ANNEX 8: ESTIMATING IMPACTS OF CLIMATE CHANGE ON LARGE HYDROPOWER PLANTS IN ALBANIA

This Annex outlines the approach to estimating the impacts of climate change on large hydropower plants (LHPPs) in Albania. These estimates are required to make an initial assessment of climate change risks to Albania's energy sector, which will feed into the high-level cost–benefit analysis of adaptation options.

It was outside the scope of this vulnerability assessment to undertake hydrological assessments including climate change for Albania's LHPPs, and the data needed were not available to do this. The report therefore utilizes information from existing studies for Albania and other countries.

It is recognized that Albania could benefit from additional investment in hydrological and meteorological monitoring and research/assessments to understand these issues better.

A8.1 EXISTING AVAILABLE INFORMATION ON LHPPS AND CLIMATE CHANGE IMPACTS

The following information was reviewed linking climate change and hydropower production:

a. Work by IEWE (formerly HMI) at Tirana Polytechnic University for Albania's First National Communication to the UNFCCC
b. Recent work by IEWE on the Vjosa Basin in southern Albania
c. Recent work by IEWE on the Mati River catchment for Albania's Second National Communication
d. A correlation of annual average inflows to Fierze and electricity generation
e. Verbal information from the World Bank's Senior Energy Economist in Albania[1]
f. Roberto Schaeffer *et al.* (2009), recent assessment of climate change impacts on LHPP in Brazil[2]

These are reviewed in turn as follows.

[1] Meeting with Demetrios Papathanasiou, Senior Energy Economist at the World Bank, on April 22, 2009.
[2] Reported in: Pereira de Lucena, A.F., Szklo, A.S., Salem, A., Schaeffer, R. de Souza, R.R., Borba, B.S.M.C., da Costa, I.V.L, Junior, A.O.P., da Cunha, S.H.F. (2009). The vulnerability of renewable energy to climate change in Brazil, *Energy Policy*, **37**: 879–889 and Roberto Schaeffer's presentation on the above at World Bank Energy Week 2009.

A8.2 ALBANIA'S FIRST NATIONAL COMMUNICATION

The range of projected climate changes for Albania presented in the 1NC[3] is shown in Table A8.1

Table A8.1 Climate Change Scenarios for Albania (CCSA)

Scenarios for Albania		Time Horizon		
		2025	2050	2100
Annual	Temperature (°C)	0.8+1	1.2+1.8	2.1+3.6
	Precipitation (%)	-3.8+-2.4	-6.1+-3.8	-12.5+-6
Winter	Temperature (°C)	0.8+1.0	1.3+1.8	2.13.7
	Precipitation (%)	-1.6+0	-1.8+0	-3.7+0
Spring	Temperature (°C)	0.7+0.9	1.0+1.5	1.8+3.0
	Precipitation (%)	-2.7+-1.3	-3.6+-2.1	-7.4+-3.4
Summer	Temperature (°C)	0.9+1.2	1.2+2.0	2.3+4.1
	Precipitation (%)	-0.8+-5.6	-20.0+-9.1	-27.0+-14.4
Autumn	Temperature (°C)	0.9+1.1	1.1+2.0	2.1+3.8
	Precipitation (%)	-4.3+-3.4	-11.2+-2.1	-16.2+-8.6
Sea Level (cm)			20-24	48-61
Cloud Cover (%)		-1.3+-1.5	-2.6+-2.0	-4.6+-3.1
Wind Speed (%)		0.7	1+1.3	1.6+2.3

To assess the impact of climate change on the mean annual runoff, two models that relate runoff forming factors (annual sum of precipitation and mean annual evapotranspiration) to the long term mean annual runoff were used.

The 1NC states that: "*The models forecast a decrease in the long term mean annual runoff, respectively from –9.8 percent to –13.6 percent and from –6.3 percent to –9.1 percent, for 2025*" (see the black line in Figure A8.1).

According to Figure A8.1:

a. The projected climatic changes for 2050—that is, decreases in annual precipitation of –6.1 percent to –3.8 percent and temperature increases of +1.2 deg C to +1.8 deg C—translate into a decrease in annual runoff of about –15 percent by 2050.

b. The projected climatic changes for 2100—i.e. decreases in annual precipitation of –12 percent to –6 percent and temperature increases of +2.1 deg C to +3.6 deg C—result in a decrease in annual runoff of about –35 percent by 2100.

[3] Islami, B., Kamberi, M., Demiraj, E., Fida, E. (2002). The First National Communication of the Republic of Albania to the United Nations Framework Convention on Climate Change (UNFCCC). Ministry of Environment, Republic of Albania.

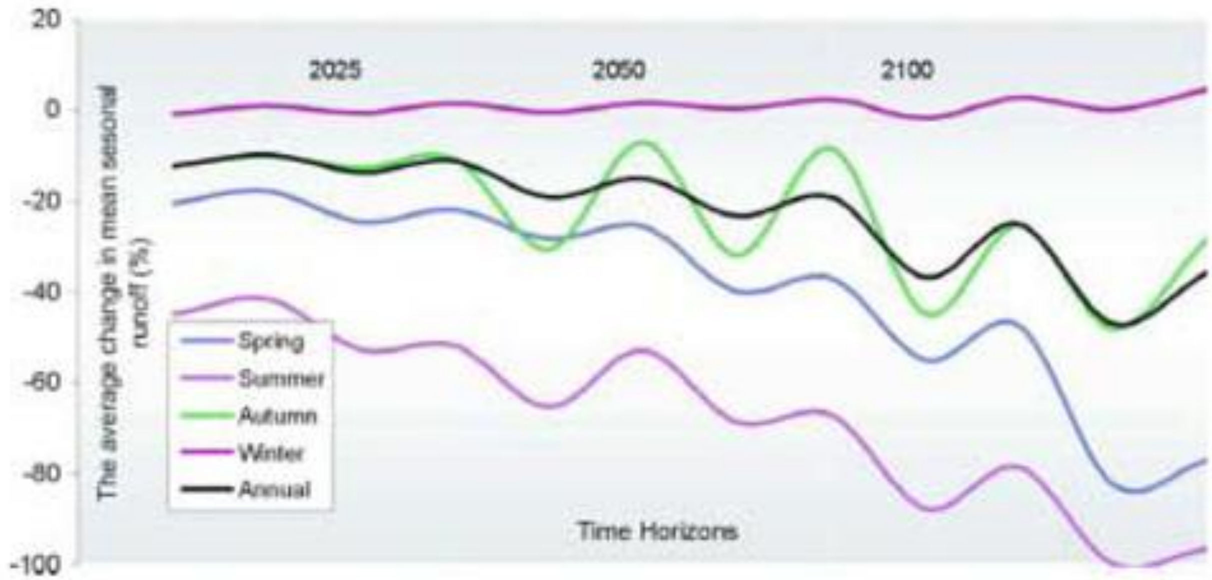

Figure A8.1: Average change in mean runoff according to CCSA for three time horizons: 2025, 2050, 2100

A8.3 ASSESSMENT OF CLIMATE CHANGE IMPACTS ON THE VJOSA BASIN

The assessment of climate change impacts on the Vjosa Basin[4] presented a slightly different set of climate change scenarios, with larger changes for Albania than the 1NC, as shown in Table A8.2.

Table A8.2: Climate Change Scenarios for Three Time Horizons: 2025, 2050, 2100

Scenarios for Albania		Time Horizon		
		2025	2050	2100
Annual	Temperature (°C)	0.8 to 1.1	1.7 to 2.3	2.9 to 5.3
	Precipitation (%)	-3.4 to -2.6	-6.9 to -5.3	-16.2 to -8.8
Winter	Temperature (°C)	0.7 to 0.9	1.5 to 1.9	2.4 to 4.5
	Precipitation (%)	-1.8 to -1.3	-3.6 to -2.8	-8.4 to -4.6
Spring	Temperature (°C)	0.7 to 0.9	1.4 to 1.8	2.3 to 4.2
	Precipitation (%)	-1.2 to -0.9	-2.5 to -1.9	-5.8 to -3.2
Summer	Temperature (°C)	1.2 to 1.5	2.4 to 3.1	4.0 to 7.3
	Precipitation (%)	-11.5 to -8.7	-23.2 to -17.8	-54.1 to -29.5
Autumn	Temperature (°C)	0.8 to 1.1	1.7 to 2.2	2.9 to 5.2
	Precipitation (%)	-3.0 to -2.3	-6.1 to -4.7	-14.2 to -7.7

A rainfall-runoff model was used to assess the impacts of these changes on Vjosa River runoff. The projected changes in runoff are shown in Figure A8.2.

[4] M. Bogdani Ndini and E. Demiraj Bruci, 2008

The paper notes that during winter, precipitation feeding the Vjosa River falls as snow and that the presence of deep karst aquifers "*assure an abundant underground supply during the dry season.*"

According to Figure A8.2 which presents data drawn from that paper:

a. The projected climatic changes for 2050—that is, decreases in annual precipitation of –6.9 percent to –5.3 percent and temperature increases of +1.7 deg C to +2.3 deg C—translate into a decrease in annual runoff of about –18 percent to –25 percent by 2050.

b. The projected climatic changes for 2100—that is, decreases in annual precipitation of –16 percent to –9 percent and temperature increases of +2.9 deg C to +5.3 deg C—translate into a decrease in annual runoff for the Vjosa River in the range –30 percent to –47 percent by 2100.

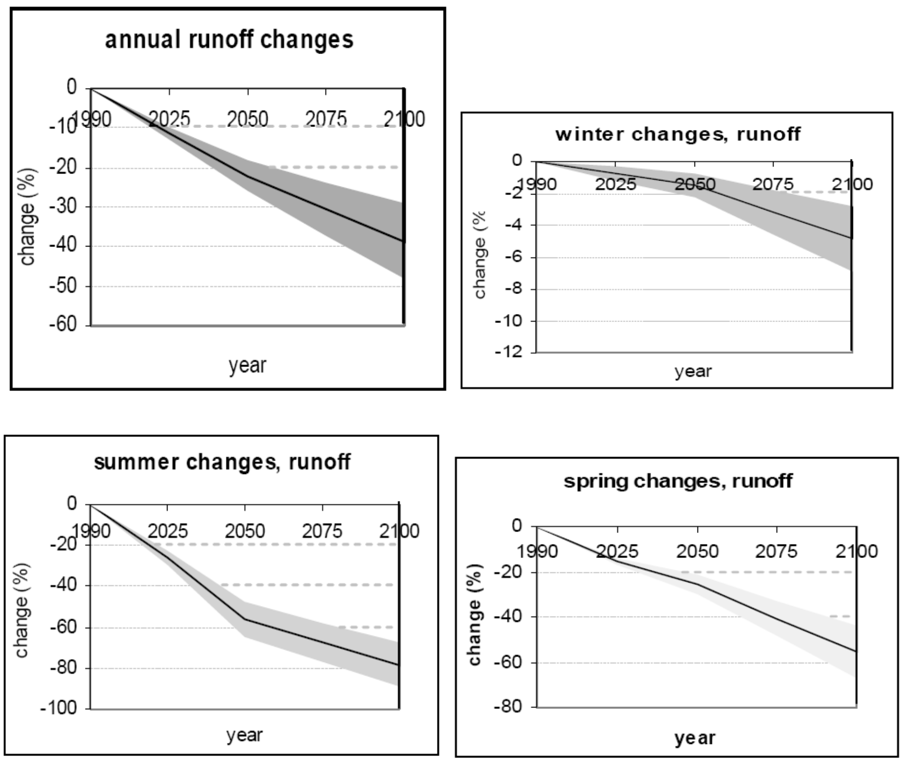

Figure A8.2 Projected Climatic Changes to 2100

A8.4 Assessment of Climate Change Impacts on the Mati River Basin

The assessment of climate change impacts on the Mati River[5] presented the same set of climate change scenarios as the assessment of the Vjosa River (see Table A8.2).

The assessment states that "*snowfall is not a frequent phenomenon, even in the hilly part of the study area*" and notes that increasing temperatures will make snow in future even rarer.

[5] B. Islami and E. Demiraj Bruci, 2008. Impacts of Climate Change to the Power Sector and Identification of the Adaptation Response Measures in the Mati River Catchment's Area.

According to Figure A8.3:

a. The projected climatic changes for 2050—that is, decreases in annual precipitation of –6.9 percent to –5.3 percent and temperature increases of +1.7 deg C to +2.3 deg C—translate into a decrease in annual runoff of about –18 percent to –25 percent by 2050.

b. The projected climatic changes for 2100—that is, decreases in annual precipitation of –16 percent to –9 percent and temperature increases of +2.9 deg C to +5.3 deg C—translate into a decrease in annual runoff for the Vjosa River in the range –30 percent to –47 percent by 2100.

Note that these are the same graphs as were presented above for the Vjosa River study.

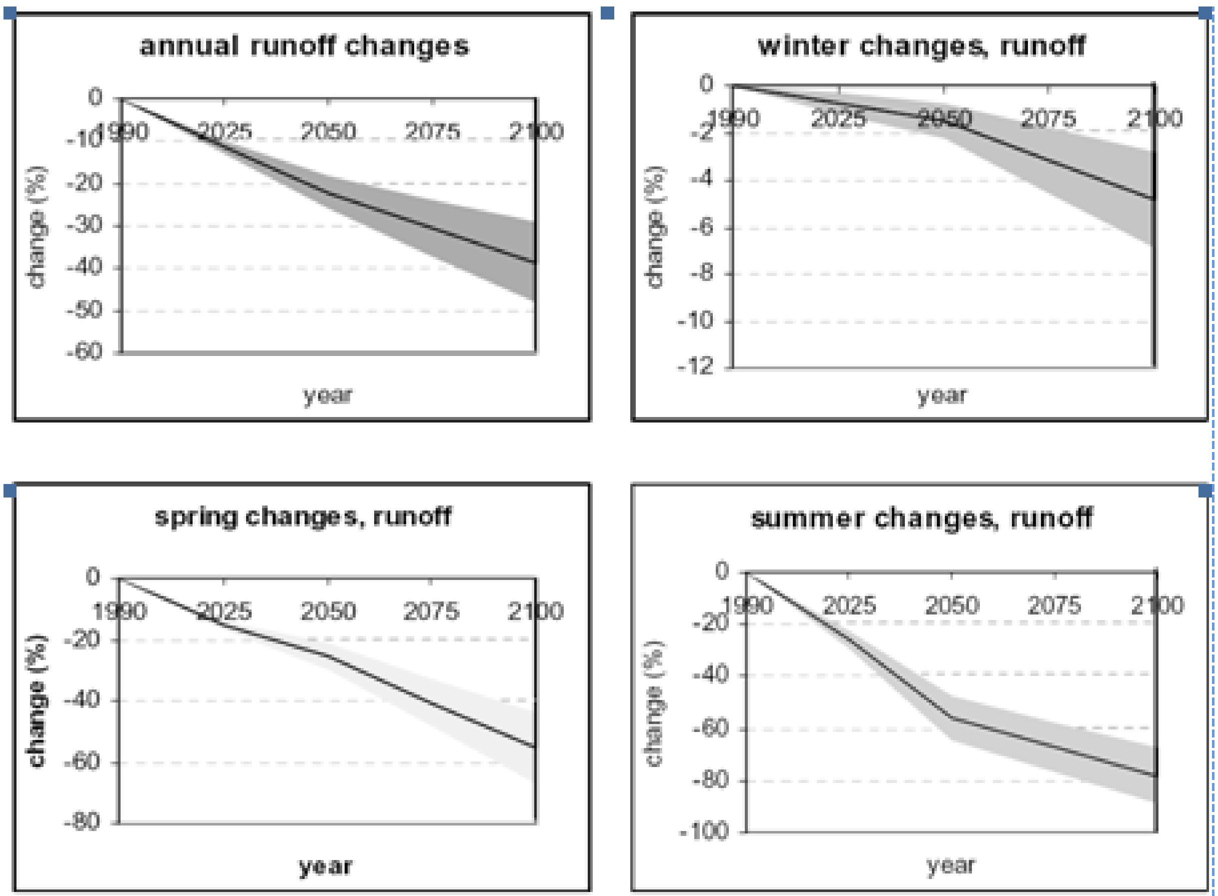

Figure A8.3 Expected changes in runoff, Mati catchment's area

This report states that there is a strong correlation between Mati River flow and power production from Ulëza and Shkopeti HPP, as shown in Figure A8.4 (taken from the report).

This graph implies that if the flow of the Mati River declined by 20 percent, electricity generation would fall by about 15 percent.

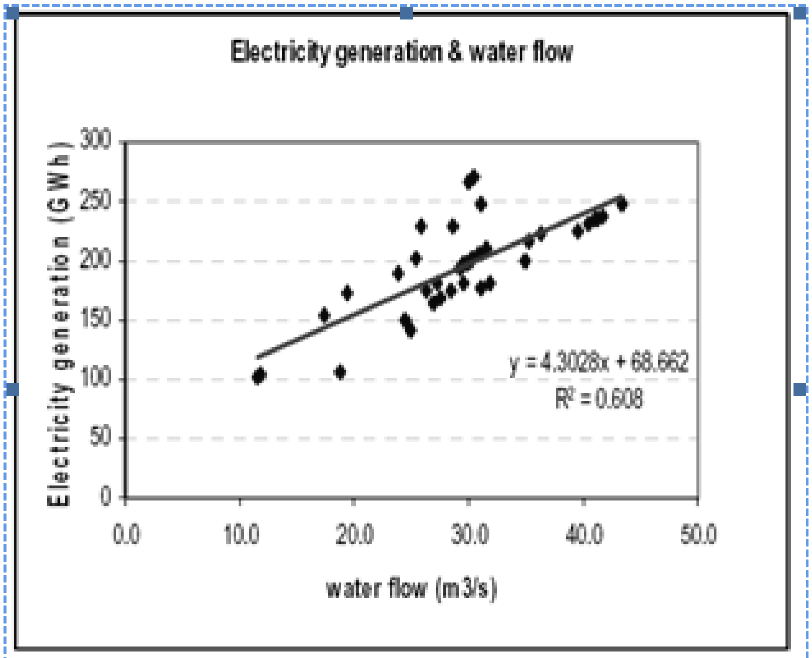

Figure A8.4: Relation of electricity production to river flow, MRCA

A8.5 Correlation of Annual Average Inflows to Fierze and Electricity Generation

The World Bank office in Albania has provided Excel spreadsheets that include data on monthly and annual average inflows (m^3s^{-1}) to Fierze from 1948 to 2007, as well as annual energy generated (GWh) from all sources for the years 1999 to 2007.

A linear correlation of these data is provided in Figure A8.5. It indicates that a 20 percent fall in inflow leads to a reduction in energy generated of approximately 15 percent.

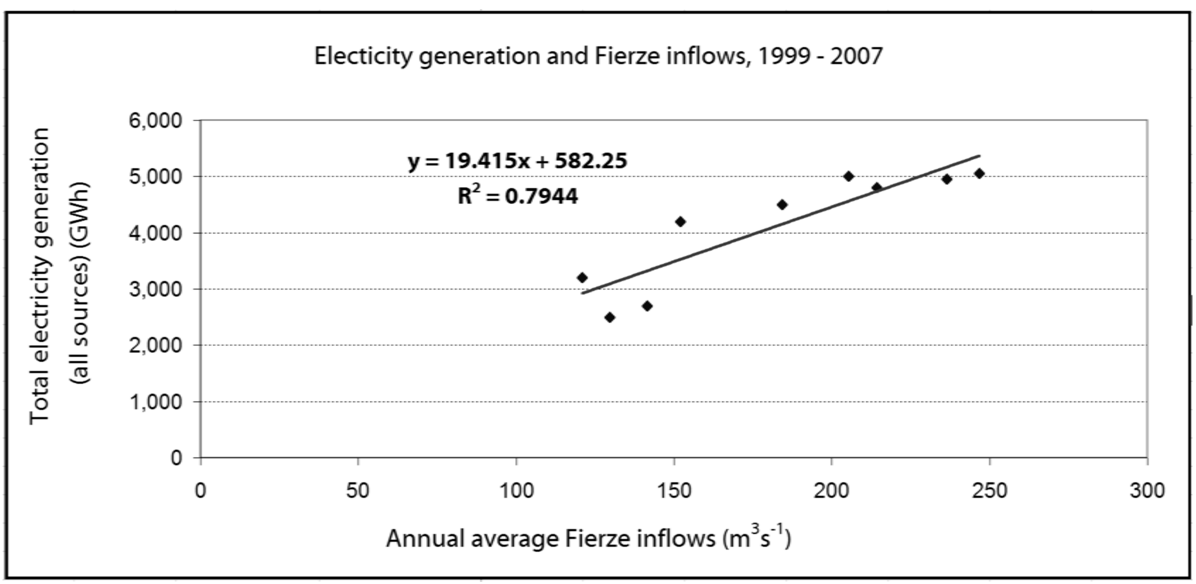

Figure A8.5: Electricity generation and Fierze inflows, 1999–2007

A8.6 VERBAL INFORMATION FROM THE WORLD BANK

The World Bank's Senior Energy Economist in Albania reported verbally that at Skavica a 20 percent reduction in precipitation translated into an approximate 20 percent reduction in HPP output.

A8.7 ASSESSMENTS OF LHPP IN BRAZIL

Research undertaken by Schaeffer and colleagues (Schaeffer, *et al,.*2009) used regional climate modeling for Brazil at 50 km × 50 km spatial resolution and on monthly timesteps to project impacts on LHPP.

First, projected changes in climate were used to generate perturbed river flows taking account of climate change. Then, using the SUISHI-O HPP operation simulation model, projected changes in HPP output were generated.

The projected changes in hydropower production for the period 2071 to 2100 are summarized in Table A8.3, (from Schaeffer *et al*., *op. cit.*)

Table A8.3: Results for Hydropower (Deviation from the Reference Projections) and Relative Participation of Each Basin in the Brazilian Hydropower System

Basin	Average Annual Flow		Average Power		Firm Power		Percent	
	A2 (%)	B2 (%)	A2 (%)	B2 (%)	A2	B2	Brazil	SINa
Parana River	-2.40	-8.20	0.70	-1.20			15.90	17.60
Grande	1.00	-3.40	0.30	-0.80			9.20	10.20
Paranaiba	-5.90	-5.90	-1.40	-1.90			10.20	11.30
Paranapanema	-5.00	-5.70	-1.40	-2.50			3.00	3.30
Parnaiba	-10.30	-10.30	-0.80	-0.70			0.30	0.30
Sao Francisco	-23.40	-26.40	-4.30	-7.70			8.50	9.40
Tocantins-Araguaia	-14.70	-15.80	-0.30	-0.30			15.80	17.60
Brazil (SIN)	**-8.60**	**-10.80**	**-0.70**	**-2.00**	**-1.58%**	**-3.15%**	**62.80**	**69.80**

a SIN – Sistema Interligado Nacional (Brazil Interconnected Electric Power System)

Schaeffer and colleagues state that in some of the river basins, reservoir management could go some way to mitigating the runoff changes in some basins, but not all: *"The Parana River, Paranaiba Basin, Paranapanema Basin and the Grande Basin—which all belong to the major Basin of Parana—show similar results. Besides the estimated negative average effect on flow, the seasonal variations in flow tend to be positive in the months when flow is increasing and negative in the months when it is falling. If this were the case, these power plants would face an earlier dry period, as well as an earlier start of the humid period. Given the not so relevant net annual results and the favourable seasonal pattern (higher flows in the beginning of the wet season), by adjusting the reservoir management in these existing power plants the estimated effects of GCC would be attenuated. The remaining basins all show an average negative impact on flow, especially the Sao Francisco Basin, where there is an installed hydroelectric capacity of*

6.8GW. In that case, reservoir management would not be enough to compensate for the losses in the inflows to the hydropower plants." (Schaffer et al., 2009)

A8.8 SUMMARY

The range of projected changes in annual climatic conditions, runoff, and hydropower production from the above studies are summarized in Table A8.4.

The research in Brazil indicates less severe impacts than the analyses above suggest for Albania, and Schaeffer and colleagues state that in Brazil reservoir management can compensate to some extent for reduced river flows.

According to this analysis, the high-level cost–benefit analysis for Albania uses an estimated decrease in annual hydropower output of 15 percent by 2050, associated with an average annual decrease of 20 percent in runoff. In addition, if possible, the CBA should test the sensitivity of these results to changes in annual power output in the range –20 percent to –5 percent.

Table A8.4: Projected Changes in Annual Climatic Conditions, Runoff, and Hydropower Production

Study	Change in annual average climatic conditions by 2050	Change in annual runoff by 2050 (%)	Change in annual hydropower output (%)
First National Communication	Precipitation: –6.1% to –3.8% Temperature: +1.2°C to +1.8°C	–15%	
Vjosa River	Precipitation: –6.9% to –5.3% Temperature: increases of +1.7°C to +2.3°C	–18% to –25%	
Mati River	Precipitation: –6.9% to –5.3% Temperature: increases of +1.7°C to +2.3°C	–18% to –25%	Figure A8.4 indicates that a 20% reduction in runoff would cause a reduction of 15% in power generation
Correlation of Fierze inflows and energy generation			A 20% reduction in inflows to Fierze is associated with a 15% reduction in power generation
Verbal information from World Bank			*"20% reduction in precipitation translates into a 20% reduction in HPP output"*
Schaeffer *et al.*		Parana River (2071–2100) –8.2% to –2.4% Sao Francisco (2071–2100) –26.4% to –23.4%	–1.2% to +0.7% –7.7% to –4.3%