ENVIRON/ENERGY 590.05 - Economics of Modern Power Systems
Fall 2021

Instructor	**TA**
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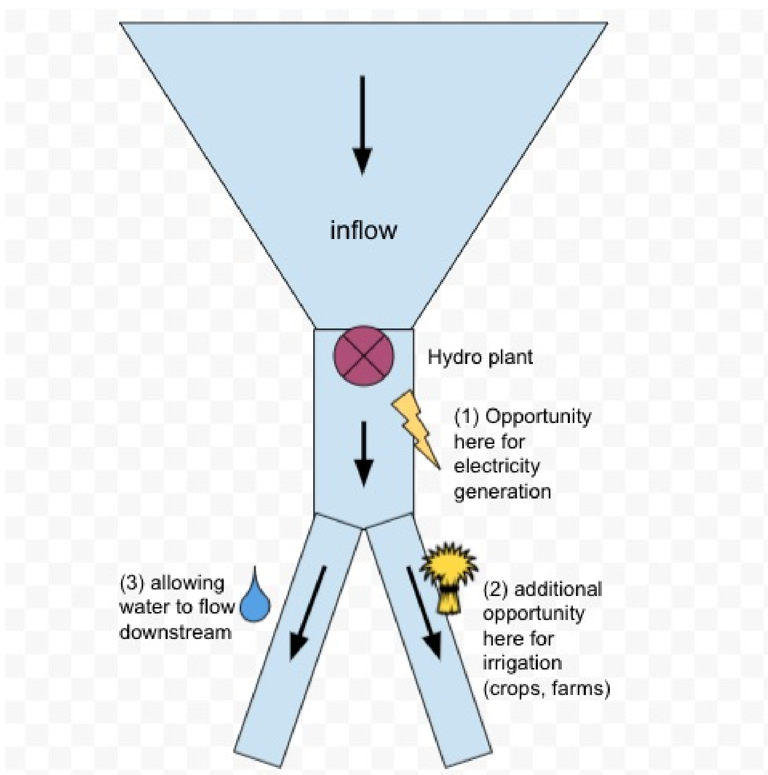
Assignment #2

Due date: 10/07/2022

An Independent Power Producer (IPP) invested in a hydro power plant with a small reservoir a couple years ago. The reservoir is designed to provide hydroelectric power and water for irrigation, i.e., the outflow/release from the reservoir is used to generate hydroelectric power and **after** passing through the turbines it can be diverted toward an irrigation project or it can continue to flow downstream as depicted in the diagram[1] below.



[1]Huge thanks to Brenda Warger who created the diagram for this assignment!

There are some constraints associated with the reservoir operation on a monthly basis.

- At least 1 unit of water must be released down the stream each month.
- The reservoir has a capacity of 10 units of water.
- It currently contains 5 units of water and must contain 5 units of water at the end of the year.
- The maximum amount that can be released in any month is 7 units.

The return for each unit of water released for hydroelectric power and irrigation and the estimated inflow for each month of a year are shown in the table below. Here we do not need to worry with units, the prices are already in $ per Unit of Water [UoW].

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Ago**	**Sep**	**Oct**	**Nov**	**Dec**
Inflow [UoW]	2	2	3	4	3	2	2	1	2	3	3	2
Electricity price [$\$10^6$/UoW]	1.6	1.7	1.8	1.9	2.0	2.0	2.0	1.9	1.8	1.7	1.6	1.5
Irrigation price [$\$10^6$/UoW]	1.0	1.2	1.8	2.0	2.2	2.2	2.5	2.2	1.8	1.4	1.1	1.0

The IPP has no background in operations research (optimization) and is having a hard time operating this reservoir. You were hired to develop a model that will help maximize the IPP's return in 2023. Note that this is a multi-period linear programming (LP) because the reservoir is able to store water. Therefore, the decision made in January will affect the return in February and subsequent months. In your report to your client, please make sure you clearly state the procedure used to solve the problem.

1. List all the parameters/inputs of the model and the notation you will use to represent them. Don't forget all parameters and decision variables should be indexed by time (i.e. month).
2. Define the decision variables associated with this problem. Hint: Think about what's the decision the IPP face every month.
3. Formulate the optimization model as a linear programming. You may use the values in the table to state the problem or the parameter notation as defined in part 1.
4. Explain how you will solve the problem. And clearly show the procedure. You may use Excel solver, R or Python. If you solve in Excel, please submit you spreadsheet

together with the report. If you solve in R or Python, please copy and paste your code and append to the report.

Since you took ENVIRON/ENERGY 590.05 course, you know that this solution is only optimal if the value provided by the IPP in the table are actually observed in the future. We have been discussing the increased uncertainty that renewables add to energy systems operation since our fist class.The table the IPP gave you is a projection based on the last couple years of observed data. But there are uncertainties associated with those values. The inflow and prices in 2023 are unknown. If you want to provide your client with a complete report and anticipate possible variations to the optimal solution you found in part 4, you need to provide some sensitivity analysis.

5. What will happen with the optimal solution if the IPP experiences a year with more than usual inflows? Interpret more inflows as either every month will be higher than the average value in the table or just one or two months with higher than usual values.

6. What will happen with the optimal solution if the IPP experiences a year with less than usual inflows?

7. Could you give some sensitivity in the optimal solution with respect to electricity price?

8. Could you give some sensitivity in the optimal solution with respect to irrigation price?

Discuss with your peers ways to incorporate the uncertainty in the model to help the IPP prepare for other possible scenarios. There is no right and wrong way to perform the sensitivity analysis, use your creativity! One way to do it is by changing the values provided in the table above and re-running the model.

Note: You don't need to consider correlation among the unknown variables. For example, more inflows may affect irrigation price, but you don't need to worry about that for this assignment.

This assignment should be done in pairs and only one submission is needed per group. Enjoy!