OPPORTUNITIES FOR PUMPED STORAGE HYDROPOWER PLANTS IN KENYA: UTILIZING HIGH HEADS IN RIFT VALLEY

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PRESENTATION OUTLINE

- ✓INTRODUCTION
- ✓OBJECTIVES
- ✓DATA REVIEW, PRESENTATION AND ANALYSIS
- ✓DISCUSSION
- ✓CONCLUSION

1. INTRODUCTION – 1/7

- ✓What are Pumped Storage Hydropower Plants (PSHP)?
- ✓Why in the Rift Valley?
- ✓Austria, Germany, France, Italy, Liechtenstein, Monaco, Slovenia and Switzerland) have PSHP.
- ✓Prof. Christian Bauer, Dr. Edward Doujak and Dr. Philipp Unterger from Austria - PSHP have improved over 140 years.
- ✓First known hydro-mechanical pumped storage was developed in Zurich, Switzerland in year 1882.

1. INTRODUCTION CONTINUED-2/7

✓Twenty Benefits of Pumped Storage Hydropower Plants

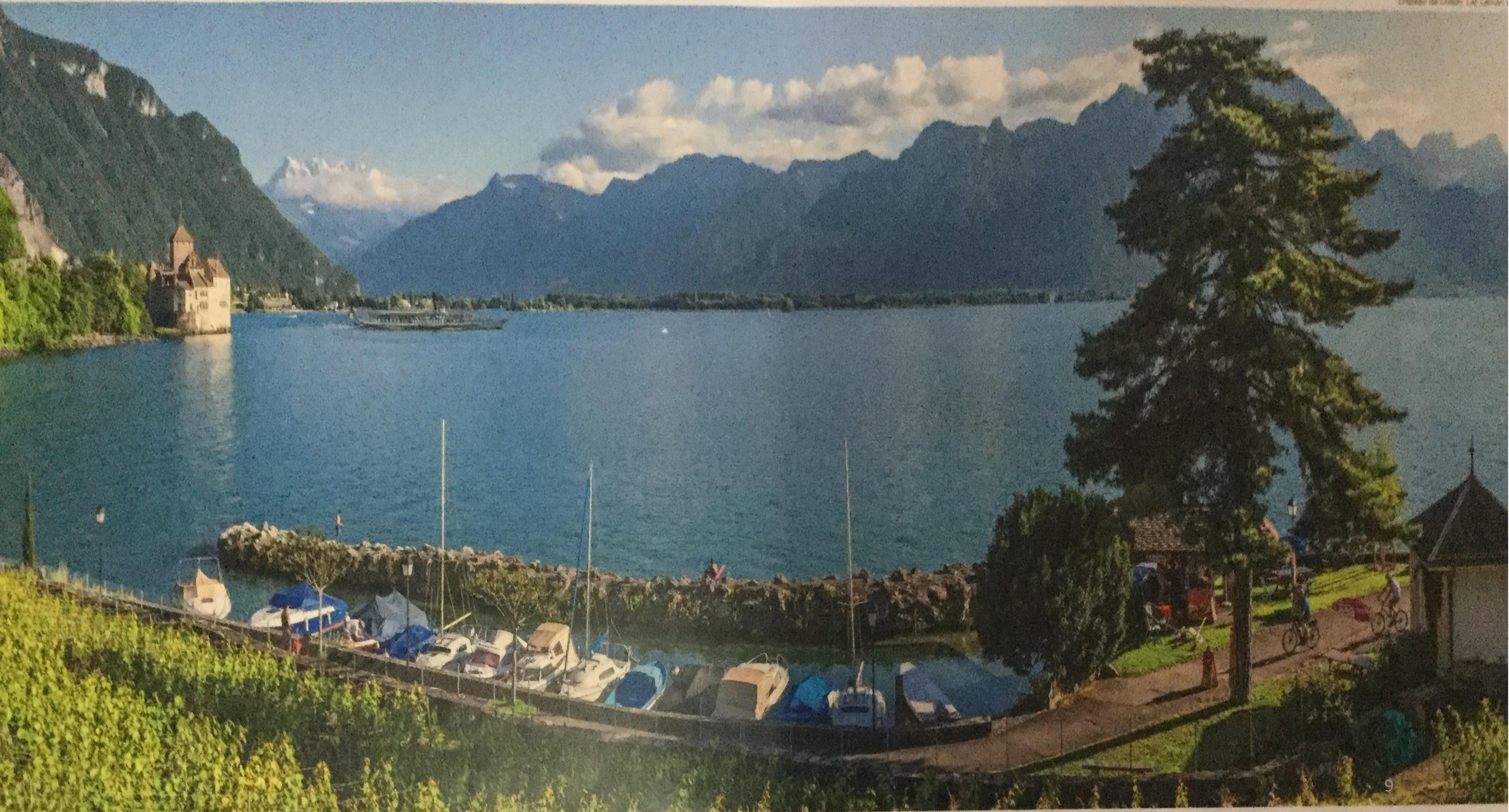
- ➢(1)Inertial response (2)Governor response/frequency responses/primary control
- ➢ (3) Frequency regulation/regulation reserve/secondary control (4) Flexibility reserve
- ➢(5) Contigency spinning reserve (6) Contigency non-spinning reserve
- ➢(7) Replacement/supplemental reserve (8) Load following

1. INTRODUCTION CONTINUED-3/7

- (9) Load levelling/energy arbitrage (10) Generating capacity
- (11) Reduced environmental emissions (12) Integration of variable energy resources (VERs),
- (13) Reduced cycling and ramping of thermal units, (14) Other portfolio effects
- (15) Reduced transmission congestion (16) Transmission deferral (17) Voltage support
- (18) Improved dynamic stability (19) Black start capability and (20) Energy Security [Koritarow et. al. of DOE-USA (Hydro 2014)]

1. INTRODUCTION CONTINUED-4/7

- ✓**The Rift Valley in Kenya has a topography similar to that of the Alps in Europe.**
- ✓ **This author visited Alps in October, 2016 during Hydro 2016 International Conference in Switzerland and France in April, 2018 during study tour of pumped storage hydropower.**
- ✓ **Visit to France was part of ongoing Feasibility Study of Pumped Storage Hydropower Plants in Kenya by Electricite de France funded by AFD (Agence Francaise de Developpement).**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2. OBJECTIVES

- ✓ Present and discuss **published** data on pumped storage hydropower plants (PSHP) in Alpine countries of Europe so as to demonstrate potential in the African Rift valley;
- ✓ Examine the **heads** in the PSHP in alpine countries and determine how they relate to those in the Africa Rift Valley;
- ✓ Examine the benefits of PSHP in national and regional power grids for integration of **intermittent** wind and solar power development;
- ✓ Make a case for **feasibility studies** on PSHP in the African Rift Valley.

3. DATA REVIEW, PRESENTATION AND ANALYSIS – 1/9

- ✓Next six slides show selected PSHP in Europe
- ✓Special focus is given to those in the Alps-blue
- ✓PSHP in Europe but not in the Alps-black

- ❑Hydropower and Dams Conference Papers from Hydro2004 to Hydro2017

- ❑Practical data from the French CIH (Centre for Hydropower Engineering), GE Laboratory for Turbine Modelling in Grenoble and study visits to pumped storage Hydro Plants in French Alps in April, 2018.

- ❑Practical data from EPFL (Ecole Polytechnique Federale de Lausanne) Hydraulic Laboratory (Switzerland) and study visits to pumped storage Hydro Plants in Swiss Alps in October, 2016 (Hydro 2016 International Conference).

No	Name of Power Plant (PSHP)	Rating in Megawatts (MW)	Country	Remarks (Blue colour shows PSHP in Alpine Countries)
1.	The Nant de Drance	900 (H=250 - 395m)	Switzerland	6 Units x 150MW Years 2008 – 2019 construction
2.	Veytaux II	240 (2 x 120MW) 240 (6 x 60MW)	,,	Veytaux I and Veytaux II
3.	Grimsel 1E and 2E	150 + 350 = 500MW (H= 83 – 197m)	Switzerland	Initially built 1928 – 1932 Grimsel 3 at 220MW temp. stopped in year 2014
4.	Linthal-Limmern	1480MW (H=1045m)	Switzerland	Developed in stages between 2009-2017
5.	FMHL- Forces Motrices Hongrin Leman	480MW (H=880m)	Switzerland	Developed in 1972 and upgraded in 2017

6.	Revin PSP	800 (H=228m)	France	4 Units – year 1976
7.	Grand Maison	1800MW (H= 918m)	France	1983
8.	Le Cheylas	480MW (H= 260m)	France	1979
9.	La Coche	320MW (H= 900m)	France	1983
10.	Endersee Hydropower Complex	Waldeck I-140MW, Waldeck II-440MW and Hemfurth – 20MW	Germany	1932 Germany has over 30 PSP with total of 6500MW as at 2016
11.	Goldisthal	1060	Germany	Turkey-Nest Type Dam Year 2004

12.	**Avce-Soca River**	**178/175 Gen/Pump**	**Slovenia**	**Turkey-Nest Type Dam Year 2009**
13.	**Nine sites studied for PSH on Drava River**	**N/A**	**Slovenia**	**Feasibility study completed for 9 sites in 2005**
14.	**Obervermuntwerk II**	**360**	**Austria**	**2 Units x 180MW Const. 2008 - 2018**
15.	**Kops II PSP**	**450MW**	**Austria**	**3 Units x 150MW Year 2008**
16.	**Limberg II**	**480MW**	**Austria**	**2012**
17.	**Foxi Murdegu**	**130/173 Gen/Pumping (H=350m)**	**Italy**	**Sea used as Lower reservoir for the SWPSHEPP**

18.	Coo-Trois-Ponts	1,164	Belgium	Turkey-Nest Type Dam
19.	Dlouhe Strane	650	Czech Republic	,,
20.	Turloug Hill	292	Ireland	,,
21.	Cortes-La Muela Hydropower Complex	1720/1280 Gen/Pump	Spain	In 1989 but upgraded in 2012 – 7 Units. Has a Turkey-Nest Type dam,La Muela II has 850MW/740MW (Gen/Pumping modes).
22.	Belesar III	215	Spain	Est. 2017
23.	Acqueva I	130 (H=45-73m)	Portugal	Year 2004 – 2 Units

24.	Acqueva II	130 (H=53 - 73m)	Portugal	Year 2012 – 2 Units
25.	Cruachan	123 (H=36.8m)	Scotland	Year 2001 – 2 Units
26.	Nygaard	52 (H=395m)	Norway	Year 2002 – 1 Unit
27.	Oeljusjoen	49.5 (H=215m)	Norway	Year 2006 – 1 Unit
28.	Kyviv	236 (H=72.7m)	Ukraine	6 Units
29.	Tashlyk	1396 (H=89.5m)	Ukraine	6 Units

30.	Dniester	2947 (H=161.9m)	Ukraine	Year 2009 - 7 Units Biggest PSH in Europe
31.	Kaniv	1120 (H=107m)	Ukraine	4 Units
32.	Chebren, Gagshte, Sretkovo, Mavrovo, Janche, Tashmarunishe and Demir Kapia PSHEPP in Macedonia	Total of 2820 MW from 7 PSP with average size of 200-800MW	Macedonia	Feasibility Study completed for 7 sites
33.	Pournari, Kastaraki, Sfikia, Kremasta, Assomata, Thissavros and Platanovryssi – 7 PSH in Greece	A total of 400MW from 7 sites of PSH-existing conventional HEPP in Greece 135MW to 11MW	Greece	Feasibility Study completed for the 7 sites for PSHEPP

3.1 FINDINGS FROM THE DATA REVIEW AND STUDY VISITS OF PSHP IN SWISS ALPS (OCT, 2016) AND FRENCH ALPS (APRIL, 2018) - 8/9

- Items 1 to 17 show PSHP in Alps of Europe have higher ratings
- EDF and EPFL confirmed ratio of length of Headrace to Net Head (L/H) in PSHP inversely affects viability
- Ratios (L/H) < 5 are better those > 10
- Heads >500m quite attractive
- Power = Head X Flow X Density X Gravitational force X Efficiency

3.1 FINDINGS FROM THE DATA REVIEW AND STUDY VISITS OF PSHP IN SWISS ALPS (OCT, 2016) AND FRENCH ALPS (APRIL, 2018) – Cont’d – 9/9

- ✓Sites in Rift Valley e.g Arror HPP have heads > 1000m.
- ✓ Apart from high heads in Rift Valley, there exist also several sources of water.
- ✓ R**ivers like Kerio**, **geothermal brine** and **seven natural lakes** (Turkana, Baringo, Bogoria, Nakuru, Elementeita, Naivasha and Magadi).
- ✓ From these sources, artificial water basins can be developed at high altitude sites for PSHP.

4. DISCUSSION- 1/2

- ✓Requirements for PSHP - availability of safe reserve margin in grid connected power.
- ✓Peak demand was 1802MW (6^{th} June,2018).
- ✓ Installed capacity of 2300MW gives 500MW reserve margin
- ✓Geothermal power 672MW and hydropower 820MW
- ✓Base load and peaking respectively.
- ✓Special tariff (time of use tariff) can be designed to enable PSHP utilize the “excess” geothermal power.

4. DISCUSSION Cont'd – 2/2

- ✓Wind power 335MW in Kenya (14% of installed capacity)
- ✓ Solar power (55MW) growing at fast rate
- ✓Used for pumping when available in the grid
- ✓ In special case of Geo-hydro innovation, **geothermal brine** used in PSHP projects.
- ✓ Seven lakes in the Rift Valley can also be used as sources of water for PSHP.

5. CONCLUSION

- ✓**While it is true that high heads greater than 500m in Rift Valley of Kenya have potential for pumped storage power plants as discussed in this paper using examples from Alpine countries of Europe, there is need to professionally establish actual (bankable) viability (business case) of the potential in terms of technical, economic, financial, environmental and regulatory aspects plus an appropriate implementation strategy/model.**
- ✓**To achieve this, Government of Kenya is doing a study on Pumped Storage Hydro for Kenya this year, 2018 (March- October) with the help of experts from Electricite de France (EDF) funded by AFD and KenGen is the implementing agency for the study. This author is head of KenGen Energy Planning Section that is directly involved in the study.**