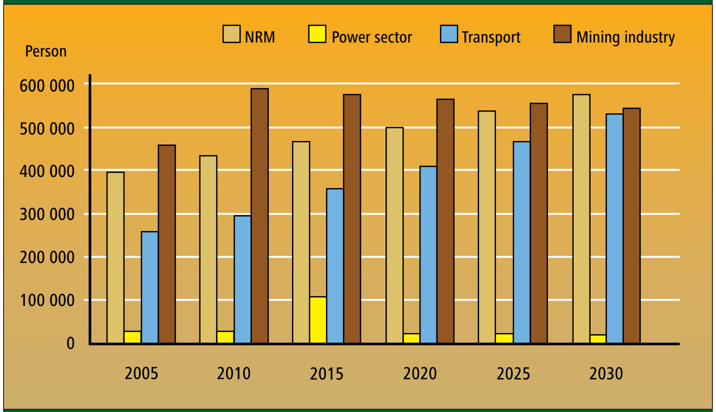


Figure 8. Comparison of population in BAU and data

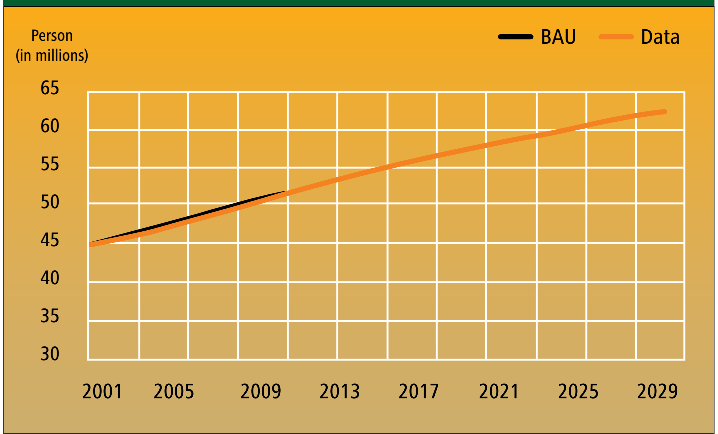
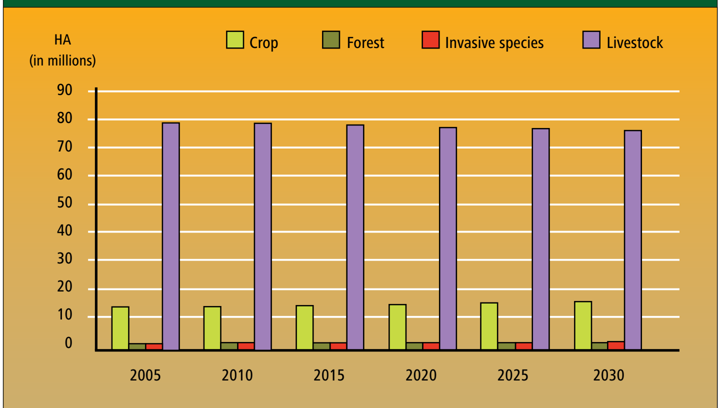


Figure 9. Selected land use changes in the BAU scenario



In a similar manner, water demand is projected to increase due to population and GDP growth, where the demand reaches 13,955 billion litres, representing an 8 per cent increase relative to 2012. With South Africa facing water stress and receiving only an average of 500 mm rainfall per annum, an increase in the water demand obviously increases the water stress index. Therefore, there is a need for sustainable water management practices, in order to avoid compromising the already stressed water resources.

In terms of land use changes (see Figure 9), the cropland will increase to 16.5 million hectares by 2030, representing a 9 per cent growth relative to 2012. This expansion, although marginal, is due to the increasing food demand from the growing population.

The area infested by the invasive alien species is observed to increase by 28 per cent in 2030 relative to 2012. While the WfW programme is incorporated in the BAU, the rate of spread of invasive alien species is greater than the rate of restoration – hence the increase in the invasive alien species land. With similar programmes and targets in the BAU on the Working for Woodlands programme, forestland is observed to increase by 0.9 per cent per annum from 2012 to 2030. Similarly, settlement land also grows by 1 per cent on average, reaching 2.14 million hectares. On the other hand, the growth in livestock land, as well as area infested by invasive alien species, decreases by 2 per cent and 6 per cent respectively.

The simulation result of the annual CO_2 emissions fits well with the World Development Indicators data, with an R-square of 80 per cent and an average deviation of 0.09 per cent (see Figure 10). The annual CO_2 emissions are observed to be relatively increasing, reaching 475 billion kilograms by 2030. This is a result of the increasing energy demand, population and GDP. The key sectors contributing to the increasing emissions are the energy, mainly due to power generation, and transport sectors (see Figure 11).

The power generation sector contribution to CO_2 emissions is projected to reach 297 million tons. Initially, the emissions from the power generation are shown to increase due to the planned coal generation that was modelled in the BAU scenario. In addition, the renewable energy generation that is committed in the

IRP 2010 was modelled as part of the BAU scenario, which explains why CO_2 emissions are growing at a decreasing rate. On the other hand, the emissions increase in the transport sector follows a different trend, with a growth rate of 1.6 per cent per annum, between 2012 and 2030. The share of the transport sector in CO_2 emissions is thus projected to rise from 11.1 per cent in 2012 to 13 per cent in 2030.

7.2 Results of green economy scenarios (GE2% and GETS)

An additional investment of 2 per cent GDP in green economy has impacts on the environment, society and economy. A summary of the main impacts of green economy scenarios in relation to BAU and BAU2% are presented in Table 8.

The green investment scenarios show that promoting investment in the key areas of low carbon development and ecosystem services management provides a sustained growth in the longer term. At the same time, the green scenarios show a reduction in emissions, a reduced dependence on conventional fuels, in particular the power sector, and a sustained utilisation of natural resources.

The growth in real GDP in the green economy scenarios is projected to reach ZAR 2.867 billion in GE2% and ZAR 2.907 billion in GETS. These exceed the projections in the BAU scenarios, which were projected to be ZAR 2.850 billion in BAU and ZAR 2.879 billion in BAU2%. The lower GDP growth projected in the BAU and BAU2% scenarios relative to GETS and GE2% is attributed to strained, depleted or polluted natural resources. The green economy scenarios build up resilience in the environment, economy and society, which is partly observed in, for instance, improved water stress index, reduced reliance on coal power generation and increased ecosystem services as a result of the removal of invasive species (see Box 2).

The green economy scenarios also stimulate total employment (see Figure 12), where GE2% contributes more to the total employment relative to other scenarios, reaching 28.347 million persons in 2030. When considering the contribution of specific sectors to employment, the two green investment scenarios provide a different picture (Table 8).

Figure 10. Comparison of CO_2 emissions in BAU and data

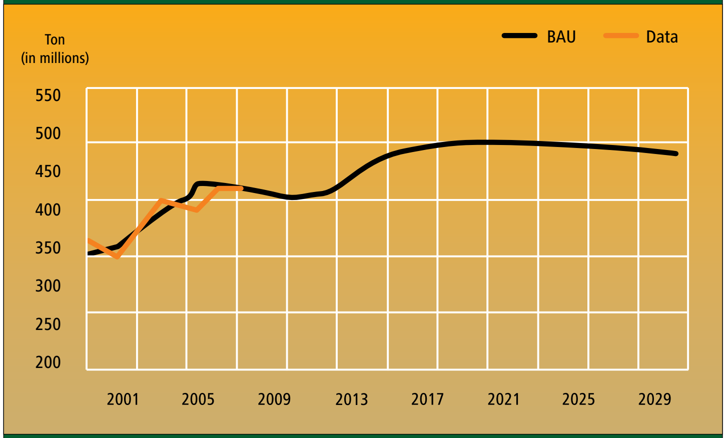


Figure 11. BAU CO_2 emissions in transport and power sectors

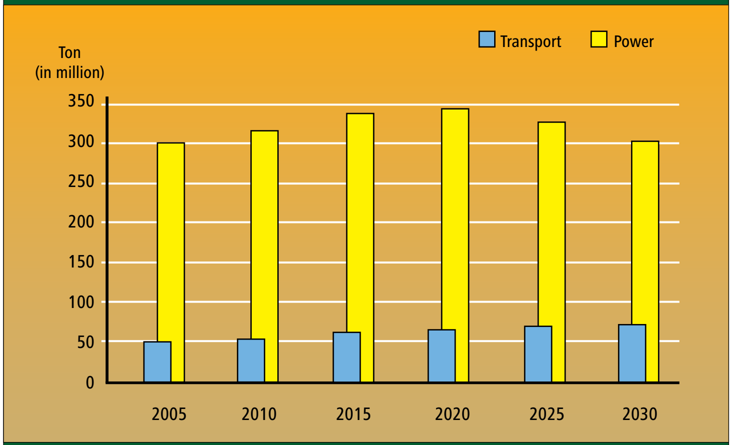


Figure 12. Total employment in BAU, BAU2%, GE and GE2% scenarios

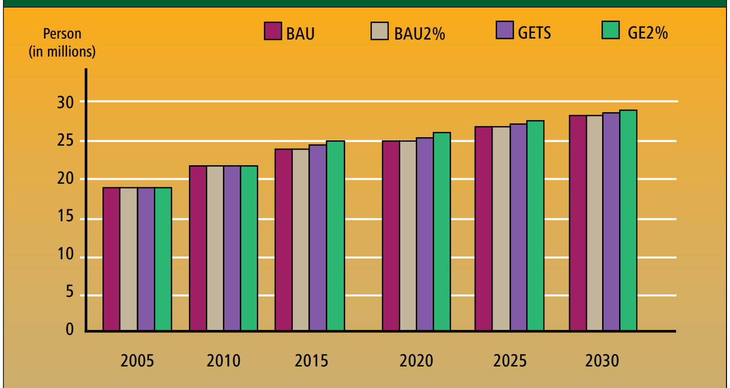


Figure 13. Potential job creation benefits with respect to a high import scenario in GE

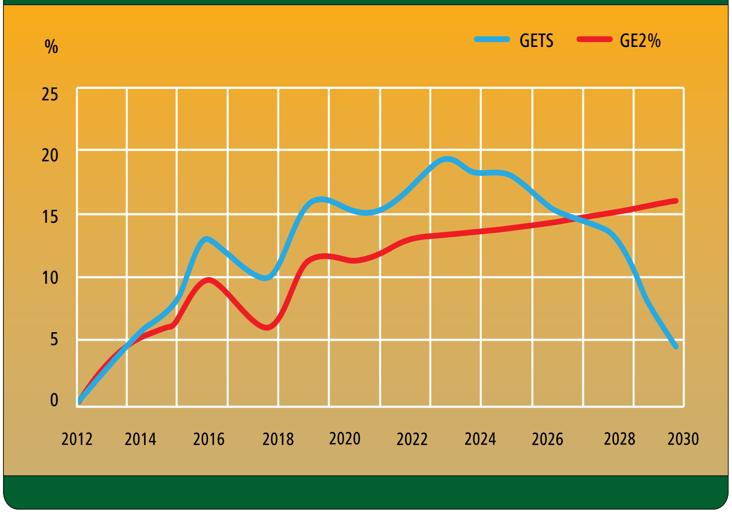
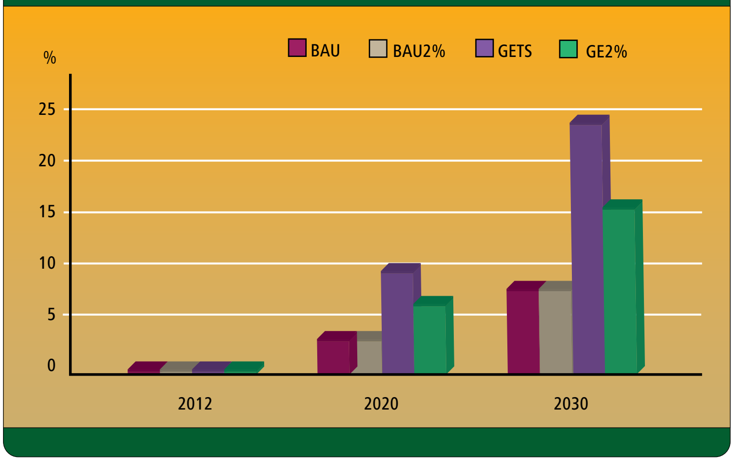


Figure 14. Comparison of share of renewable energy in BAU, BAU2%, GE and GE2% scenarios



In the BAU scenario, the jobs created in the power sector assume that 100 per cent of the manufacturing and assembling of renewable energy plants will take place in South Africa.

When accounting for the possibility of importing 90 per cent of the components, the potential domestic jobs avoided from undertaking a less optimistic approach is significant. With 100 per cent power components manufactured and assembled in the country, GETS potentially creates, on average, 12 per cent more jobs between 2012 and 2030 than a situation where 90 per cent of components are imported.

On the other hand, the GE2% scenario potentially creates, on average, 10.5 per cent more jobs between 2012 and 2030, with manufacturing and assembling of power sector components occurring in the country. In the case of the GETS scenario, there is a wide fluctuation in the short- and medium-term, which results from the differences in the prioritisation of renewable energy technology development (see Figure 13).

The GE2% scenario contribution to jobs created in NRM is higher than those generated in the GETS scenario (see Table 8). In addition, both the green economy scenarios yield higher job creation in NRM relative to BAU and BAU2%. The job creation in NRM is mainly from the restoration of the invasive alien species (see Table 8), employing 701,000 persons and 737,000 persons in GETS and GE2% respectively. Jobs are also generated in the development of electricity generation from biomass, but only play a minor role compared to the total potential of jobs creation in NRM.

The GETS and GE2% scenarios also contribute to the diversification of the energy mix in the power sector. According to IRP 2010, the target is to achieve 17.8 per cent of newly built electricity generation from renewables. In the GETS scenario, this is achieved by 2030 (see Table 8), as this share reaches 24.4 per cent. In the GE2%, renewable energy constitutes 16 per cent of total electricity generated.

On the other hand, BAU and BAU2% scenarios have a lower share of renewable energy, which is 8.2 per cent for both scenarios. Thus, the GE2% scenario results in almost double the share of renewable energy relative to the BAU and BAU2% scenarios (see Figure 14). Other documents, such as the NDP, have prescribed a higher target of 33 per cent of new generation from renewables. Such targets would require a more aggressive green economy investment intervention than GETS and GE2%.

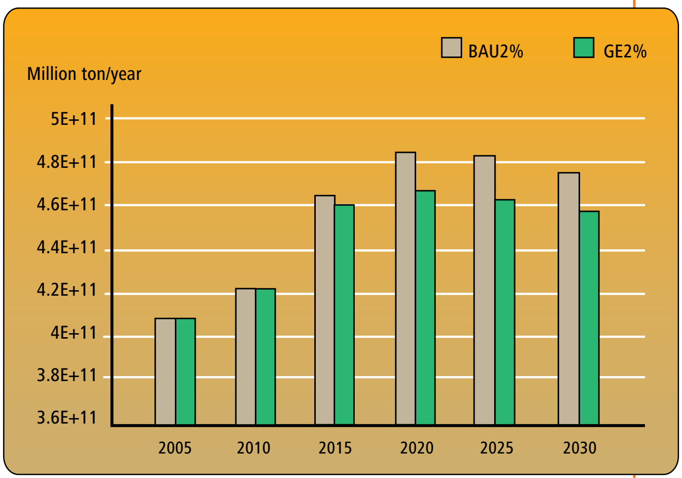
Green economy investments provide an opportunity for achieving the target of diversifying the energy mix and job creation, as well as CO_2 emissions reduction. The priority for the development of renewable energy in the GETS scenario leads to decreasing annual emissions, which will reach 415 million tons of CO_2 by 2030 (see Figure 15). On the other hand, the GE2% scenario shows a lower reduction of emissions, with emissions projected to reach 461 million tons of CO_2 by 2030. The

Box 2. Comparison of economic and environmental consequences of the BAU2% and GE2% scenarios

The approach used to simulate the green economy investment in South Africa consisted of an analysis of additional investment in green economy and BAU activities. In order to ensure consistency, the impact of allocating 2 per cent of GDP to BAU2% activities is compared with the 2 per cent additional investment in a green economy, all else being equal. The BAU2% scenario was developed to emphasise the outcomes of a green economy, as compared to a similar investment allocated to BAU activities.

The result shows that, using the same assumption for additional investment, BAU appears to yield similar results for economic growth and employment, but worse results concerning the environment.

Comparing the GDP for the two scenarios, it appears that investing in a green economy is not worthwhile in the short-term. However, in the medium- to long-term, the GE2% GDP rises towards 2020 and 2030, getting closer to the GDP projected in the BAU2% scenario. Moreover, the GE scenarios result in environmental benefits such as reduced CO_2 emissions. Air emissions for BAU2% reach 477 million tonnes of CO_2, while that of GE2% is 461 million tonnes.



Other environmental benefits in the GE2% scenario include a reduced water stress index, which reaches 2.82 per cent in 2030, compared to the BAU2% which is about 1.1 times more than GE2% scenario.

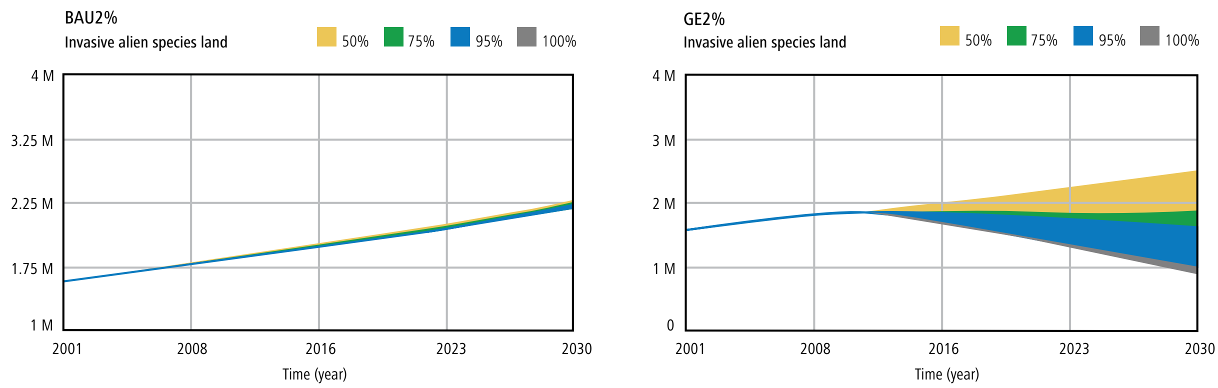
Furthermore, the GE2% scenario also creates slightly more employment relative to BAU2%, which in 2030 reaches 28.347 million persons, while the BAU2% creates employment for 27.853 million persons in 2030.

The share of renewable electricity generation in the GE2% scenario is about two times more than the BAU2% scenario. This is projected to reach 16 per cent in 2030 in the GE2% scenario, while the BAU2% scenario reaches 8.2 per cent.

Comparing the results of the BAU2% and GE2% scenarios, it is clear that across all sectors the BAU2% scenario yields fewer overall benefits than the GE2% scenario. Comparatively speaking, the GE2% scenario supports the environment more and creates jobs in sectors that support production (e.g., water).

A green economy is therefore projected to be able to deliver as much as a BAU case, but in a more sustainable manner. By considering extreme conditions in terms of the cost for clearing invasive species, it is observed that a relatively large area is restored in the GE2% scenario relative to the BAU2% scenario.

Sensitivity analysis for invasive alien species land with uncertain cost of clearing invasive species for GE2% and BAU2%



Sensitivity analysis for water savings from restoration with uncertain cost of clearing invasive species for GE2% and BAU2%

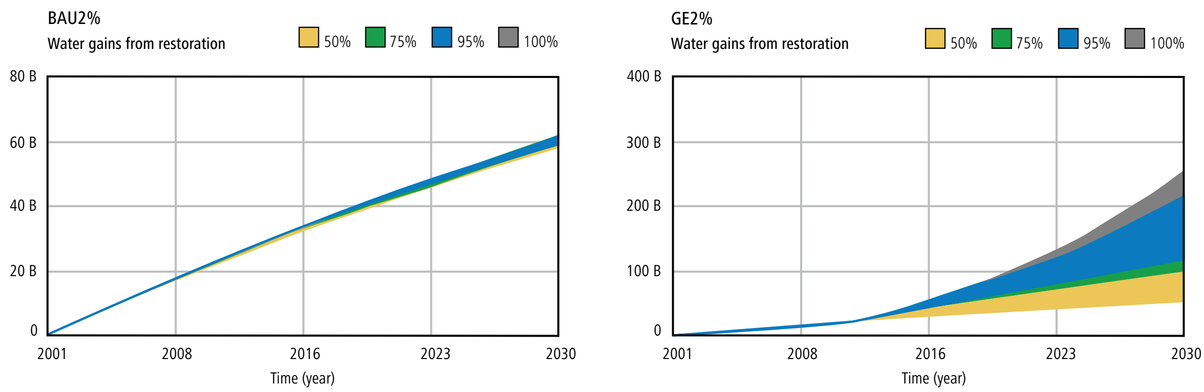


Table 8. Summary of main indicators for 2012, 2020 and 2030

Main indicators	UNIT	2012				2020	
		BAU	BAU2%	GETS	GE2%	BAU	BAU2%
Economic sector							
Annual CO_2 emission	Million ton/year	425	425	425	425	488	489
Emissions intensity	Ton/GWh	1 523	1 523	1 523	1 523	1 477	1 477
Share of emissions in transport	%	11.1	11.11	11.11	11.11	11.5	11.5
Water demand	Million ton/year	12 982	12 983	12 982	12 975	15 205	15 216
Water stress index	%	2.85	2.85	2.85	2.85	3.34	3.34
Forest land	Million ha	1.95	1.95	1.95	1.95	2.14	2.14
Crop land	Million ha	15.16	15.16	15.16	15.16	15.76	15.76
Invasive alien species land	Million ha	1.89	1.89	1.89	1.85	2.11	2.11
Oil demand	Thousand TJ	80 943	80 960	80 949	80 957	99 037	99 486
Gas demand	TJ	75 965	75 981	75 971	75 978	92 353	92 759
Electricity demand	GWh	208 673	208 685	208 662	208 667	221 211	221 471
Share of coal	%	91.7	91.7	91.7	91.7	88.6	88.6
Share of nuclear	%	5.4	5.4	5.4	5.4	4.5	4.5
Share of pumped storage	%	1.7	1.7	1.7	1.7	2.7	2.7
Share of solar	%	0	0	0	0	2.5	2.5
Share of wind	%	0	0	0	0	0.7	0.7
Share of hydro	%	1.2	1.2	1.2	1.2	1.0	1.0
Share of renewable energy	%	0	0	0	0	3.2	3.2
Economic sector							
Real GDP	Billion ZAR	1 896	1 897	1 897	1 897	2 320	2 331
Additional investment	Billion ZAR	0	38	13	37	0	47
Real GDP per capita	ZAR	36 655	36 663	36 658	36 662	41 156	41 344
Agriculture production	Billion ZAR	42	42	42	42	42	43
Industry production	Billion ZAR	507	507	507	507	668	671
Services production	Billion ZAR	1 149	1 149	1 149	1 149	1 368	1 374
Industry efficiency improvement	%	0	0	0	0	0	0
Transport efficiency improvement	%	0	0	0	0	0	0
Social sector							
Total population	millions	51.74	51.74	51.74	51.74	56.38	56.38
Total employment	Thousand people	22 320	22 320	22 670	23 190	24 585	24 607
NRM employment	Thousand people	439	439	734	1 087	493	493
Agriculture employment	Thousand people	1 254	1 254	1 310	1 476	1 155	1 155
Industry employment	Thousand people	4 601	4 601	4 601	4 601	5 215	5 222
Services employment	Thousand people	15 126	15 126	15 126	15 126	16 748	16 763
Mining employment	Thousand people	573	573	573	573	556	556
Power sector employment	Thousand people	17	17	17	17	15	15

2020		2030				UNIT	Main indicators
GETS	GE2%	BAU	BAU2%	GETS	GE2%		
							Environmental sector
469	471	475	477	415	461	Million ton/year	Annual CO_2 emission
1 378	1 419	1 404	1 404	831	1 275	Ton/GWh	Emissions intensity
11.9	11.4	13.0	13.1	15.0	12.9	%	Share of emissions in transport
15 281	14 839	13 955	13 984	14 221	12 857	Million ton/year	Water demand
3.35	3.26	3.06	3.07	3.12	2.82	%	Water stress index
2.14	2.14	2.26	2.26	2.26	2.26	Million ha	Forest land
15.76	15.76	16.53	16.53	16.53	16.53	Million ha	Crop land
1.82	1.46	2.43	2.43	1.73	0.99	Million ha	Invasive alien species land
99 151	99 796	121 643	122 863	122 383	124 063	Thousand TJ	Oil demand
92 456	93 039	112 783	113 877	113 448	114 961	TJ	Gas demand
213 526	213 842	232 644	233 152	222 146	221 662	GWh	Electricity demand
82.1	83.8	83.6	83.6	46.1	73.0	%	Share of coal
4.4	5.8	4.6	4.6	26.9	7.6	%	Share of nuclear
2.7	2.7	2.7	2.7	1.9	2.5	%	Share of pumped storage
5.2	3.4	7.6	7.6	12.9	9.7	%	Share of solar
4.6	2.3	0.5	0.5	11.4	4.2	%	Share of wind
1.0	1.0	1.0	1.0	0.7	0.9	%	Share of hydro
9.8	6.7	8.2	8.2	24.4	16.0	%	Share of renewable energy
							Economic sector
2 323	2 338	2 850	2 879	2 867	2 907	Billion ZAR	Real GDP
14	46	0	58	20	57	Billion ZAR	Additional investment
41 204	41 473	46 432	46 895	46 714	47 352	ZAR	Real GDP per capita
42	47	48	48	48	56	Billion ZAR	Agriculture production
669	672	855	863	860	867	Billion ZAR	Industry production
1 369	1 376	1 650	1 667	1 659	1 680	Billion ZAR	Services production
5.9	5.9	0	0	8.1	9	%	Industry efficiency improvement
0	4.4	0	0	0	5.5	%	Transport efficiency improvement
							Social sector
56.38	56.38	61.38	61.38	61.38	61.38	Millions	Total population
24 891	25 404	27 753	27 853	27 974	28 347	Thousand people	Total employment
737	968	568	569	701	737	Thousand people	NRM employment
1 194	1 470	1 084	1 083	1 116	1 380	Thousand people	Agriculture employment
5 217	5 221	6 237	6 265	6 250	6 269	Thousand people	Industry employment
16 753	16 762	18 794	18 863	18 826	18874	Thousand people	Services employment
556	556	535	533	534	533	Thousand people	Mining employment
32	23	12	12	19	21	Thousand people	Power sector employment

Figure 15. Comparison of emissions in BAU, BAU2%, GE and GE2% scenarios

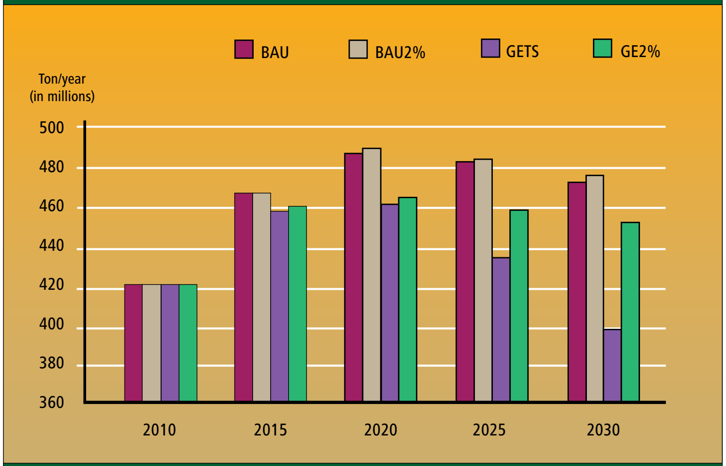
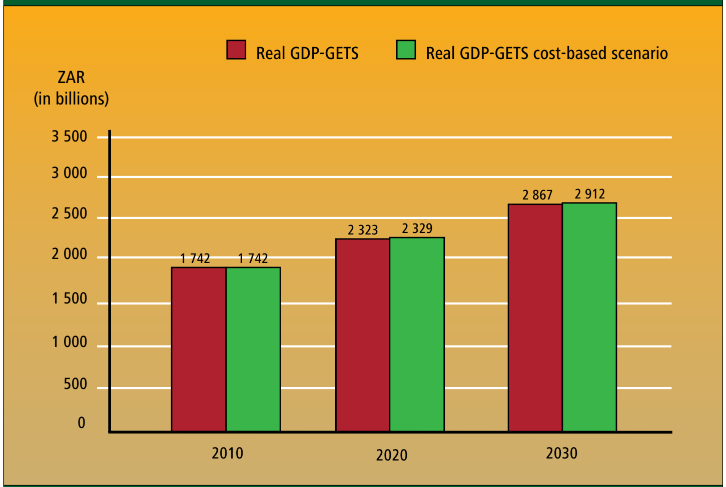


Figure 16. Comparison of centralised management and cost-based scenario in electricity pricing in GETS



BAU and BAU2% projections reach 475 million tons of CO_2 and 477 million tons of CO_2 by 2030, respectively. As a result of reduced emissions and increased power generation in the green economy scenarios, the emissions intensity in a green economy scenario is reduced relative to the BAU scenarios. Emissions intensity is projected to reach 831 tons per GWh for GETS and 1,275 tons per GWh for the GE2% scenario.

The NDP also stipulates a target of achieving a per capita real income of ZAR 110,000 per person by 2030. This target is not achieved in all scenarios by 2030, but the green economy scenarios yield relatively higher per capita income relative to the BAU scenarios. The projected per capita income is ZAR 46,714 per person for the GETS scenario and ZAR 47,352 per person for the GE2% scenario. On the other hand, the BAU and BAU2% scenarios per capita income projections in 2030 reach ZAR 46,432 and ZAR 46,895 per person, respectively.

Green economy investments are thus observed to provide numerous benefits in terms of resource use, energy consumption and emissions reduction. These reductions result from investments in energy efficiency, which reduce energy demand, and ultimately decrease the coal capacity requirements for electricity generation. It is observed that in a GE2% scenario, a potential cumulative energy demand reduction of 3,648 MW is achieved by 2030. This is comparable to the largest coal plants that are being constructed in South Africa (i.e. the Medupi coal plant, which will have a capacity of 4,788 MW).

The BAU scenario for electricity prices follows a centralised management approach, where NERSA is the regulating agent for electricity prices in South Africa. In the modelling exercise, a cost-based approach scenario was also tested, where the price of the renewables and electricity remains constant while the price of coal increases. This is based on the expectation that, in the longer term, the price of the coal-generated electricity will increase while that of renewable energy will decrease (with significant capacities). With such a scenario (GE2% and GETS), the cost of electricity will go down and the productivity of agriculture, industry and services will go up, which will ultimately increase the economic growth (GDP) (see Figures 16 and 17).

7.3 Investment scenarios for key sectors

The investment scenarios for each of the key sectors of focus in the South African context are discussed further in the following sections.

7.3.1 Natural Resource Management

The projected average investment in NRM from 2012 to 2030 is ZAR 52 million for the GETS scenario and ZAR 9.4 billion for the GE2% scenario. The investment is directed at the expansion of the programme of WfW, which mainly focuses on the improvement of the water ecosystem services, through the elimination of invasive alien species.

Due to inadequate information in this sector, an assumption was made that, with NRM increased investment in the GE2% scenario, more effort would be put in place to increase the rate at which the invasive alien species is cleared, albeit to a certain threshold. The additional benefit of reducing the area infested with invasive alien species is the improvement in the ecological water flow. The invasive alien species land is projected to decrease by 1.09 times in the GETS scenario and 1.87 times in the GE2% scenario, reaching 1.73 million hectares and 0.992 million hectares, respectively.

Thus, in 2030, the targeted investment that prioritises restoration of natural resources (GETS) results in an additional 28.8 per cent restored land relative to the BAU scenario, therefore reducing the size of the land under invasive alien species. Similarly, the GE2% scenario results in an additional restored land of 59 per cent relative to the BAU2% scenario. Another current consideration is the use of biomass resulting from invasive alien species to generate electricity, although this is not a primary priority. The projected electricity generation in 2030 is 30 MWh per year and 4,870 MWh per year for the GETS and GE2% scenarios, respectively. The case for the BAU scenario is about five times less than the GETS scenario.

Water gains from restoration of land infested with invasive alien species reach 113 million tons and 242 million tons for the GETS and GE2% scenarios, respectively. This improvement is mainly the result of water gains from the restoration process since invasive species consume more water relative to the indigenous species. The water savings thus provide a source of renewable water resources, reducing water stress. In addition, only the GE2% scenario provides an added benefit of decreasing the water stress index, which, in 2030, is expected to reach 2.82 per cent. The BAU and BAU2% scenarios' water stress indexes are projected to reach 3.06 and 3.07 per cent, respectively.

The improved water stress index in the GE2% scenario is the added benefit of reducing water demand, which is projected to reach 12,857 million tons by 2030, while the other scenarios reach 13,955 million tons, 13,984 million tons and 14,221 million tons for the BAU, BAU2% and GETS scenarios, respectively.

Figure 17. Comparison of centralised management and cost-based scenario in electricity pricing in GE2%

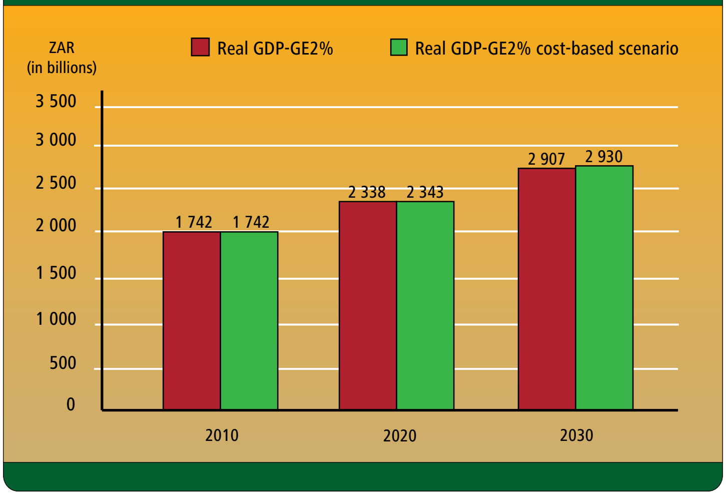
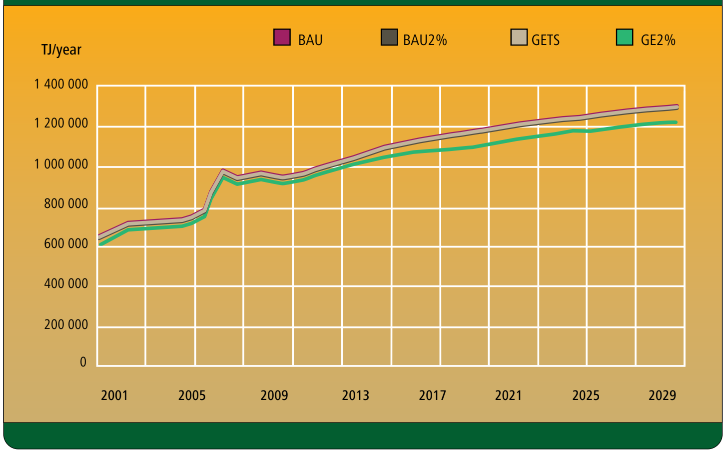


Figure 18. Comparison of transport energy use in BAU, BAU2%, GE and GE2% scenarios



The results in the NRM sector have a critical implication for water resource management of a water-scarce country such as South Africa. Concretely, a focus is needed on both water supply (or) gains and water savings (through demand reduction) that can be achieved, for instance, by reducing coal power generation.

Employment in the NRM sector occurs both in the restoration of the water ecosystem services and in the utilisation of biomass for energy. Most of the employment, however, arises from alien species elimination. With a GETS scenario, employment is created for 701,000 people in 2030 while the GE2% scenario is projected to create 737,000 jobs. The employment opportunities created in the green economy scenarios are higher than what is projected in the BAU (568,000 persons) and BAU2% (569,000 persons) scenarios.

7.3.2 Agriculture

Green investment scenarios in the agricultural sector allocate an additional investment of ZAR 24 million and ZAR 9.4 billion in the GETS and GE2% scenarios, respectively. These investments are directed to organic fertilizer use. Such investments provide a sustained increase of the yield per hectare, as opposed to the short-term gains from the use of conventional fertilisers. With these green economy investments, the crop yield is projected to increase by 5.5 per cent and 23.9 per cent by 2030 for the GETS and GE2% scenarios, respectively. The small difference for the massive increase in investments in the GETS and GE2% scenarios is due to water stress index, which is a dominant factor influencing the crop yield. Due to the increase in the yield per hectare, this is expected to result in the reduction of land requirements for agricultural crop production. However, the effect of population growth on the agricultural cropland requirements is higher than the cropland reduction from the increase in yield per hectare due to ecological agriculture. An additional benefit of avoided CO_2 emissions due to the use of organic fertilizer is observed in the GE2% scenario. In 2030, this is close to ten times the reduction in CO_2 emissions relative to the BAU, BAU2% and GETS scenarios (see Table 9).

7.3.3 Transport

Green investment in the transport sector is aimed at improving energy efficiency, which in turn translates into reduced energy consumption in the sector. The investment allocated in transport is on average ZAR 0.7 billion in the GETS scenario and ZAR 9.4 billion in the GE2% scenario. In the GETS scenario, efficiency investments in the transport sector are not enough to reduce the energy demand by 9 per cent by 2015, as stipulated in the energy efficiency strategy of 2005. The demand still continues to increase over the simulation period. Thus, in the GETS scenario, there is no visible improvement observed in the energy intensity, given the fact that the demand for energy will continue to grow as a result of GDP and population growths.

A more aggressive investment scenario, such as GE2% scenario, is observed to contribute to the reduced energy consumption in the transport sector (see Figure 18). The efficiency improvement in the GE2% scenario reaches 5.5 per cent by 2030. As a result, transport energy use, as well as CO_2 emissions, is expected to decline in the GE2% scenario relative to the BAU scenario.

7.3.4 Energy

Green investments in this sector allocate ZAR 33.2 billion and ZAR 94 billion to the GETS and GE2% scenarios, respectively (see Table 9). These investments are mainly aimed at energy supply, in particular at the diversification of the energy mix in electricity generation.

In the GETS scenario, the projected share of the electricity mix for the following sources of energy supply is: 26.9 per cent for nuclear; 1.9 per cent for pumped storage; 0.7 per cent for hydroelectric; 12.9 per cent for solar; 11.4 per cent for wind; and 46.1 per cent for coal.

In the case of the GE2% scenario, the share of electricity mix is projected to be 7.6 per cent for nuclear, 2.5 per cent for pumped storage, 0.9 per cent for hydro, 9.7 per cent for solar, 4.2 per cent for wind and 73 per cent for coal.

Similarly, these investments also aim at improving energy efficiencies in the transport and industry, commerce and residential sectors. Improvements in the energy efficiency are projected to decrease energy demand in the various energy use sectors (transport, industry, residential, agriculture and commerce).

Table 9. Main SAGEM indicators for the prioritized sectors

Priority sectors		2012				2020				2030			
	UNIT	BAU	BAU2%	GETS	GE2%	BAU	BAU2%	GETS	GE2%	BAU	BAU2%	GETS	GE2%
Natural resource management													
Additional investment in NRM	Million ZAR	0	0	41	7 360	0	0	51	9 189	0	0	63	11 412
Electricity generation from biomass	MWh/year	0	0	0	0	1	1	13	2 264	1	1	30	4 870
Invasive alien species land	Million ha	1.9	1.9	1.9	1.9	2.1	2.1	1.8	1.5	2.4	2.4	1.7	1.0
Water gains from restoration	Million ton/year	26	26	26	29	43	43	63	99	61	61	113	242
Agriculture													
Agriculture additional investment	Billion ZAR	0	0	0	7	0	0	0	9	0	0	0	11
Fertilizer consumption	Thousand ton/year	934	934	934	934	1 093	1 093	1 093	1 093	1 321	1 321	1 321	1 321
Chemical fertilizer use	Thousand ton/year	743	743	740	93	909	909	905	109	1 227	1 227	1 221	132
Organic fertilizer use	Thousand ton/year	128	128	128	135	110	110	114	1 088	132	132	138	1 452
Fertilizer CO_2 emission	Ton/year	7 433	7 433	7 396	934	9 092	9 092	9 045	1 093	12 266	12 266	12 209	1 321
Transport													
Transportation additional investment	Million ZAR	0	0	606	7 360	0	0	753	9 189	0	0	928	11 412
Industries additional investment	Million ZAR	0	0	61	7 360	0	0	75	9 189	0	0	93	11 412
Employment transport sector	Thousand people	310	310	310	310	402	403	402	404	524	529	527	533
Transport electricity use	TJ/year	4 848	4 848	4 848	4 848	5 266	5 274	5 268	5 049	5 767	5 787	5 779	5 490
Transport oil use	Thousand TJ/year	963	963	963	963	1 145	1 151	1 147	1 103	1 267	1 280	1 275	1 222
CO_2 emissions from transport	Thousand ton/year	47 064	47 068	47 065	47 068	55 935	56 182	55 999	53 874	61 867	62 507	62 249	59 683
Energy													
Energy additional investment	Billion ZAR	0	0	12	7	0	0	13	9	0	0	18	11
Emissions from power sector	Million ton/year	301	301	301	301	337	337	321	325	297	297	242	291
Coal electricity generation	GWh/year	181 101	181 101	181 101	181 101	201 934	202 040	191 096	194 323	176 537	176 537	134 270	171 253
Nuclear electricity generation	GWh/year	10 711	10 711	10 711	10 711	10 291	10 291	10 291	13 320	9 789	9 789	78 379	17 299
Renewable energy electricity generation	GWh/year	43	43	43	43	7 375	7 375	22 880	15 294	17 235	17 235	71 086	36 529

8 Comparison of SAGEM and T21-World

8.1 Introduction

Both SAGEM and the T21-World model, which was developed for UNEP's Green Economy Report (GER), use the T21 family of models as starting point. T21 is a comprehensive planning tool that integrates social, economic and environmental dimensions of national development into a single framework of analysis. SAGEM is based on T21, but is further customised for the South African context to represent the key issues and policy interests of the country, as defined in the initial stakeholder workshop of the project.

A comparison of the major differences between SAGEM and the T21-World model, in terms of the analysis and the structure of the model itself, is discussed in the following sections.

8.2 Comparison of the green economy analyses

8.2.1 Simulation of scenarios

Both SAGEM and T21-World analyse a green economy transition by simulating investments that target low carbon development, resource efficiency and natural resource conservation. Both models are used to simulate an investment reaching 2 per cent of GDP, which are compared to a BAU scenario with an additional investment – BAU2% – in conventional activities. The SAGEM analysis also includes an additional scenario, called GETS, which is driven by existing planned investments and goals, prioritised by government. The GETS scenario allows for an estimation of the investment costs required to achieve the desired goals for different sectors, while the 2 per cent scenarios are used to evaluate to what extent the GE scenario competes with a BAU case for a variety of indicators across all sectors. In this respect, the GETS scenario is a more realistic and probably more useful scenario to inform decision-making, while the 2 per cent investment case is more illustrative of the concept, as well as the pros and cons, of a green economy strategy.

8.2.2 Allocation of investments

Despite the similarity in the assumption of total investments in the 2 per cent case, the sectoral allocation of such investments differs considerably between SAGEM and T21-World. In the GER analysis, GE scenarios have been developed for a total of twelve sectors in order to cover a broad range of aspects of the potential green economy transition at a global scale and provides a broad range of considerations, by sector, on what a green economy is and how it can be operationalized. Furthermore, the modelling work for the GER was developed over the course of two years, while only a few months were available for SAGEM. In this respect, SAGEM should be seen as a pilot project that would require more extensive follow-up work to make the best of the integrated nature of the model to support decision-making. Regarding the allocation of investments across sectors in SAGEM, the stakeholders selected four key sectors: natural resource management, energy, agriculture and transport.

8.3 Comparison of models

8.3.1 Selection of sectors

In terms of the structure of the two models, which have key social and economic sectors in common (e.g., population and sectoral production), each model also has its unique sectors. This is due to the high degree of customization of the models, which are tailored around a specific set of issues (and sectors) to be analysed, and a geographical context (national vs. global). Data availability also defines the level of detail included in the model, and the presence of specific sectors for which relevance and data may be peculiar for one or the other model.

In concrete terms, SAGEM includes mining of primary minerals in South Africa (which are not included in the T21-World model) and takes into account the important role of the mining sector in the country's economy, as well as energy consumption and natural resource exploitation. The NRM sector is also unique to SAGEM and allows for the analysis of investment interventions in an especially relevant area for South Africa. Finally, in the economic sphere of the model, the government and households' accounts were added to represent more fully the System of National Accounts (SNA) and Social Accounting Matrix (SAM), for which global data are not available.

On the other hand, SAGEM is not equipped with sectors included in T21-World that the stakeholders did not select, or for which data are not available (e.g., waste recycling and reuse).

8.3.2 Structure of sectors

The sectors included in both SAGEM and T21-World do not necessarily share the same variables and equations. Since the SAGEM is fully customized to the South African context, the level of detail represented in T21-World could not always be achieved (due to both data and time constraints).

This is the case of the energy sector, for instance, where the production of fossil fuels (i.e. oil, gas and coal) is not modelled with the same detail as in the T21-World model because of the high level of uncertainty surrounding world fossil fuels production, as opposed to the higher stability of the coal and mining sectors for South Africa. In addition, the SAGEM energy sector emphasizes primarily electricity (power demand and supply), as this is a key issue currently facing the country. Furthermore, SAGEM's electricity supply sectors, which are highly customized for South Africa, represent production, generating capacity, costs and employment in plant construction and operations – all of which were disaggregated by energy source into coal, nuclear, wind, pumped storage, hydro and solar, excluding those sources that are mentioned in T21-World but are not used in the context of South Africa. The potential generation from biomass is further represented to estimate the impacts of green economy investments.

Another example is the water sector, where the representation of three major categories of water resources (i.e. surface water, groundwater and reservoir) in T21-World had to be simplified for SAGEM due to a lack of data on water stocks and flows as well as water consumption. On the other hand, SAGEM has more details on interventions that could improve water supply, such as water gains from land restoration (clearing of invasive alien species), one of the NRM interventions analysed in the study. Finally, SAGEM includes the estimation of water requirements for power generation separately from other water requirements, an indicator that is not included in T21-World.

8.3.3 Data availability

Both T21-World and SAGEM are developed based on statistical information available for each sector, which is used for model calibration and validation. Thus, the availability of data would largely influence the level of detail a model can provide, as well as the modelling approach employed.

The T21-World model is supported by historical data and baseline projections at both global and national levels. Global level data by sector, often highly disaggregated, have been collected from a range of international databases and reports (see Table 10).

In some cases, data at the regional or national levels are used, such as the value of natural resources used to estimate natural capital.

With data available from 1970 for most of the key variables, T21-World simulates almost 40 years of

Sector	Source of data
Population	• World Population Prospects (WPP) (UNPD, 2009)
Economy	• World Development Indicators (WDI) (WB, 2009) • Environmental Outlook to 2030 (OECD, 2008)
Agriculture	• FAOSTAT (FAO, 2010)
Forests	• State of World's Forests (FAO, 2009)
Water	• AQUASTAT (FAO, 2009) • Charting Our Water Future report (McKinsey, 2009)
Biofuels	• Sustainable Production of Second Generation Biofuels (IEA, 2010)
Transport	• IEA's Mobility Modelling Model and Transport, Energy • CO_2 report (IEA, 2009)

Table 10. Sources of data for T21-World models

trends (from 1970 to around 2010) for model validation, which allows reliable projections of the future up to 2050. In the case of SAGEM, data on earlier periods were lacking and consequently, simulation could only start in 2001. In addition, due to the shorter historical period simulated for validation, the modelling period was set to 2030. Moreover, some of T21-World data are not available for South Africa.

As listed in the data collection section above, data on the most essential social and economic indicators (e.g., population, education, healthcare, road infrastructure, GDP and the three production sectors) have been collected from both domestic (e.g., STAT SA) and international sources (e.g., World Bank's World Development Indicators database). However, the detailed data on fishery and forestry sectors, as well as poverty and Human Development Index, are not available for SAGEM.

On the other hand, the data on government expenditure allocated to various functions in South Africa allows for the inclusion of the government sector in SAGEM, while T21-World does not include a government sector at the global level.

Larger data gaps mainly exist in various environmental sectors. In the case of the water sector, national data on water demand and water stress index are available and thus modelled in SAGEM. However, data on the stocks of South African water sources are not available from the FAO database for T21-World. On the other the value of additional water from interventions (such as the removal of invasive alien species) is available for South Africa and modelled in SAGEM, but not in T21-World. Additional information has been collected related to water gains from land restoration from a number of documents.

Similarly, with regard to non-renewable natural resources, data on the stocks of oil and gas, as well as main exploration and supply flows, have been collected from EIA and USGS for T21-World based on data, but they are are not available for South Africa. The total stock of coal, however, is provided by reports on minerals for South Africa, while the level of detail in SAGEM is limited due to the lack of disaggregated information (e.g., discovered versus undiscovered reserves). Mineral data is available on the stocks and flows of gold and PGM, along with relevant employment and economic benefits, which are included in SAGEM, but not in T21-World.

In the energy sector of SAGEM, a range of detailed data is available on the key issue of electricity, including electricity production by energy source from national sources, costs and load factors of electricity production, and employment in power plant construction and operations. Data of all these variables are available disaggregated by energy source. On the demand side, national data on South Africa's electricity, oil and gas demand by end-users are available from national data sources, and a calculation of energy and transport data has been conducted to remove inconsistency of data from different sources. The information on total or sectoral coal demand, however, is not available, and thus is not included in SAGEM.

8.4 Main results

Due to the aforementioned differences in the availability of data, the definition of key issues by stakeholders and selection of key sectors to be analysed, as well as the results produced by SAGEM and GER, are not directly comparable on a sector by sector basis. On the other hand, the results are generally consistent concerning the social, economic and environmental impacts of interventions.

As discussed above, the simulation period for SAGEM is shorter than for T21-World due to the availability of data. Thus, SAGEM estimated results till 2030 under various scenarios, while longer-term projections up to 2050 can be calculated with T21-World.

Due to the different key sectors selected by the stakeholders, the indicators in GER sectors that are not prioritised for this study, and are not essential to other sectors, are not calculated in SAGEM. These include variables related to waste collection and disposal and the disaggregation of agriculture (into livestock, fishery and forestry production). On the other hand, the amount of government expenditures (total and disaggregated into various functions) are analysed in SAGEM, which are linked to other economic sectors, and also used as drivers for a number of social and environmental sectors, such as land protection, mining, among others. The indicators on restoration of land under invasive alien species and on mining of primary minerals are calculated in SAGEM only, as they are considered as key issues for South Africa, but not at the global level.

Considering the common sectors in the two models, stocks of renewable resources cannot be estimated by SAGEM due to lack of data. For example, the stocks and most supply flows of water cannot be evaluated as it was done in GER. However, the model estimates the amount of water gains from land restoration under invasive alien species and how it is influenced by green economy investments, along with the employment created and area of land restored, variables which are not included in GER.

With regard to non-renewable natural resources, the stocks and main supply flows of oil and gas fuels are not estimated in SAGEM due to data and time constraints. On the other hand, the model calculates stocks and exploration flows of coal, gold and PGM in the mining sector. The latter two resources are only estimated in SAGEM in order to take South Africa's important mining sector into account. SAGEM further calculates the contribution of mining to employment and the economy, which is not among the key issues analysed in GER.

Concerning the energy sector, electricity is SAGEM's main focus. A series of results for electricity has been calculated, including production, generating capacity and employment, all of which are further categorised by energy source. The sources are customized for South Africa according to coal, nuclear, wind, pumped storage, hydro, solar and biomass.

On the demand side, the consumption of resources are calculated by sector for both models, while the end-using sectors in SAGEM are selected and customized for the context of South Africa. Due to the importance of the electricity sector in South Africa, water demand is also driven by the amount used for electricity generation, creating a water-electricity nexus; whereas in T21-World, water used for electricity generation is not listed apart from water demand by other industries. In terms of the demand for energy, the additional components of primary minerals in SAGEM allow for the estimation of mining sector demand for electricity, oil and gas, as part of total demand for each of these fuels. In terms of coal, however, while the mining sector demand is calculated, the demand for coal by other sectors, as well as the total demand for coal, can only be estimated due to lack of data. As such, total fossil fuel demand or primary energy demand cannot be evaluated in SAGEM. Total emissions from fossil fuels are calculated in both models, and the impact of green economy interventions is consistent.

In terms of socio-economic results, employment by sector is estimated in both analyses, and shows consistent projections. The sectors in SAGEM are selected to account for the key issues in South Africa that have been identified by stakeholders, namely, agriculture, industry (including mining), services, electricity, transport, and natural resource management, while the main focus of GER is broader.

Other GER social results, which are not estimated in SAGEM, include poverty level and HDI, for lack of sufficient data for South Africa. In addition, GER evaluates the changes in natural capital (values of fossil fuels, forest and fish stocks), which is not included in the SAGEM analysis. This is mainly because the stocks of fossil fuels are not estimated due to lack of information, while fish stocks were not prioritised as key issues by stakeholders. In addition, the estimation also requires data on economic values of these natural resources, which are not available for South Africa.

9 Conclusions

The South African Green Economy Modelling (SAGEM) report is primarily aimed at assessing the impacts of green economy investments in selected cases within the identified sectors pertaining to the South African economy. Based on planned targets and expenditures and/or costs of interventions, the modelling identifies the possible opportunities to achieving these targets. Four scenarios were defined: BAU, or business-as-usual; BAU2% representing a 2 per cent investment of GDP in the BAU activities; GE2% representing an allocation of 2 per cent of gross domestic product in green economy sectors (energy, natural resource management, agriculture and transport); and GETS, which is a target-specific scenario aimed at identifying whether policy-makers can achieve the medium- to long-term targets following green economy interventions in specific cases within these sectors.

The two green economy scenarios (GE2% and GETS) clearly show that green economy investment interventions have positive impacts on the main indicators representing the transition of South Africa to a green economy.

The BAU2% scenario was aimed at emphasising the outcomes of a green economy, when a same investment allocation is directed to BAU activities rather than green investment. It was clearly shown that, using the same assumptions for additional investment, the BAU scenario appears to yield roughly the same economic benefits as the GE scenario, but underperforms when it concerns environmental performance. In other words, while the GE2% and BAU2% scenarios are aimed at allocating a similar proportion of GDP to different investments, the results show the added benefits of the GE2% scenario in the long-term. This includes not only sustained economic growth, but also increased value in the natural resources through the reduction of emission intensity, water stress index, reduced energy and water demand as well as the restoration of natural capital. For, the projected reduction in coal capacity requirements is 3,648 MW by 2030 in the GE2% due to investments in energy efficiency. This is comparable to the largest coal plants in South Africa under construction (e.g., Medupi, 4,788 MW).

It should, however, be noted that although synergies can be found, the specific green economy interventions simulated do not allow the achievement of all the targets set by the government simultaneously. Thus, there are some investment allocations that tend to provide more employment, while others tend to reduce emissions more. Finally, as a recommendation, the modelling could be used to test several different investment allocation options depending on the indicators that are considered to be of higher priority.

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[1] www.millennium-institute.org

[2] www.sustainabilityinstitute.net

[3] This is based on a Social Accounting Matrix and on Cobb-Douglas production functions.

[4] Water quantity and water quality are two different ecosystem services, though related. Given that South Africa is a water scarce country, the main threat of the invasive alien species is that of water quantity. The WfW programme has thus mainly focused on improving water quantity (or availability); this is then also the focus of SAGEM. Nevertheless, the importance of water quality impacts is not disregarded; at this stage, there are not well-founded scientific facts on the extent or seriousness of the impact of invasive alien species on water quality that could be used for SAGEM.

[5] Usually regarded as input variables.

[6] Idem.

[7] It should be noted that the energy sub-model is estimated using a variety of endogenous inputs (e.g., GDP and population) and exogenous inputs (e.g., the case of electricity price).

[8] http://www.energy.gov.za/files/petroleum_frame.html

[9] For instance, in GER, a 1% green economy scenario was analyzed.

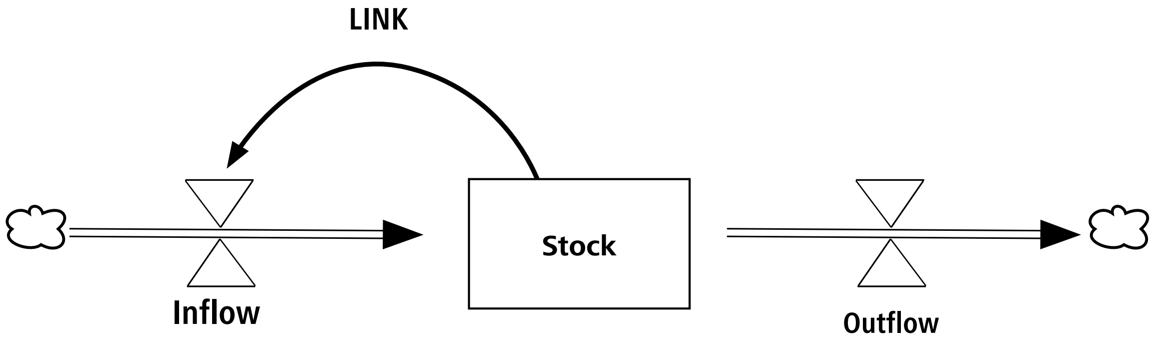
[10] Based on 2005 data.

Annexes

Annex 1

Annex 2

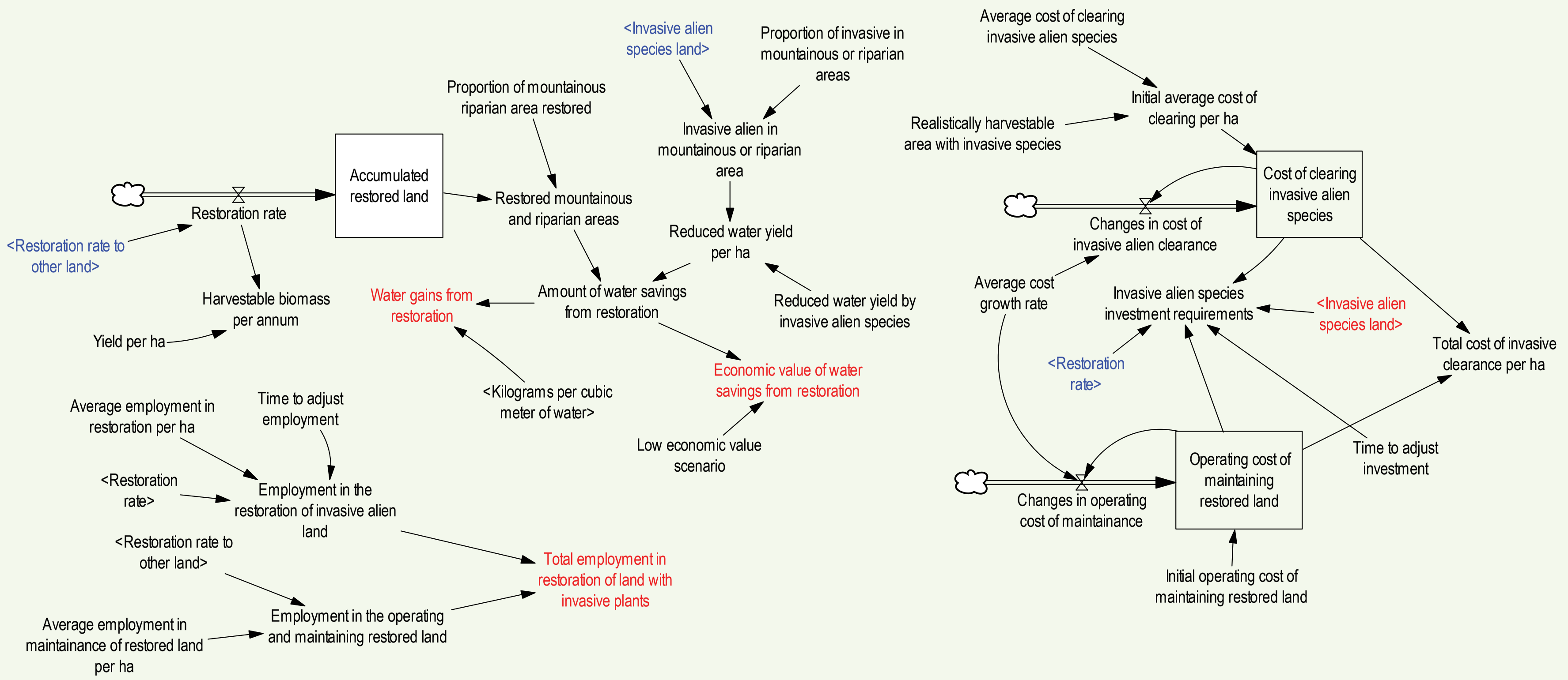
There are three symbols that are used in system dynamics modeling; a stock, a flow (can be inflow or outflow), and a link (arrow).



A stock is a foundation of any system and it is like a store; an accumulation of material or information that has been built up over time. Stocks change over time through the actions of a flow. Flows are filling and draining.

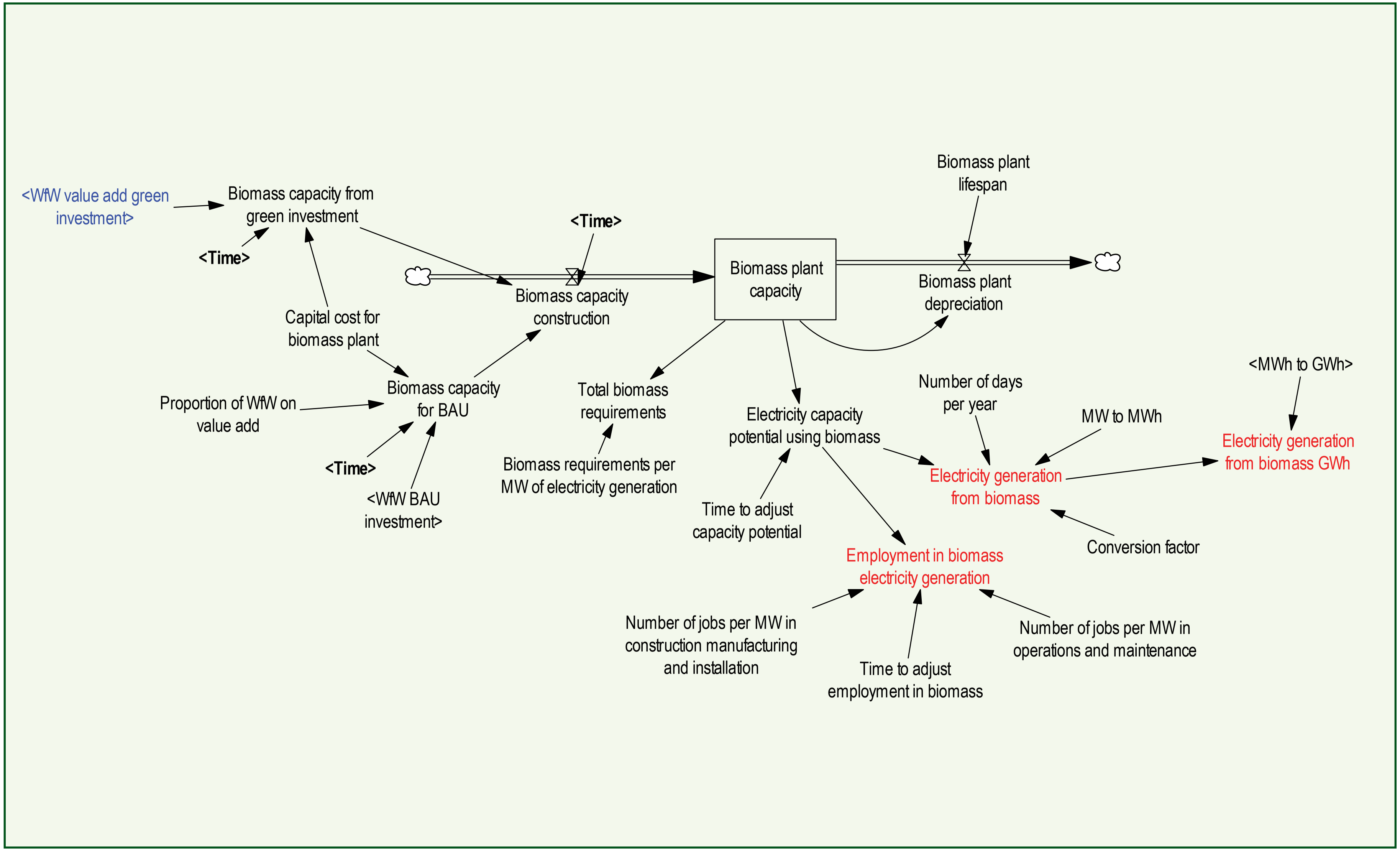
As an illustration, a mineral deposit is a stock, which is diminished through mining. The arrow, often regarded as an information link, as shown above, implies that the information in the stock influences the value of the flow. The cloud on the flow symbol represents either a source (for an inflow) or sink (for an outflow); that is, where the flow originated and vanished.

Annex 2.1 Water quantity provision with WfW module

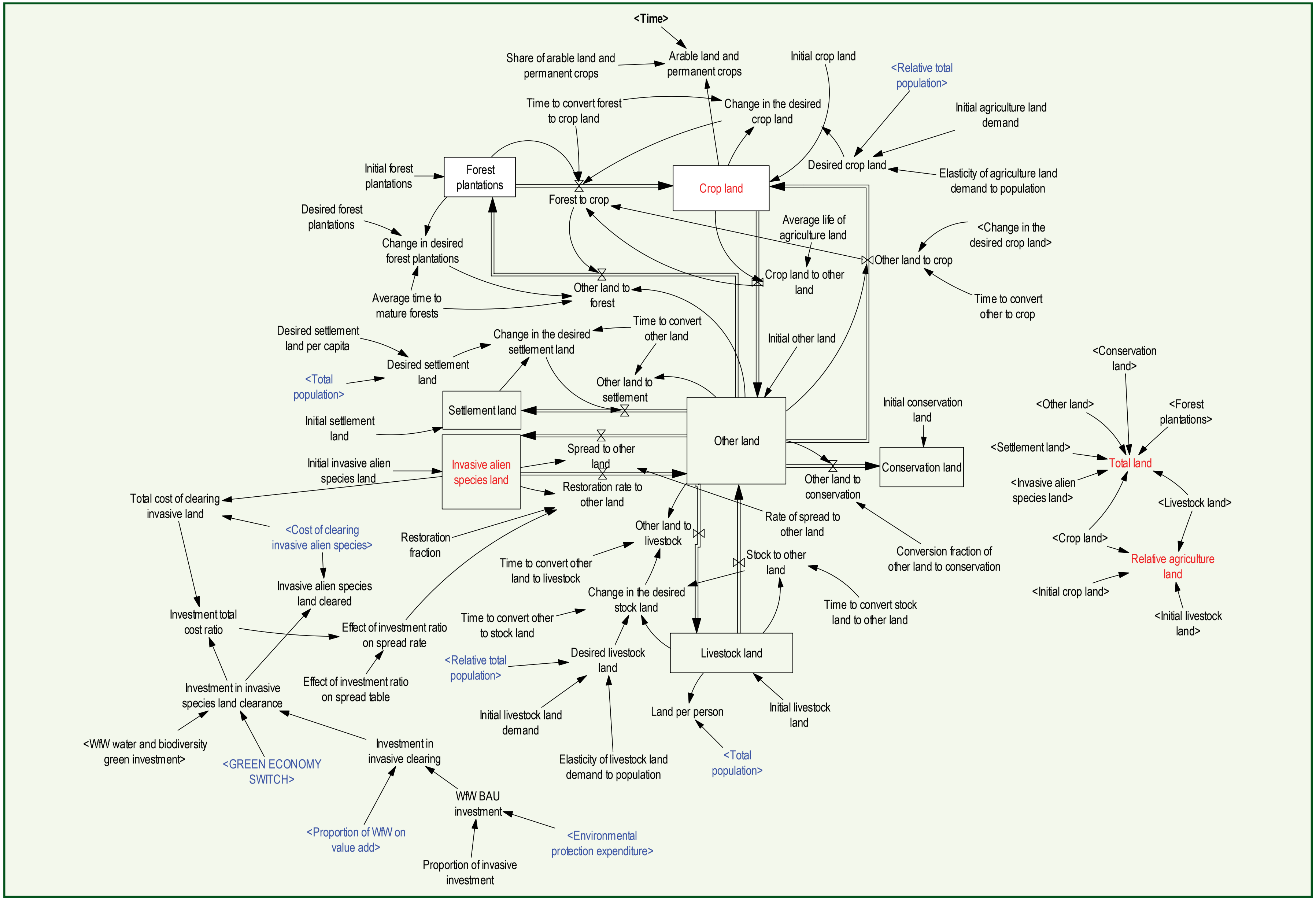


The **water quantity provision** module is aimed at estimating the amount of water savings that results from the restoration activities of the Working for Water (WfW) programme. In addition, the total employment from restoring invasive alien land and costs associated with the restoration are also estimated. The module consists of three stocks namely: accumulated restored water cost of clearing invasive alien species (capital cost) and operating cost of maintaining the restored land. The accumulated restored land is driven by the changes in the rate of restoration. Using an exogenously determined proportion of the restored mountainous areas, the amount of the water savings from restoration is estimated. On the other hand, the changes in costs influences both capital and operations costs. Similarly, the growth in cost of restoring invaded land is driven by an exogenously determined growth rate. Since this value is uncertain, sensitivity analysis taking into account of a low and high average growth rate in costs was carried out. The endogenously determined restoration rate, together with the coefficient of the average employment restoration estimates the total employment generated.

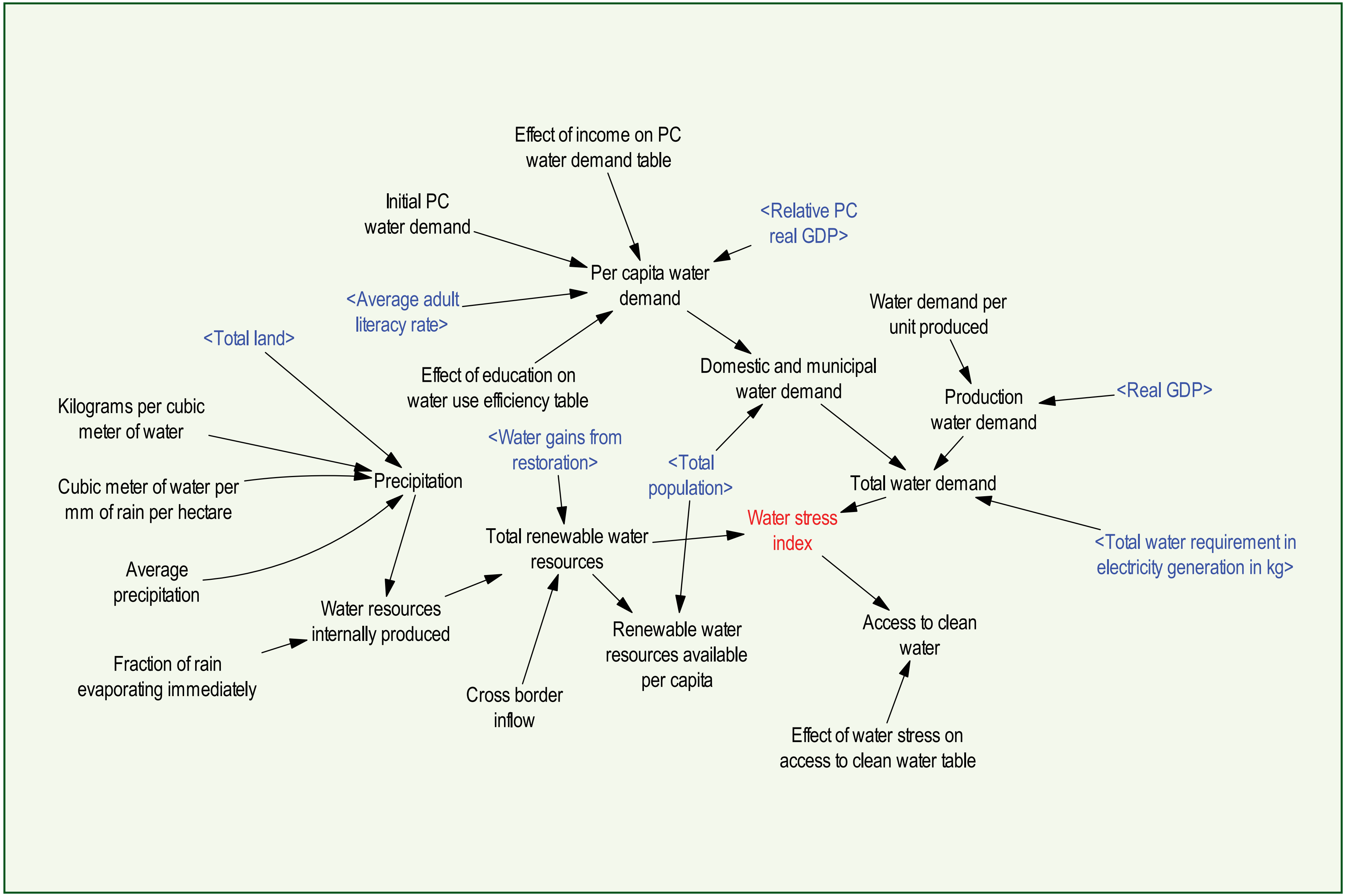
Annex 2.2 Potential electricity generation from invasives module



The **potential electricity generation from invasives** module estimates the amount of electricity generation from biomass harvested in the WfW programme and the respective employment in the biomass electricity generation. The module consists of one stock, namely biomass plant capacity, which increases with due to construction of the biomass capacity and decreases with depreciation of the biomass electricity plant. The main driver for the biomass capacity construction is investments in the value added activities of the WfW programme. The electricity generated is thus dependent on the capacity of the biomass electricity plant, its conversion factor and the number of days the plant is in operation. Employment created in the biomass electricity generation is estimated given the exogenously determined coefficient of employment in constructing, manufacturing and installation of the biomass electricity plant, and in the operations and maintenance.

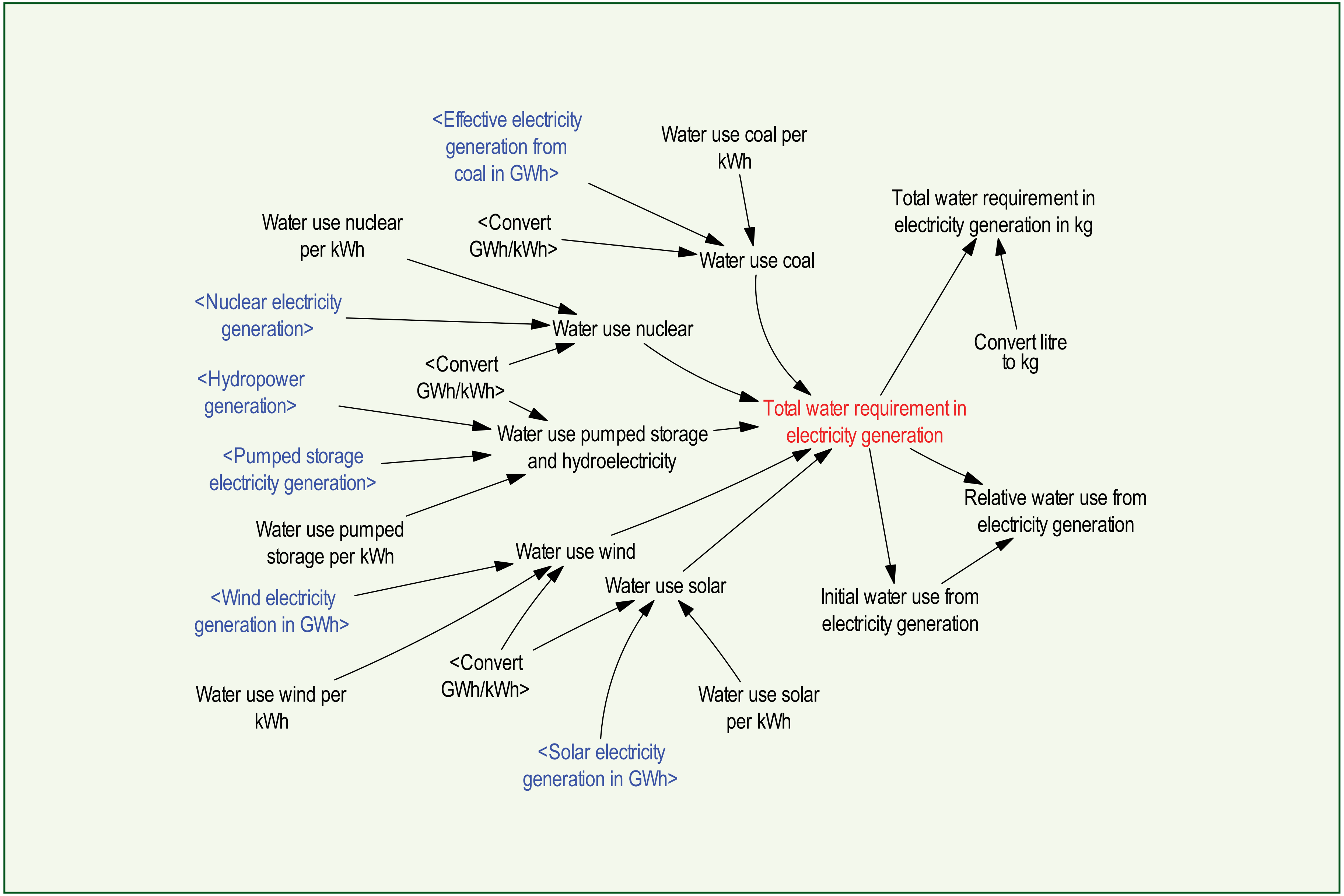

<Time>
Share of arable land and permanent crops
Arable land and permanent crops
Initial crop land
<Relative total population>
Time to convert forest to crop land
Change in the desired crop land
Initial agriculture land demand
Forest plantations
Crop land
Desired crop land
Elasticity of agriculture land demand to population
Initial forest plantations
Forest to crop
Average life of agriculture land
Desired forest plantations
<Change in the desired crop land>
Change in desired forest plantations
Other land to crop
Crop land to other land
Average time to mature forests
Other land to forest
Time to convert other to crop
Time to convert other land
Desired settlement land per capita
Change in the desired settlement land
Initial other land
Desired settlement land
<Conservation land>
<Total population>
Other land to settlement
Initial conservation land
<Other land>
<Forest plantations>
Initial settlement land
Settlement land
Other land
<Settlement land>
Total land
Spread to other land
Conservation land
Initial invasive alien species land
Invasive alien species land
<Invasive alien species land>
Other land to conservation
Total cost of clearing invasive land
Restoration rate to other land
<Livestock land>
Rate of spread to other land
<Cost of clearing invasive alien species>
Restoration fraction
Other land to livestock
<Crop land>
Conversion fraction of other land to conservation
Relative agriculture land
Stock to other land
Time to convert other land to livestock
Invasive alien species land cleared
<Initial crop land>
Change in the desired stock land
Time to convert stock land to other land
Investment total cost ratio
<Initial livestock land>
Time to convert other to stock land
Effect of investment ratio on spread rate
Livestock land
Desired livestock land
<Relative total population>
Investment in invasive species land clearance
Effect of investment ratio on spread table
Initial livestock land demand
Land per person
Initial livestock land
<WfW water and biodiversity green investment>
Investment in invasive clearing
<GREEN ECONOMY SWITCH>
Elasticity of livestock land demand to population
<Total population>
WfW BAU investment
<Proportion of WfW on value add>
<Environmental protection expenditure>
Proportion of invasive investment

The **land module** represents the land size in South Africa and the dynamics of the various categories of land uses in the country. The total land size of the country is 1,214,470 km^2, which is divided into seven competing uses namely: forest plantations; crop land; livestock land; conservation land; settlement land, other land and invasive alien species land. Thus, there are seven land use stocks. Most of the land uses stocks could be converted from their current use to other land use and vice versa. Exceptions are settlement and conservation land, where the assumption made was that the land cannot be converted to other land once they are in these states of land use. The invasive alien species land was separated from other land in order to account for the changes in the land use with the restoration of infested land. The South African government's WfW programme is key to converting the invasive infested land to other land, which is dependent on the investment allocated to the programme and the cost implicated in the restoration. On the other hand, settlement land, crop land and livestock land are mainly influenced by the population dynamics. Despite the dynamic changes in the seven land uses, the total land size in South Africa is maintained throughout the simulation analysis.


Effect of income on PC water demand table
Initial PC water demand
<Relative PC real GDP>
Per capita water demand
<Average adult literacy rate>
Water demand per unit produced
<Total land>
Effect of education on water use efficiency table
Domestic and municipal water demand
Production water demand
<Real GDP>
Kilograms per cubic meter of water
<Water gains from restoration>
<Total population>
Cubic meter of water per mm of rain per hectare
Precipitation
Total water demand
Water stress index
Total renewable water resources
<Total water requirement in electricity generation in kg>
Average precipitation
Water resources internally produced
Renewable water resources available per capita
Access to clean water
Fraction of rain evaporating immediately
Cross border inflow
Effect of water stress on access to clean water table

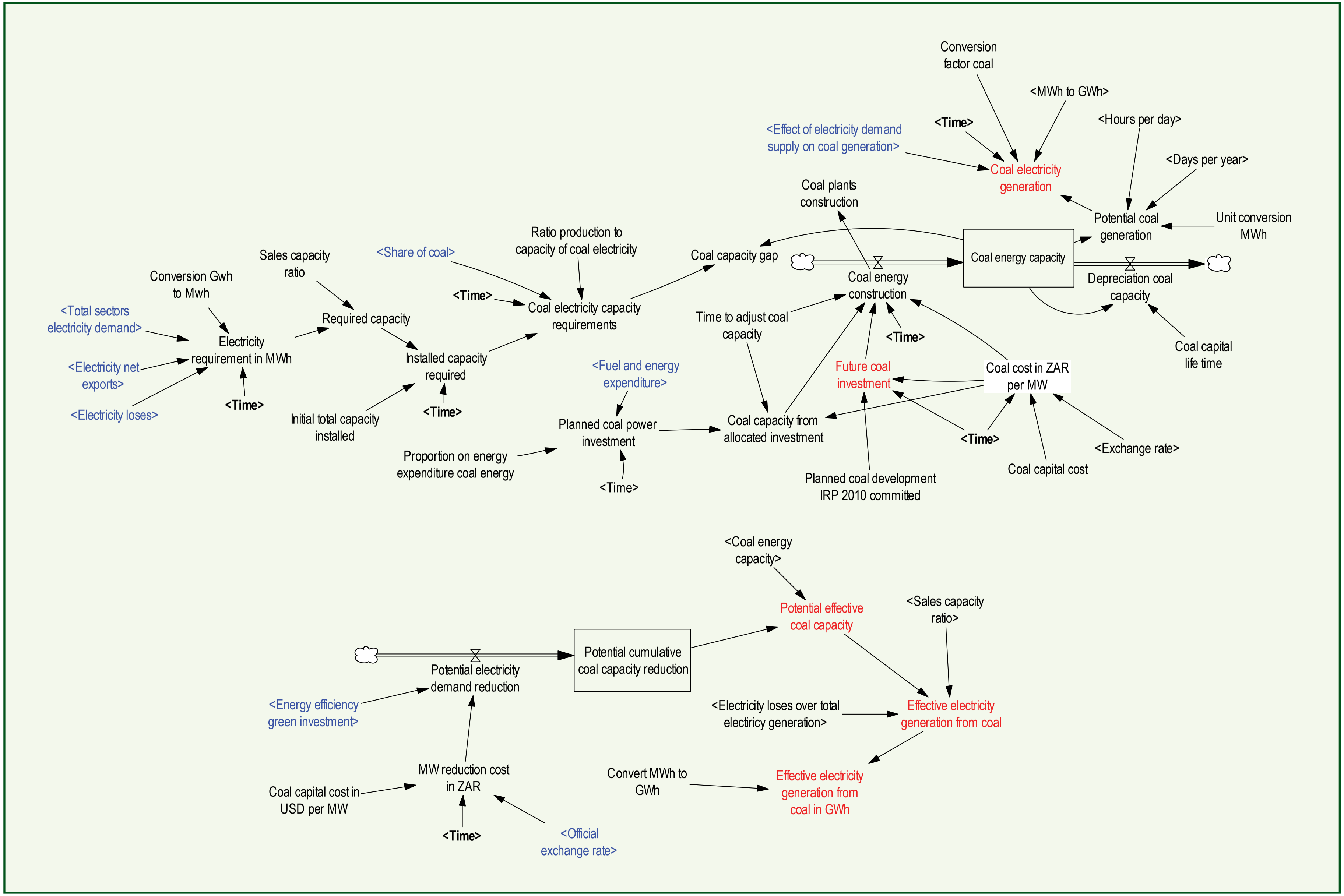
Water is one of the input resources required in the country's economic production. The water supply module is mainly used to estimate the availability of water relative to its demand. The total water demand is categorised into (i) production water demand, arising from three main production activities (agriculture, industry and services); (ii) water requirement in electricity generation and (iii) domestic and municipal water demand – the sum of these different water demand calculates the total water demand. The other total of renewable water resources is determined by the water resources that is produced internally in South Africa, as well as cross-border inflows and water gains from restoration activities. Both total water demand and total renewable water resources are utilised to estimate the water stress index, which in turn influences the production activities and hence the economic growth.

Annex 2.5 Water demand electricity generation module



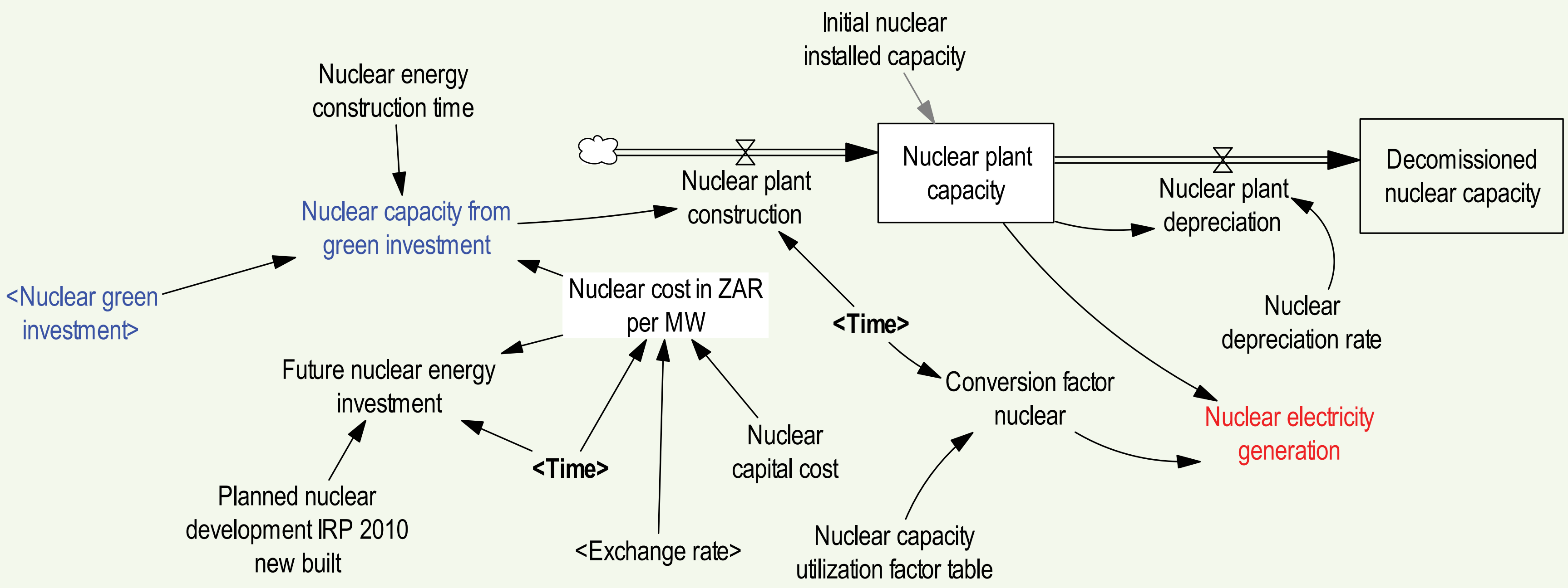
Electricity generation contributes significantly to water use. The **water demand electricity generation** module estimates the amount of water that is required for electricity generation for the different generation technologies. It makes use of endogenously estimated electricity generation from coal, nuclear, pumped storage, hydro, solar and wind as well as their respective coefficients of water use per unit of electricity generation. Water use for the specific electricity generating technology is thus estimated by multiplying the electricity generated by that technology at each time (year) with the coefficient of unit water use of that technology. The total water use in electricity generation is the sum of all water use from the various technologies. The total water requirement in electricity generation further becomes part of the total (overall) water demand, which in turn determines the water stress index given the current water availability.

Annex 2.6 Coal electricity module



Currently, **coal electricity generation** contributes about 92 per cent of the total electricity generation and it is utilised to cater for the base load demand. In addition, electricity generation from coal contributes significantly to GHG emissions. This module estimates the amount of electricity generation from coal and the potential coal capacity reduction resulting from the energy efficiency measures. The module thus consists of two stocks, coal energy capacity and the potential cumulative capacity reduction. The coal capacity is increased through coal plant construction and decreased due to depreciation. The planned coal plant investment as stipulated in the IRP 2010 is accounted for. Investments in energy efficiency can result in the reduction of coal plant requirements, or rather avoided coal capacity, as a result of efficiency measures. The difference between coal capacity and the cumulative capacity reduction estimates the effective coal capacity, which in turn is used to estimate the effective electricity generation from coal. The coal electricity generation estimated in this module is utilised in other modules to estimate, among others,: (i) the share of this technology's contribution to the overall electricity generation; (ii) the resulting emissions from coal; (iii) employment created; and (iv) water use in coal electricity generation.

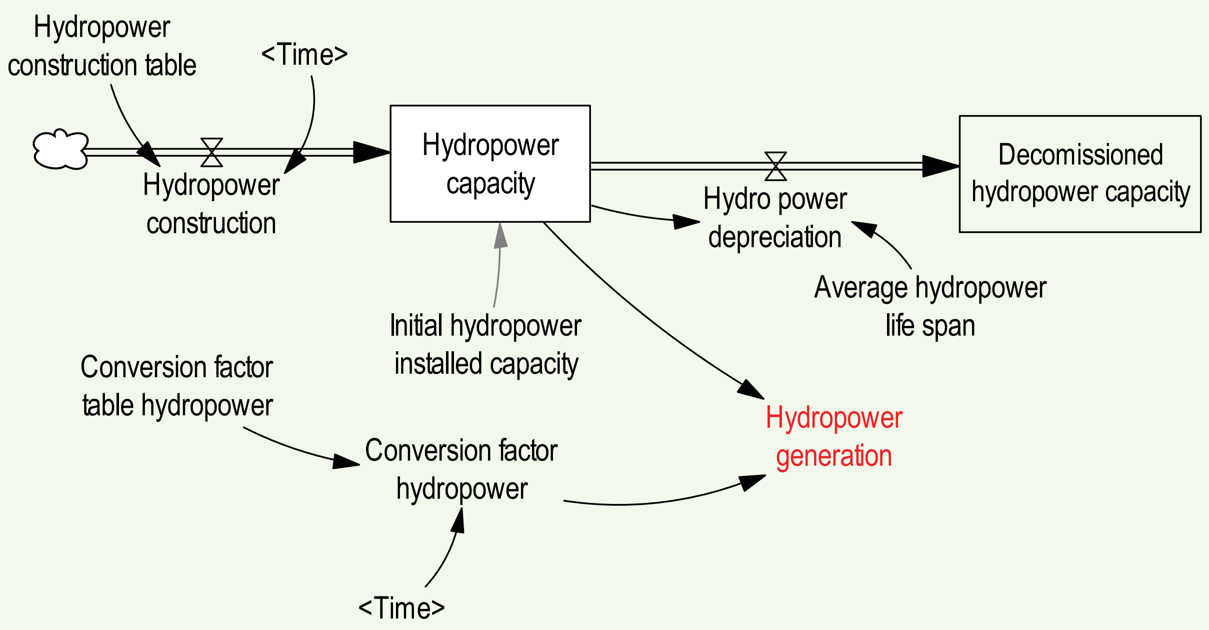
Annex 2.7 Nuclear electricity module



Nuclear power is similarly used to cater for base load demand in South Africa.

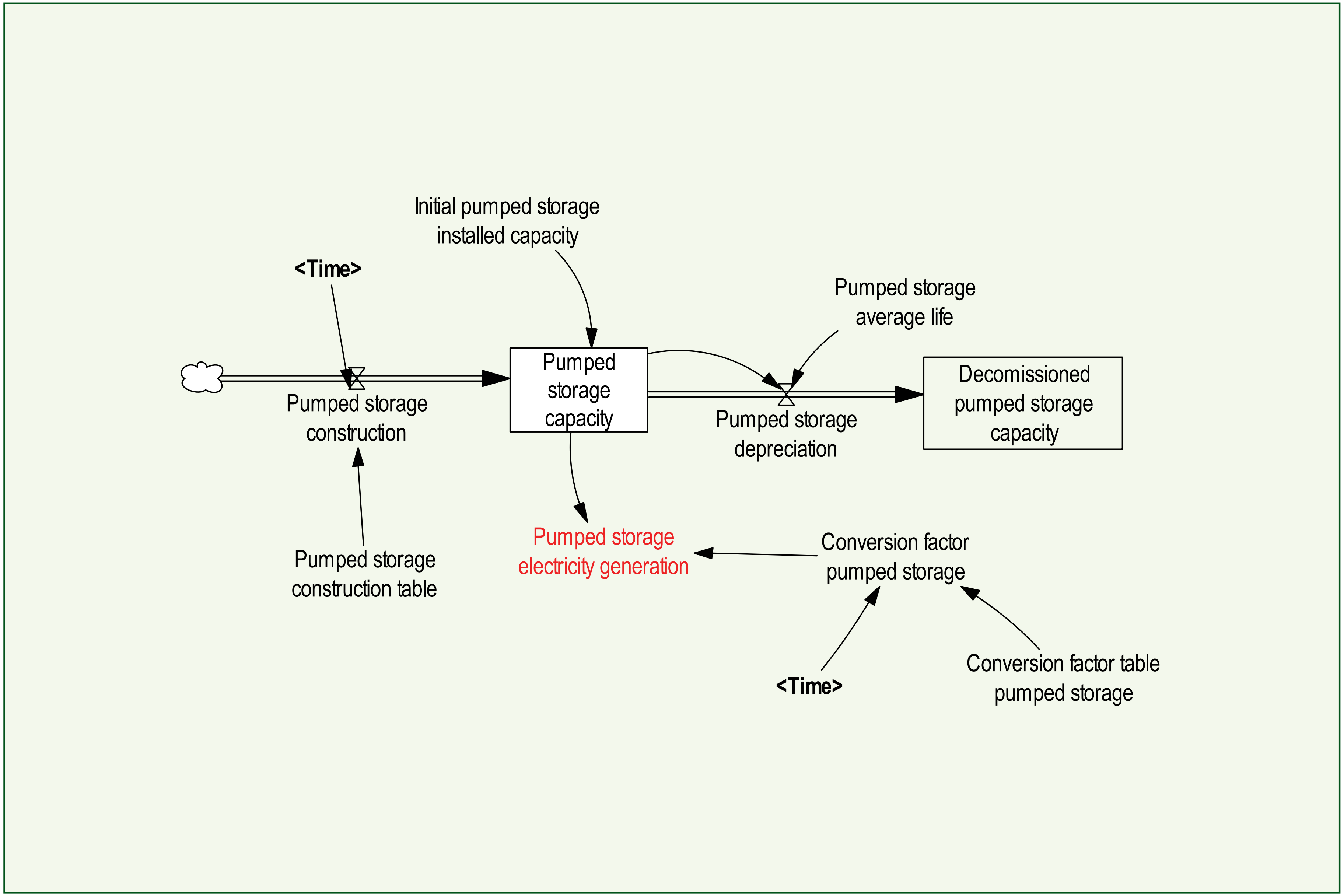
This module is used to estimate the amount of electricity generated from nuclear energy. The module thus consists of two stocks, nuclear plant capacity and decommissioned nuclear capacity. The nuclear capacity is increased through plant construction and decreased due to depreciation. The planned nuclear plant investment as stipulated in the IRP 2010 is accounted for. The nuclear electricity generation estimated in this module is utilised in other modules to estimate among other things: (i) the share of this technology contribution to the overall electricity generation; (ii) the resulting emissions from nuclear; (iii) employment created; and (iv) water use in nuclear electricity generation.

Annex 2.8 Hydroelectricity module



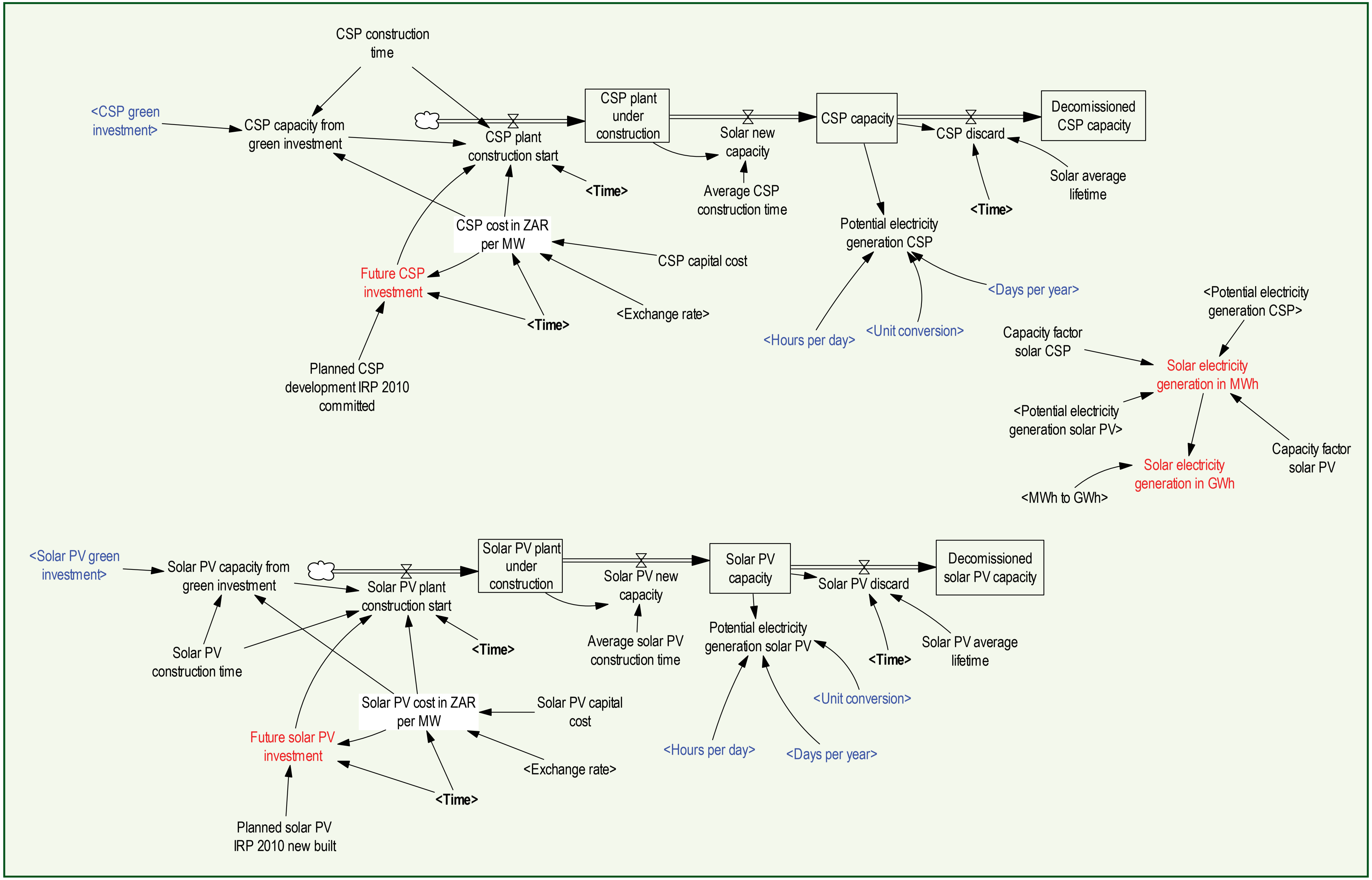
The **hydroelectric module** is used to estimate the amount of electricity generation from hydropower. The module thus consists of two stocks, hydro plant capacity and decommissioned hydro capacity. The hydro capacity is increased through plant hydropower construction and decreased due to depreciation. Being a water scarce country, hydropower development is not a major electricity generation in the country. The major hydropower contribution to the energy mix is through imports from the neighbouring countries. This was, however, not taken into account since the consideration for the modelling process is on the hydroplant investments planned within the country. Micro and mini-hydro projects are also stipulated to be developed although the planned development over the years is not explicit in the IRP 2010. Similarly, the hydroelectricity generation estimated in this module is utilised in other modules to estimate, among other things: (i) the share of this technology's contribution to the overall electricity generation; (ii) the resulting emissions from hydro; (iii) employment created; and (iv) water use in hydroelectricity generation.

Annex 2.9 Pumped storage electricity module



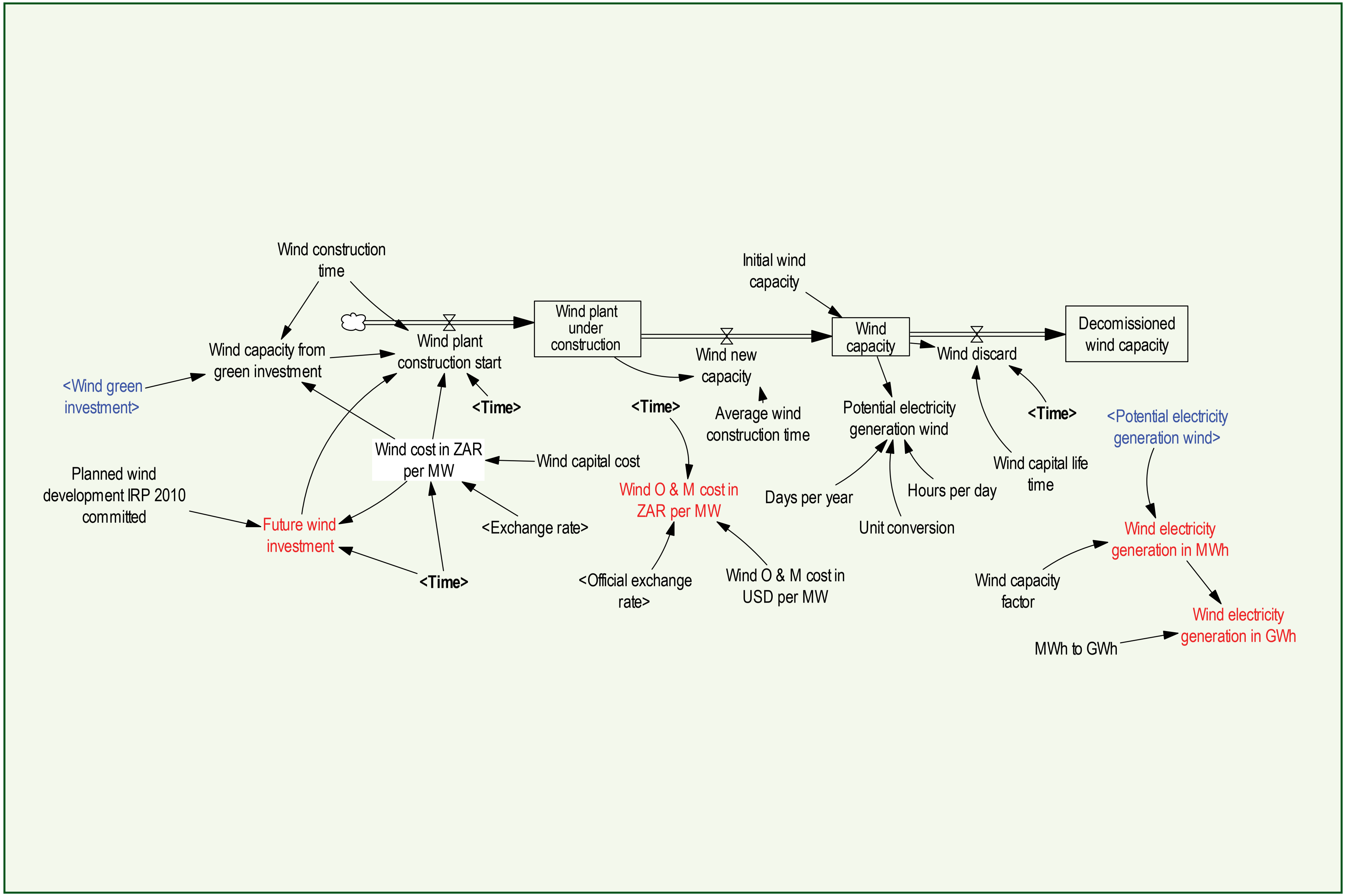
The **pumped storage electricity** module is used to estimate the amount of electricity generation from pumped storage. It consists of two stocks, pumped storage capacity and decommissioned pumped storage capacity. The pumped storage capacity is increased through power plant construction and decreased due to depreciation. The two pumped storage plants that are currently under construction were taken into account in the module. Similarly, the pumped storage electricity generation estimated in this module is utilised in other modules to estimate among other things: (i) the share of this technology contribution to the overall electricity generation; (ii) the resulting emissions from pumped storage; (iii) employment created; and (iv) water use in pumped storage electricity generation.

Annex 2.10 Solar electricity module



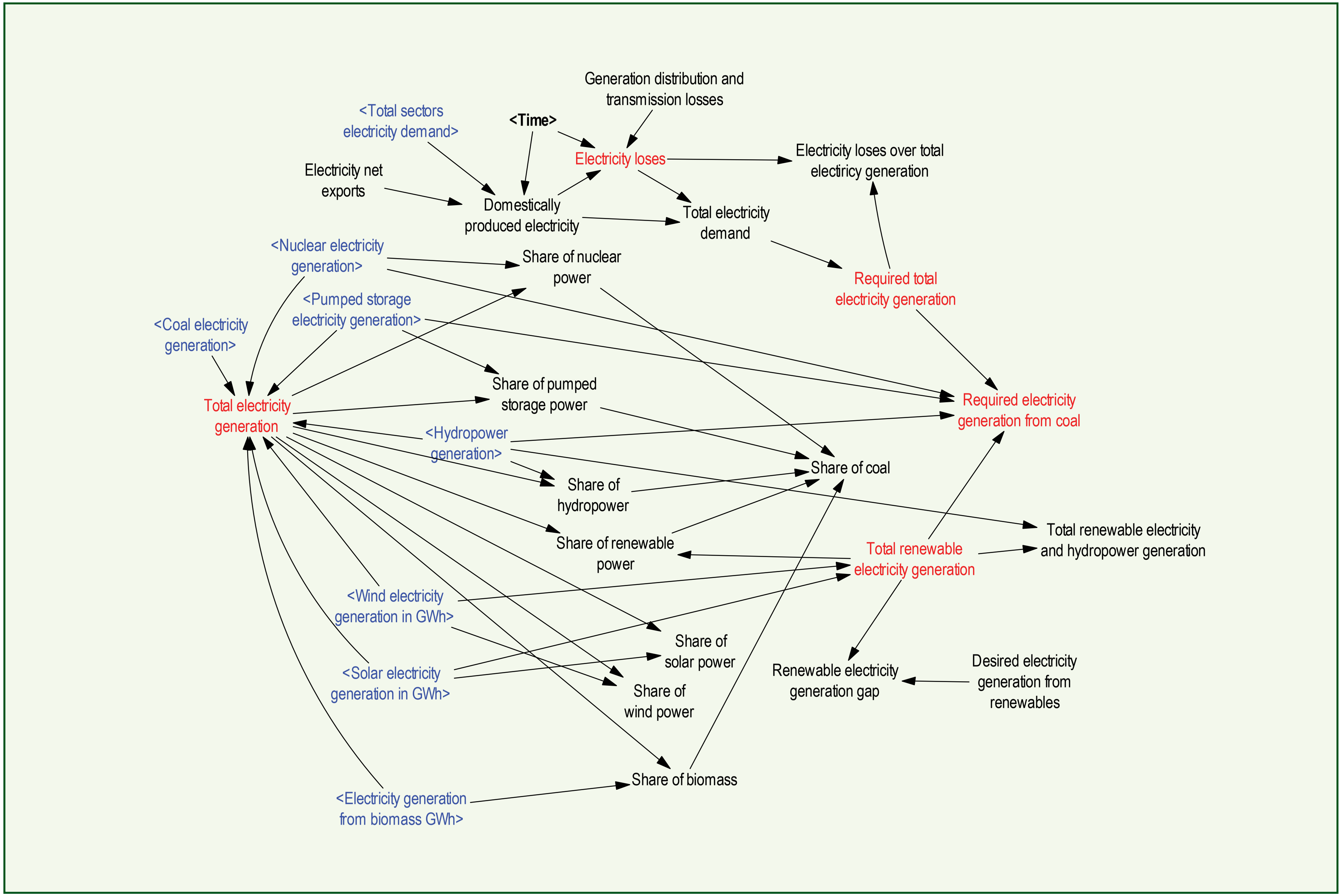
The **solar electricity module** estimates the amount of electricity generation from two solar energy technologies, namely, concentrated solar power (CSP) and solar photovoltaic (PV). Currently, these technologies are non-existent in the South African energy mix. However, IRP 2010 has stipulated the development of these solar technologies and processes are underway to bring these into the electricity generation mix. The module thus consists of three stocks for each of the solar technology namely: (i) CSP plant under construction and solar PV plant under construction; (ii) CSP capacity and solar PV capacity; and (iii) decommissioned CSP capacity and decommissioned solar PV capacity. Both technologies are increased through power plant construction and decreased due to depreciation. The planned solar PV and CSP development as per the IRP 2010 were taken into account in the module. Similarly, the solar electricity generation estimated for both technologies is utilised in other modules to estimate among other things: (i) the share of these technology contribution to the overall electricity generation; (ii) the resulting emissions from solar PV and CSP; (iii) employment created; and (iv) water use in solar PV and CSP electricity generation.

Annex 2.11 Wind electricity module



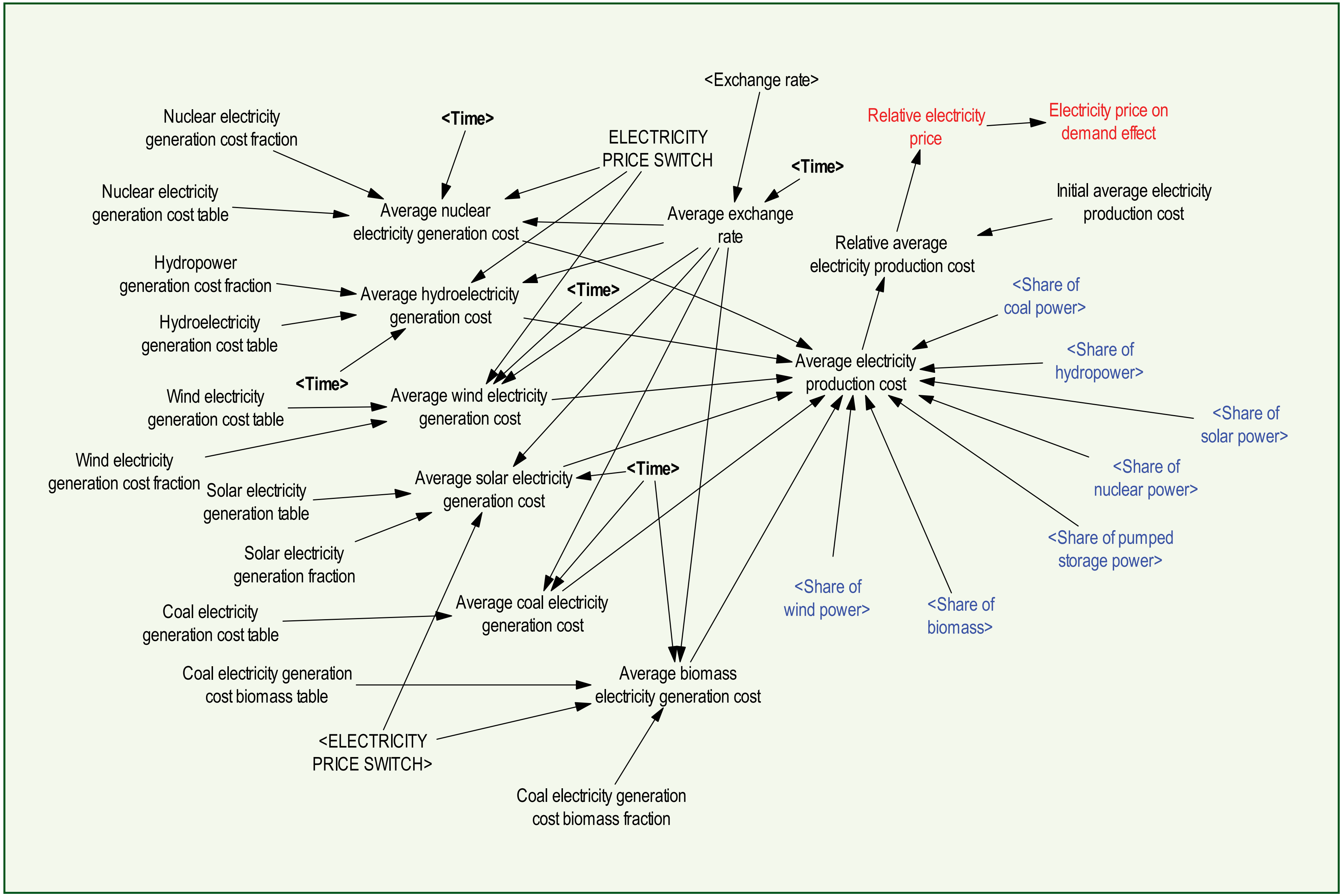
The **wind electricity module** estimates the amount of electricity generation from wind. Currently, wind plays a very minor role in South Africa's energy mix, where only a demonstration plant is in existence (Darling Wind Power). IRP 2010 has, however, stipulated further development of wind and processes are underway to bring this technology into the electricity generation mix. The module thus consists of three stocks for each of the wind technology namely: (i) wind plant under construction; (ii) wind capacity; and (iii) decommissioned wind capacity. Wind capacity is increased through power plant construction and decreased due to depreciation. The planned wind power development as per the IRP 2010 was taken into account in the module. Similarly, wind electricity generation estimated is utilised in other modules to estimate, among others: (i) the share of this technology's contribution to the overall electricity generation; (ii) the resulting emissions from wind electricity generation; (iii) employment created; and (iv) water use in wind electricity generation.

Annex 2.12 Electricity generation technology share module



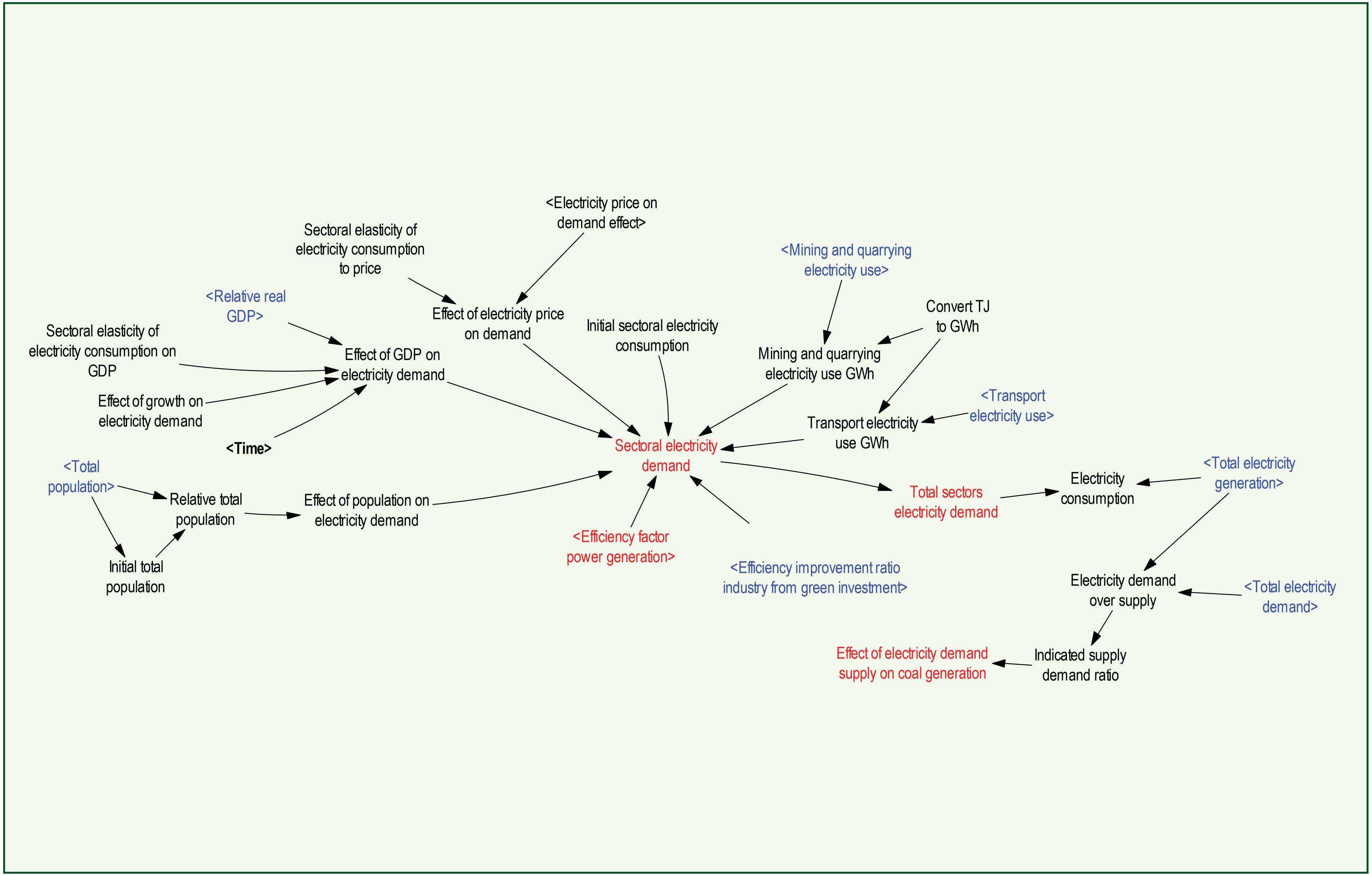
The **electricity generation technology share** module endogenously estimates the share of each of the technologies to the electricity generation mix throughout the simulation period, that is up to 2030. The technologies considered are coal, nuclear, pumped storage, hydro, solar, wind and biomass. The information on the electricity generated for each of the technologies is obtained from the respective modules that estimate the generation. The share of the specific technology in a specific year is given as electricity generation by the technology divided by the sum of the electricity generated from all the technologies. The module further estimates the required electricity generation from coal, which is the difference between the total electricity required and the sum of electricity generation from other technologies excluding coal. What makes up the total required electricity generation is the total electricity demand. Total electricity demand is the sum of demand from the various electricity consumers, net exports and electricity losses.

Annex 2.13 Electricity price module



The electricity price module endogenously estimates the average electricity production cost which is used as a proxy for electricity price. The key variables in the estimation is the exogenously determined electricity generation costs for all the technologies, which follows NERSA's determination on electricity growth after 2013; and the share of electricity generation from each technology, which is endogenously determined. The average electricity production cost is the sum of average cost of electricity generation for each technology, multiplied by the respective share of each technology to the electricity generation mix. Using the average production cost as a proxy for electricity price, the relative electricity price is used to influence other modules, such as the production modules (agriculture, industry and services) and electricity demand by different users.

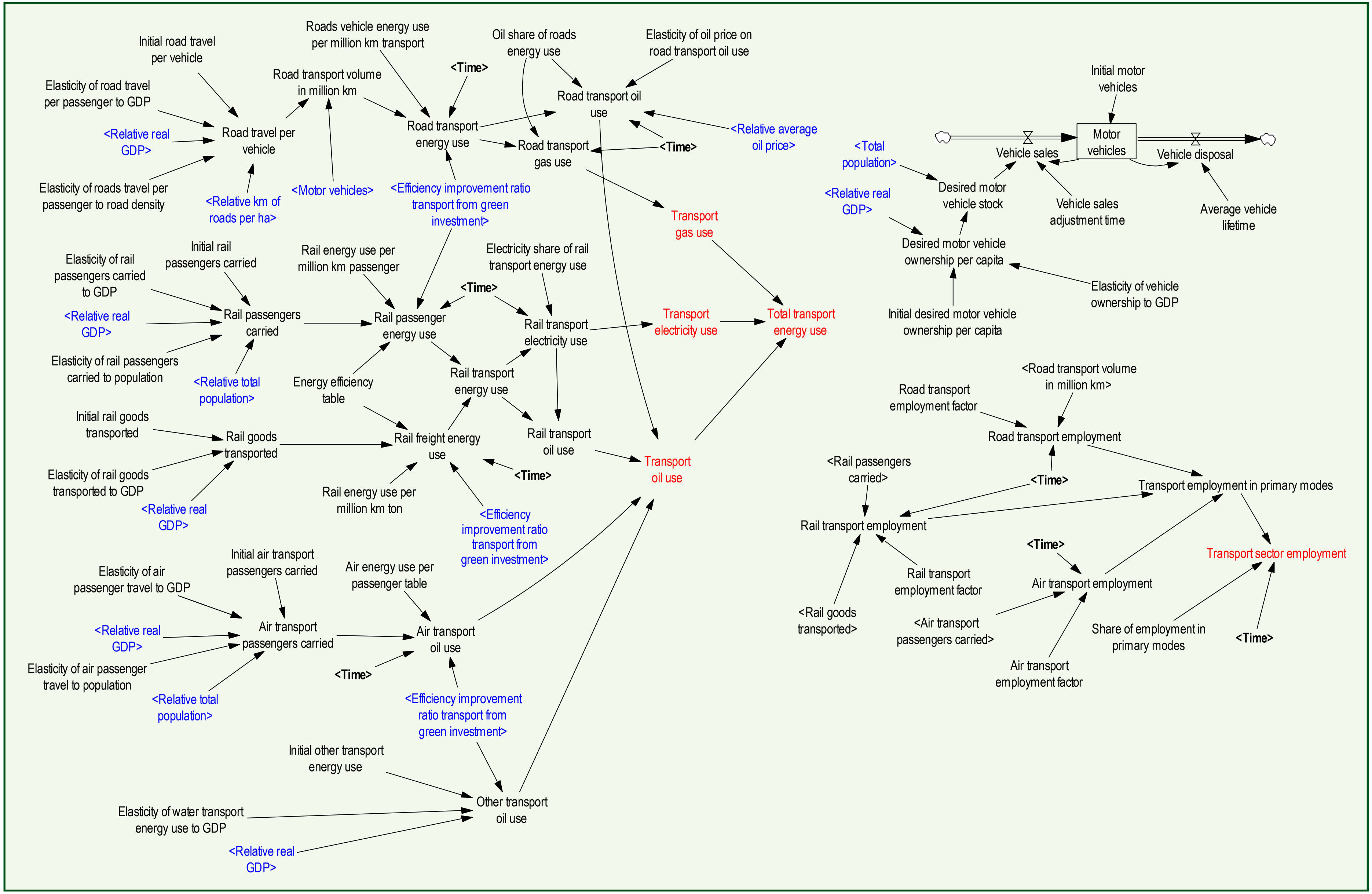
Annex 2.14 Electricity demand module



The **electricity demand module** estimates the total electricity demand by the various electricity users. There are two main purposes of electricity demand sub-model: firstly, to calculate the electricity demand and secondly, to provide inputs of the required electricity generation capacity. The demand for electricity sub-model calculates the electricity demand for industry, transport, agriculture, commerce and residential sectors, which are the key electricity users in South Africa.

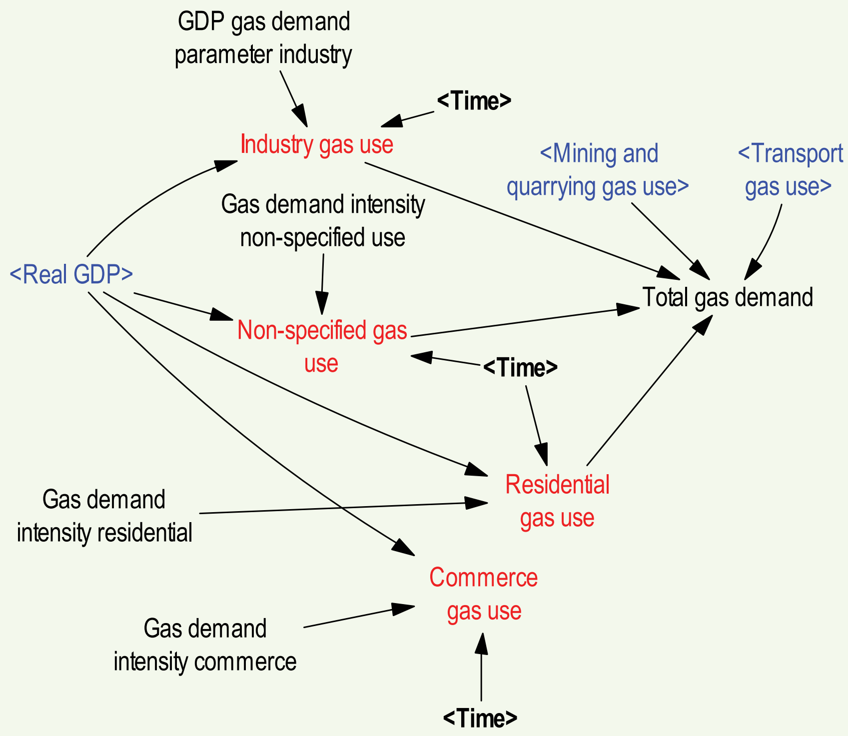
The electricity demand is modelled as an endogenous variable and is influenced by changes in endogenous GDP, electricity prices and efficiency in the electricity consumption due to improved technology. This in turn affects electricity production from the different technologies.

Annex 2.15 Oil demand module



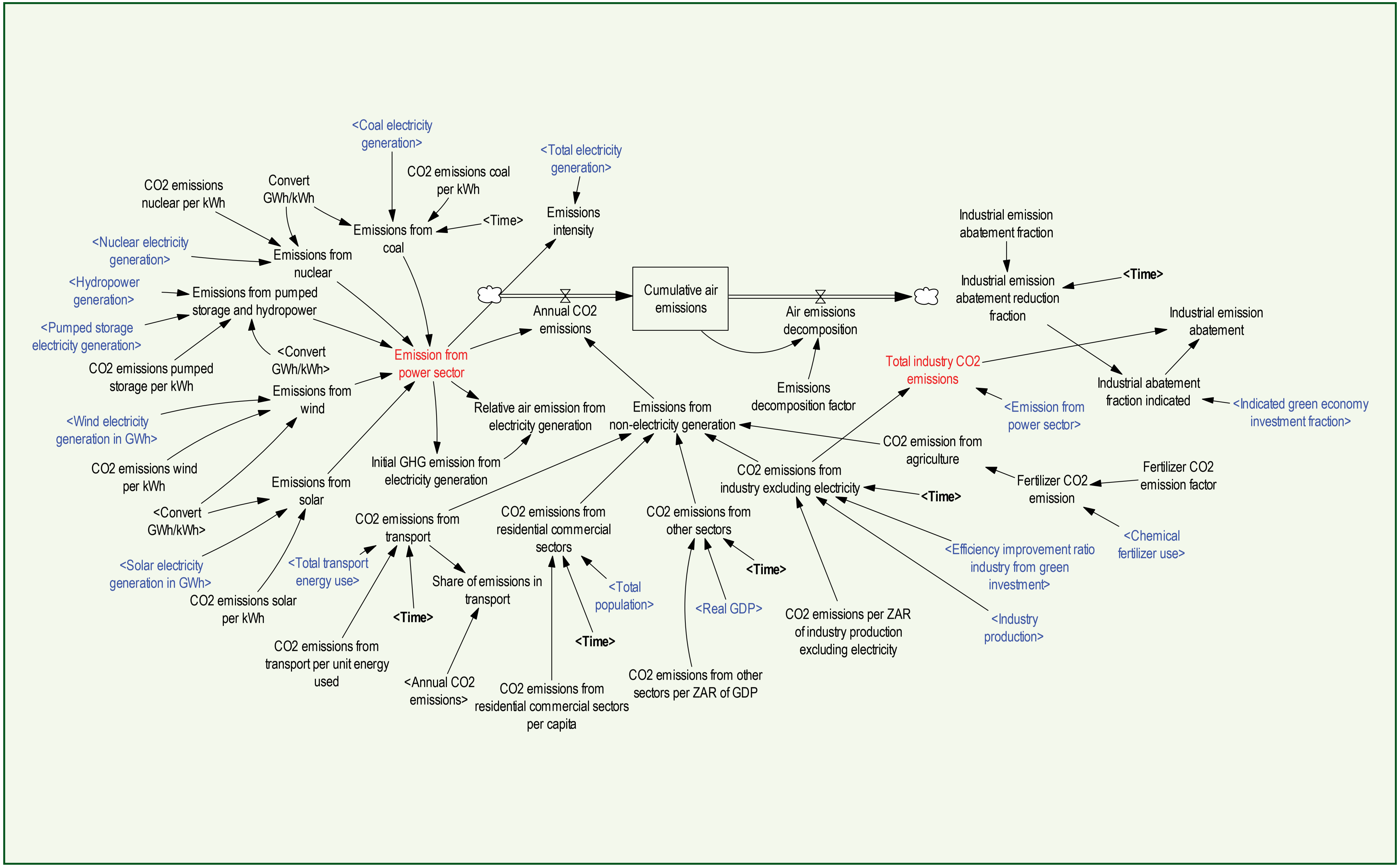
The **oil demand module** estimates the total oil demand by the various liquid fuel users, which include industry, commerce, residential, agriculture, non-energy oil use and non-specified oil use. The total oil demand is the sum of oil use by different users. Oil price and GDP are the main factors influencing changes in oil demand.

Annex 2.16 Gas demand module



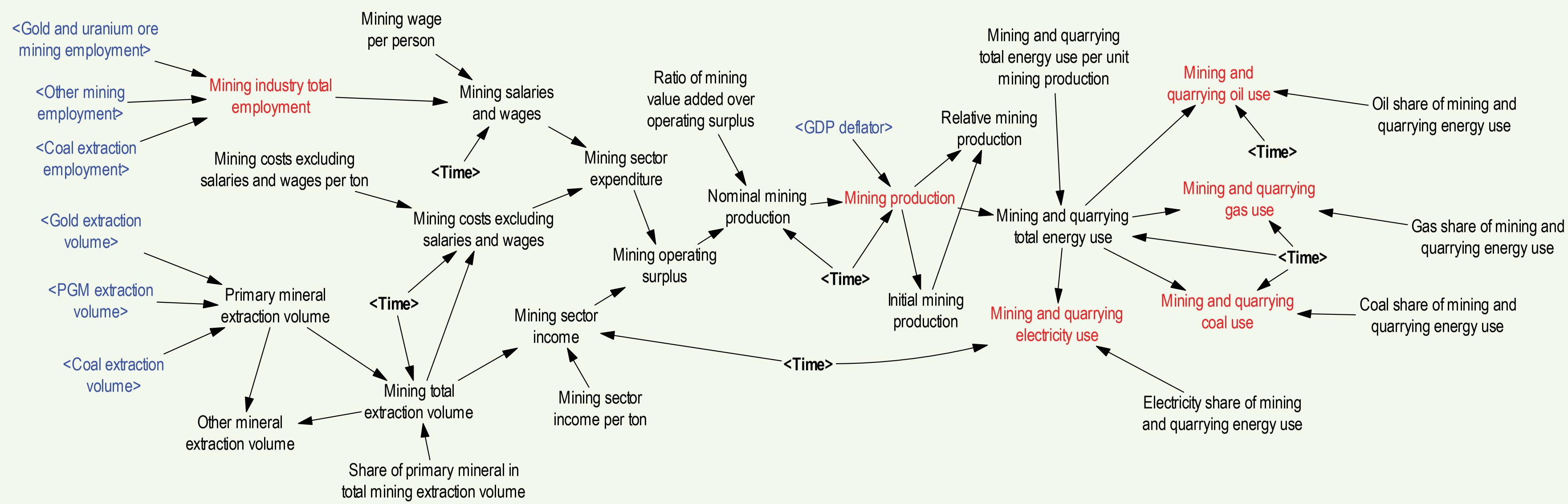
Gas plays a minimal role in the South African energy market. This module estimates the total gas demand by the various gas users. These are categorised as: industry, commerce, residential, mining and quarrying, transport and non-specified gas use. The total gas demand is the sum of gas use by different users. Only GDP is the main driver influencing changes in gas demand.

Annex 2.17 Air emissions module



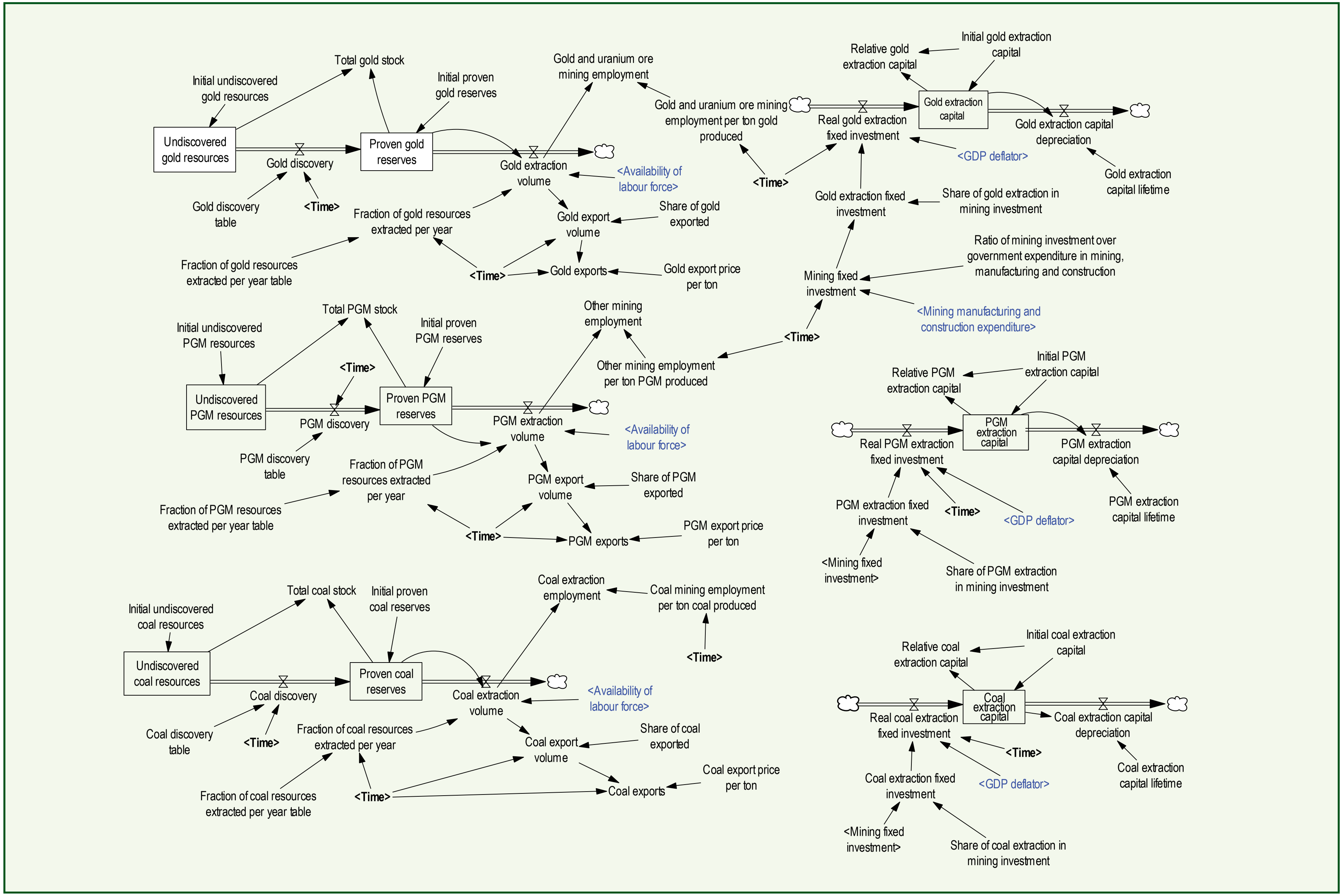
The **air emissions module** calculates the carbon emission equivalents from various sources. Air emissions dynamics, by its nature, is complex and influenced by the characteristics of the emission source. The module consists of one stock, cumulative air emissions. This is increased by the annual CO_2 emissions and decreased by air emissions decomposition. There are different sources of CO_2 emissions that are used in the estimation of the annual emissions. These include emissions from the power sector and other industries, excluding power sector, agriculture, transport, residential and commerce sectors. Thus, the sum of emissions from the different sources provides the estimate of the annual CO_2 emissions. Generally, power sector emission is considered as the largest contributor of the total CO_2 emissions in South Africa. The total emission from this sector is the sum of the annual electricity generated by each technology, multiplied by each technology respective of life cycle CO_2 emissions.

Annex 2.18 Minerals module (a)



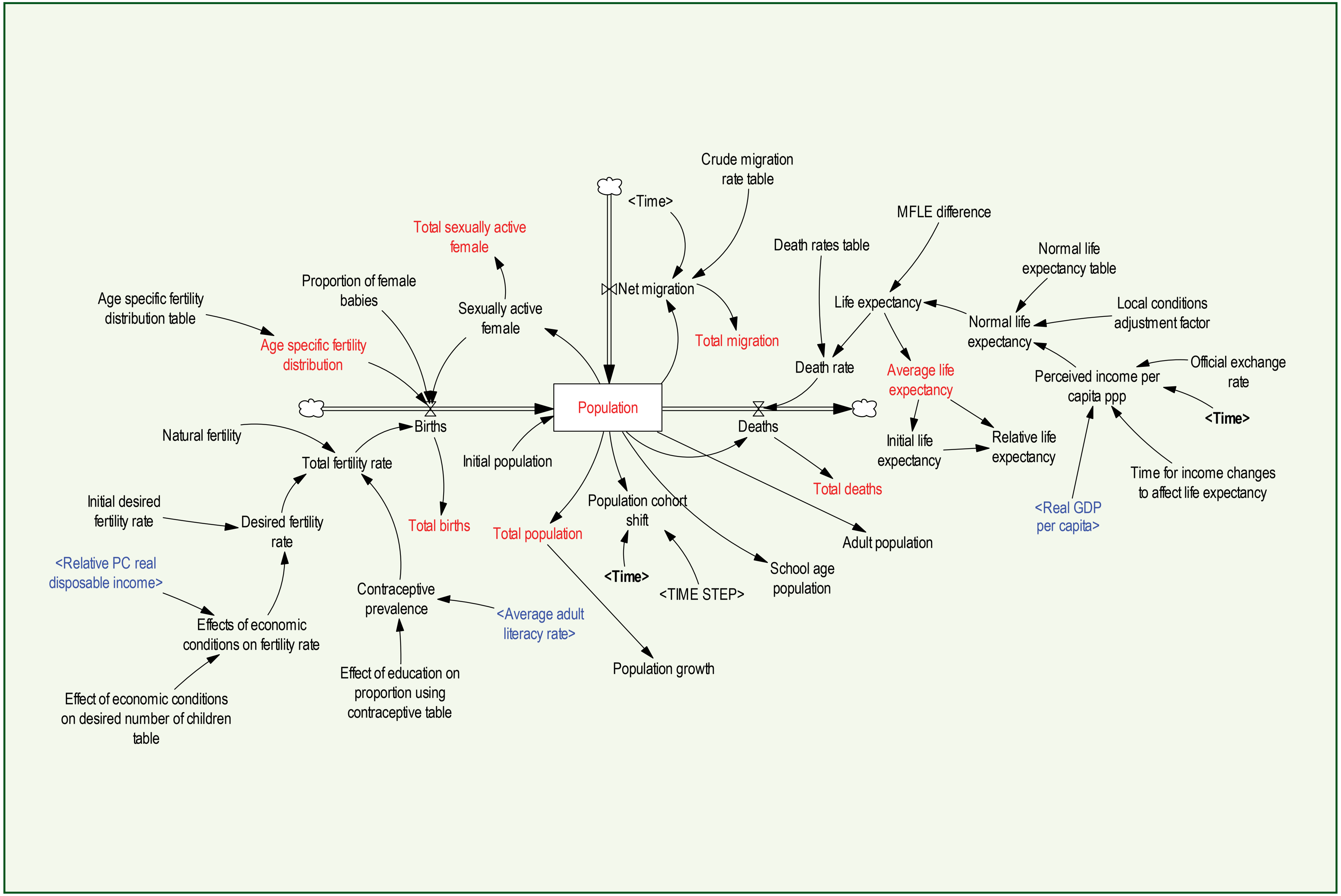
The **minerals module** (a) shows the section of the minerals module that estimates employment from mining, mining production and mining energy use, that is oil, gas and electricity. The mining employment is categorized into gold and uranium ore mining employment, coal extraction employment and other mining employment (PGM). The employment estimates are based on the mining extraction volumes for each mining category and their respective employment coefficients. The primary extraction volumes are used to estimate the economic value of the mining activities, which in turn is utilised to estimate the amount of energy used in the mining sector. Some of the variables estimated in this module, such as mining industry employment, are used in other modules.

Annex 2.19 Minerals module (b)

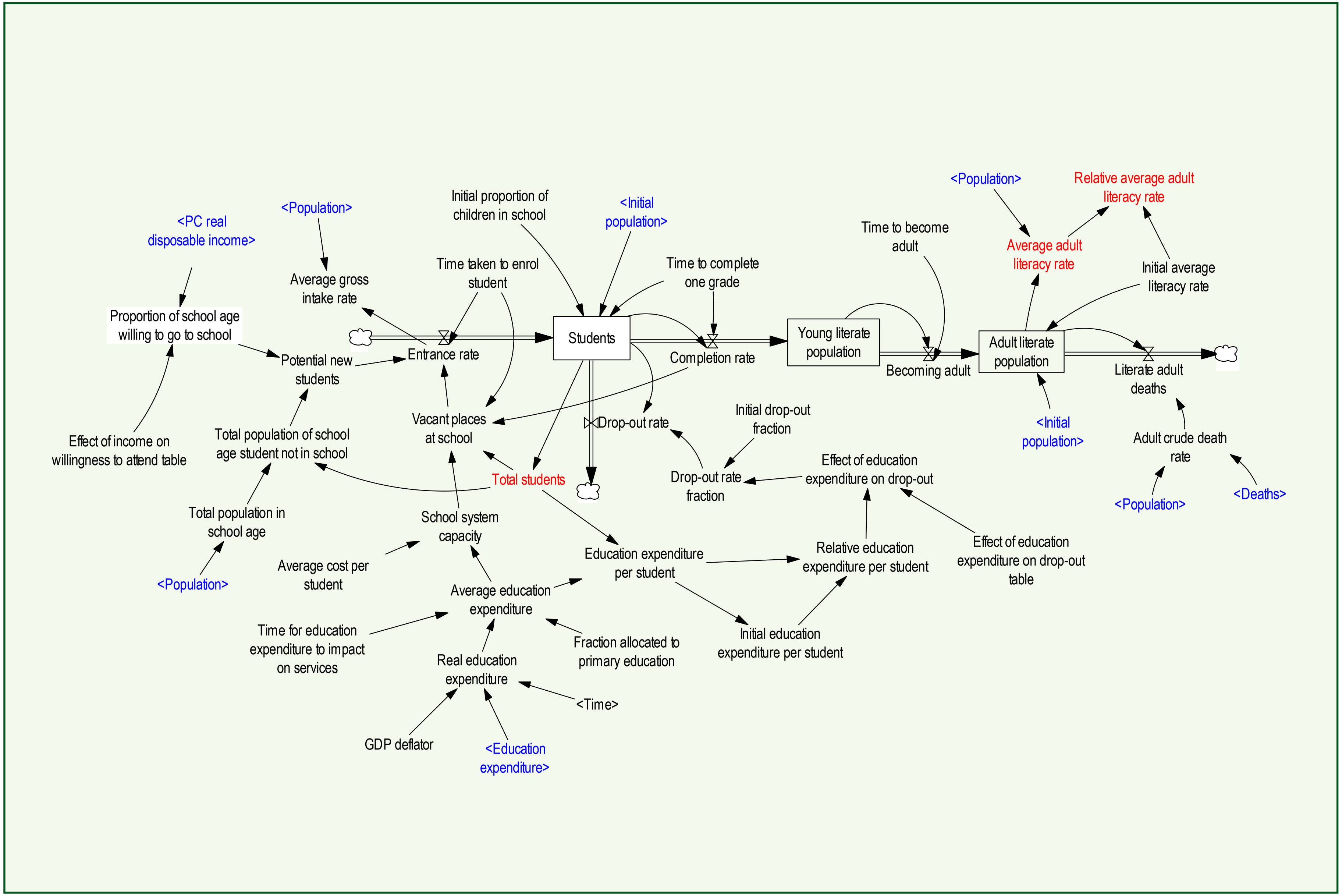


The **minerals module (b)** shows the section of the minerals module that estimates the primary extraction of the mineral resources and their respective extraction capital. The primary mineral extraction is categorised into coal, gold and PGM. Each of the mineral extraction consists of two stocks namely: undiscovered mineral resources and proven mineral resources. The proven reserves are influenced by changes in the mineral discovery and the minerals extraction volumes. As mentioned earlier, the extraction volumes are used to estimate the employment created in the mining industry. The extraction capital for each mining industry consists of one stock, which is influenced by the fixed investment (which increases it) and depreciation of capital (which decreases it).

Annex 2.20 Population module



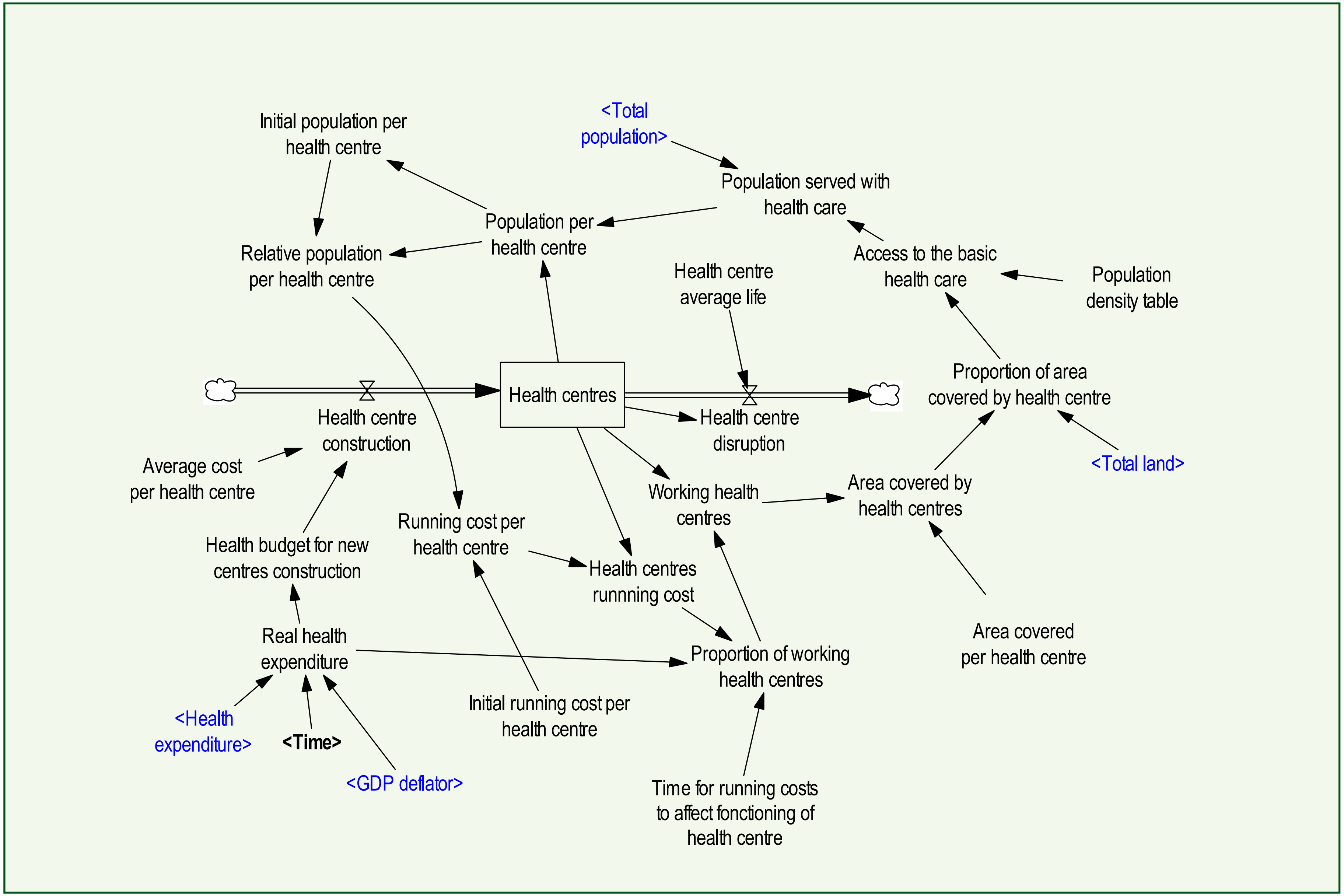
The **population module** is important since the variables estimated were used to estimate some social, environmental and economic indicators in other modules. The module represents the South African population, which is categorized according to sex and age groups. These include, among others, primary school age, working age and adult age. The module consists of one stock variable – population – which influences three rate variables namely: births, deaths and net migration. It is estimated that the birth and death variables are both influenced by the economic conditions, which in turn influence the level of the population stock. Changes in population influence variables in other modules, such as water demand, energy demand and GDP.



<PC real disposable income>
<Population>
Initial proportion of children in school
<Initial population>
Time to become adult
<Population>
Relative average adult literacy rate
Average adult literacy rate
Initial average literacy rate
Time taken to enrol student
Time to complete one grade
Average gross intake rate
Proportion of school age willing to go to school
Students
Young literate population
Adult literate population
Entrance rate
Completion rate
Becoming adult
Literate adult deaths
Potential new students
Vacant places at school
Drop-out rate
Initial drop-out fraction
<Initial population>
Adult crude death rate
Effect of income on willingness to attend table
Total population of school age student not in school
Total students
Drop-out rate fraction
Effect of education expenditure on drop-out
<Population>
<Deaths>
Total population in school age
School system capacity
Effect of education expenditure on drop-out table
Average cost per student
Education expenditure per student
Relative education expenditure per student
<Population>
Average education expenditure
Time for education expenditure to impact on services
Real education expenditure
Fraction allocated to primary education
Initial education expenditure per student
<Time>
GDP deflator
<Education expenditure>

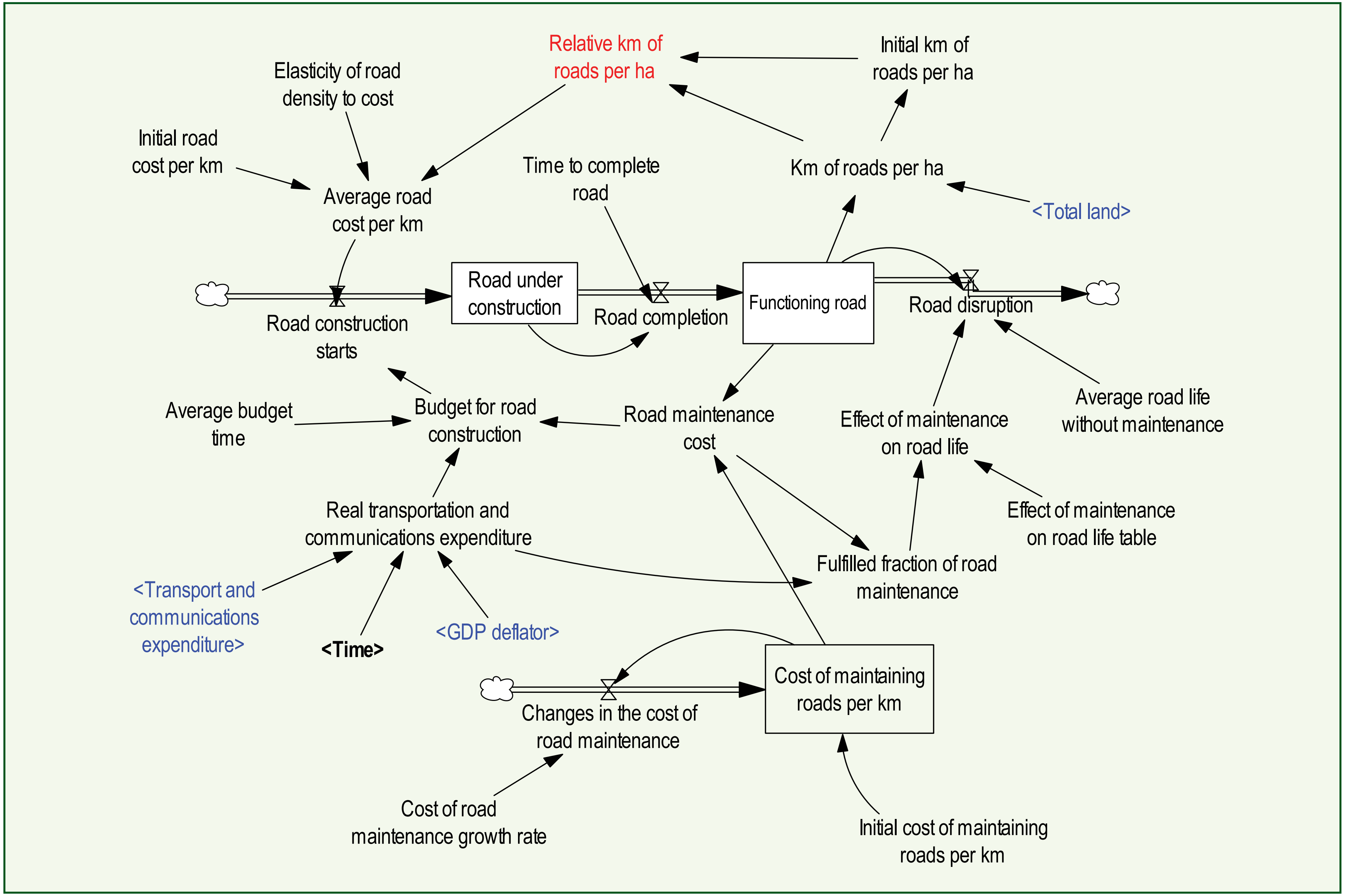
Similar to the population module, the **education module** is also important since the variables estimated are useful in influencing social, economic and environmental indicators. The module shows in a systematic manner the movement of the population from school-age to adulthood. The module is categorised into three stocks: student, young literate population and adult literate population. Entrance and dropout rates determine the number of population of students (pupils – from primary school to matric). The factors influencing entrance rate includes the number of population who are of school-age (7 years), income and vacant places at school. Students move to be part of the young literate population once they complete their higher education, and then on to adult literate population when their age as part of the young population lapses. Average adult literacy rate, which is estimated in this module, is utilised in other modules, such as population and production modules (agriculture, industry, services).

Annex 2.22 Health module



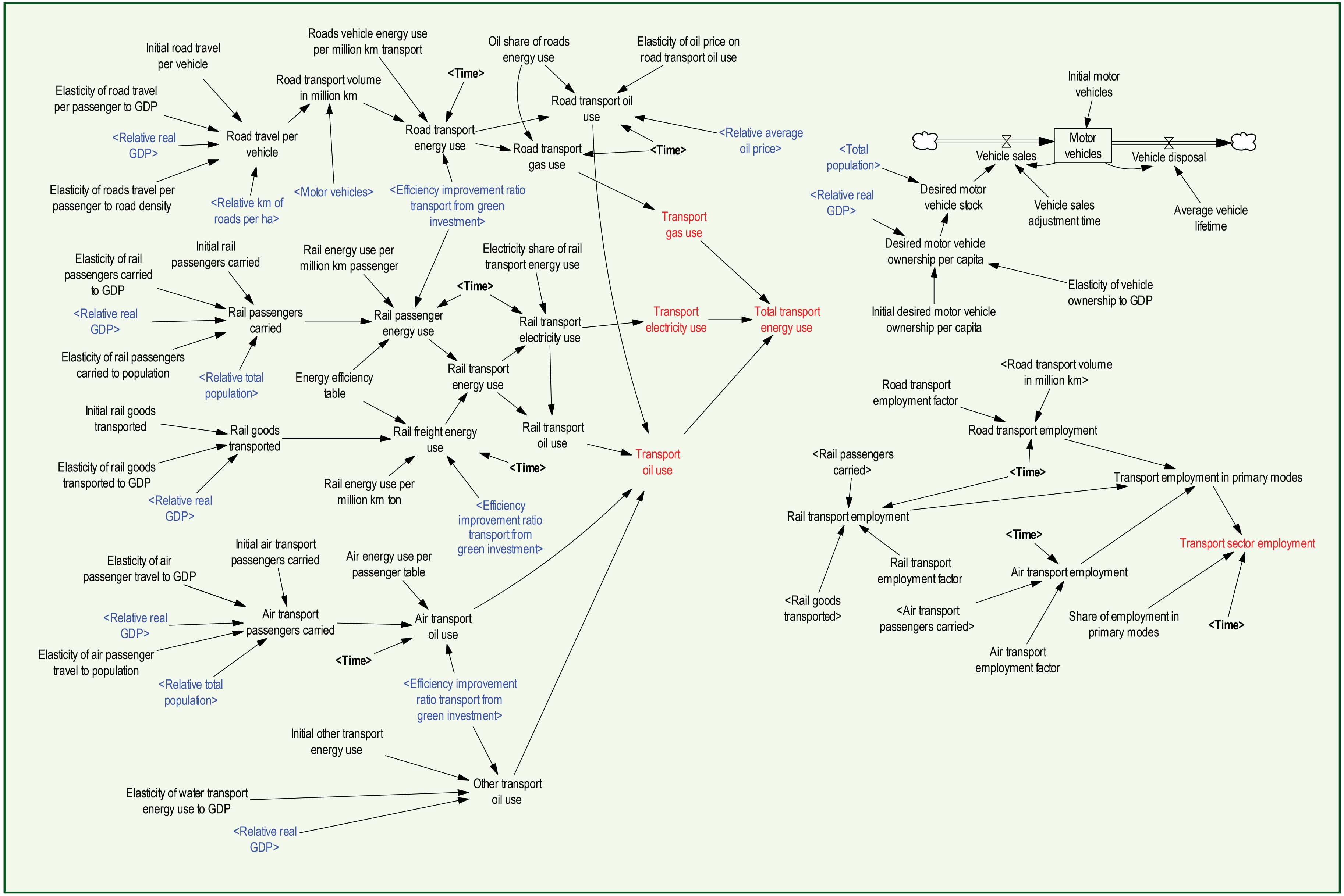
The **health module** is aimed at estimating access to health centres by the South African population. It consists of one stock – health centres – which is increased by construction and decreased by disruption (due to depreciation). The factors influencing heath centres construction is the health expenditure that is allocated to heath centre construction and the associated average costs of construction. There are two main variables estimated in this module: the number of population per health centre and access to the basic health care based on the area covered by the health centres relative to the total land of South Africa. Given that the data on the health centres was sparse, the estimates from this module were not linked to other modules.

Annex 2.23 Access to roads module



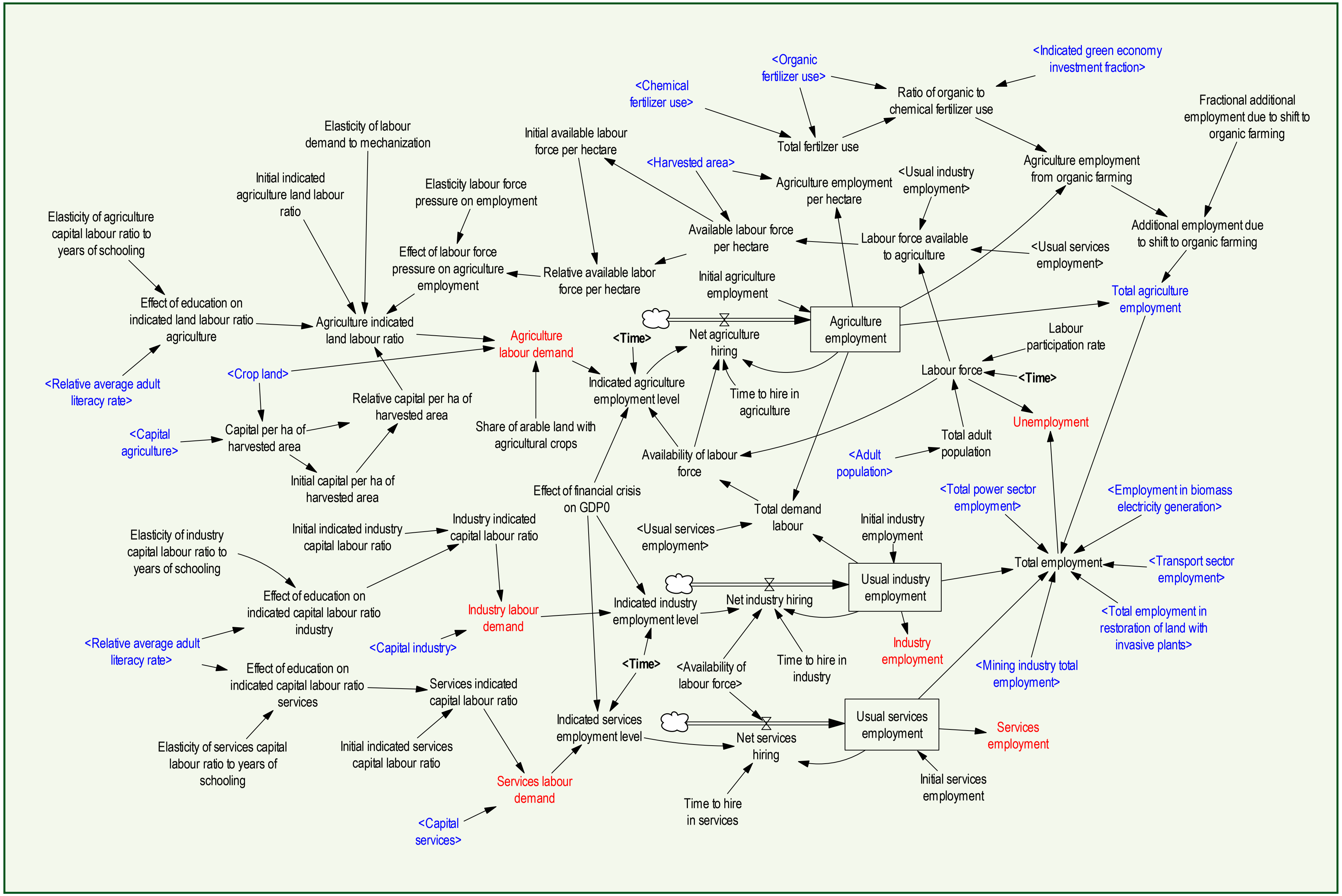
The **access to roads module** is utilised to estimate access to roads infrastructure. The module consists of three stocks: the first two are road construction and functioning roads, which systematically shows the dynamics involved in the road development, and the third stock is the cost of maintaining roads per kilometre, which shows the changes in cost over time for maintaining roads. Starting the construction of roads increases the stock of roads that are under construction. Once they are completed, these move to the stock of functioning roads. Functioning roads, however, are decreased by disruptions resulting from depreciations. Maintaining the roads decreases disruptions as this increases the average road life. The relative kilometre of roads per hectare, which is the measure of road access, is utilised in other modules such as the production sectors (agriculture, industry and services).

Annex 2.24 Transport module



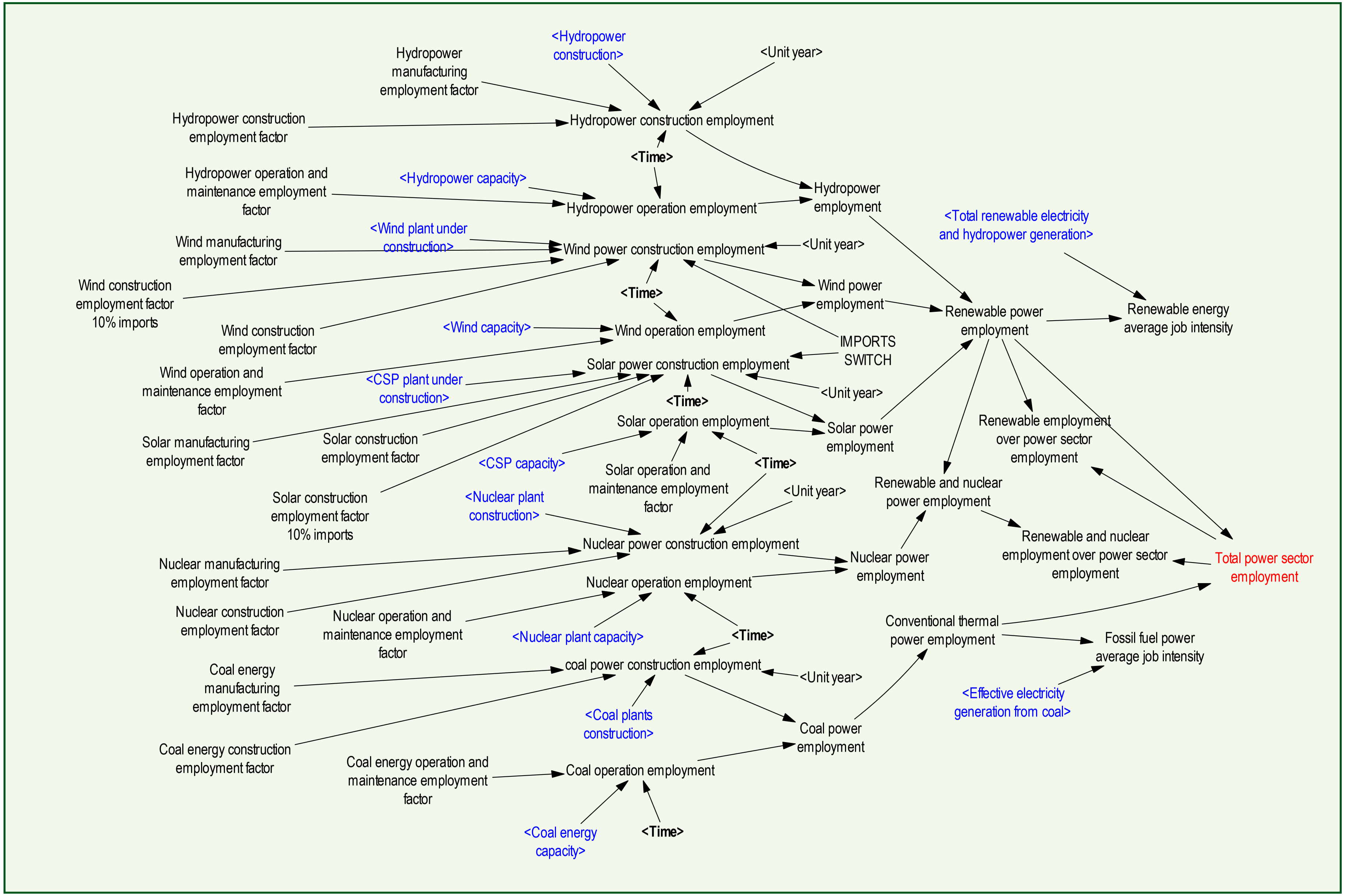
The **transport module** is used to estimate a number of variables such as transport energy use (electricity, oil and gas) and employment in the transport sector. Transport is categorised into three modes – roads, rail and air – and the commodities transported are passengers and goods/cargo. In the case of roads transportation, the number of vehicles is estimated, where this is a stock, to be increasing with vehicle sales and declining due to vehicle disposal. The volume of passengers and goods are thus estimated, which in turn is used to calculate energy use by the different forms of transportation. Investment in transport efficiency has an influence in energy use in the sector. Similarly, employment in the transport sector is determined by the volume of passengers and goods handled in each of the transport mode. Energy use and employment from transport variables estimated are utilised in other modules.

Annex 2.25 Employment module



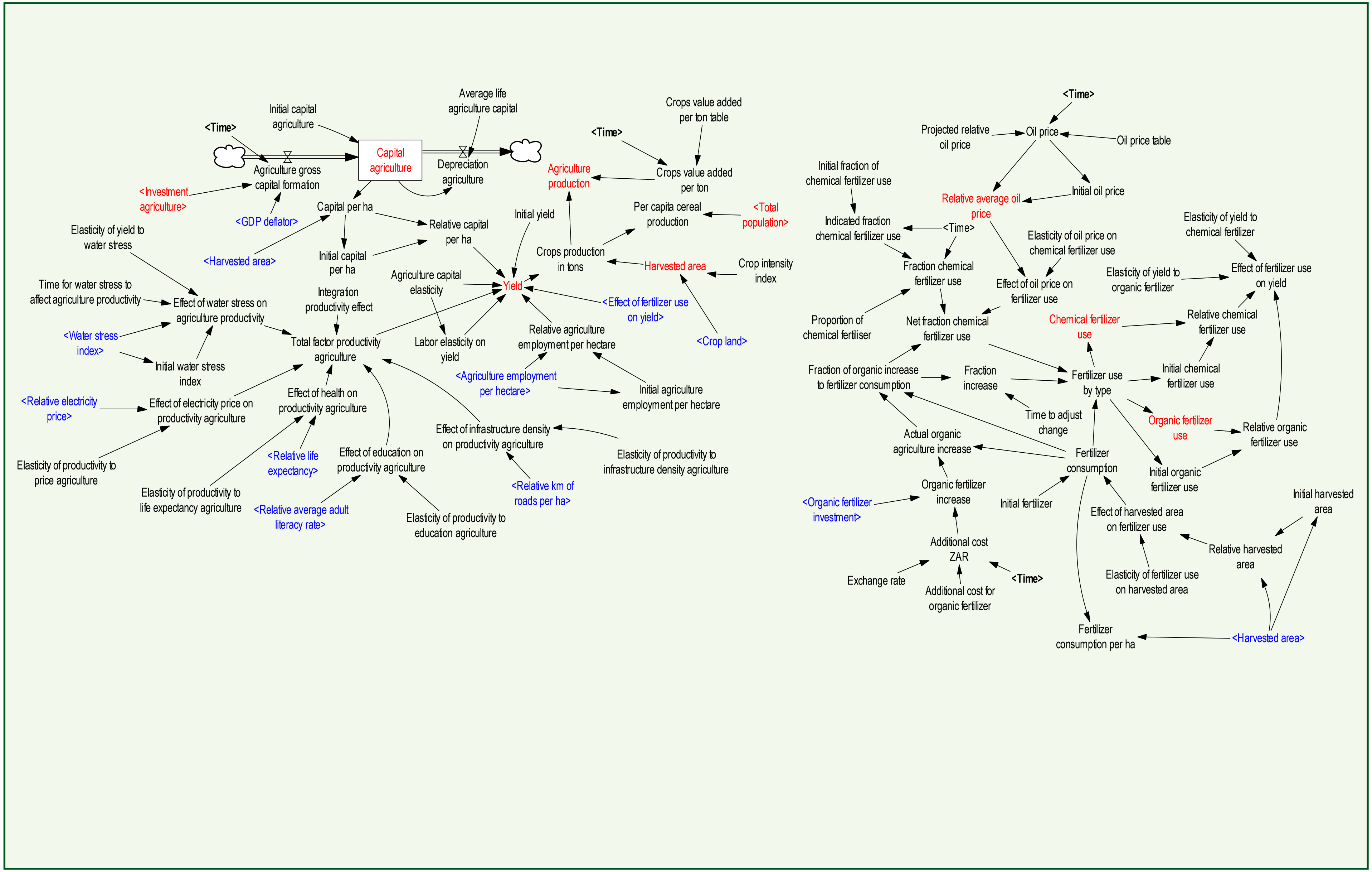
Employment is generated as a result of different activities taking place in the economy. This module estimates some of these employments, particularly from the production sectors (agriculture, industry and services). Each of the employment in the production sector is represented by one stock, representing employment in the specific sector, which is influenced by net hiring in the specific sector. The labour demand in each of the production sector is determined by the capital investment in each production sector. The total employment in the economy is also estimated in the module as the sum of all the employment, which include employment in following: power sector, biomass electricity generation, transport, restoration of invasive alien species, mining, agriculture, services and industry.

Annex 2.26 Power sector employment module



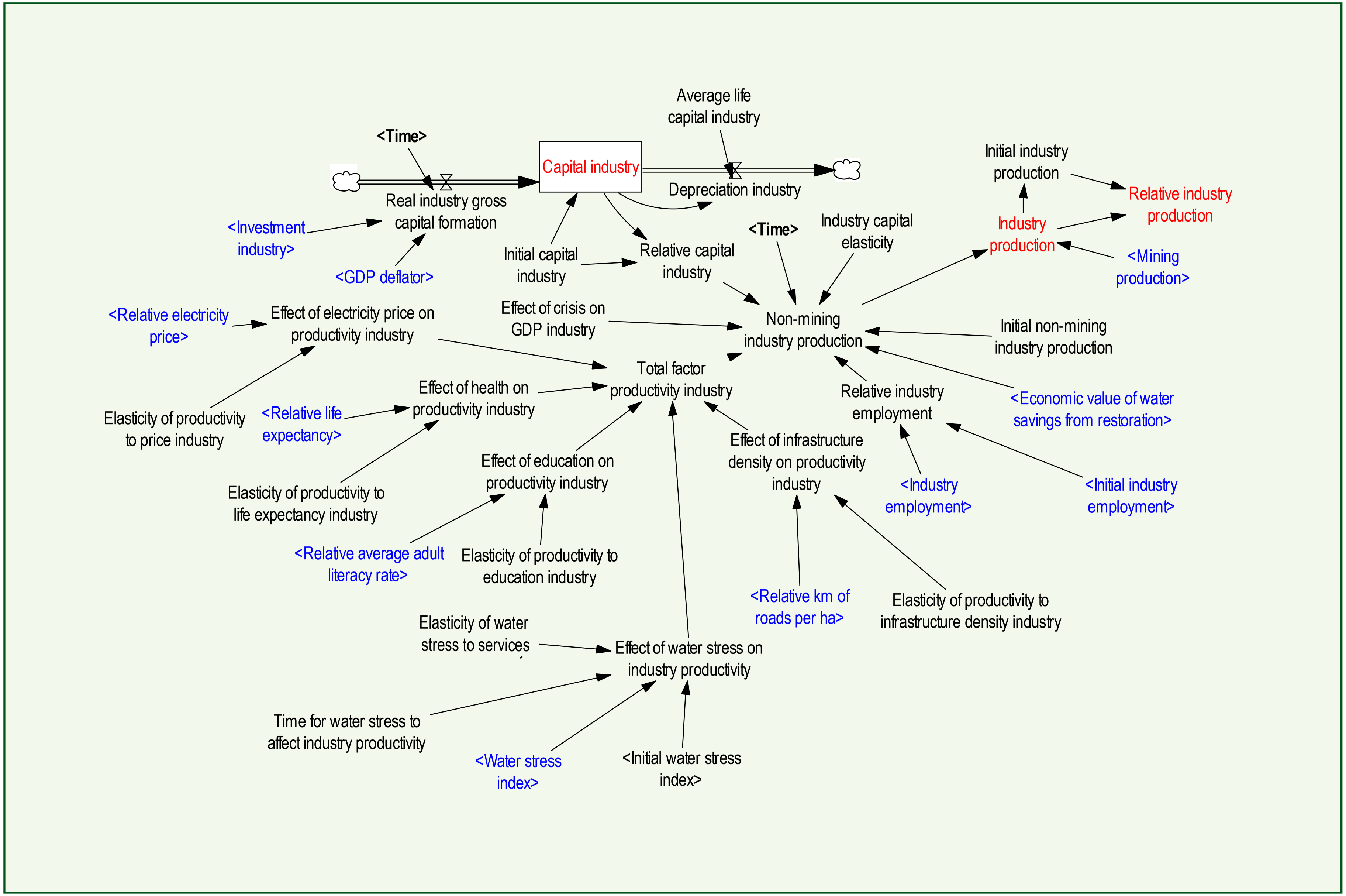
The **power sector employment module** is dedicated to estimate the total employment in the power sector only, due to additional electricity generation plant. The employment estimated refers to the various electricity generation technologies, namely: coal, nuclear, CSP, solar PV, wind and hydro. The jobs generated are further categorised into construction jobs and manufacturing jobs. Each of the specific electricity generation technology corresponds exogenously to determined coefficients of jobs. The total power sector employment is mainly used in the employment module discussed in Annex 2.25.

Annex 2.27 Agriculture module



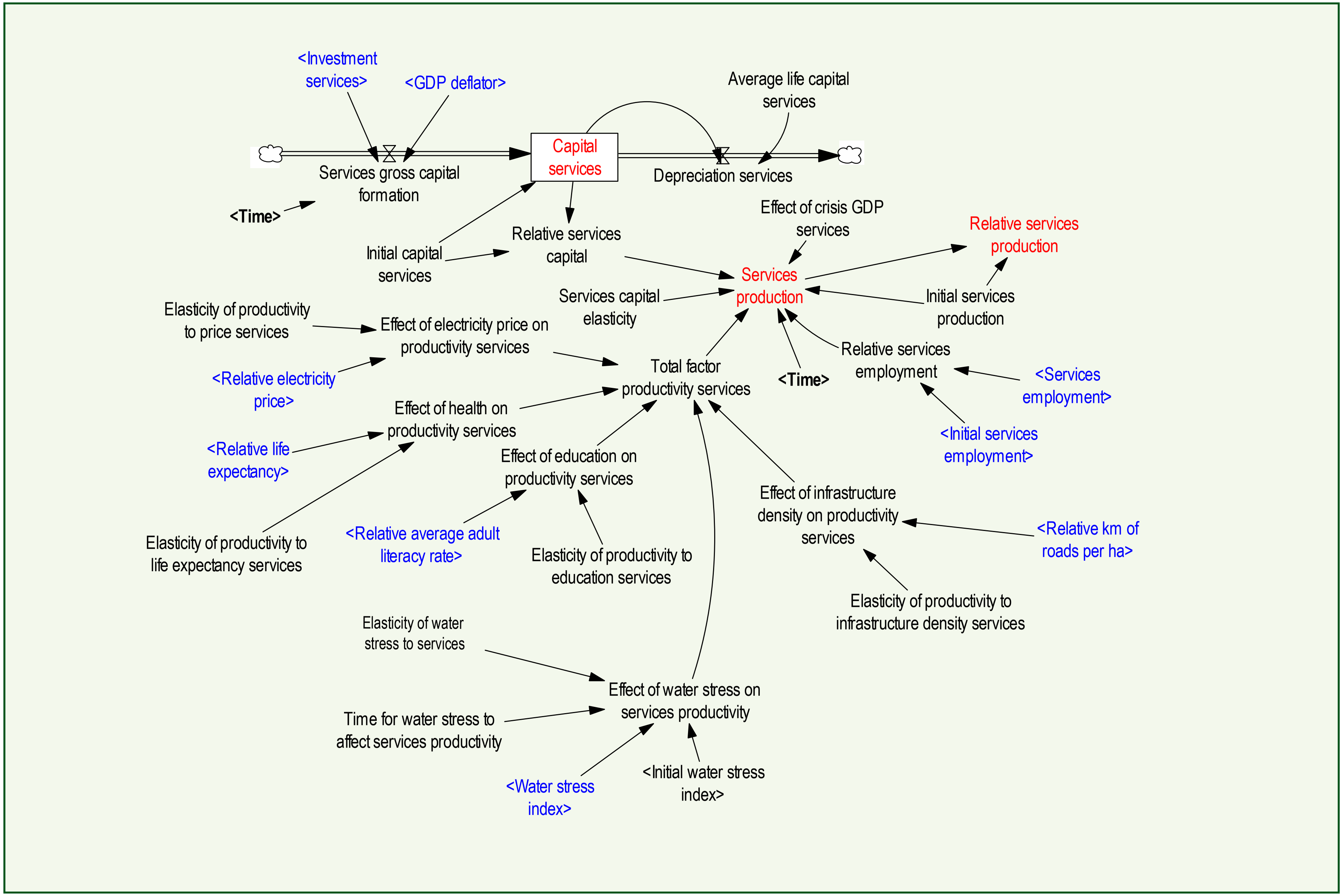
The **agriculture module** one of the production modules that estimate agricultural production. It is based on the Cobb-Douglas production function, which assumes capital and labour as the main factors of productivity. Agriculture capital investment is modelled as a stock, which increases with investments and decreases due to depreciation. Amount of agriculture capital, employment in agriculture (labour) and total factor productivity influences the yield in this production sector. A number of variables endogenously estimated in other modules have an influence on the total productivity in agriculture. These were also taken into account and include water stress index, electricity price, access to roads, literacy rate and life expectancy. Yield in agriculture is also determined by the type of farming practices, that is where they follow organic farming or conventional farming using chemical fertilisers. The agriculture production estimated in this module is utilised in the GDP module to estimate GDP.

Annex 2.28 Industry module

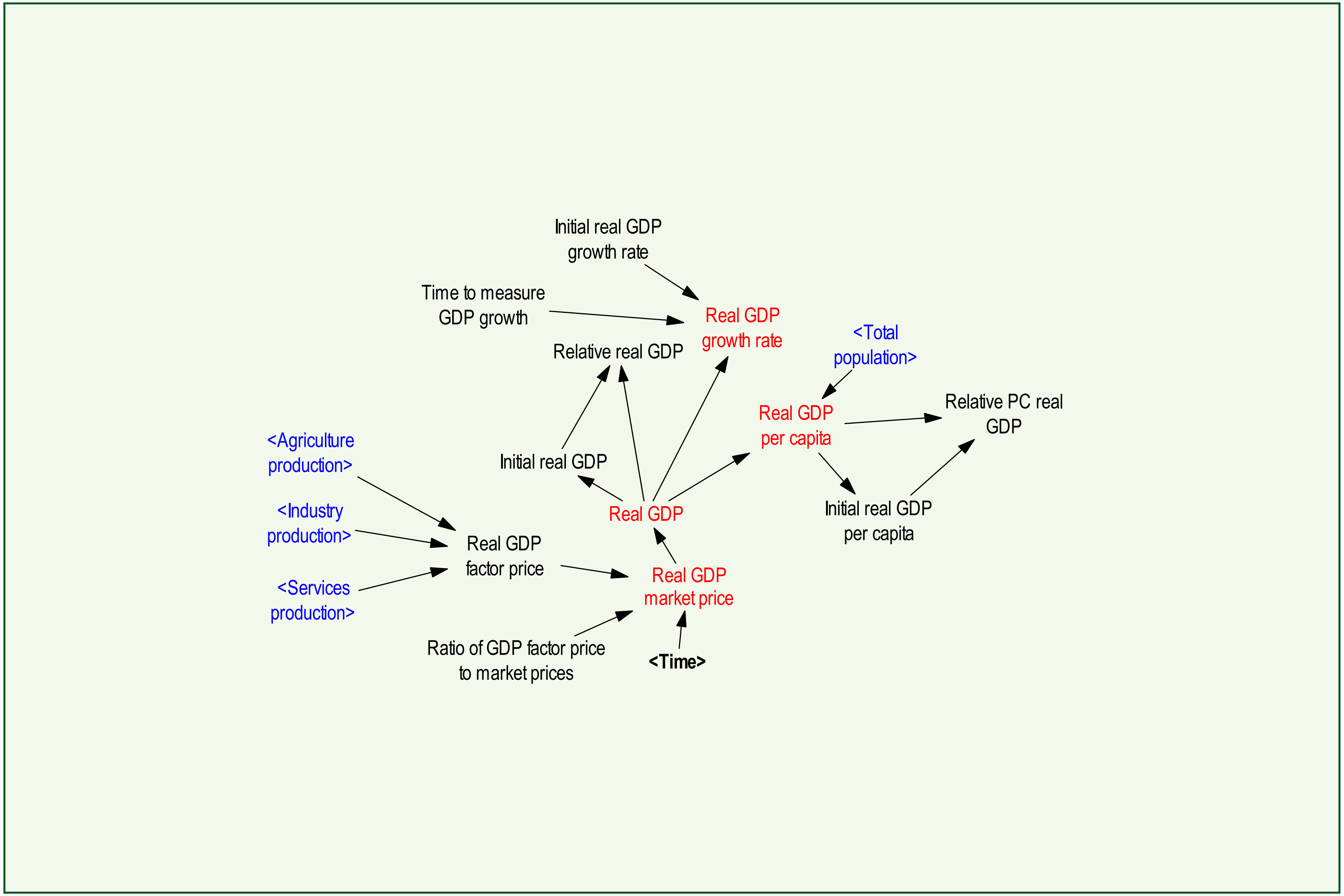


The **industry module** is also a production module that estimates industry production. It also follows the Cobb-Douglas production function, which assumes capital and labour as the main factors of productivity. Industry capital investment is modelled as a stock, which increases with investments and decreases due to depreciation. The amount of industry capital, employment in industry (labour) and total factor productivity influences the yield in this production sector. A number of variables endogenously estimated in other modules have an influence on the total productivity in industry. These were also taken into account and include water stress index, electricity price, access to roads, literacy rate and life expectancy. Industry production estimated includes both mining and non-mining production and is utilised in the GDP module to estimate the GDP.

Annex 2.29 Services module

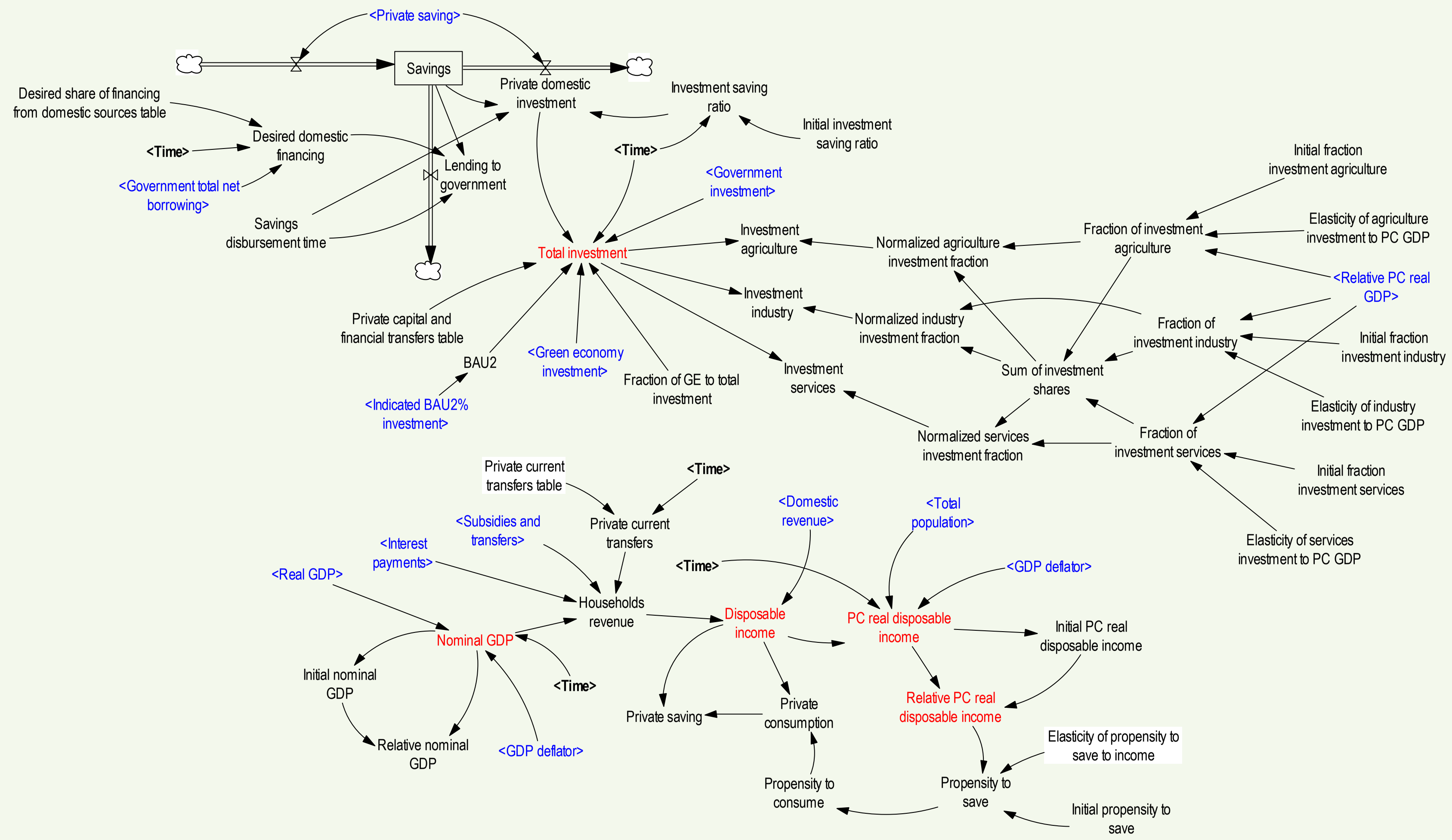


The **services module** is one of the production modules that estimate services production. It is also follows Cobb-Douglas production function, which assumes capital and labour as the main factors of productivity. Services capital investment is modelled as a stock, which increases with investments and decreases due to depreciation. Amount of services capital, employment in services (labour) and total factor productivity influences the yield in this production sector. A number of variables endogenously estimated in other modules have an influence on the total productivity in services. These were also taken into account and include: water stress index, electricity price, access to roads, literacy rate and life expectancy. Services production estimated is utilised in the GDP module to estimate GDP.


Initial real GDP growth rate
Time to measure GDP growth
Real GDP growth rate
Relative real GDP
<Total population>
Real GDP per capita
Relative PC real GDP
<Agriculture production>
Initial real GDP
<Industry production>
Real GDP
Initial real GDP per capita
Real GDP factor price
<Services production>
Real GDP market price
Ratio of GDP factor price to market prices
<Time>

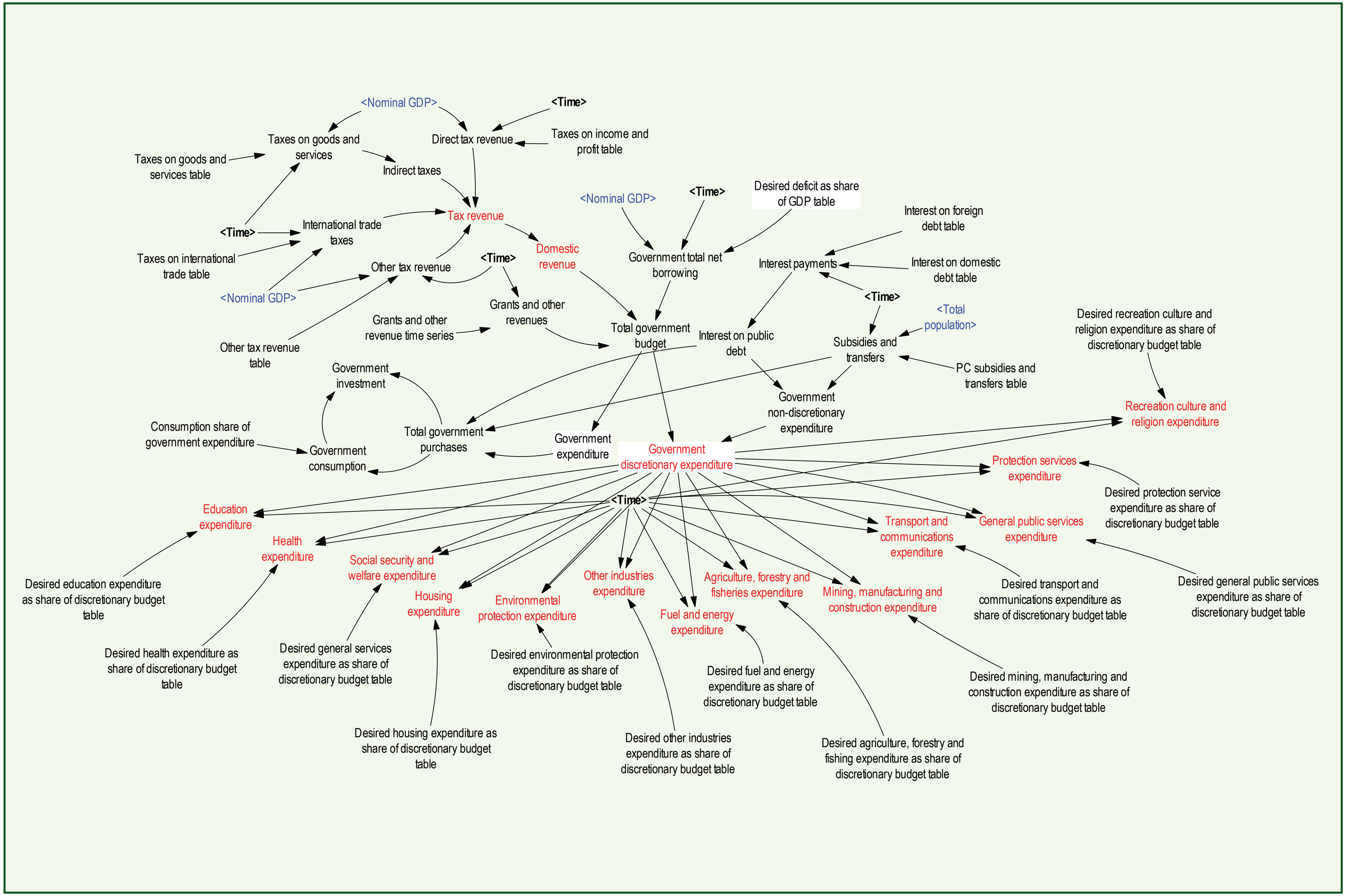
Th **GDP module** estimates the dynamics of GDP, which is determined by gross capital formation and depreciation of the capital in the production sectors (agriculture, industry and services). Thus, the real GDP at factor prices is the South African Rand (ZAR) value of the three production sections, which in turn is converted to market prices when multiplied with the conversion ratio. Other variables estimated in this module are real GDP per capita and real GDP growth rate. Real GDP and real GDP per capita are key variables that are utilised in most of other modules.

Annex 2.31 Investment and household module



The **investment and household module** estimates the household accounts and total investment, and calculates a number of output variables for use in some of the above discussed modules. These include relative per capita and real disposable income, nominal GDP and private saving, and total investment. The total investment is endogenously estimated using endogenous private domestic investment, partly exogenous government investment and the exogenous private capital, and financial transfers time series. Total investment is a key variable in estimating the investment in the production sectors, which ultimately calculates the GDP.

Annex 2.32 Government module sketch



The **government module** shows the South African government accounts, which are based on the social national accounts. The government expenditure in the different sectors (e.g., education, fuel and energy expenditures) is dependent on exogenously determined time series of the desired share of the expenditure in each of these sectors and the amount of the government discretionary expenditure. The discretionary expenditure is the difference between the total government budget and the government non-discretionary expenditure. Non-discretionary expenditure is the sum of subsidies and transfers, interest on foreign debt and interest on domestic debt.

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South Africa's Department of Environmental Affairs views a green economy as a sustainable development path that is based on addressing the interdependence between economic growth, social protection and natural ecosystems. At its National Summit held in May 2010, the resolutions included a commitment for national coordinated efforts in pursuing and exploring opportunities "towards a resource efficient, low carbon and pro-employment growth path".

In contributing to knowledge generation, this modelling study is primarily aimed at assessing the impacts of green economy investments in selected four sectors pertaining to the South African economy. Based on planned targets and expenditures and/or costs of interventions, the modelling identifies possible options and opportunities to achieve these targets. Four scenarios are defined: BAU, or business-as-usual; BAU2% representing a 2 per cent investment of gross domestic product in the BAU activities; GE2% representing an allocation of 2 per cent of gross domestic product in green economy sectors (natural resource management, agriculture, transport and energy); and GETS, which is a target-specific scenario aimed at identifying whether policy-makers can achieve the medium- to long-term targets following green economy interventions in the prioritised sectors.

The United Nations Environment Programme (UNEP) commissioned an analysis of the opportunities and options for South Africa's transition to a green economy, focusing on four of its nine sectors, at the request of the national Department of Environmental Affairs. The analysis was conducted with technical assistance from the Millennium Institute and the Sustainability Institute, in collaboration with the Centre for Renewable and Sustainable Energy Studies (CRSES) of Stellenbosch University. The United Nations Development Programme supported stakeholder consultations and capacity building activities related to the implementation of the project. UNEP is grateful for the funding support provided by the European Commission.

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