Hydro energy potential - modeling climate change impacts

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Hydro in Croatian power system

- Half of electricity production in Croatia from 2000 – 2007 came from hydro power plants
- 50% of installed Croatian power capacities are in hydro

- Heat wave in 2003: electricity production in hydro`s down 25%, similar appeared in 2007

	2005.	2006.	2007.	2008.	2009.	2010.
	GWh					
Production	12458,9	12429,6	12245,1	12325,6	12777,1	14104,9
-hydro power plants	6438,6	6123,5	4400,2	5325,9	6814,4	8435,2

Hydro in Croatian power system

Most hydro power plants located in Southern Croatia, with water inflow depending on water situation in Bosnia and Herzegovina

Hydro in Croatian power system

- Lower precipitation means less water inflow to hydro reservoirs
- Macro-scale hydrological models predict that production in Southern European HPP will decrease by between 20-50% by the 2070s (CEC 2007, Lehner et al. 2005)
- Recent experience from new small HPPs in Bosnia and Herzegovina show in some cases 20-30% lower electricity generation than planned (water flow data used were mostly from 1970s)

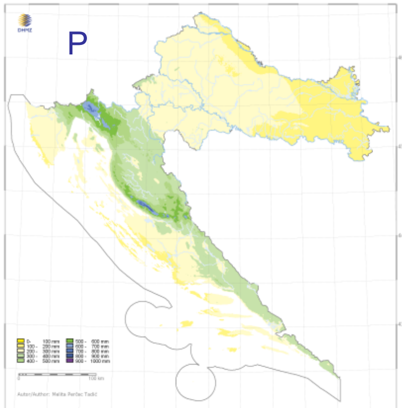
Cost for replacing 35% loss of hydro production annually:

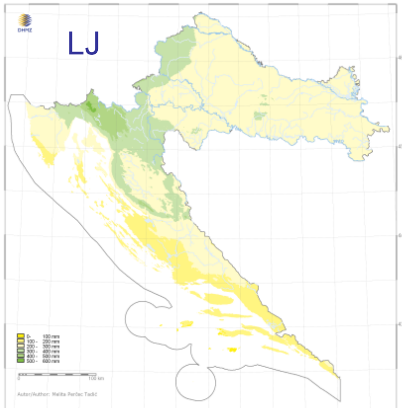
-65 million € (if replaced with coal, 50 €/MWh)

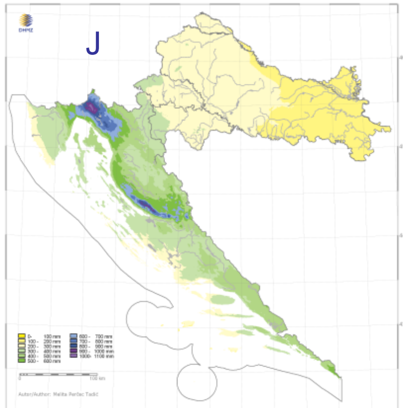
-117 million € (if replaced with imported electricity, 84 €/MWh)

Seasonal percipitation

from winter to autumn…







Complexities with modeling hydro energy systems

Hydro energy models are more complex than those for solar and wind energy because of:

- stochastic value of water inflow on a short, medium and long term time
- value of water that is in energy storage
- spill over
- technical concerns that needs to be taken in account for energy calculation from hydro power plants,
- decrease in 20-30% of water inflow to hydro power plant might result in much larger energy outputs due to some restrictions such as biological minimum,
- cascade hydro power plants where water output from one hydro power plant can be water inflow for the next one down the waterway;

Hydro modeling in PLEXOS model

• PLEXOS is an electricity simulation model developed by Energy Exemplar
• Modeling from short term (1 minute) to long term planning (30 years)
• Modeling hydro generators and networks of storage with four dominant classes:
    ❖Generator (hydro power plants)
    ❖Storage (water storage used for power plant)
    ❖Waterway (connecting two different storages)
    ❖Constraint (to define custom constraints on elements or combination of elements in hydro system)

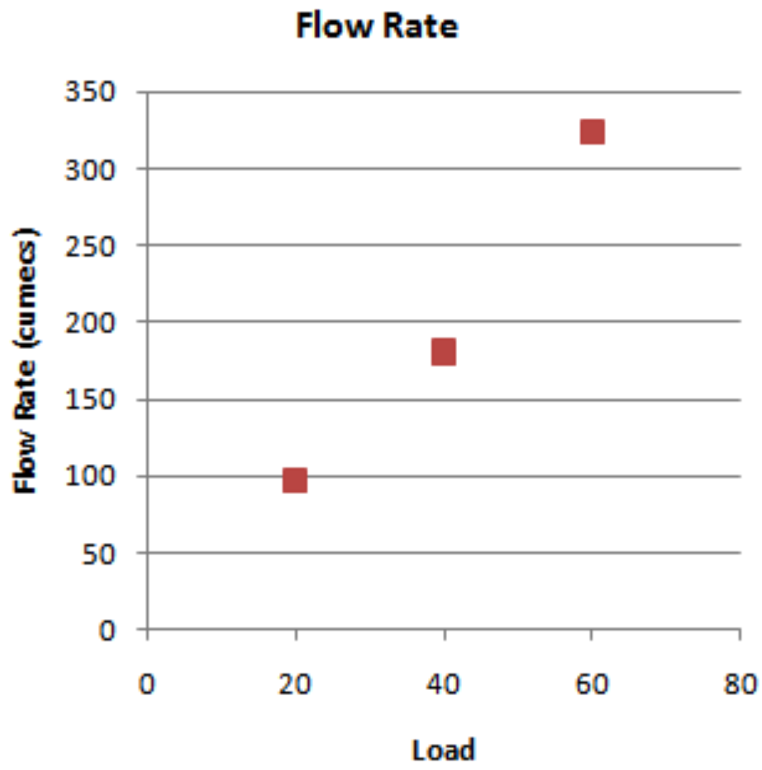
Hydro modeling in PLEXOS model

Property	Value	Units	Date From	Date To	Pattern
Units	1	-			
Max Capacity	60	MW			
Min Load	5	MW			M1-4,10-12
Min Load	15	MW			M5-9
Max Energy MONTH	15	GWh			M1-4,10-12
Max Energy MONTH	27	GWh			M5-9

Simple energy-constrained hydro during different months in a year (M1 is a January, etc)

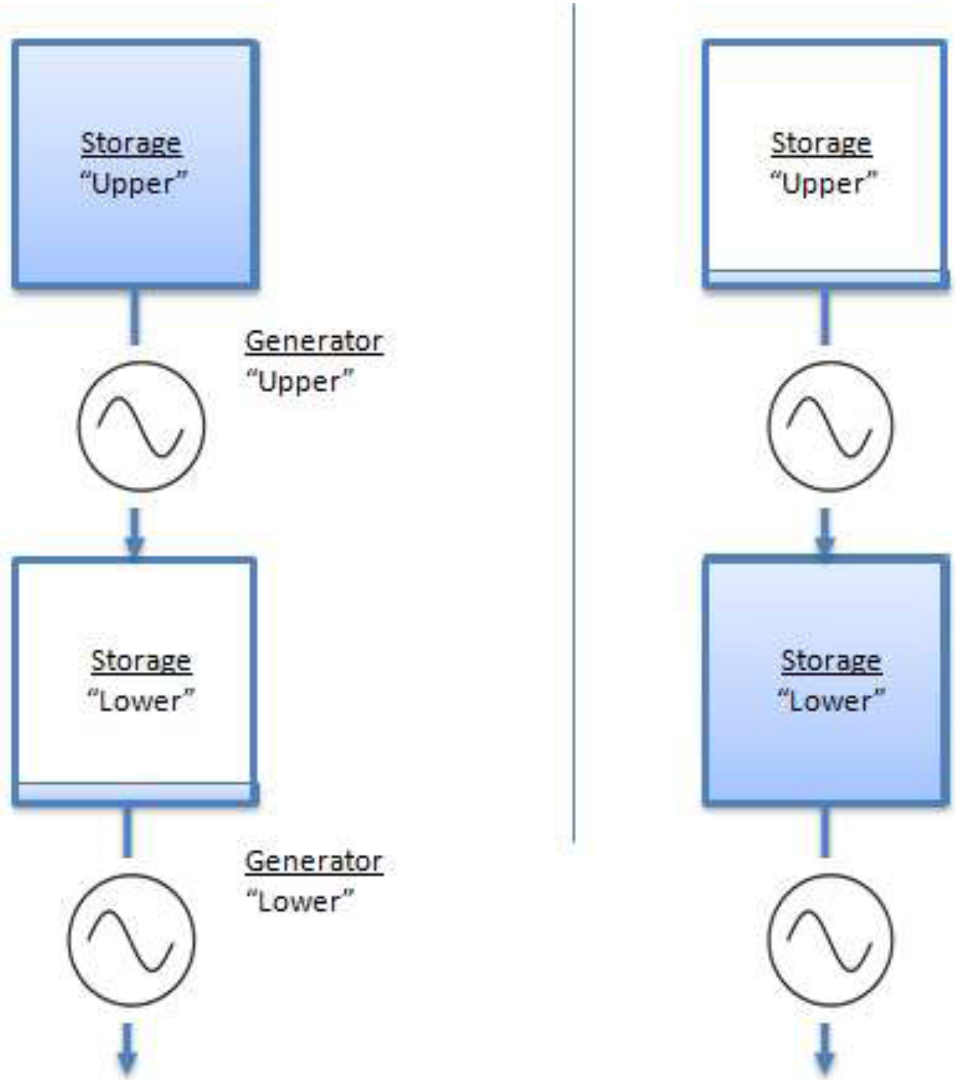
Property	Value	Units	Band
Units	1	-	
Max Capacity	60	MW	
Load Point	20	MW	1
Load Point	40	MW	2
Load Point	60	MW	3
Efficiency Base	58	cumec	
Efficiency Incr	0.5	MW/cumec	1
Efficiency Incr	0.48	MW/cumec	2
Efficiency Incr	0.42	MW/cumec	3

Hydro efficiency curve (metric)



Hydro modeling in PLEXOS model

Cascade system - the potential energy in the left-hand system is double that of the right-hand system



Hydro modeling in PLEXOS model

Year	Month	Day	Period	Value
2010	3	15	1	51,711
2010	3	15	2	51,711
2010	3	15	3	51,711
2010	3	15	4	51,711
2010	3	15	5	51,711
2010	3	15	6	51,711
2010	3	15	7	51,711
2010	3	15	8	51,711
2010	3	15	9	51,711
2010	3	15	10	51,711
2010	3	15	11	51,711
2010	3	15	12	51,711
2010	3	15	13	51,711
2010	3	15	14	51,711
2010	3	15	15	51,711
2010	3	15	16	51,711
2010	3	15	17	51,711
2010	3	15	18	51,711
2010	3	15	19	51,711
2010	3	15	20	51,711
2010	3	15	21	51,711
2010	3	15	22	51,711
2010	3	15	23	51,711
2010	3	15	24	52,502

Input files – hour periods, separate for each inflow

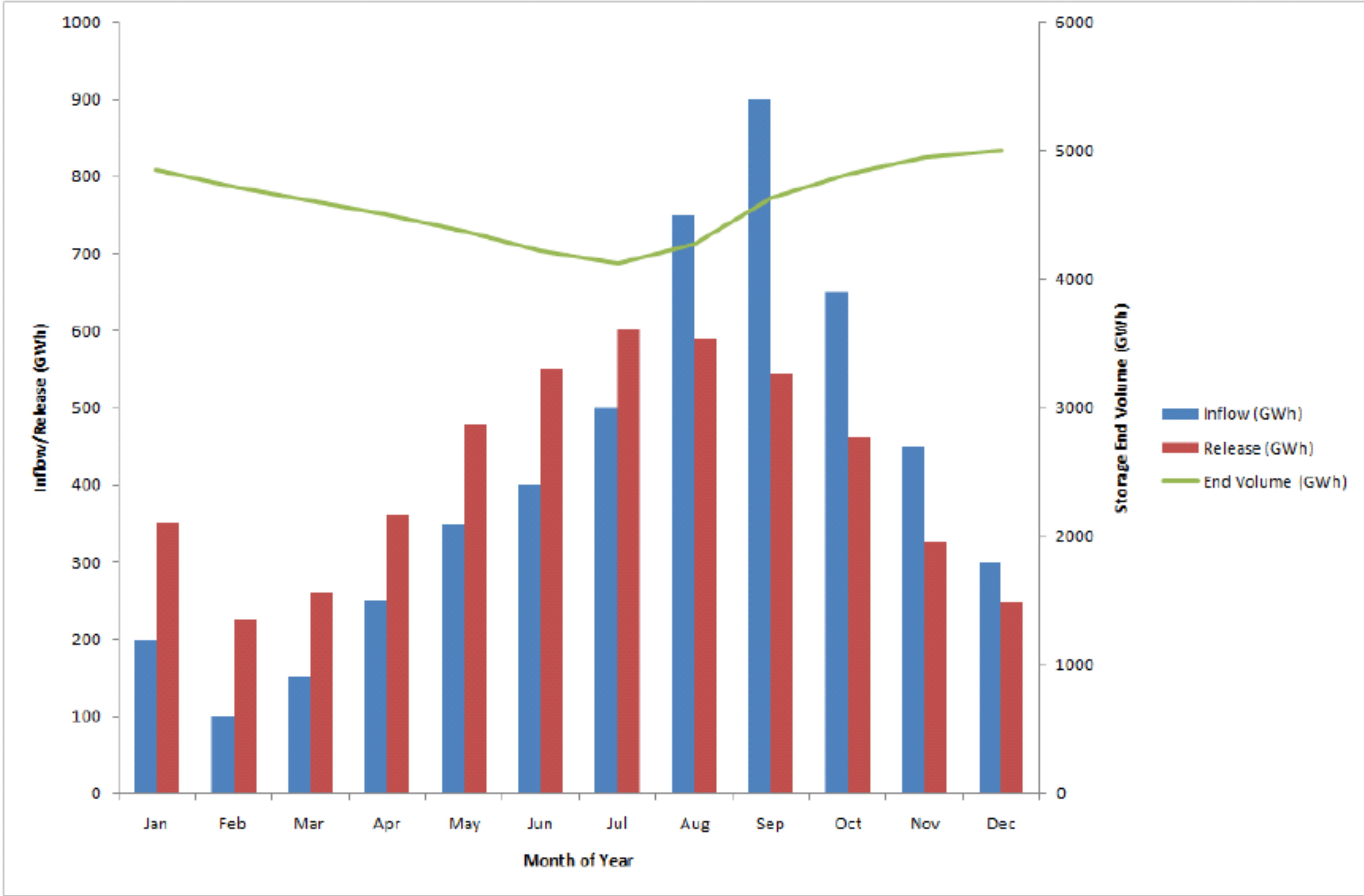
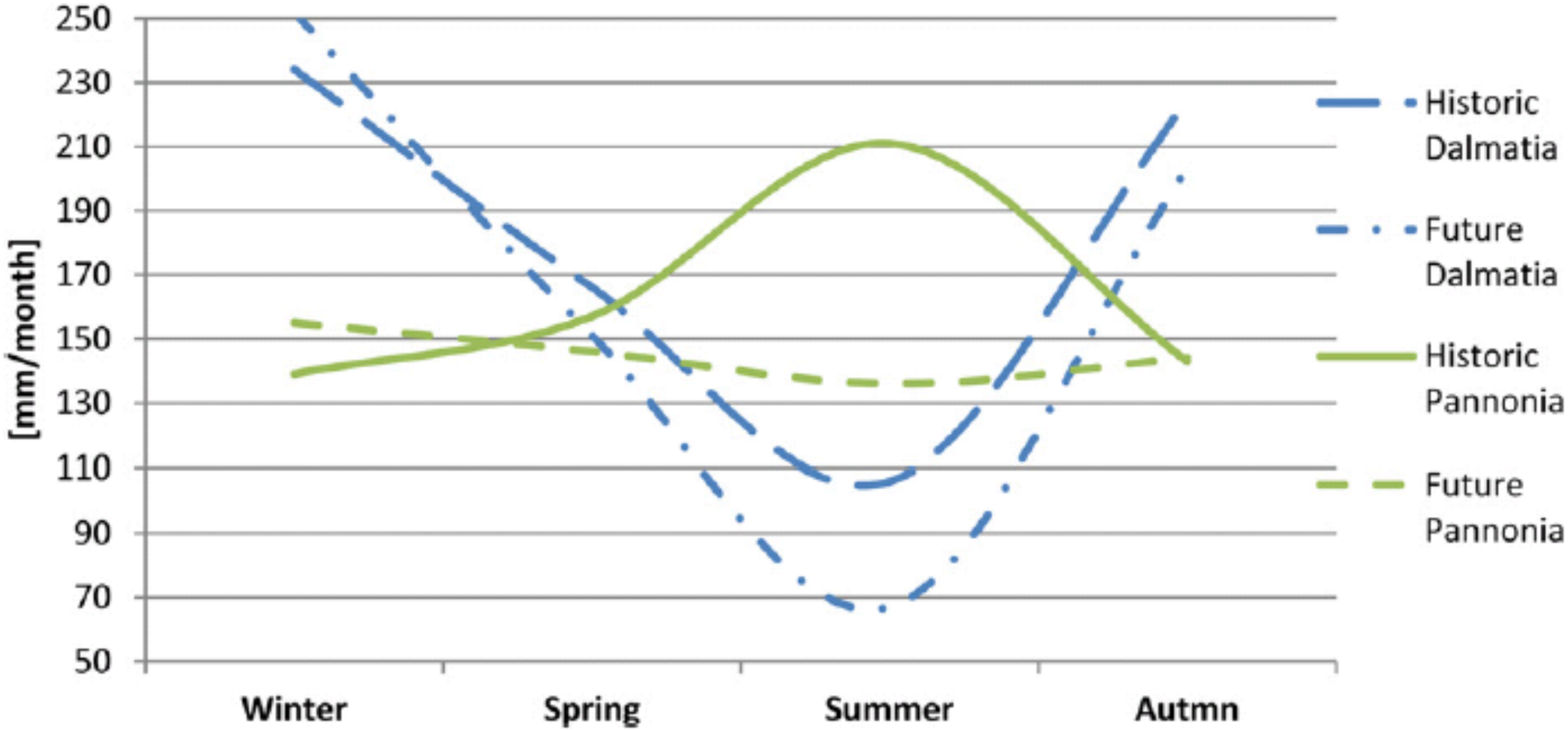


Figure 8: Case 3 storage inflow, release and volume by month



Historic (1961-1990) and future (2080-2100) average seasonal precipitation (mm/month) for northern (Pannonia) and southern regions in Croatia

Climate change impacts on hydro generation

- Change in precipitation (especially in the regions where most of the hydro power plants are located)
- Increased evaporation due to expected increase in the mean temperature (reduces the water levels in the power plant reservoirs)
- A reduction in water inflow implies that the energy generation is expected to decrease by 10% by 2050 and 15-35% by the end of the 21st century.