A pragmatic approach to assess the climate resilience of hydro projects

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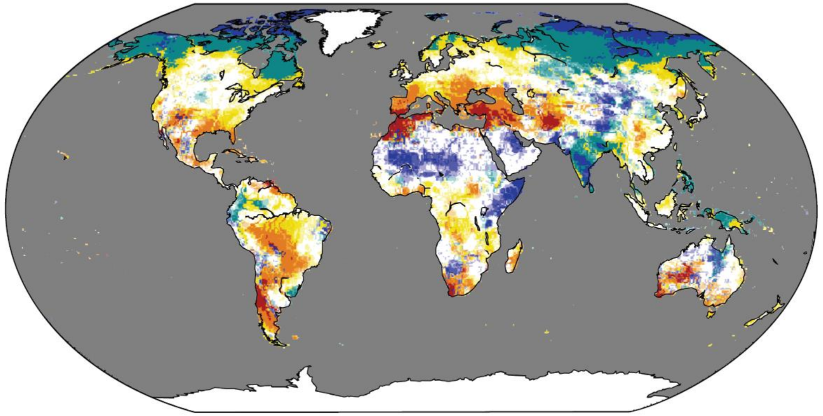
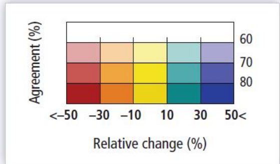
Background

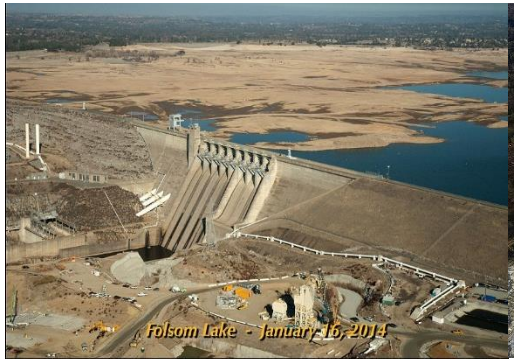
- There is little doubt that **climate change** will have a profound impact on the distribution and availability of water resources concerning both **average** and **extreme events** (IPCC).

- Therefore, the prospect of climate change and **climate resilience** has become a key issue for the dam and reservoir design, operation and safety community.





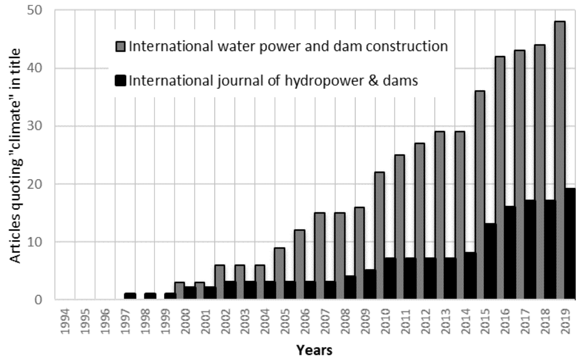
Change in mean annual runoff for a +2°C increase in global average temperature (Schewe et al, 2013)



source: California Dpt. of Water Resources

Increasing Awareness and Actions

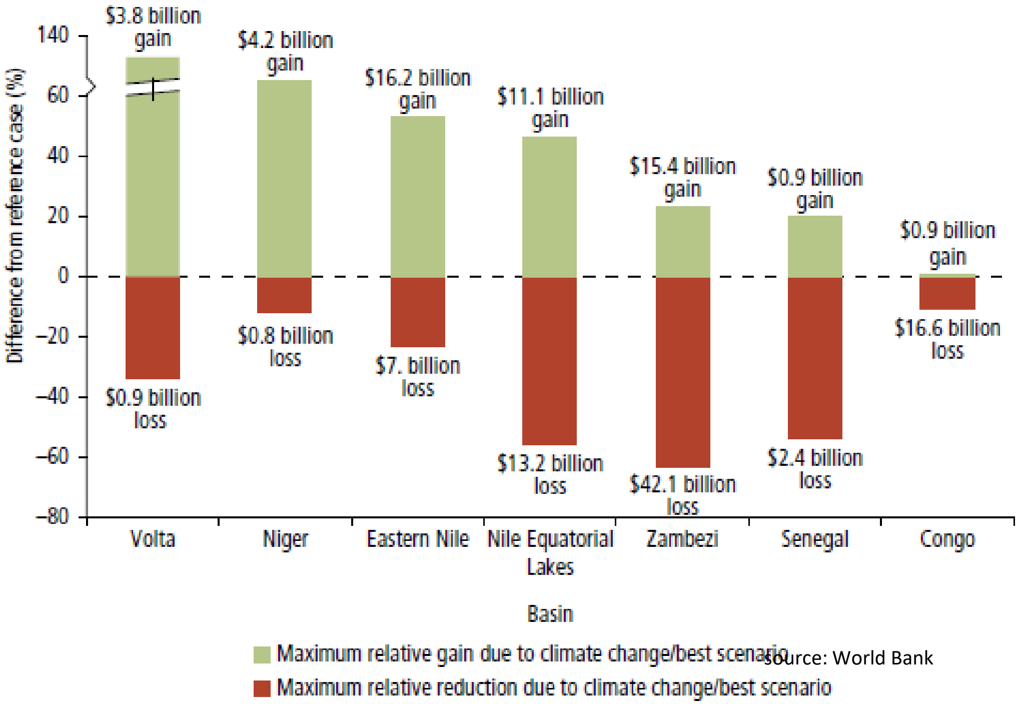
- ICOLD Bulletin 168 Climate Change, Dams, Reservoirs and Associated Water resources (2016)
- Hydropower Sector Climate Resilience Guide (IHA, 2019)
- Climate Impacts on Africa Hydropower (IEA, 2020)
- Papers in professional journals (and scientific papers)
- Theme in conferences (ICOLD Q.96 & 97 (2015), Q.107 *Dams and Climate Change* (2022))
- Terms of Reference for Consultancy services
- Climate Change Risk Assessment (CCRA) ordered by Donors, Banks, Developers and Owners/Operators
  - Climate Vulnerability of Hydropower sector in Ivory Coast (AFD) or Cameroon (World Bank)
  - Cahora Bassa Hydropower plant in Mozambique
  - Neskra HPP Project in Georgia/ Volobe HPP Project in Madagascar



Impacts on Dams & Reservoirs: Performance and Safety

- **Regional variability** (inflow regime dominated by snowmelt ≠ seasonal monsoon ≠ semi-arid to arid)
- Negative impacts on hydropower generation in North Africa, Congo and Zambezi River Basins but possibly positive impacts in Nile River Basin - Climate Impacts on Africa Hydropower (IEA, 2020)
- Van Vliet et al. (2017) in Nature Climate Change show "reductions in usable capacity for 61–74% of the hydropower plants worldwide"
- Climate change is a « **threat multiplier** » for extreme (flood) events: cyclones, heavy rainfalls, GLOFs, LDOFs

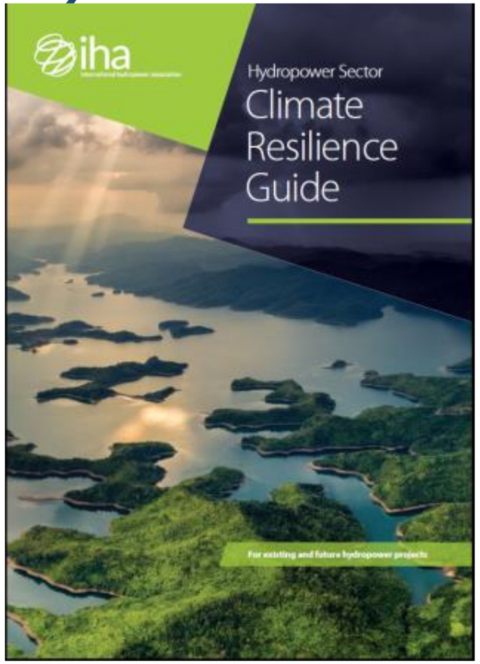
Figure 0.4 Changes in Hydropower Revenues from Climate Change, 2015–50
(Present value)

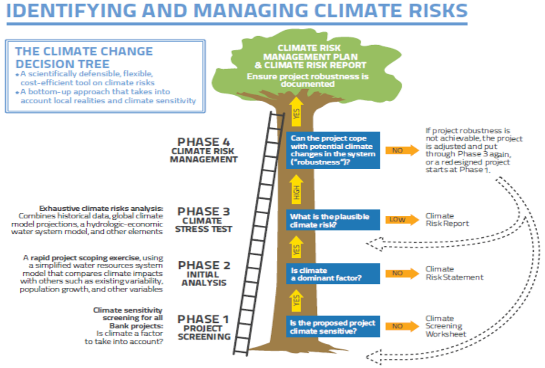


Source: World Bank

Impacts on Dams & Reservoirs: Performance and Safety

- **« [Climate] stationnarity is dead** » -> the common approach assuming that the past hydrological conditions are also representative for the project's lifetime should now be discarded - Future is **uncertain**
- New engineering challenge: plan and design **robust infrastructure**
- IHA Guide
- **Decision Management under Uncertainty**
- Principles and Framework (Decision Tree Framework)
  - Applicability to any type and scale of hydropower project
  - Suitable for both existing and future hydropower projects
  - Adaptable to single and cascade projects
  - Relevant to any geography
  - Aligned to the hydropower project's functions
  - Compatible with all data availability and quality

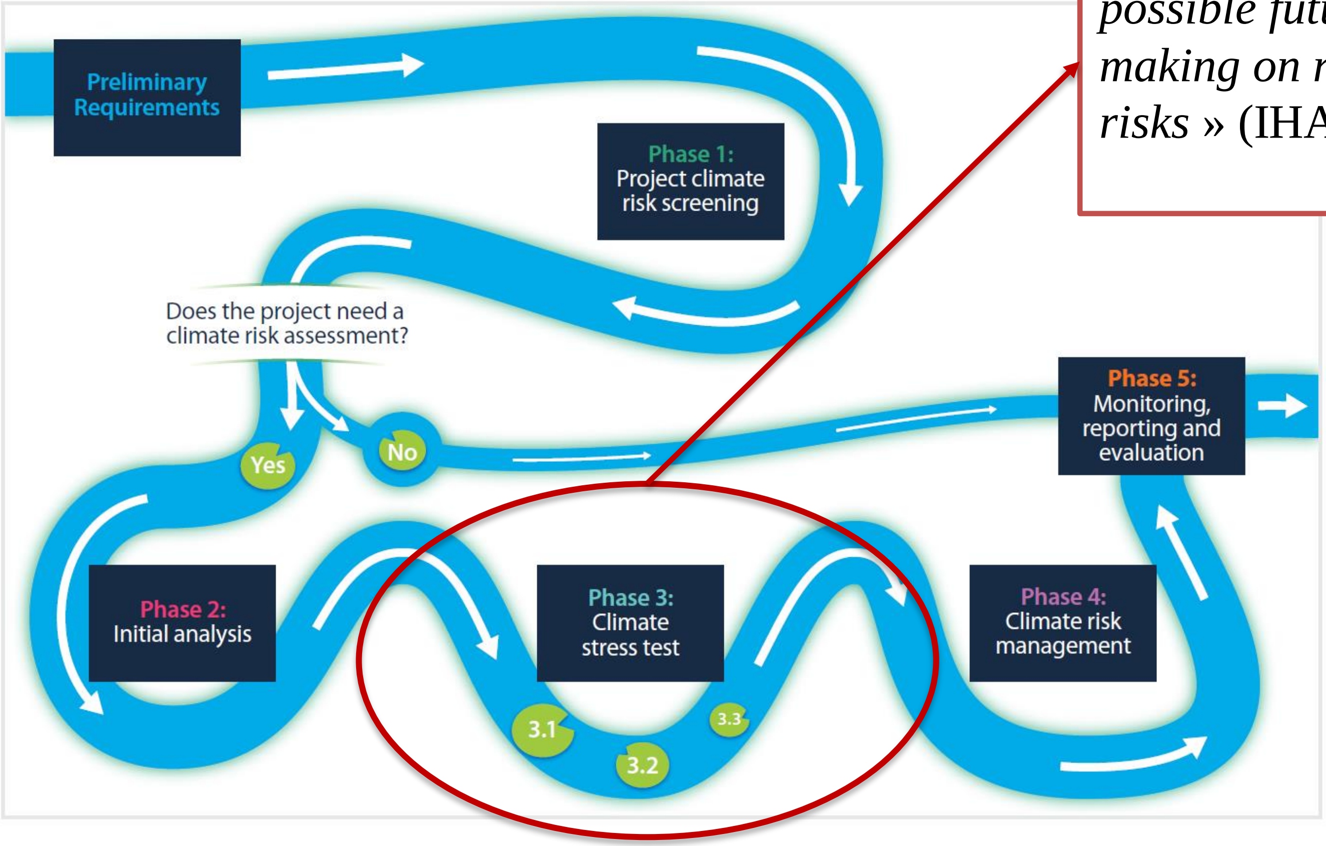




source: World Bank

Phase 3: Climate stress test

[the objective] is « *to assess project performance under different possible future climate scenarios in order to support decision making on resilient design and operation, and to quantify climate risks* » (IHA Guide)



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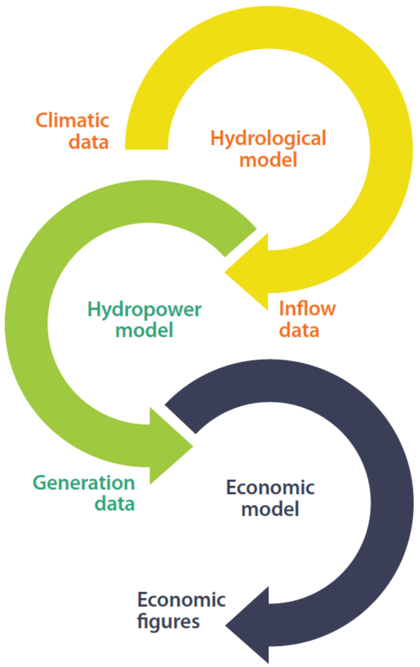
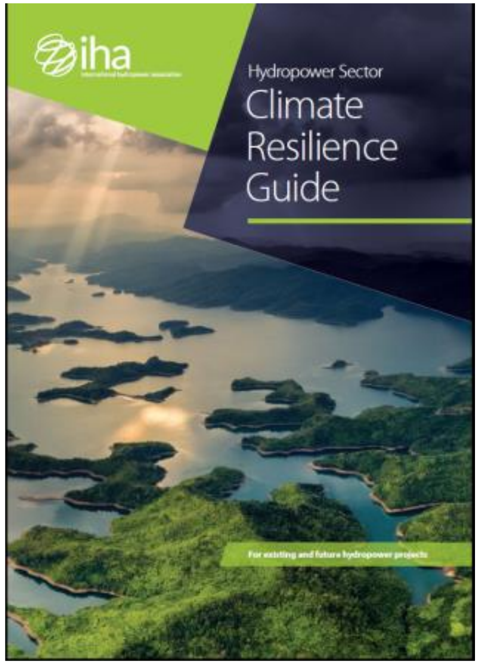
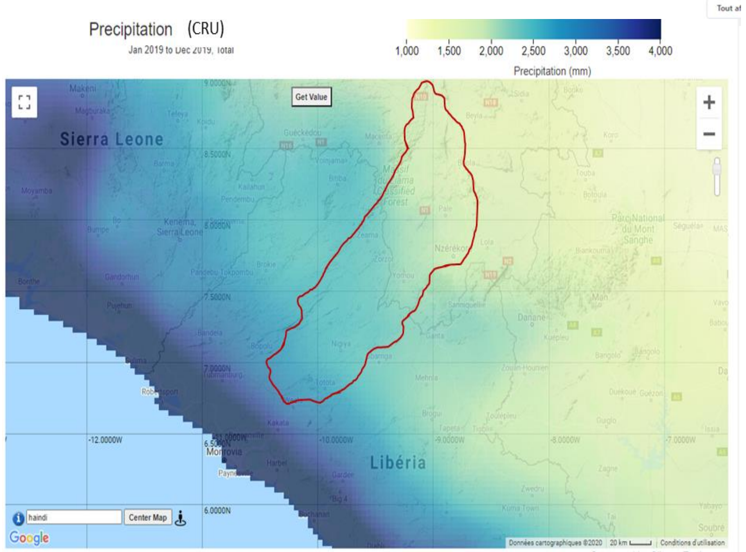
The process of the Hydropower Sector Climate Resilience Guide

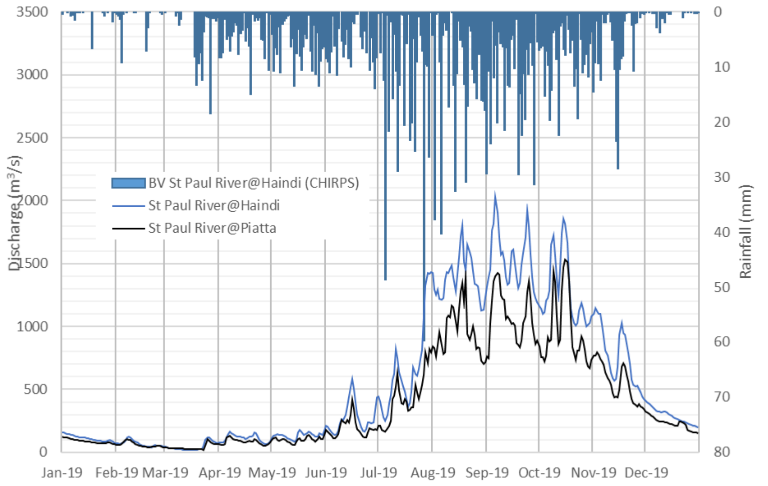


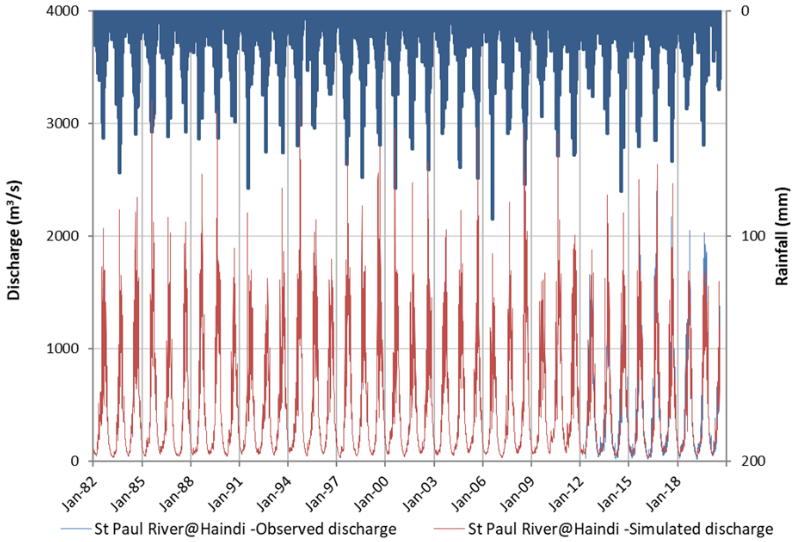


Saint Paul River in Liberia

- West African monsoon tropical regime
- Haindi gauging station in operation since 2012 (~ 18,300 km²) – Liberia Hydrological Service
- Global climate dataset (CRU, CHIRPS)
- **GR4J Rainfall-Runoff** model (INRAE) - global, conceptual and parsimonious

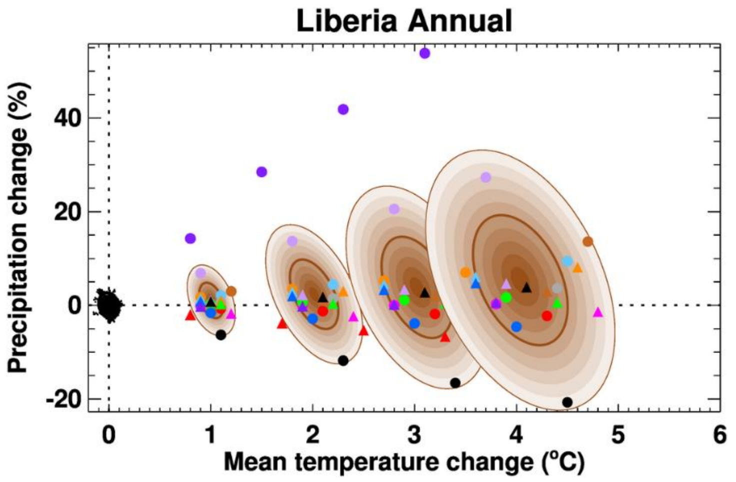






« Climate stress » scenarios

- The change factors (T°, Rainfall) adopted for the stress test extends the typical range of the ensemble of climate model projections to ensure that no vulnerabilities are missed
- The changes are applied uniformly throughout the year
- (27-1) scenarios for possible future climate
- Inputs for rainfall-runoff model



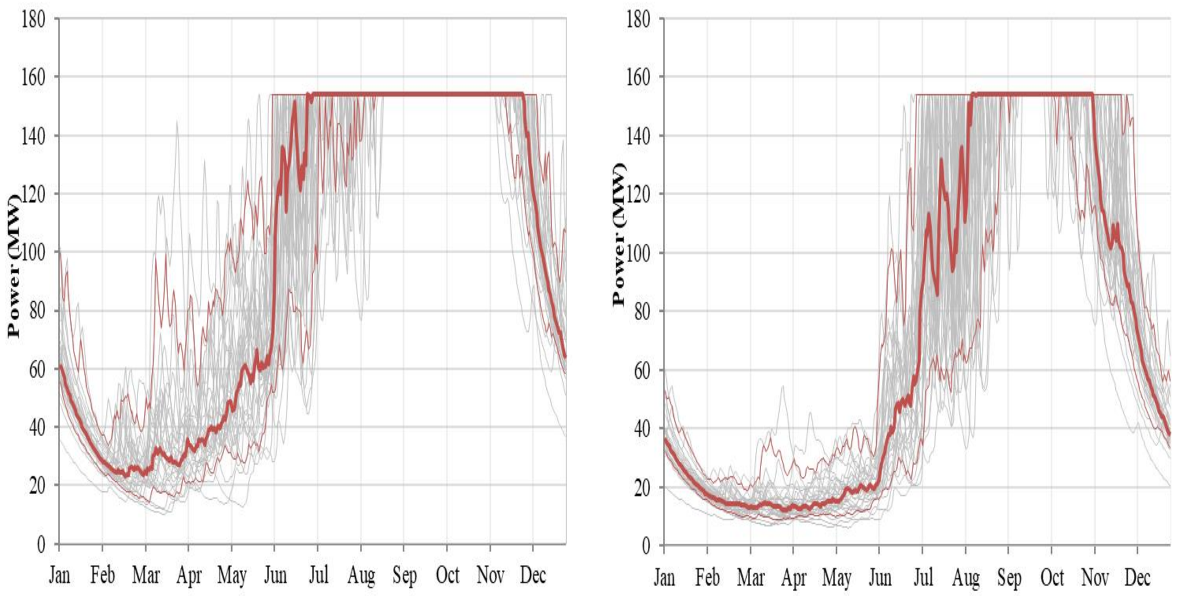
Projections of national average climate change in Liberia (source: ClimGen)

	Change in Precipitation (%)								
Change in Temperature (°C)	**-40%**	**-20%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**20%**	**40%**
0°C	-80%	-40%	-22%	-9%	0%	10%	23%	46%	88%
+2°C	-84%	-51%	-30%	-20%	-9%	2%	13%	36%	81%
+4°C	-87%	-58%	-38%	-28%	-17%	-6%	5%	27%	72%

Change in mean annual runoff for the climate scenarios

Impacts on power generation

- Hydropower Model = Mike Hydro Basin
- Decrease in expected annual generation for most of the climate scenarios (even with +5% increase in rainfall)
- Decrease is more prononced for dry season generation (or firm power in the case of run of river type power plant)



Daily power generation for the baseline scenario (left) and the climate scenario (+2°C, -20% rainfall) (right)

	Change in Precipitation (%)								
Change in Temperature (°C)	**-40%**	**-20%**	**-10%**	**-5%**	**0%**	**5%**	**10%**	**20%**	**40%**
0°C	-60%	-22%	-9%	-5%	0%	4%	8%	14%	25%
+2°C	-67%	-28%	-15%	-10%	-5%	-1%	3%	9%	20%
+4°C	-73%	-34%	-21%	-15%	-10%	-6%	-2%	5%	16%

Change in expected annual generation for the climate scenarios