The contribution of pumped storage schemes to energy generation in South Africa

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The total installed capacity of the large pumped storage schemes (PSSs) in South Africa is at present some 2910 MW. There are four large PPSs operating currently around the country, with the Steenbras (180 MW) being the municipal asset of the City of Cape Town, and three plants owned by the national entity Eskom SOC namely the Drakensberg (1000 MW), Palmiet (400 MW) and now new Ingula (1330 MW). The utility has a few another conventional hydropower plants owned and administered together with the Department of Water and Sanitation (DWS), two situated on the Orange River and others attached to the dams on the perennial rivers in the Eastern Cape Province. These hydropower plants do not have the same function as the pumped storages, but all can generate hydro-energy within a few minutes contrary to the coal-fired energy generation plants, most of the located in one specific area of South Africa.

All installed PSSs are serving to the SA as the conventional energy storages supplementing hydro-energy to the national grid in the specific times of the high demand for electricity. A PSS comprises two large water storages (typically two sizeable dam facilities), one lower and the other at the upper elevation providing usually for static head between 100 and 700 m. The choice of a location of a PSS is depending on the availability of fresh or saline water (if a plant is located on the sea coastline) and a suitable geo-morphological configuration. However, a PSS requires certain amount of energy for pumping of raw water to the upper storage which is effectively a battery of energy ready to be utilized when needed. The requirements for essentially two storage reservoirs (on an ocean coast not absolute necessity) and associated pumping and generation infrastructure together with typically large penstocks (i.e. connecting pipeline between lower and upper storages), dictate for rather extensive initial capital costs, but ongoing benefits outweigh typically the capital invested.

There are four large PPSs operating currently around in South Africa, with the Steenbras (180 MW) being the municipal asset of the City of Cape Town, and other three plants are owned by the national entity Eskom SOC namely the Drakensberg (1000 MW), Palmiet (400 MW) and now new Ingula (1 330 MW). Since early 1980 the Drakensberg PSS has been for many years listed amongst the top twenty PSSs globally installed, sharing fifteenth place for many years with another 1000 MW PSS capacity installed in Iran.

In recent twenty years the capacity of pumped storages increased several fold with China having now some 23 100 MW installed (accounting only for the PSSs above or equal to 1000 MW), with another 6600 MW under construction. The USA with some total installed pumped storage capacity of 14 800 MW at present, identified another 40 viable sites to be developed, primarily at existing lower dam to economize on the costs and optimising on utilisation of infrastructure assets and water resources. The tendency worldwide is to develop PSSs in conjunction with a development of other renewable resources as wind and solar PV. The coastline PSS locations are investigated in several countries as well as at several island locations to avoid the costs of the lower dam storage, using the saline water and other renewable in pumping. The examples which can given are: first PSS using saline water in Okinawa, Japan; seawater PSS on the Isle of Lewis in Outer Hebrides, Scotland; a hybrid hydro-wind PSS on Canary Islands; etc.

Table 1: The position of SA's PSSs amongst other installations of the same kind

Ranking amongst other PSSs	Pumped Storage Scheme (PSS)	Installed capacity (MW)	Country of installation location
1	Bath Country	3003	USA
2	Huizhou	2448	China
3	Guangdong	2400	China
4	Okutataragi	1932	Japan
5	Ludington	1872	USA
6	Tianhuangping	1836	China
7	Tumut-3	1800	Australia
8	Grand Maison Dam	1800	France
9	La Muela II	1772	Spain
10	Dinorwig	1728	United Kingdom
USA (1652 MW), Taiwan (1602 MW), Japan (1600 MW), USA (1566 MW), China (1500), Japan (1500 MW), Bulgaria (1455 MW), India (1450 MW) : *See Wikipedia 2017*			
19	Ingula	1332	South Africa
Between SA's Ingula and Drakensberg pumped storages (accounting for the PSSs above or equal to 1000 MW), China has installed pumped storage capacity of some 10 900 MW and another 4 000 MW capacity is listed after the Drakensberg PSS)			
57	Drakensberg	1000	South Africa
NB: There are eight PSSs under construction at present, with Fenguing PSS in China with capacity to be installed at 3600 MW to be the largest in the world when completed.			

It is estimated that the overall pumped storage capacity worldwide is at present some 165 000 MW with China leading the development. The development of pumped storages on the African continent is presently far behind, with South Africa leading at present with a 2910 MW of PSS capacity installed.

History of development and key parameters of existing PSSs in South Africa

The South Africa's hydro-electricity generation sector has a legacy of almost fifty years since early 1970 when the Gariep Hydro had been commissioned at the large dam on the Orange River. The sector benefited (now already for some 35 years), besides generating hydro-electricity from a few conventional hydropower plants owned and administered together between the Department of Water and Sanitation (DWS) and Eskom also for its energy storage and a peak supplementary supply from the country's existing pumped storage schemes (PSS). Eskom together with the DWS generate hydroelectricity from several conventional hydroelectric plants, two situated on the Orange River and others attached to the dams on the perennial rivers in the Eastern Cape Province. These hydropower plants do not have the same function as the pumped storages, but all can generate hydro-energy within a few minutes contrary to the coal-fired energy generation plants and even the nuclear energy generation.

Table 2: The hydro-electricity generation installations in South Africa

Hydroelectric plant	Location, river or town (province)	Owner/administrator/ operator	Installed capacity (MW)
Ncora	Ncora River (E. Cape)	Eskom	2
First Falls	Umtata River (E. Cape)	Eskom	6
Second Falls	Umtata River (E.Cape)	Eskom	11
Colley Wobbles	Mbashe River (E. Cape)	Eskom	42
Vanderkloof	Orange River (N. Cape)	DWS/Eskom	240
Gariep	Orange River (N. Cape)	DWS/Eskom	360
Steenbras PSS	Cape Town (W. Cape)	City of Cape Town	180
Drakensberg PSS	Bergville (KZulu-Natal)	DWS/Eskom	1000
Palmiet PSS	Grabow (W. Cape)	DWS/Eskom	400
Ingula PSS	Van Reenen (KZulu-Natal)	DWS/Escom	1332
NB: There several hydro-electric schemes of significance (e.g. Stortemelk, Neusberg, etc.) connected recently to the national grid developed under the DoE's REI4Ps and owned by the IPPs.			

Steenbras pumped storage scheme – The installation is located some 60 km from Cape Town at the foothill of the Sir Lowry's Pass. The planning and design processes had taken six years. It is a first PSS installed in South Africa and also the first on the African continent. The Steenbras Power Station (180 MW) is owned and operated by the City of Cape Town and it is in operation since 1979. The scheme comprises upper dam storage with water run to the lower dam through turbines coupled to generators. The hydro-electricity generated is absorbed into the local (municipal) grid. Two dam storages at different elevations of some 300 m are connected by a low pressure tunnel installed through the mountain range connected to the high pressure tunnel connected to a steel penstock of 3,5 m in diameter. Most of the penstock is buried below the ground to reduce the environmental impacts.

Four 45 MW pump/turbine machines are located in pairs, each pair situated at the bottom of a shaft 40 m deep to provide for necessary minimum submergence when pumping 27 m below the surface of the lower storage dam. The transient pressure effects (e.g. water hammer and surges) caused while changing from pumping to generating modes are compensated through the surge shaft situated at the end of the low pressure tunnel. The maximum water flow when generating is 75 m^3/sec, if all four turbines operating at the same time. Water can be pumped back to the upper storage at the rate 60 m^3/sec and it will take 12 hours to fill the upper dam.

The Steenbras PSS is serving in reducing the peak loads of the metropolitan electricity supply system. The generation output is automatically controlled so as to maintain the Eskom power in-feed to the CT Metro constantly at a predetermined monthly target demand. This way the PSS serves to the CT City for almost 40 years for the initial investment cost of R 60-million in 1979.

As far as critical maintenance is concerned, the steel pipe of penstock was refurbished with new epoxy lining after some 18 years in operation. The hydraulic machines have been subjected to extensive refurbishment due to wear and tear between 1990 and 1996.

Drakensberg pumped storage scheme – The scheme is situated between the foothill and upper plateau of the lower Drakensberg with the upper storage in the Free State and lower storage in the KwaZulu-Natal provinces of South Africa. This is the first large PSS in SA installed in collaboration between the Eskom and DWS. The PSS has a dual purpose. The primary purpose is to generate hydro-energy when Eskom is experiencing the peak demands within the national electricity grid. The second very important purpose is to supplement the water collected in the KwaZulu-Natal by the system of canals, weirs and dams for the inter-basin water transfer to Sterkfontein Dam impoundment which is an integral component of the Thukela-Vaal Water transfer Scheme (WTS), one of the largest and most complex in SA.

The original WTS was completed in 1979 without of the PSS. Subsequently, Eskom together with DWS redesigned the original pumping component of the Thugela-Vaal WTS, replacing the Jagersrust pumping station and adjacent feeding canals to Sterkfontein Dam with the underground pumped storage system and installing 27-million m^3 Driekloof Dam situated at the very upper reaches of the Sterkfontein Dam. The Drakensberg PSS was commissioned in 1982 comprising extensive underground excavations of tunnels, halls, chambers and shafts. The machine hall contains four 250 MW reversible turbine/generator units. The vertical surge shaft of 14 m in diameter is excavated to a height of 86 m above the headrace tunnels.

During the generating mode water is drawn from the upper located storage of the Driekloof Dam situated in the Sterkfontein Dam and discharged into the lower 29-million m^3 Kilburn Dam located at the bottom of the escarpment. The Driekloof Dam is pumped full, mainly during the nights (at the low demand periods) with certain amount of water overflowing into the Sterkfontein Dam to supplement the key stand-by storage of the T-V WTS. When a pumping rate head is 71 m^3/sec, it takes about 35 hours to pump the Driekloof Dam full against 41l m net head. The original type of cycle operation is weekly and the cycle efficiency of about 73%.

According to Moodley (2002) the operation and maintenance processes at the Drakensberg PSS started to be hampered around 1995 (i.e. after some 13 years in operation) by repeated failures of the plant's excitation control system causing significant production and rehabilitation losses. An refurbishment project was implemented between 1999 and 2001, which restored the installation's excitation control system to near-100 percent reliability. At present three of four Drakensberg generator units are being modernized by a contractor from overseas, to be fully operational in 2018.

Palmiet pumped storage scheme – The 400 MW pumped storage scheme is an integral to the Palmiet River GWS situated near Grabow in the Western Cape Province. The scheme has also dual purpose similar as the Drakensberg PSS, providing for the generation of hydro-energy between the upper 17-million m^3 Rockview Dam and lower 15-million m^3 Kogelberg Dam storages and supplementing water to nearby Steenbras Dam PSS reservoir. The overspill water from the Rockview Dam is to supply the water supply system of Cape Town Metropolis. This is then also an inter-basin water transfer scheme. The scheme has been developed jointly by Eskom and DWS and commissioned in 1988 after some 5 years of construction predominantly within the Kogelberg Nature Reserve.

The connecting conduit between upper and lower dam comprises a headrace tunnel, which is 750 m long and 6,2 m in diameter. Water flows through a 130 m deep shaft to a pressure tunnel of 482 m long and 5,4 m in diameter and reaching subsequently cut-and-cover steel penstock, 561 m long and 5,4 m in diameter. Two reversible 200 MW pump/generator units are housed on the right bank of the Kogelberg River. From the operation point of view, the time required to pump 15-million m^3 is about 40 hours. The original type of operational cycle is weekly with the cycle efficiency of some 78%.

The International Hydropower Association (IHA) awarded to the Palmiet PSS its 2003 Blue Planet Prize for a contribution to sustainable development and good practice in utilising hydropower resources.

Ingula pumped storage scheme – This scheme is situated not very far from the Drakensberg PSS and is also located between lower Drakensberg plateau and its foothills some 23 km from Van Reenen Pass. The upper 19-million m^3 Bedford Dam and lower 22-million m^3 Braamhoek Dam are situated at some 470 m difference in elevation. The dams are connected by a system of underground waterways with a powerhouse hall housing four reversible 333 MW pump/turbine units. Two 6,1 m in diameter inclined headrace tunnels, each 1940 m long provide for the flow of water to the turbine/generator units. The underground system comprises twin surge chambers, twin extended draft tubes and a single tailrace tunnel.

The upper storage dam can be pumped by all four units within 21 hours and is designed to provide for 16 hours of generation. The overall efficiency of the scheme is determined at 76%.

The Ingula PSS installation has been finalized in the middle of 2016 after some ten years under construction. Eskom synchronised Unit 1 with the national grid in June 2016. The pumped storage peaking capacity in South Africa has thus increased by 333 MW to present operational 1733 MW. The full connection to the national grid, by remaining 1000 MW, is anticipated by late 2017 or early 2018 when all units will be synchronised with the national grid.

The cost of this PSS amounted to-date to R25-billion, increased from the original estimate by at least R7-billion.

According to the technical paper by Otieno, et al (2017) discusses the likely attack of soft water on the Ingula's concrete tunnel lining. Numerous samples were laboratory tested. The samples tested indicating possible reduction of tunnel system efficiency by about 3% down to about 93% over some ten years of water tunnels in operation. The results are a warning that in years to come the water conduit tunnels will have to be likely relined to maintain the integrity of tunnel infrastructure and required efficiencies.

As-built characteristics and parameters of pumped storage schemes in South Africa

The characteristics and essential parameters gathered from as-built PSSs in South Africa together with the time series of PSSs outputs since installation of the Drakensberg PSS in the early 1980 are summarized in the following tables:

Table 3: Summary on civil details of PSS installations in South Africa

Name of PSS (owner)	**Installed capacity (MW)**	**Names of PSS upper and lower reservoir**	**Active storage (10^6 m^3)**	**Type of upper and lower storage dam walls**	**Purpose of PSS installation**
Steenbras (CTCC)	**180**	Upper Steenbras	31	Earth-fill embkmt. wall	Power gen. & water transfer
		Steenbras (lower)	3	Earth-fill embkmt. wall	
Drakensberg (Eskom)	**1000**	Driekloof (upper)	27	Rock-fill embkmt wall	Power gen. & water transfer
		Kilburn (lower)	29	Earth-fill embkmt wall	
Palmiet (Eskom)	**400**	Rockview (upper)	17	Rock-fill with clay core	Power gen. & water transfer
		Kogelberg (lower)	15	Concrete gravity arch	
Ingula (Eskom)	**1332**	Bedford (upper)	22	Concrete faced rock-fill	Power generation
		Bramhoek (lower)	26	Rollcrete gravity wall	
Sources of info: Generated from various public domain documentation available at the ESKOM, Cape Town City Council (CTCC), SA Institution of Civil Engineers (SAICE) and Dept. of Water and Sanitation (DWS).					

The energy generation sector in SA represented by the Department of Energy and executed by the Eskom recognises the advantages in having hydro-pumped storages as the energy storage provision, a stand-by and peaking generation facilities to some 40 000 MW base-load thermal (coal-fired) plants (ten plants are in operation at present, three plants are return-to-service and two new plants are being build). It takes a hydro-pumped storage plant two to three seconds of a hydraulic starting time and some 15 seconds to get into full load production. The PSSs are still to date the most efficient storages (i.e. batteries) of energy. Table 4 below illustrates the details on pumping/generating equipment for existing plants and the newly developed Ingula PSS.

Table 4: Summary on pumping/generating machinery of existing PSS installations in SA

Name and (owner) of PSS	**Total peaking capacity (MW)**	**Average gen. head (m)**	**Pump/turbine unit flow rates (m^3/sec)**	**Type of reversible unit**	**Year of plant commission**
Steenbras (CTCC)	4 units at 45 MW = **180**	286	15/19	Francis pump/turbine	1979
Drakensberg (Eskom)	4 units at 250 MW = **1000**	430	55/78	Francis Pump/turbine	1982
Palmiet (Eskom)	2 units at 200 MW = **400**	265	45/70	Single stage Francis p/turbine	1987
Ingula (Eskom)	4 units at 333 MW = **1332**	450	67/85	Francis pump/turbine	Unit 1 in 2016
NB: Very little information is available on the maintenance of particularly the PSSs belong to Eskom.					

From the analysis of the characteristics and as-built parameters of the PSSs developed to-date in South Africa the general planning/design guidelines applied by the planners and designers adhered primarily to the following:

(i) A large PSS site should have a static head between 100 and 700 m.
(ii) A gradient of at least 1:10 between the upper and lower reservoirs is typically applied.
(iii) The assessment of water availability at selected site including water losses and evaporation is essential to establish.
(iv) To prevent cavitations to the pump/turbine assembly should be placed at least 25 m below the lower reservoir level.
(v) The viability of a PSS is depending on the land configuration and subsequent costs in developing the upper and lower reservoir.
(vi) Where a lower reservoir already exists, the priority is given to such a site, reducing thus the overall investment costs of a PSS.
(vii) The PSS installations are build in SA for the peaking loads and as the stand-by facilities to the coal-fired base load power plants.
(viii) Three of four PSS installations analysed are having a dual purpose – generating hydro-energy and providing for an inter-basin water transfer.
(ix) Due to environmental issues most, if not all, of a PSS infrastructure is buried and/or excavated underground.
(x) The key stakeholders in a development, O&M and upgrading of the PSSs are the Department of Water and Sanitation, Department of Energy and the national electricity supplier Eskom.

Ntsone, et al (2016) established that Eskom is finding difficult to cope with the demands for electricity, which are notoriously outstripping (almost daily) the conventional supply options. The existing PSSs are to generate far more frequently than they were operationally designed for (i.e. weekly operational cycle). This implies that Eskom pumped storage installations are forced to change from a weekly balance to be balanced on a daily basis.

Table 5: The South African's power stations output between 1970 and 2016 (GWh)

Year	Coal fired stations	Nuclear station	Hydro-electric stations	Diesel & gas turbines	RE sources W + IPPs	Pumped storage stations	The commissioning date and capacity of the PSSs in SA
1969/70	37 321						
1970/71	40 645		94				
1971/72	43 662		813				
1972/73	49 570		189				
1973/74	55 141		1110				
1974/75	60 400		1098				
1975/76	64 309		1853	26			
1976/77	65 114		1924	12			
1977/78	69 004		1887	11			
1978/79	74 485		1144	14			**Steenbras (180 MW)**
1979/80	82 342		992	28			
1980/81	95 675		1653	81		**415**	**Drakensberg (1000 MW)**
1981/82	100 217		1016	17		1519	
1982/83	100 738		595	5		1957	
1983/84	110 094	3925	560	8		994	
1984/85	113 941	5315	624	0		2107	
1985/86	114 298	8803	1623	2		1785	
1986/87	122 947	6167	1617	2		**1774**	**Palmiet (400 MW)**
1987/88	123 777	10 493	3162	2		1403	
1988/89	128 304	11 099	2759	3		1039	
1989/90	134 744	8449	1010	3		1841	
1990/01	135 743	9144	1980	0		1804	
1991/02	136 830	9288	752	4		1333	
1992/03	145 514	7255	146	0		1345	
1993/04	148 003	9697	1074	2		1517	
1994/05	151 730	11 301	529	0		1274	
1995/06	163 541	11 775	1319	0		2220	
1996/07	170 464	12 647	2092	0		2608	
1997/08	165 473	13 601	1596	3		2420	
1998/09	165 665	12 837	726	0		2590	
1999/00	172 362	13 010	1343	1		2591	
2000/01	175 223	10 719	2061	0		1587	
2001/02	181 651	11 991	2357	0		1738	
2002/03	194 046	12 663	777	0		2732	
2003/04	202 171	14 280	720	0		2981	
2004/05	251 914	16 912	903	0	Wind + IPPs	3675	
2005/06	206 606	11 293	1141	78	3	2867**	
2006/07	215 211	11 780	2443	62	2	2947**	
2007/08	222 908	11 317	751	1153	1	2979**	
2008/09	211 941	13 004	1082	143	2	2772**	
2009/10	215 940	12 806	1274	49	1	2742**	
2010/11	220 219	12 099	1960	197	2 + 1833*	2953**	
2011/12	218 212	13 502	1904	709	2 + 4107*	2962**	
2012/13	214 807	11 954	1077	1904	1+ 3516*	3006**	
2013/14	209 483	14 106	1036	3621	2+ 3671*	2881**	
2014/15	204 838	13 794	851	3709	1+ 6022*	3107**	
2015/16	199 888	12 237	688	3936	311+ 9033*	2919**	**Ingula Unit 1 (332 MW)**
2016/17	200 893	15 026	579	29	345+11529*	3294**	
Notes: * The amount of GWh obtained from the IPPs. ** The amount of GWh required for pumping is on average about							

1000 GWh over above production (i.e. about 30 % on average). ***A PSS is a net consumer of energy.

Potential for future development of pumped storages in South Africa

Firmly evaluated potential for future development of PSSs

Now, after Ingula PSS peaking capacity (1332 MW) will go fully on a stream, the future development of another PSS in South Africa appears to be postponed until 2030. Eskom already between 1985 and 1995 identified several highly potential PSS sites around South Africa. Louwinger (2008) highlights that all selected sites were scrutinised according to the environmental, technical, economical and legal requirements. The next large PSSs to be developed by Eskom after Ingula PSS, were listed the Lima PSS (renamed to Tubatse PSS) and Mutale PSS.

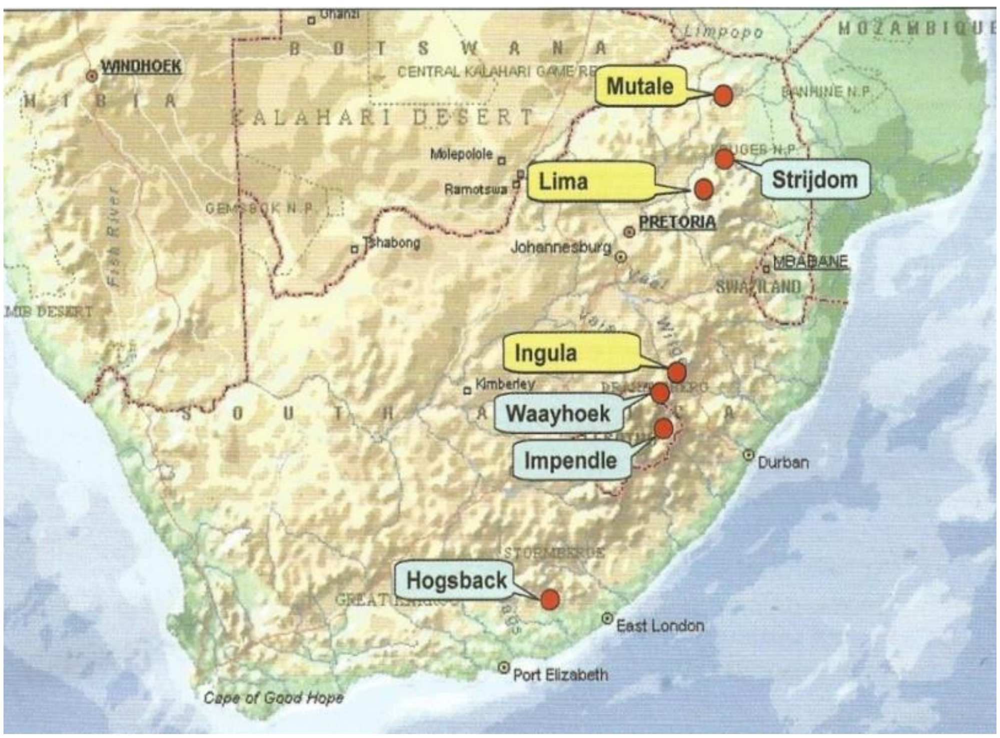

Fig. 1: Eskom long-term programme for development of viable pumped storages.

The layout in Fig. 1 above illustrates other six potential sites besides Ingula PSS suitable for future development. Most promising is a site named Lima (Tubatse) where it is needed only to develop an upper reservoir as the lower very large De Hoop Dam impoundment was commissioned in 2014. The purpose of this dam storage is to provide water for the residential/industrial use in the northern region of South Africa. As the water requirements of a PSS are non-consumptive, this scheme would be not impacting on the dam storage (only marginal evaporation losses at the upper reservoir) and can be likely build for some 25% less than the Ingula PSS, if implemented soon.

The development of Tubatse PSS (planned at 1500 MW capacity) has been detailed around 2008/09 and Eskom has been that far as applying for the generation license from NERSA. However, any development of this site has been put on a back-burner. In the meantime it is obvious that Eskom need more peaking capacity due to recent changes in generation patterns, connecting and receiving electricity amounts from several IPPs and grappling with reduced demands for electricity as the national economy is stagnating. See Table 5 for relevant patterns observed within energy generation mix operated by the Eskom.

Position of potential PSSs in future energy mix in SA

According to the SA's Integrated Resource Plan 2010 (IRP 2010-2030) and its recent revision, the country is contemplating to participate in developing of a hydropower installation at Inga Falls on the Congo River in the Democratic Republic of Congo (DRC). A capacity of a 2500 MW from the overall to be installed capacity at the Inga site is offered by the DRC to SA. In the local hydropower terms, this is a capacity termed as the "imported hydropower" which would be rather expensive to pay for and particularly maintaining transmission over very long distances as well as paying for the security of supply. There are vital issues needing more explanation from the socio-political platform.
Also, two coal-fired power stations (Kusile and Medupi) are nearing their completion, increasing the overall energy generation capacity of SA. These two plants are base-load installation as far a generation is concerned and their production is necessary to be supported by an additional peaking capacity, which should not come from by increasing the diesel and gas turbines generation.

Table 6: Energy mix generation capacity as per IRP 2010 to 2030.

Energy sources mix		*Final policy adjusted IRP 2010 to 2030		**New capacity layout introduced/revised	
		MW	%	MW	%
Hydrocarbon Resources	Coal	16 383	29,0	6250	14,7
	OCGT (diesel)	4930	8,7	3910	9,2
	CCGT (gas)	2370	4,2	2370	5,6
Alternative Resources	**Pumped storages (PSSs)**	**1332**	**2,4**	**-**	**-**
	Nuclear	9600	17,0	9600	22,6
	Imported hydropower	2659	4,7	2609	6,1
Renewable Energy Resources	Wind	9200	16,3	8400	19,7
	CSP	1200	2,1	1000	2,4
	PV	8400	14,8	8400	19,7
	SHP, biomass, landfill, etc.	465	0,8	-	-
Total		56 539	100	42 539	100
Source: *IRP 2010 (May 2011), ** Uncommitted in 2015, SHP = Small Hydro Power					

As illustrated in Table 6 above, the group of Alternatives – PSSs lists the capacity of 1332 MW which represents the Ingula PSS capacity now already installed. No further PSS capacity is listed in the New Capacity Layout and the Draft Revision 2016 of the IRP 2010 also does not indicate any PSS capacity to be developed before 2030.

The prospects in development of small scale pumped storages with other renewable

South Africa is blessed with rather extensive water supply infrastructure developed over the years in both the urban and rural context. There are several viable opportunities in developing small scale pumped storages together with other renewable energy resources and technologies (i.e. primarily PV-solar in SA). The suitable technologies are now on the market and prices becoming affordable to the municipalities and even to the rural communities, if eligible for the subsidies or grants.

Most suitable location for a small scale pumped storage within a water supply system would be already existing elevated concrete reservoir, where only a lower another concrete/steel reservoir is needed to be installed (i.e. if the potable water supply is going to be involved). The research has been done particularly in Europe and several suitable sites selected. Table 7 given below illustrates a theoretical sizing for a small scale pumped storages of 2, 5, and 10 MW.

Table 7: Examples of the small scale pumped storages within existing water supply system

Item of pumped storage scheme	Size of pump as turbine (PaT)		
	2 MW	5 MW	10 MW
Rate of flow in PaT (m^3/sec)	0,809	2,023	4,046
Pipeline size (mm)	700	1000	1200
Friction head of pipeline : steel material	7,2 m	9,5 m	14,4 m
Friction head of pipeline (fibre glass option with length of 1200 m)	4,0 m	5,3 m	8,0 m
Capacity of reservoirs (m^3)	20 000	40 000	80 000
NB: The PaT's pumping demand can be connected to the PV-solar systems.			

At present there is no any small scale pumped storage system installed in South Africa. However, the installation of pumps as turbines is now tested at the Annlin Reservoir by the Tshwane Metropolitan Municipality in Pretoria.

The prospects in development of PSS in Lesotho

Lesotho has already a 72 MW hydro-electric scheme installed at the Muela Dam situated at the Katse Tunnel Outlet as a component of the LHWP Phase 1.

LHWC together with the local consultants are conducting a master plan study of the Kobong (or Monont'sa) 1200 MW pumped storage scheme. The selected site in close proximity of the Katse Dam impoundment offers max gross head of 600 m. Existing Katse Dam impoundment is the location of the lower reservoir and only upper dam storage will need to be installed.

Conclusion

- A pumped storage scheme is effectively a large energy storage battery, energy is stored in the form of water during off-peak periods and released during the peak electricity demands,
- A PSS using reversible pump/turbine assembly is so far most effective way to store electrical energy at acceptable costs,
- A PSS is the source of energy that can deliver positive or negative reserve to the grid for balancing intermittent resources such as wind and solar,
- A grid needs energy for rapid balancing the PSS can provide such, and
- new pumped storage installations benefit from the technological achievements of the recent past in the development of hydraulic and electrical machines and progresses in automatisation

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