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South Africa's integrated energy planning framework, 2015–2050

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Abstract

The Integrated Energy Plan (IEP) was designed to consider South Africa's energy needs from 2015 to 2050, as a guide for energy structural savings and the development of energy policy. The main aim of the Department of Energy is to ensure the security of energy supply. The current energy situation in the country has its gains and challenges. With the growing population and infrastructural development, the country requires prudent measures to meet the country's energy needs for 2020–2050. The country's energy is currently dominated by coal-fired plants, which represent about 70% of the total installed capacity, crude oil contributes about 21%, with only 9% from all other energy sources, including renewables. This paper examines the scope of the IEP framework, key objectives of the IEP, the methodology applied to achieve those objectives, and the projections made for attaining the framework target. The paper further reviews the energy requirements for the key sectors of the economy and analyses the effects of CO_2 emissions and the benefits of job creation for the entire period. Despite substantial renewable potential in South Africa, at present it contributes as little as 2% of the energy mix. The global renewable energy policy on CO_2 emissions reduction, improvement of energy efficiency and deployment of renewable development are not met in the IEP framework.

Keywords: *renewable energy, energy policy, energy efficiency, installed capacity*

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1. Introduction

The Integrated Energy Plan (IEP) is South Africa's overall energy plan of action for electrical power, gas and liquid fuels. The Integrated Resource Plan (IRP), on the other hand, as a component of the IEP gives an elaborate strategy for energy requirements. The IEP is responsible for the energy demand forecasts for a certain period and provides alternatives as to how these demands can be supplied [1, 2]. It includess four scenarios that give rise to different stages of energy demand; however, the IRP uses the Council for Scientific and Industrial Research (CSIR) electricity demand projections [3]. In 2016, the South African Cabinet approved and promulgated the final IRP policy, thereby giving a legal backing for the energy ministry to decide the required capacity to be added onto the grid system. The revised edition of the IRP energy policy was published in 2019, but the CSIR's initial assessment indicated that the document plans for the short term and does not provide energy policy beyond 2030 [4, 5]. Technological disturbance makes it difficult to plan beyond 2030, but long-term energy planning is needed in this instance [70].

The lifeblood of every economy largely depends on energy for all sectors. The IEP is, therefore, needed to make sure that energy service requirements are met in the most efficient, affordable, and sustainable way, while curtailing negative influences on the environment [6]. A dearth of planning for the energy sector can lead to underinvestment in the desired energy infrastructure. The main objectives and purpose of the IEP are clearly stated in SA Act No. 34 of 2008 on energy [7]. The IEP is also a complex, long-term energy plan with many aims. It is therefore imperative to develop a workable mechanism for energy policymakers to measure and provide answers to the challenges the energy sector may encounter [4, 8].

The IEP includes an exhaustive investigation into the gains as well as inadequacies of the entire energy scheme [9, 10]. The IEP is therefore intended not only to ensure that the required energy is supplied, but also that the cross-sectorial influences are investigated and dealt with methodically [11]. Accordingly, it is vital to consider the broader objectives of the country and outside influences that typify the sector in the energy planning process [12]. This paper, therefore, reviews the entire IEP framework and proposes future directions, with a specific focus on renewable energy sources (RES) and CO_2 emission reduction.

2. Methodology

Content analysis [69] was used as the main methodology for the paper. Seven criteria were identified from the ten papers in reputed journals (selected from the seventy-one listed references), presented in Table 1. Directed content analysis [69] was used

Table 1. Titles of journal articles used

No.	*Author(s)*	*Topic*	*Journal*
1	Wright, J.G., et al (2019)	Integrated Resource Plan 2019: Initial CSIR insights and risks/opportunities for South Africa.	CSIR
2	Quansah, D.A., et al (2017)	Cost-competitiveness of distributed grid-connected solar photovoltaic in Ghana: case study of a 4 kWp polycrystalline system.	*Clean Technologies and Environmental Policy*, *19* (10): 2431-2442
3	Adom, P.K., et al (2017)	Does renewable energy concentration increase the variance/uncertainty in electricity prices in Africa?	*Renewable Energy*, *107:* 81-100.
4	Paska, J., et al (2020)	Electricity generation from renewable energy sources in Poland as a part of commitment to the Polish and EU energy policy.	*Energies*, *13*(16): 4261
5	Serra, F., et al (2020)	Optimal integration of hydrogen-based energy storage systems in photovoltaic microgrids: A techno-economic assessment.	*Energies*, *13*(16): 4149.
6	Benavente-Peces, C. et al (2020)	Building energy efficiency analysis and classification using various machine learning technique classifiers.	*Energies*, *13*(13): 3497.
7	Zhang, L., et al (2020)	Impacts of investment cost, energy prices and carbon tax on promoting the combined cooling, heating and power system of an amusement park in Shanghai.	*Energies*, *13*(16): 4252.

No.	Author(s)	Topic	Journal
8	Tucki, K., et al (2020)	Perspectives for mitigation of CO_2 emission due to development of electromobility in several countries	*Energies*, *13*(16): 4127.
9	Zoundi, Z., (2017)	CO_2 emissions, renewable energy and the environmental Kuznets curve, a panel co-integration approach.	*Renewable and Sustainable Energy Reviews*, *72*: 1067-1075
10	Akom, K., et al (2020)	Energy framework and policy direction guidelines: Ghana 2017–2050 perspectives.	*IEEE Access*, *8*: 152851-152869

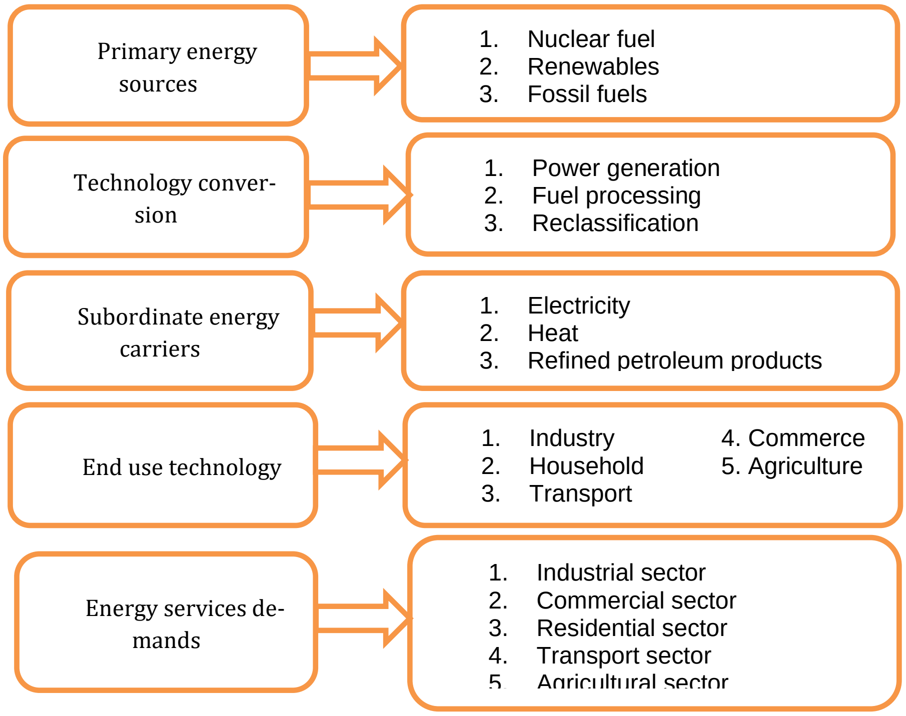

Figure 1: The scope of the IEP [5].

where existing theory or prior research studies were observed, and the unit of observation was the use of renewable energy and the IEP. Wright *et al* [15] explained and thoroughly discussed the shortfalls of the 2016 IRP and the need for the implementation of the 2019 IRP. The cost-competitiveness of solar and grid integration were discussed by Quansah *et al* [7]. Adom *et al* [21] quizzed the variance/uncertainties in prices of electricity in the African context. Paska *et al* [32] worked on RES with regards to the EU energy policy and its impact on energy planning systems in Africa. Optimal integration and other economic considerations like hydrogen-based energy storage systems were discussed by Serra *et al* [35]. Benavente-Peces *et al* [38] analysed energy efficiency and classification of energy usage in various sectors. Revenues and impacts of invest-ment costs were discussed by Zhang *et al* [42]. Both Tucki *et al* [45] and Zoundi *et al* [56] worked on CO_2 emission reduction and, finally, Akom *et al* [70] suggested energy policy direction guidelines and framework.

3. Panorama of energy planning

The IEP reflects on the steadiness of the national energy demand and supply, and suggests other plans for capacity development, according to the varying sets of expectations and constraints. It gives details on grid systems and electricity transmission and distribution – controlled by Eskom [14, 16]. Other areas covered by the IEP are the Gas Utilisation Master Plan (GUMP), checks on the bottlenecks and volume, and restraints of the natural gas structures. All the aforementioned had to be considered in the IEP to allow general progress via sporadic iterations to guarantee alignments [17, 18].

4. The scope of the IEP

The IEP framework considers every energy transporter, every technological possibility and every important national energy policy necessity and suggests alternative policy recommendations of the energy mix [4, 15]. Figure 1 indicates the scope of the IEP framework that covers all the important features of the national energy value-chain [19], done to ensure the attainment of the energy sector objectives in an optimum manner.

5. The IEP key objectives, scenarios and assumptions

5.1 Objectives

The development of the IEP started with a comprehensive review of the previous policies such as the National Development Plan (NDP), the New Growth Plan (NGP), the National Transport Master Plan (NTMP), the Climate Change Response Policy, and the carbon tax proposals. All these overarching national policies were reviewed thoroughly and put together to form the IEP as a single document to provide a roadmap of the future energy sector landscape for South Africa. Nine key objectives were identified in the IEP: the assurance of energy security; affordable energy supply; diversification of energy sources; regular access to energy; CO_2 emission reduction; energy efficiency improvement; localisation and job creation; conservation of water resources; and technology transfer [4, 14, 20]. Figure 2 indicates three main thematic areas: economic development, social development, and environmental sustainability. These are key sectors of the country's energy development and the development of the IEP. The IEP's overall objective was to make sure that sufficient, maintainable, and dependable forms of energy for the consumers are provided. A sufficient backup margin of about 19% for power generation should be adopted for the energy sector, business and all other aspects of the economy as well as for citizens to ensure an affordable energy supply.

5.2 Scenarios

Four scenarios were created by the IEP to identify possible future energy generation for South Africa; they are [5, 20]:

- To assume the implementation of the existing policies and to make sure the country benefits from it financially.
- The constraint of resources was identified as a result of high prices of the fossil fuel used for the generation
- The country will pay more for externality costs coupled with constricted emission restrictions in order to create environmental awareness.
- The NDP can only be implemented for high economic growth by shifting from primary minerals to industrialisation.

5.3 Assumptions

The IEP considers the rate of GDP growth as essential when future energy demands are calculated for economic assumptions. The assumptions were classified into three stages – for short-, medium- and long-term planning. The IEP assumptions on microeconomics are seen in the upper part of Table 2a [21]. Here, the figures are obtained from the recent National Treasury estimates of in-house growth data, while the figures at the bottom line of Table 2b were obtained from the November 2016 presentation made by the Treasury [22]. Both tables include some projections on GDP growth based on current statistics.

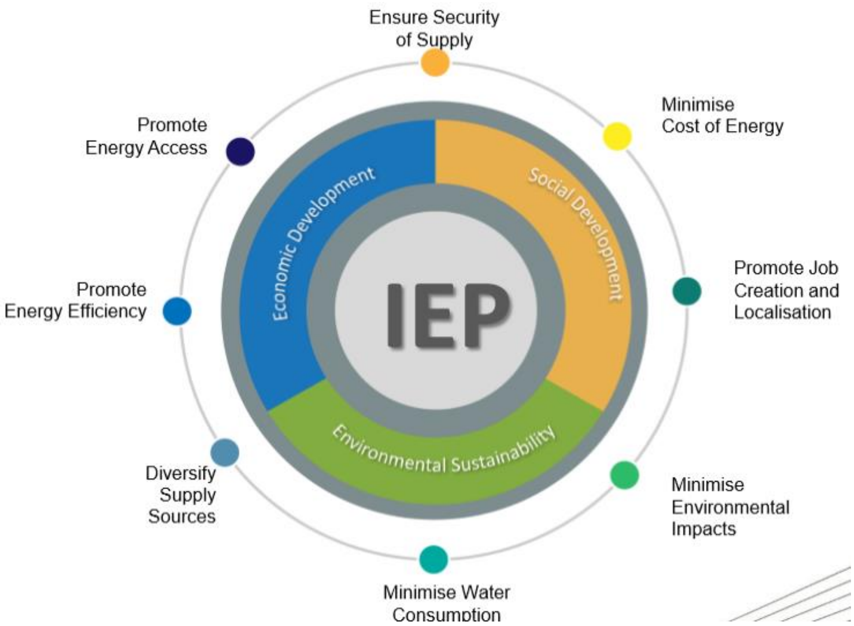

Figure 2: Eight key IEP objectives [4].

Table 2a: GDP growth and projections [4, 23]

SN	*GDP growth*	*Short-term*				*Medium-term*	*Long-term*
		2014	*2015*	*2016*	*2017*	*2018- 2022*	*2023-2050*
1	Low	1.5	1.8	2.3	2.5	2.8	3.0
		2.4	2.5	2.9		3.1	3.0
2	Moderate	1.8	2.7	3.2	3.5	3.7	4.2
		3.0	3.2	3.5		3.7	4.0
3	High	2.0	3.3	3.7	4.0	4.9	5.5
		3.3	3.6	4.0		4.9	5.4

Table 2b: GDP growth projection and actual growth [4, 23]

No.	*GDP growth*	*Short-term*				*Medium-term*	*Long-term*
		2014	*2015*	*2016*	*2017*	*2018-2022*	*2023-2050*
1	Low	1.5	1.8	2.3	2.5	2.8	3.0
2	Moderate	1.8	2.7	3.2	3.5	3.7	4.2
3	High	2.0	3.3	3.7	4.0	4.9	5.5
4	Actual	1.6	1.3	0.5			

6. Policies and statistics on Co_2 emissions

The IEA statistics provide carbon dioxide emissions figures for most African nations, and the most dependable current relative accessible figures. The 2014 IEA figures for selected countries have been compiled [24] to offer a viewpoint, with GDP attuned for acquiring power equality, which is also used for the emissions intensity figures [25]. The energy sources available put South Africa's CO_2 emissions between 1.1% and 1.2% of the global total, although its portion of Africa's CO_2 emissions has waned from about 50% to about 40% since the turn of the century [26]. The key policies, targets and measures which would have enhanced the South Africa's IEP are: adequate investment in energy infrastructure; decommissioning of 35 GW from the 42 GW presently operating coal-fired energy; and generating at least 20 GW of energy needed by 2030 from RES. This could bring down the CO_2 emission targets [17].

7. Overview of the energy sector

In 2014, South Africa was placed 83rd on the Energy Sustainability Index of129 countries by World Energy Council [46]. However, in 2020, South Africa improved its performance to 74th position [46]. The supply of South Africa's energy is dominated by coal, which represents about 70% of the total installed capacity; crude oil, natural gas and nuclear power contribute about 29%, with less than 2% from renewables [49, 50], as indicated in Figure 3. A further check-in [47, 51] discloses that coal contributes about 90% of the power generated, 3% of nuclear, Natural gas 5%, and other RES such as biomass, wind, solar, bagasse, and landfill gas together contribute only 2% of the total energy mix, which falls below the global standard.

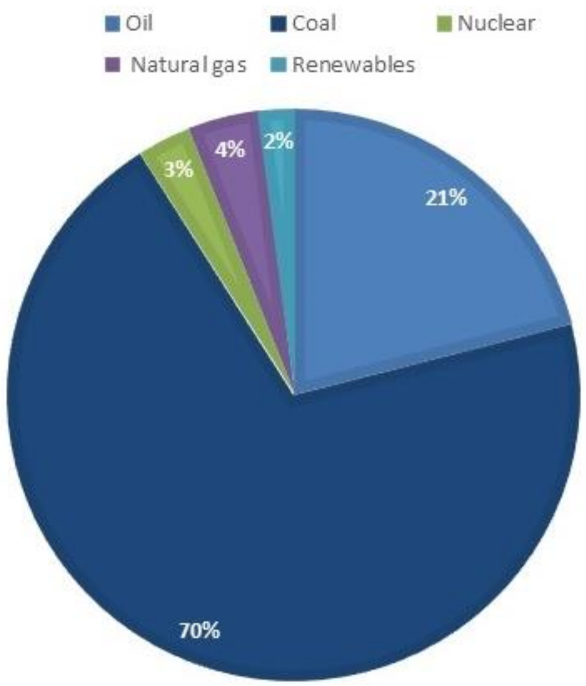

Figure 3: South African primary energy supply, 2016 [27].

8. Key policy issues

The major challenges facing the South African energy sector, such as energy security assurance, CO_2 emissions reduction, and energy efficiency enhancement in the economy, can never be resolved by market activity alone [24]. For proper delivery of service to the general public, government intervention in some cases, through policies and directives, is needed to attain certain policy goals [29]. The 2016 IEP framework was developed with all sectors of the economy in consideration with the existing policies. Though several policies of government have impacted positively on the energy sector, some strategies ought to be technologically advanced in energy usage on petrol, electricity, gas, and coal. Another important element that was identified through the IEP process was to safeguard alignment and recognise collaborations made with other government strategies [5, 32]. This section also recognises some of the important strategy subjects that have been well thought-out in the IEP process and sector plan as indicated by Szabo et al (2013) [33].

9. Demand and supply energy forecast and analysis

9.1 Demand

To ensure energy security is the first aim of the 2016 IEP, to make sure that South Africa is not short of energy supply within the time frame [37]. To achieve this target, broader consultations were made between the energy and the economic sectors, such as commerce, transport, industry, agriculture, and residential [38]. Each sector was mandated to provide the policy planners with a breakdown of energy consumed in 2010 on cooling, heating, pumping, petrol, electricity, gas, and coal. They also collected figures on energy used from 1993 to 2010 as well as projected figures from 2010 to 2050 [39]. Energy projections up to 2050 for all sectors were presented, as shown in Figure 5. The green shoot scenarios were exempted. In their estimations, energy demand will rise more steadily in all scenarios with time until 2030 and 2035 levels, which were presumed higher [41, 42].

The numbers shown in Table 3 indicate a big increase in projected demands from 2015 to 2050. The outcome of Environmental Awareness (EA) is mostly identical to the Resource Constraint (RC) of the resources available. This is as a result of the ecological internalised cost of model treats moving at the same level of increase in price treats, regardless of the benefits gained from the reduced pollution. Table 3 further shows that the IEP planners were only interested in the three scenarios: implementation of existing policies, cost of fossil fuel for energy generation, and external cost on CO_2 awareness, this is what we termed RC/EA scenarios [4].

9.2 Supply

The IEP's liquid fuel and electricity options for model supply after demand projections in each scenario involve installing new plants to replace the old ones in the power sector to increase energy supply. The process is expected to yield a considerable growth in energy generation capacity from about 50 GW in the base case to 165 GW between the 2015 and 2050. However, 120 GW will be recorded in RC and EA with green shoots value of 85 GW. By 2030, all scenarios are expected to sharply increase to 70 GW to reflect the projections in demand. The completion of Kusile and Medupi plants will see a major boost in energy production and perhaps create a surplus in capacity [23, 46].

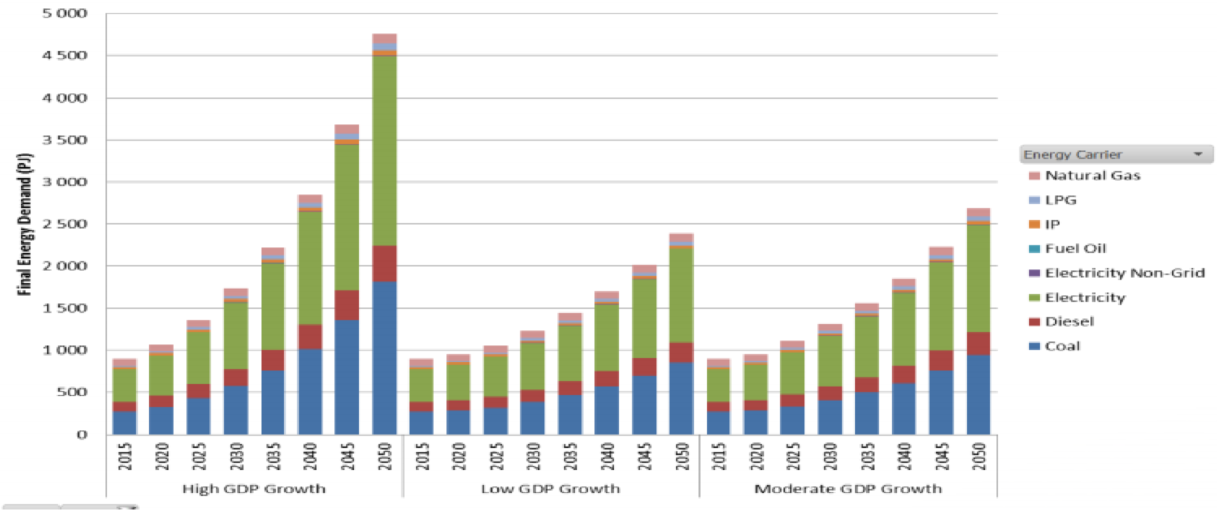

Figure 5: Total energy demand for all sectors at different levels of GDP growth [7, 40].

Table 3: Energy demand in 2050 (PJ) relative to 2010 (%) [23]

No.	*Key sectors*		*Base case*		*Green shoots*		*RC/EA*	
		2010	*2050*	*%*	*2050*	*%*	*2050*	*%*
1	Total	2850	8100	284	4050	142	5500	192
2	Industry	1200	4550	379	1350	112	2500	208
3	Commerce	200	850	425	800	400	800	400
4	Agriculture	95	155	163	145	153	150	157
5	Residential	375	480	128	300	80	345	92

Table 4. IPPs allocations for renewable energy development [17]

No.	*Energy type*	*Allocation to preferred bidders*		*Allocation per determination still available*		*MW allocation per determination*
		MW	*Percentage*	*MW*	*Percentage*	
1	Solar	631.53	43.60	818.47	56.40	1450.00
2	Solar CSP	150.00	75.00	50.00	25.00	250.00
3	Wind	633.99	34.30	1216.01	65.70	1850.00
4	Biomass	0.00	0.00	12.50	100.00	12.50
5	Landfill gas	0.00	0.00	12.50	100.00	12.50
6	Small hydro	0.00	0.00	75.00	100.00	75.00
7	Total MW	1415.52	39.00	2209.48	61.00	3625.00

The programme organised by the independent power producers (IPPs) indicated that renewable energy is now preferable in terms of cost. International prices recently also confirm that RE prices are lower, and expected to come down more [47]. However, both IEP and IRP still rely on coal-fired generation even after Kusile and Medupi agreements. The IEP is, however, optimistic that South Africa still stands a chance of hitting an incomparable jackpot with coal or shale gas or both. The largest cost component of the entire energy system for 2014 to 2050 is imported fuel, but slightly cheaper than the current fuel and oil import cost [48–51].

10. Renewable energy and the role of IPPs in the IEP

South Africa has a relatively infant but growing RE industry. This industry is expected to increase the contribution of RE to a total of 18.2 GW by 2030, about 42% of the country's installed capacity. Table 4 shows the criteria given to the RE IPPss to produce RE for the country. The total capacity of bids received was 2127.66 MW, about 66.5% of preferred bidders. Twenty-eight bidders passed with the expectation of providing RE to the tune of 3 625 MW, representing 39% of the total energy mix [10, 17]. It is interesting to note that all those details as indicated in Table 4, which were part of the previous policy, were not factored into the 2016 IEP framework.

11. Energy statistics classifications used in South Africa

The major stakeholders in South Africa's energy sector are the Department of Minerals and Energy (DME), Stats SA, and Eskom. DME and Stats SA depend on Eskom as their main source of electricity data [52]. The South African economy comprises five major sectors as classified by the DME [53]: Industrial, commercial, agricultural, residential and transport. The IEP covered all five sectors, with particular emphasis on the energy demand per sector. [4]. Details of current demand and future projections are given in Table 5.

Table 5: Figures of demand for each sector [4]

No.	*Sectors*	*Current figures in PJ*	*Future projection in PJ*
1	Industrial	500	1, 700
2	Commercial	50	180
3	Agricultural	68	98
4	Residential	80	140
5	Transport	500	1, 700
6	Total	1198	3 818

The table shows the industrial sector, which has eight sub-sectors, and is one of the three major consumers of energy. The biggest users of electricity in the commercial sector are machines used in offices. Urban and rural areas make up the residential sector. The main source of energy for the transport sector is liquid fuels. It is the second highest consumer of electricity in South Africa [4, 54-58].

12. Potential job creation

Constructional and, to a lesser degree, operational jobs are the two main work opportunities that the IEP can offer. Comparing this with the 33 000 workforce at Sasol and the 1.5 million job potential at a shale gas extraction firm within the same period [59]. Figure 6 shows a decline between 2040 and 2050. This is a period of methodology and modelling which only requires a skilled labour force. At this point, the engineers only rely on technical competence [59–61]. The new gas-to-liquid plant and shale gas exploitation were estimated to create 90 000 and 2 575 jobs respectively in the IEP by 2040, but they are no longer considered economically viable options [62, 63]. Instead, technological developments such as electrification of transport, the use of hydrogen-based power in industry, electrical storage, and distributed energy generation are currently seen as economically viable options [35]. This has dramatically altered the framing of centralised planning, with particular emphasis on the evolution of demand modelling. The job potentials of the IEP were categorised as indicated in Table 6, which indicates the category of job creation, definitions, and types of jobs created.

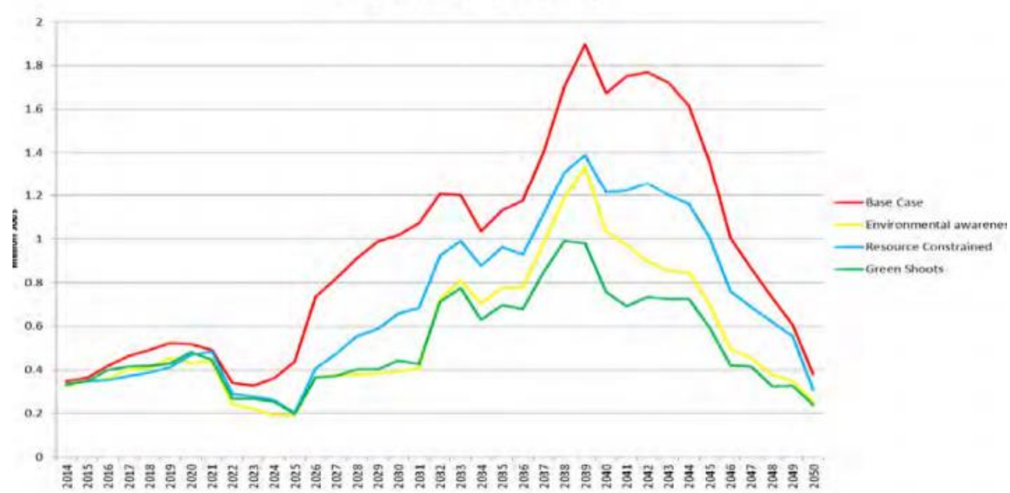

Figure 6: Job potentials in the energy sector by scenario [59].

Table 6: Job categories considered [77]

No.	*Category*	*Definition*	*Example*
1	Direct jobs	Jobs resulting from construction or operation of technology.	Construction workers, bricklayers and plant operators.
2	Supplier jobs	Jobs resulting from first-level suppliers during construction and/ or operation.	Turbine manufacturers, cement producers, and steel manufacturers.
3	Indirect jobs	Jobs resulting further down the value chain during construction and/ or operation. i.e. suppliers to suppliers.	Iron ore miners and smelters
4	Induced jobs	Jobs resulting from more money in the economy because of the project.	Restaurants, transportation services and medical facilities.
5	Permanent jobs	These jobs have a longer duration and are more permanent in nature. Services are usually established in-house within the organisation.	All operation jobs are considered to be permanent jobs. Estimated per unit of capacity installed.
6	Temporary jobs	These are jobs that have relatively short duration. Services are usually contracted.	All construction jobs are considered to be temporary jobs. Estimated per unit output.

Table 7: Peak, plateau and decline, 2010–2050, Mt CO_2e [56]

No.		2010	2015	2020	2025	2035	2040	2045	2050	Total 2010–2050
1	Upper	547	562	583	614	614	552	490	428	23 050
2	Mid	473	480	491	506	506	444	382	320	19 560
3	Lower	398	398	398	398	398	336	274	212	14 830

13. CO_2 emissions and climate change

The lower and the upper limits of Table 7 show the peak, plateau and decline (PPD) permits, CO_2 emissions, and the last column of the table shows the entire period cumulative emissions from 2010 to 2050. The figures shown were built on the 2009 Copenhagen offer of 505 Mt. emissions in 2025. If other nations act proportionally, the upper range suggests a world-wide increase of temperature above 4°C by 2100 and 2°C by 2036 [56].

The base case again of Table 6 has permissible emission of power generation from 2020 to 2050 of 7 857 Mt. Additional 10 years will increase the emissions to about 10 400 Mt. With a permissible rate of 45% power generation will give PPD full period by putting emissions value at the upper limit of 4°C by 2050 and more afterward. Emissions decrease from power generation in fosile fuel may lead to zero emissions in 2050 [49]. Thus, the emission proportion credited to the power sector must sharply reduce to the required target. The second scenario of DoE was implementation of renewable energy policy, which moved higher from 2020 to 2050, to 7.37 Gt from 5.09 Gt. These figures will bring the national emissions figures to 16.37 for the PPD's full period [65].

For the RE scenario, 8, 430 MW with 1.59 Gt emission is produced within the period of 2020 to 2050. Therefore, it seems that building the same amount within the same period of renewable's budget in 2020–2050 will produce an emissions value of 4.79 Gt. The implications are that PPD's full period will produce 7.07 Gt and, as a result, the national emissions figure will be 15.71Gt. But both renewables and gas should produce 6.43 Gt emission according to the least cost of CSIR for the full period. [66]. The 2016 IEP projections on CO_2 reduction as compared to the South Africa and Paris agreement on renewable energy was a total departure in areas like transport electrification, modern electrical storage systems, application of hydrogen energy, generation transmission and distribution of energy and their impacts on various sectors of the economy. The 2012 CO_2 emission was projected to reduce by 96% as compared to 40% in the 2016 IEP, by 2050m as stated in the Paris Agreement. A total decarbonised energy sector is critical for electrification trends in urban transportation system and residential housing in accordance with the Paris Agreement temperature limit. The 2016 IEP therefore should be revised to adopt these technologies [71].

14. Costs

The cost of energy systems is made up of different components from the primary energy supply to the energy delivered to the consumers [5, 67]. The modules and the analysis for the five sensitivity costs are provided in Figure 7. The total cost covers 2015 to 2050 of the IEP. It includes imports of refined products, imports of crude oil, production of existing refineries, production and capital of new builds, and fuel for gas and coal. The total cost for the base case was estimated at R2793.70 bn. Figure 7 further reveals the green shoots scenario as having the highest cost for the entire project, at an estimated R3090.70bn. The cost of RE and CO_2 emission reduction was not prominently featured in the discounted costs.

15. Observations and remarks

South Africa's energy supply is dominated by coal, which represents about 70% of the total installed capacity, while crude oil contributes about 22%. Natural gas, renewable energy and nuclear power, including biomass and hydro contribute only 9% of the installed capacity. The IEP did not add any new method of energy production pattern, but with a little on RES and CO_2 reduction. The country aimed at reducing CO_2 emissions to 40%, while maintaining coal-power generation as the main source of energy up to 2050. The major challenges facing the South African energy sector are: energy security assurance, CO_2 emission reduction, and energy efficiency enhancement, which cannot be resolved by market activity alone. For proper delivery of service to the public, government intervention, in some cases through policies and directives, is needed to attain certain policy goals. Though several policies of government have in one way or another had a serious impact on the energy sector, some strategies have more considerable effect on energy policies that ought to be technologically advanced. Another important element that was identified through the IEP process was to safeguard alignment and recognise collaborations made among other governmental

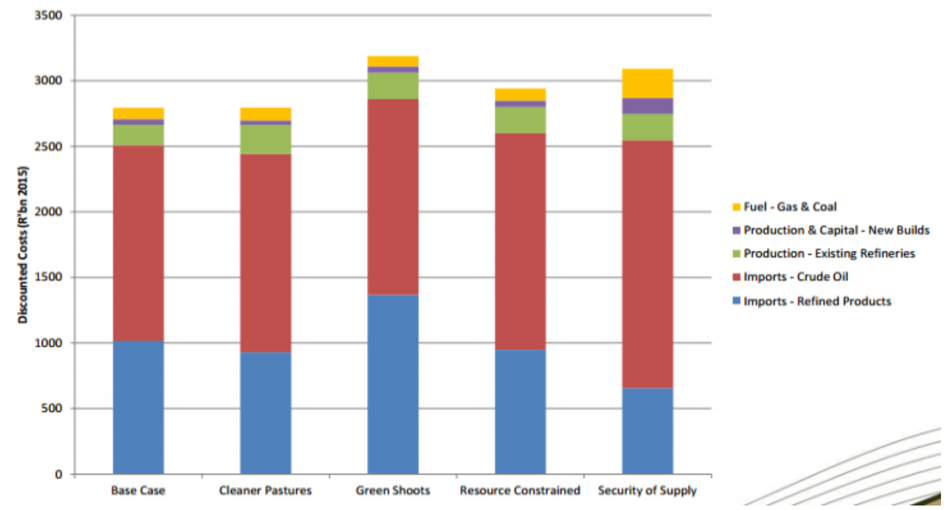

Figure 7: Energy systems cost structure (2015-2050) [15].

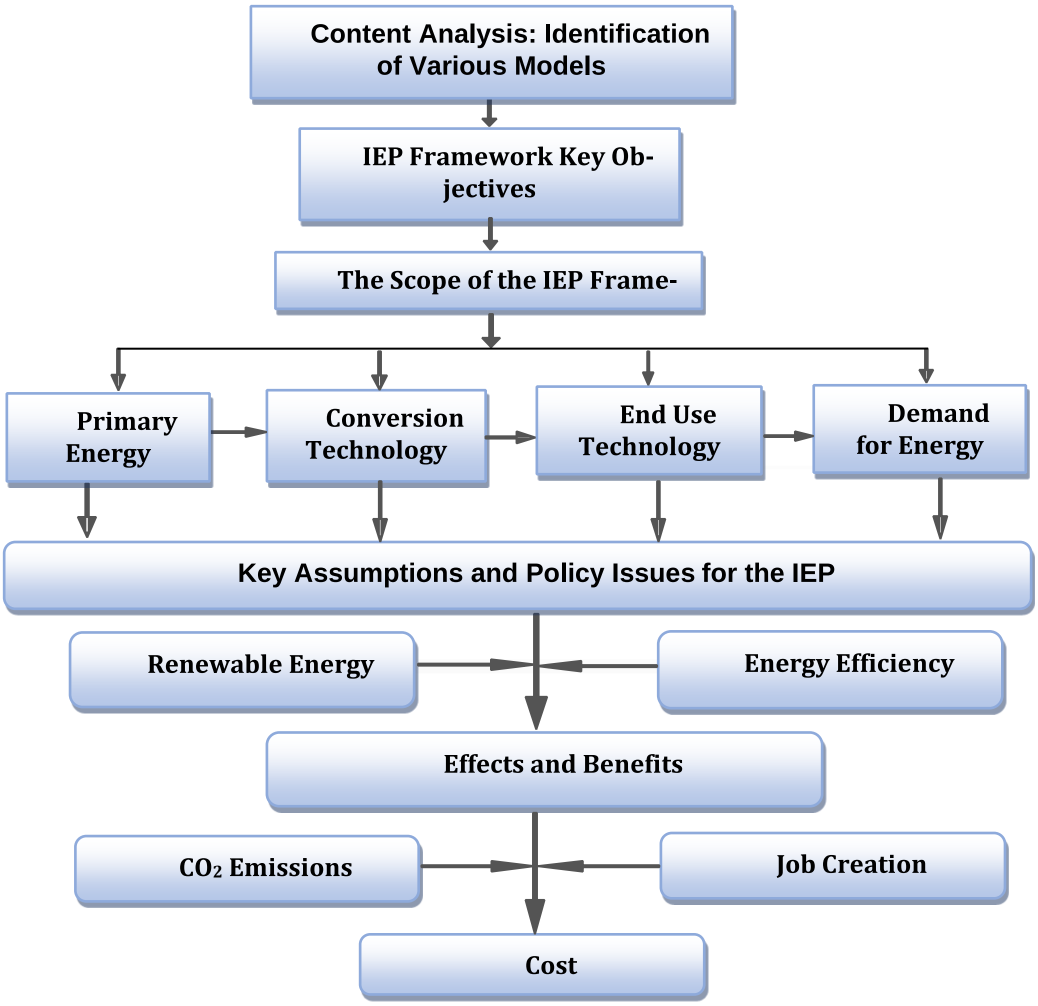

Figure 8: Schematic diagram of the conceptual approach of the IEP framework.

strategies. Figure 8 shows a proposed method designed to help identify the various models and the scope of the IEP framework, by introducing the renewables and integrating them with the grid systems, thereby reducing reliance on fossil fuels. Figure 8 further illustrates the key models, such as the main objectives of the framework, key assumptions, and policy issues where renewable energy and energy efficiency were put in perspective. The measurable effects of CO_2 emissions and the benefits of potential jobs to be created during the period as well as cost analyses are all presented in Figure 8.

16. Conclusion

The 2016 IEP framework of South Africa was designed with input from the various sectors of the South African economy and the 2016 IRP. South Africa's demand for energy renaissance and its legal commitment to total reduction of emission-producing energy by 2050 demands placing resource efficiency at the centre of a future industrial strategy on energy efficiency, modern storage systems and total utilisation of the RES available in the country. The primary energy supply in South Africa is dominated by coal-fired energy that represents about 70% of the total installed capacity and crude oil contributes about 22%. Natural gas, renewable energy and nuclear power, including biomass and hydro have a lesser role in the total energy mix, totalling 9%. However, global energy policy proposes a 50% dependence on renewable energy in order to reduce CO_2 emissions, improve energy efficiency, and to support renewable energy development. The poor performance in ecological sustainability is as a result of the energy sector's heavy dependence on coal-fired energy. This shows a shortfall with regard to the global energy policy standard. The IEP development should be a continuing process and should be reviewed from time to time, in order to keep abreast with the current changes in the macroeconomic settings, improvements in new technologies, and changes in national energy obligations. The IEA publication further emphasised modern storage systems and the implementation of hydrogen energy for transportation system to improve energy efficiency and economic benefits.

Author roles

K. Akom conducted the literature survey, and the writeup. T. Shongwe and M. Joseph (who conceptualised the study) supervised and guided on which literature to include, and read and corrected the manuscript.

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