Towards a solar-hydro based generation: The case of Switzerland

UNIL | Université de Lausanne
HEC Lausanne

J.E. Martinez-Jaramillo, A. van Ackere & E. R. Larsen

Abstract

Switzerland has voted for a gradual nuclear phase-out, starting in 2019 with the decommissioning of a first nuclear reactor; however, there is still a debate about how the country will replace nuclear generation. Electricity markets are transitioning towards renewable sources such as hydro, wind and solar. The latter two could produce a mismatch between demand and supply. Combining renewables with storage is one way to address this challenge. This paper analyzes the feasibility of 100% renewable generation in Switzerland. We consider hydro and PV generation, combined with pumped hydro storage, to address the timing problem between demand and PV generation. We explore several combinations of PV, reservoir levels and pumping capacity. Our findings indicate that Switzerland would need to double its pumping capacity and increase solar generation capacity by up to a factor between 13 and 25, while increasing reservoir size up to 100% depending on the installed PV.

Aim: Feasibility of a 100% renewable electricity system

Introduction

Annual demand: 62.6 TWh
Peak hourly demand: 8.3 GWh

Installed capacity: 19.9 GW
- 17% Nuclear
- 75% Hydro
- 8% other sources

Context
Pressure to reduce greenhouse emissions

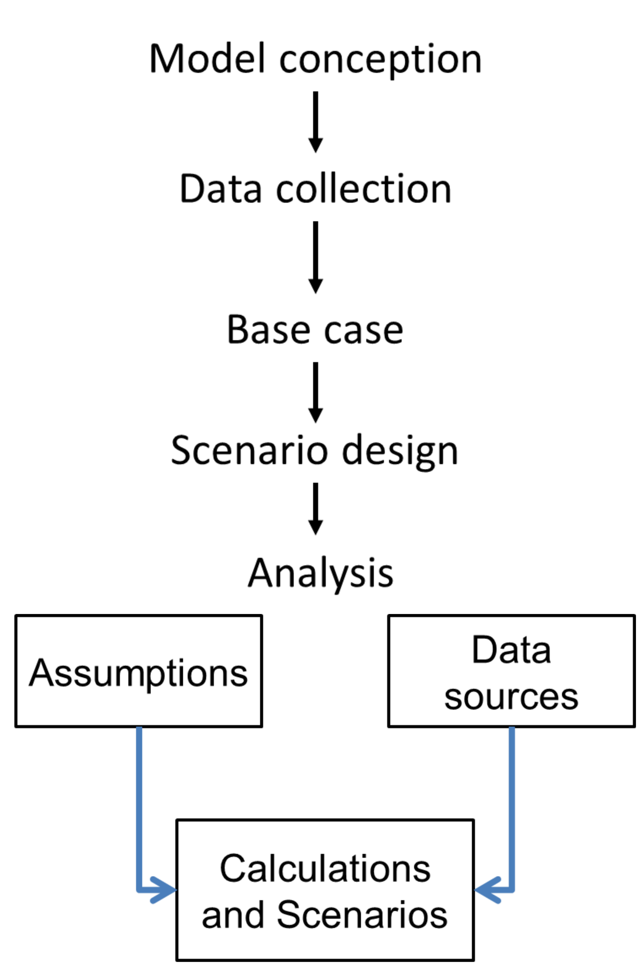
Nuclear plants will be dismantled over the next 25 years

Goal
100% renewable electricity system

Observation
Energy storage is likely to become a corner stone of VRES penetration

Method

DATA ANALYSIS

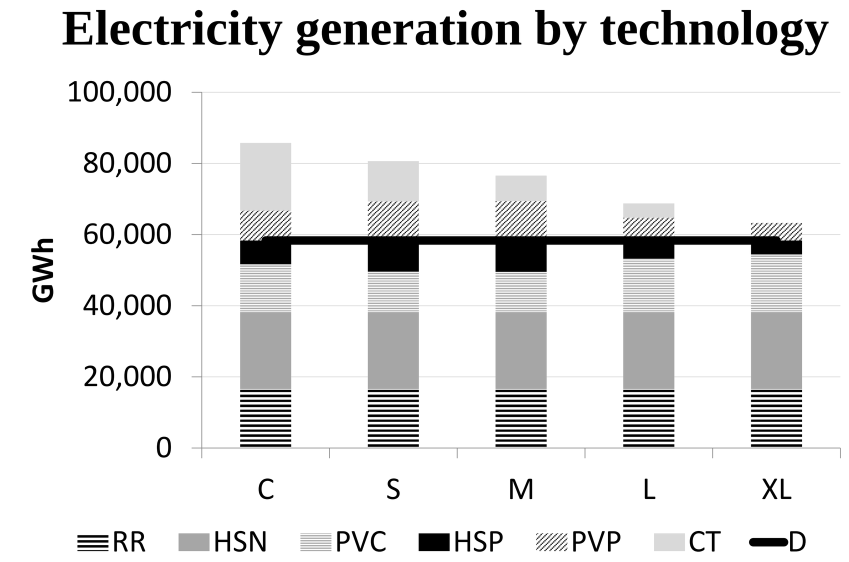


$$G = RR + HS^n + HS^p + PV^c + PV^p$$

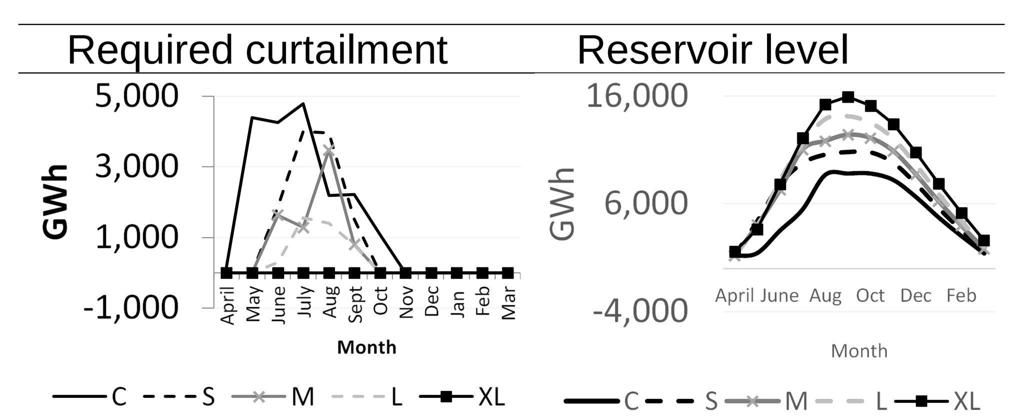
G: generation; RR: Run-of-Rivers; HS: Hydro-storage; PV: photovoltaics
n: natural inflows; p: pumped; c: consumed

Results

Electricity generation by technology



Required curtailment and reservoir level



Scenarios

5 scenarios depending on the reservoir size

Scenario	Reservoir size (GWh)	PV (GW)	Pumping capacity (GW)	Required curtailment or exports (GW)
Current (C)	8,800	43.0	16.0	19,078
Small (S)	10,600	36.0	13.0	11,350
Medium (M)	12,400	31.6	9.0	7,203
Large (L)	14,200	26.7	5.0	4,037
Extra Large (XL)	16,000	23.1	3.9	0

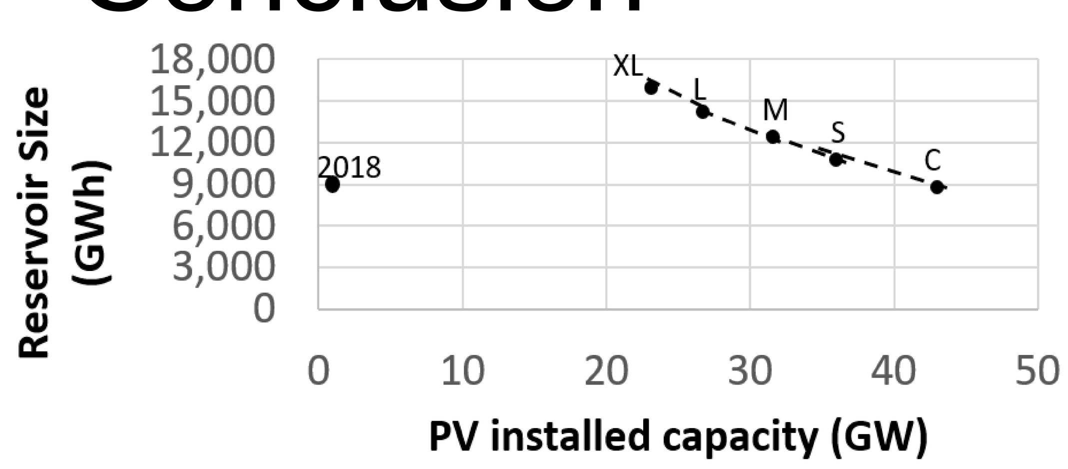
Electricity balance (GWh)

Case	C	S	M	L	XL
I^-R^-	12,450	6,291	2,051	-1,500	-8,000
I^-	16,300	9,500	5,400	1,494	-4,800
R^-	14,300	9,014	5,560	1,980	-2,350
I^0R^0	*19,078*	*12,000*	*7,203*	*3,800*	*0*
I^+R^-	17,215	10,792	7,418	4,200	900
I^-R^+	20,500	12,714	7,561	2,830	-600
PNG I^0R^0	77,420	69,690	65,546	63,380	58,343

Sensitivity analysis

natural inflows (I)
sun radiation (R)

Conclusion



It is theoretically possible to move to 100% renewable generation by relying on hydro, PV and pumping.

Scenario XL: Twice the current reservoir size, while PV capacity should increase by a factor of 13.
Scenario C: Current reservoir size, PV capacity must increase by a factor of 25.

The smaller the reservoir size, the larger the need for curtailment.

Sensitivity analysis: 12 cases with blackouts which includes 7 cases where there is enough generation on an annual basis but it cannot be delivered at the right time.

Aknowledgement
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Contact us
J.E. Martinez-Jaramillo: jmartine1@unil.ch A. van Ackere: ann.vanackere@unil.ch E.R. Larsen: erik.larsen@mgmt.au.dk