

CENTRALES DE PASADA (Q_i)

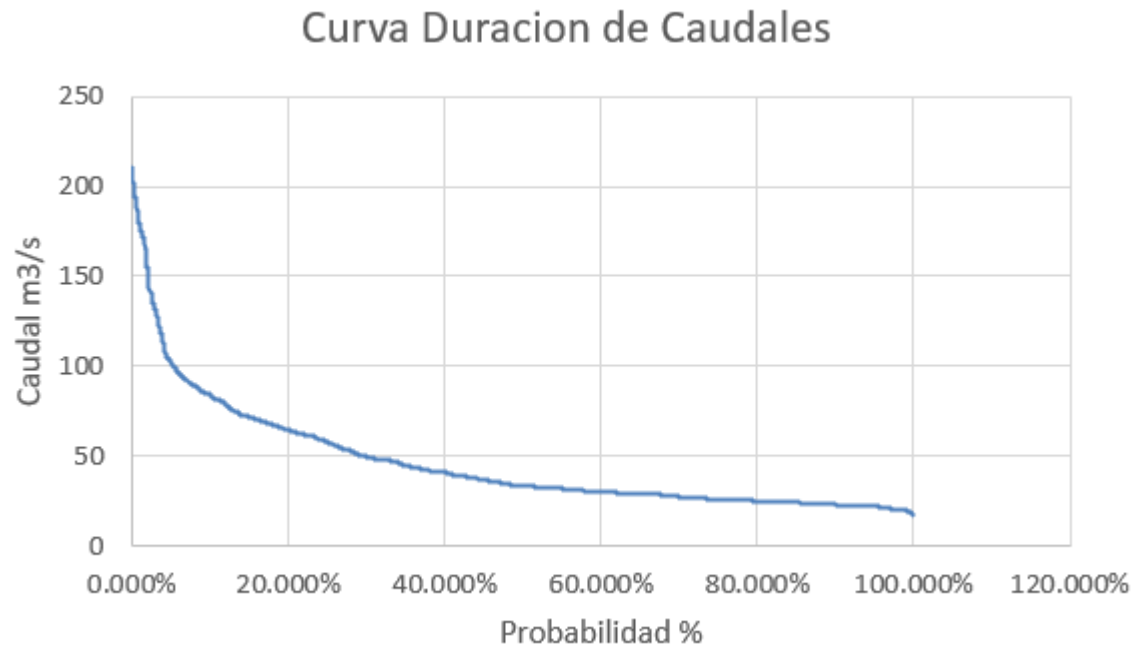
TRABAJO PRACTICO N°4 – EJEMPLO RESUELTO

Enunciado:

Dados los siguientes datos, determinar el “Gasto o Caudal de Instalación” de una Central a Pelo Libre utilizando el “Criterio Económico”.

Datos Hidraulicos:

Probabilidad (%)	Caudal (m³/s)
0.00%	200
5.00%	170
10.00%	130
15.00%	105
20.00%	85
30.00%	65
40.00%	55
50.00%	45
60.00%	38
70.00%	33
80.00%	28
90.00%	23
95.00%	20
100.00%	15
Hu=	20 m



Datos Financieros:

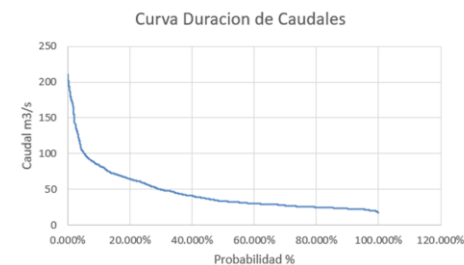
Costo de Explotación =	6%	Costo Constr
n =	30 años	
i =	12%	

Cu (u\$/Kw)	Qi (m³/s)
900	15
890	17
884	20
844	30
794	40
782	45
750	55
714	70

Detalle de las Fórmulas y Cálculos:

Paso 1: Análisis de la Curva de Duración de Caudales

No se debe elegir ni el caudal máximo absoluto (**QmaxAbs**) ni el mínimo absoluto (**QminAbs**) como **Qi**. Usar QmaxAbs sobredimensiona la instalación, y usar QminAbs la subdimensiona, **ambos resultando antieconómicos**. Seleccionar un rango de 5 o más valores de **Qi** dentro de la curva de duración. Mientras más valores se elijan, más precisa será la solución.



1						
Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)
1	0.00	5.00	200.00	170.00	5.00	5.00
2	5.00	10.00	170.00	130.00	5.00	10.00
3	10.00	15.00	130.00	105.00	5.00	15.00
4	15.00	20.00	105.00	85.00	5.00	20.00
5	20.00	30.00	85.00	65.00	10.00	30.00
6	30.00	40.00	65.00	55.00	10.00	40.00
7	40.00	50.00	55.00	45.00	10.00	50.00
8	50.00	60.00	45.00	38.00	10.00	60.00
9	60.00	70.00	38.00	33.00	10.00	70.00
10	70.00	80.00	33.00	28.00	10.00	80.00
11	80.00	90.00	28.00	23.00	10.00	90.00
12	90.00	95.00	23.00	20.00	5.00	95.00
13	95.00	100.00	20.00	15.00	5.00	100.00
	100.00		15.00			

Probabilidad (%)	Caudal (m³/s)
0.00%	200
5.00%	170
10.00%	130
15.00%	105
20.00%	85
30.00%	65
40.00%	55
50.00%	45
60.00%	38
70.00%	33
80.00%	28
90.00%	23
95.00%	20
100.00%	15

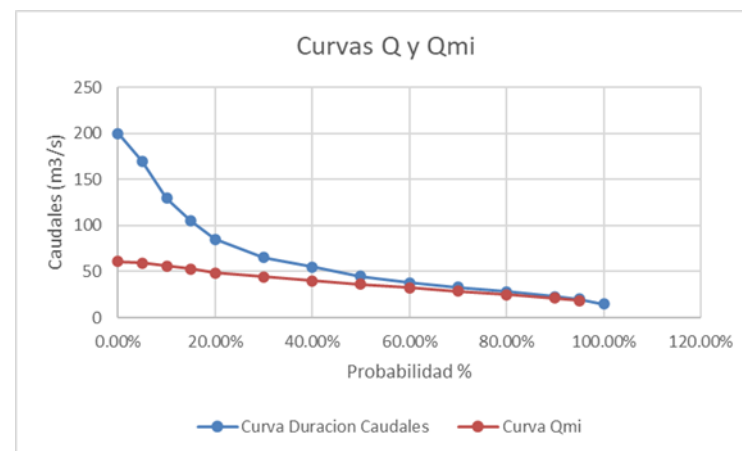
Detalle de las Fórmulas y Cálculos:

Paso 2: Determinación de los Caudales Medios (Q_{mi})

Para cada Q_i seleccionado, calcular el caudal medio (Q_{mi}). Esto se debe a que cada Q_i solo está disponible una parte del tiempo, y durante el resto del tiempo el caudal es menor. La fórmula para calcular Q_{mi} es: $Q_{mi} = \int_0^T Q_i \times dT$, donde T es el período de tiempo considerado. Graficar la curva de los caudales medios Q_{mi}.

2		
		Q _i (m ³ /s)
(Q _i +Q _{i+1})/2 (m ³ /s)	ΔQ _m (m ³ /s * %)/100	SUMA(Δq _m)
185.00	9.25	61.13
150.00	7.50	59.38
117.50	5.88	56.13
95.00	4.75	52.75
75.00	7.50	48.75
60.00	6.00	44.25
50.00	5.00	40.25
41.50	4.15	36.00
35.50	3.55	32.40
30.50	3.05	28.90
25.50	2.55	24.90
21.50	1.08	21.30
17.50	0.88	18.38

1							2		
Intervalo	P _i (%)	P _{i+1} (%)	Q _i (m ³ /s)	Q _{i+1} (m ³ /s)	ΔP (%)	Σ ΔP (%)	(Q _i +Q _{i+1})/2 (m ³ /s)	ΔQ _m (m ³ /s * %)/100	Q _{mi} (m ³ /s)
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38



Detalle de las Fórmulas y Cálculos:

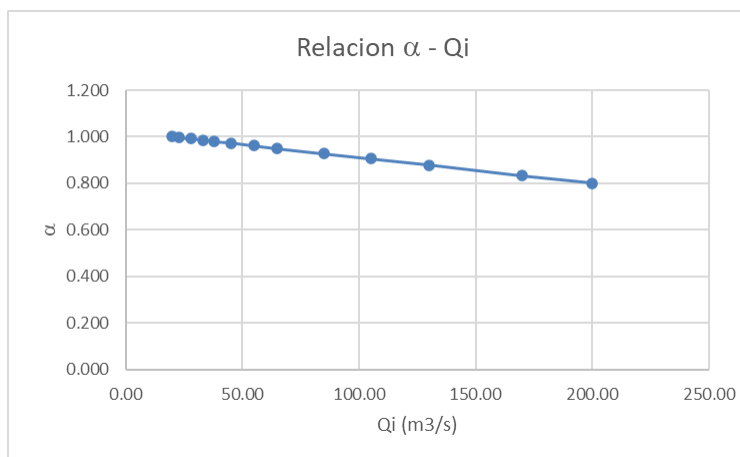
Paso 3: Aplicación del Coeficiente de Rendimiento (α)

Los Q_{mi} son teóricos, por lo que se deben ajustar con un coeficiente de rendimiento (α) que considera las pérdidas en las instalaciones hidráulicas.

α varía linealmente desde 1 para Q_{minAbs} hasta un valor menor a 1 para $Q_{maxCaract}$. El valor de α depende de la regularidad del río. Graficar la variación de α en función de Q .

Q_i (m ³ /s)	α
200.00	0.800
170.00	0.833
130.00	0.878
105.00	0.906
85.00	0.928
65.00	0.950
55.00	0.961
45.00	0.972
38.00	0.980
33.00	0.986
28.00	0.991
23.00	0.997
20.00	1.000

1							2		3
Intervalo	Pi (%)	Pi+1 (%)	Qi (m ³ /s)	Qi+1 (m ³ /s)	ΔP (%)	$\Sigma \Delta P$ (%)	$(Q_i+Q_{i+1})/2$ (m ³ /s)	ΔQ_m (m ³ /s * %)/100	Q_i (m ³ /s)
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38
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5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38



Detalle de las Fórmulas y Cálculos:

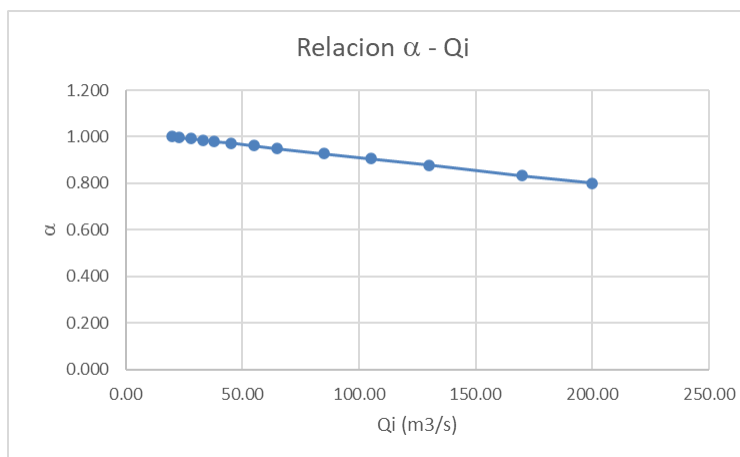
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α varía linealmente desde 1 para Q_{minAbs} hasta un valor menor a 1 para $Q_{maxCaract}$. El valor de α depende de la regularidad del río. Graficar la variación de α en función de Q .

Q_i (m ³ /s)	α
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170.00	0.833
130.00	0.878
105.00	0.906
85.00	0.928
65.00	0.950
55.00	0.961
45.00	0.972
38.00	0.980
33.00	0.986
28.00	0.991
23.00	0.997
20.00	1.000

1							2		3
Intervalo	Pi (%)	Pi+1 (%)	Qi (m ³ /s)	Qi+1 (m ³ /s)	ΔP (%)	$\Sigma \Delta P$ (%)	$(Q_i+Q_{i+1})/2$ (m ³ /s)	ΔQ_m (m ³ /s * %)/100	Q_i (m ³ /s)
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38



Detalle de las Fórmulas y Cálculos:

Paso 4: Cálculo de los Caudales Medios Utilizables

Multiplicar cada Q_{mi} por el coeficiente α correspondiente para obtener los caudales medios utilizables ($\alpha * Q_m$).

3	4
α	$\alpha * Q_{mi} \text{ (m}^3/\text{s)}$
0.800	48.90
0.833	49.48
0.878	49.27
0.906	47.77
0.928	45.23
0.950	42.04
0.961	38.68
0.972	35.00
0.980	31.75
0.986	28.48
0.991	24.68
0.997	21.23
1.000	18.38

1							2			3	4
Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	$\Sigma \Delta P$ (%)	$(Q_i + Q_{i+1})/2 \text{ (m}^3/\text{s)}$	$\Delta Q_m \text{ (m}^3/\text{s} * \%)/100$	SUMA(Δq_m)	α	$\alpha * Q_{mi} \text{ (m}^3/\text{s)}$
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38

Detalle de las Fórmulas y Cálculos:

Paso 5: Determinación del Factor de Utilización (Fu).

Calcular el factor de utilización (Fu) para cada Qi. La fórmula es: $Fu = \alpha \cdot Q_{mi} / Q_i = N_{med} / N_i$, donde Nmed es la potencia media y Ni es la potencia instalada. Fu indica el grado de utilización de la potencia instalada.

5	1							2			3	4	5
Fu	Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	QI (m3/s) SUMA(Δq _m)	α	α*Q _{mi} (m3/s)	Fu α*Q _{mi} (m3/s) / Qi
α*Q _{mi} (m3/s) / Qi	1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90	0.24
0.24	2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29
0.29	3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38
0.38	4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45
0.45	5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53
0.53	6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65
0.65	7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70
0.70	8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78
0.78	9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84
0.84	10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86
0.86	11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88
0.88	12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92
0.92	13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92
0.92													

Detalle de las Fórmulas y Cálculos:

Paso 6: Cálculo del Tiempo de Utilización (Tu)

Calcular el tiempo de utilización (Tu), que representa las horas al año que la central opera a plena carga. La fórmula es: $Tu = 8760 \cdot \alpha \cdot Q_{mi} / Q_i = 8760 \cdot Fu$ (donde 8760 son las horas en un año).

6	1							2			3	4	5	6
Tu	Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	Qi (m3/s)						
8760*Fu (hs)	1	0.00	5.00	200.00	170.00	5.00	5.00	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	SUMA(Δqm)	α	α*Qmi (m3/s)	α*Qmi (m3/s) / Qi	8760*Fu (hs)
2141.82	2	5.00	10.00	170.00	130.00	5.00	10.00	185.00	9.25	61.13	0.800	48.90	0.24	2141.82
2549.63	3	10.00	15.00	130.00	105.00	5.00	15.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63
3319.72	4	15.00	20.00	105.00	85.00	5.00	20.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72
3985.22	5	20.00	30.00	85.00	65.00	10.00	30.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22
4661.26	6	30.00	40.00	65.00	55.00	10.00	40.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26
5665.36	7	40.00	50.00	55.00	45.00	10.00	50.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36
6161.42	8	50.00	60.00	45.00	38.00	10.00	60.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42
6813.33	9	60.00	70.00	38.00	33.00	10.00	70.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33
7319.67	10	70.00	80.00	33.00	28.00	10.00	80.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67
7560.82	11	80.00	90.00	28.00	23.00	10.00	90.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82
7720.90	12	90.00	95.00	23.00	20.00	5.00	95.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90
8085.48	13	95.00	100.00	20.00	15.00	5.00	100.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48
8048.25								17.50	0.88	18.38	1.000	18.38	0.92	8048.25
													</	

Detalle de las Fórmulas y Cálculos:

Paso 7: Cálculo de la Potencia Instalada (Ni)

Calcular la potencia instalada (Ni) para cada Qi utilizando la fórmula: $Ni=8 \cdot Hu \cdot Qi$ (donde Hu es la altura útil en metros y Qi en m3/s, dando Ni en kW).

7	1							2			3	4	5	6	7
Ni	Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	SUMA(Δqm)	α	α*Qmi (m3/s)	α*Qmi (m3/s) / Qi	8760*Fu (hs)	8*Hu*Qi (Kw)
8*Hu*Qi (Kw)	1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90	0.24	2141.82	32000.00
32000.00	2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00
27200.00	3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00
20800.00	4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00
16800.00	5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00
13600.00	6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00
10400.00	7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00
8800.00	8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00
7200.00	9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00
6080.00	10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00
5280.00	11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00
4480.00	12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00
3680.00	13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00
3200.00															

Detalle de las Fórmulas y Cálculos:

Paso 8: Cálculo de la Energía Anual (Ea)

Calcular la energía anual (Ea) producida para cada Qi con la fórmula: $Ea = Ni \cdot Tu$ (en kWh).

8	1							2			3	4	5	6	7	8
Ea	Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	SUMA(Δqm)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	8760*Fu (hs)	8*Hu*Qi (Kw)	Ni*Tu (Kwh)
Ni*Tu (Kwh)	1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90	0.24	2141.82	32000.00	68538240.00
68538240.00	2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00	69350000.00
69350000.00	3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00	69050213.33
69050213.33	4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00	66951706.67
66951706.67	5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00	63393200.00
63393200.00	6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00	58919760.00
58919760.00	7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00	54220506.67
54220506.67	8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00	49056000.00
49056000.00	9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00	44503603.20
44503603.20	10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00	39921149.87
39921149.87	11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00	34589619.20
34589619.20	12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00	29754566.40
29754566.40	13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00	25754400.00
25754400.00																

Detalle de las Fórmulas y Cálculos:

Paso 9: Análisis de Costos

Distinguir entre los costos de construcción del proyecto y los costos de explotación. Los costos de construcción varían significativamente con Q_i , mientras que los de explotación varían poco. Elaborar anteproyectos para diferentes Q_i para obtener el costo unitario de construcción (CU) en \$/kW:

CU=Presupuesto de las Obras/Ni. Graficar la curva de CU en función de Q_i .

1							2			3	4	5	6	7	8	9
Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	SUMA(Δqm)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	8760*Fu (hs)	8*Hu*Qi (Kw)	Ni*Tu (Kwh)	Cu/Qi*Qi (u\$/Kw)
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90	0.24	2141.82	32000.00	68538240.00	769.50
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00	69350000.00	767.68
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00	69050213.33	768.35
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00	66951706.67	773.11
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00	63393200.00	781.40
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00	58919760.00	792.25
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00	54220506.67	804.13
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00	49056000.00	817.77
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00	44503603.20	830.31
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00	39921149.87	843.40
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00	34589619.20	859.25
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00	29754566.40	874.18
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00	25754400.00	886.93

9

Cu

Cu/Qi*Qi (u\$/Kw)

769.50

767.68

768.35

773.11

781.40

792.25

804.13

817.77

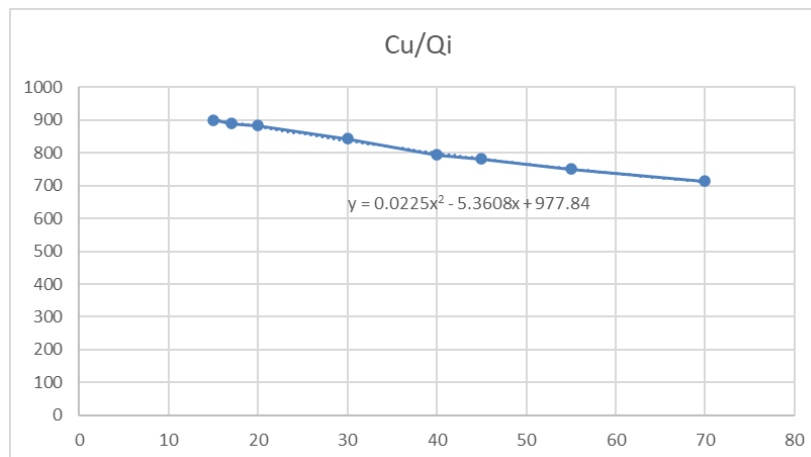
830.31

843.40

859.25

874.18

886.93



Cu (u\$/Kw)	Qi (m³/s)
900	15
890	17
884	20
844	30
794	40
782	45
750	55
714	70

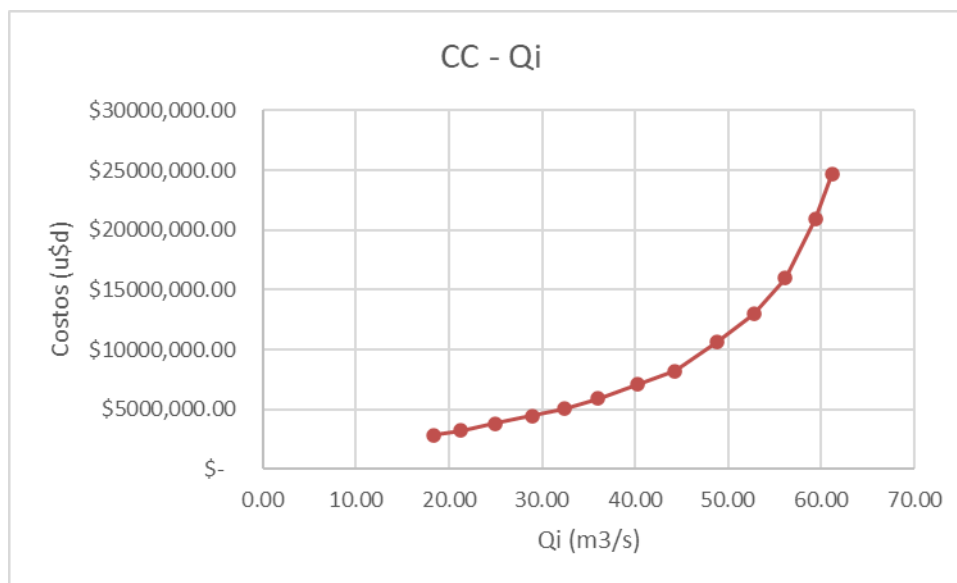
Detalle de las Fórmulas y Cálculos:

Paso 10: Cálculo del Costo de Construcción Total (CC)

Calcular el costo total de construcción (CC) para cada Qi: $CC = Cu \cdot Ni$

1							2		3	4	5	6	7	8	9	10	
Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %) / 100	Qi (m³/s)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	8760*Fu (hs)	8*Hu*Qi (Kw)	Ni*Tu (Kwh)	Cu/Qi*Qi (u\$/Kw)	Cu*Ni (u\$)
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90	0.24	2141.82	32000.00	68538240.00	769.50	\$24,623,971.36
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00	69350000.00	767.68	\$20,880,795.68
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00	69050213.33	768.35	\$15,981,632.57
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00	66951706.67	773.11	\$12,988,167.67
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00	63393200.00	781.40	\$10,627,083.89
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00	58919760.00	792.25	\$ 8,239,361.28
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00	54220506.67	804.13	\$ 7,076,347.21
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00	49056000.00	817.77	\$ 5,887,976.40
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00	44503603.20	830.31	\$ 5,048,273.50
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00	39921149.87	843.40	\$ 4,453,172.99
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00	34589619.20	859.25	\$ 3,849,421.75
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00	29754566.40	874.18	\$ 3,216,966.44
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00	25754400.00	886.93	\$ 2,838,183.09

10
CC
Cu*Ni (u\$d)
\$ 24,623,971.36
\$ 20,880,795.68
\$ 15,981,632.57
\$ 12,988,167.67
\$ 10,627,083.89
\$ 8,239,361.28
\$ 7,076,347.21
\$ 5,887,976.40
\$ 5,048,273.50
\$ 4,453,172.99
\$ 3,849,421.75
\$ 3,216,966.44
\$ 2,838,183.09



Detalle de las Fórmulas y Cálculos:

Paso 11: Cálculo del Servicio Anual del Capital (Sa)

Considerar que la inversión (CC) requiere un préstamo con su correspondiente amortización e interés.

Calcular la tasa de servicio anual del capital invertido (r).

1							2			3	4	5	6	7	8	9	10	11			
Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	SUMA(Δqm)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	Fu	Tu (hs)	8*Hu*Qi (kw)	Ni*Tu (kwh)	Cu/Qi*(u\$/Kw)	Cu*Ni (u\$/d)	CC	a	r
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90	0.24	2141.82	32000.00	68538240.00	769.50	\$24,623,971.36	0.0045	12.45%		
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00	69350000.00	767.68	\$20,880,795.68	0.0045	12.45%		
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00	69050213.33	768.35	\$15,981,632.57	0.0045	12.45%		
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00	66951706.67	773.11	\$12,988,167.67	0.0045	12.45%		
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00	63393200.00	781.40	\$10,627,083.89	0.0045	12.45%		
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00	58919760.00	792.25	\$ 8,239,361.28	0.0045	12.45%		
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00	54220506.67	804.13	\$ 7,076,347.21	0.0045	12.45%		
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00	49056000.00	817.77	\$ 5,887,976.40	0.0045	12.45%		
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00	44503603.20	830.31	\$ 5,048,273.50	0.0045	12.45%		
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00	39921149.87	843.40	\$ 4,453,172.99	0.0045	12.45%		
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00	34589619.20	859.25	\$ 3,849,421.75	0.0045	12.45%		
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00	29754566.40	874.18	\$ 3,216,966.44	0.0045	12.45%		
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00	25754400.00	886.93	\$ 2,838,183.09	0.0045	12.45%		

11	
a	r
i/(1+i)^(n-1)	a+i
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%
0.0045	12.45%

Detalle de las Fórmulas y Cálculos:

Paso 12: Cálculo del Gasto Anual por Construcción (Sa)

Calcular el gasto anual (Sa) debido a la construcción: $Sa = CC \cdot r$

1							2			3	4	5	6	7	8	9	10	11		12
Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	SUMA(Δqm)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	8760*Fu (hs)	8*Hu*Qi (Kw)	Ni*Tu (Kwh)	Cu/Qi*Qi (u\$/Kw)	Cu*Ni (u\$/d)	i/(1+i)^(n-1)	r	r*CC (u\$/d)
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90	0.24	2141.82	32000.00	68538240.00	769.50	\$24,623,971.36	0.0045	12.45%	\$3,065,339.53
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00	69350000.00	767.68	\$20,880,795.68	0.0045	12.45%	\$2,599,366.58
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00	69050213.33	768.35	\$15,981,632.57	0.0045	12.45%	\$1,989,489.40
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00	66951706.67	773.11	\$12,988,167.67	0.0045	12.45%	\$1,616,844.95
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00	63393200.00	781.40	\$10,627,083.89	0.0045	12.45%	\$1,322,923.09
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00	58919760.00	792.25	\$ 8,239,361.28	0.0045	12.45%	\$1,025,685.07
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00	54220506.67	804.13	\$ 7,076,347.21	0.0045	12.45%	\$ 880,906.11
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00	49056000.00	817.77	\$ 5,887,976.40	0.0045	12.45%	\$ 732,970.59
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00	44503603.20	830.31	\$ 5,048,273.50	0.0045	12.45%	\$ 628,439.34
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00	39921149.87	843.40	\$ 4,453,172.99	0.0045	12.45%	\$ 554,357.66
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00	34589619.20	859.25	\$ 3,849,421.75	0.0045	12.45%	\$ 479,199.09
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00	29754566.40	874.18	\$ 3,216,966.44	0.0045	12.45%	\$ 400,467.26
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00	25754400.00	886.93	\$ 2,838,183.09	0.0045	12.45%	\$ 353,314.04

12
Sa
r*CC (u\$/d)
\$ 3,065,339.53
\$ 2,599,366.58
\$ 1,989,489.40
\$ 1,616,844.95
\$ 1,322,923.09
\$ 1,025,685.07
\$ 880,906.11
\$ 732,970.59
\$ 628,439.34
\$ 554,357.66
\$ 479,199.09
\$ 400,467.26
\$ 353,314.04

Detalle de las Fórmulas y Cálculos:

Paso 13: Cálculo del Costo Unitario de la Energía por Construcción (CCU)

Calcular el costo unitario de la energía por gastos de construcción (CCU) en \$/kWh: $CCU = Sa/Ea$

1							2			3	4	5	6	7	8	9	10	11		12	13	
Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	SUMA(Δqm)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	Fu	8760*Fu (hs)	8*Hu*Qi (Kw)	Ni*Tu (Kwh)	Cu/Qi*Qi (u\$D/Kw)	Cu*Ni (u\$D)	i/(1+i)^(n-1)	a+i	r*CC (u\$D)	Sa/Ea (u\$D/Kw)
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90	0.24	2141.82	32000.00	68538240.00	769.50	\$24,623,971.36	0.0045	12.45%	\$3,065,339.53	\$	0.04
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00	69350000.00	767.68	\$20,880,795.68	0.0045	12.45%	\$2,599,366.58	\$	0.04
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00	69050213.33	768.35	\$15,981,632.57	0.0045	12.45%	\$1,989,489.40	\$	0.03
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00	66951706.67	773.11	\$12,988,167.67	0.0045	12.45%	\$1,616,844.95	\$	0.02
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00	63393200.00	781.40	\$10,627,083.89	0.0045	12.45%	\$1,322,923.09	\$	0.02
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00	58919760.00	792.25	\$ 8,239,361.28	0.0045	12.45%	\$1,025,685.07	\$	0.02
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00	54220506.67	804.13	\$ 7,076,347.21	0.0045	12.45%	\$ 880,906.11	\$	0.02
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00	49056000.00	817.77	\$ 5,887,976.40	0.0045	12.45%	\$ 732,970.59	\$	0.01
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00	44503603.20	830.31	\$ 5,048,273.50	0.0045	12.45%	\$ 628,439.34	\$	0.01
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00	39921149.87	843.40	\$ 4,453,172.99	0.0045	12.45%	\$ 554,357.66	\$	0.01
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00	34589619.20	859.25	\$ 3,849,421.75	0.0045	12.45%	\$ 479,199.09	\$	0.01
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00	29754566.40	874.18	\$ 3,216,966.44	0.0045	12.45%	\$ 400,467.26	\$	0.01
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00	25754400.00	886.93	\$ 2,838,183.09	0.0045	12.45%	\$ 353,314.04	\$	0.01

13	
CCU	
Sa/Ea (u\$D/Kw)	
\$	0.04
\$	0.04
\$	0.03
\$	0.02
\$	0.02
\$	0.02
\$	0.02
\$	0.01
\$	0.01
\$	0.01
\$	0.01
\$	0.01
\$	0.01

Detalle de las Fórmulas y Cálculos:

Paso 14: Determinación de los Costos Anuales de Explotación (Cexp)

Estimar los costos anuales de explotación y mantenimiento (Cexp). Estos costos incluyen operación, mantenimiento y mantenimiento preventivo, y pueden estimarse como un porcentaje del costo de construcción.

	1						2			3	4	5	6	7	8	9	10	11		12	13	14			
Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	SUMA(Qm)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	Fu	8760*Fu (hs)	8*Hu*Qi (Kw)	Ni*Tu (Kwh)	Cu/Qi*Qi (u\$/d/Kw)	Cu*Ni (u\$)	i/(1+i)^n(n-1)	a+i	r	r*CC (u\$)	Sa/Ea (u\$)/Kw	% CC Qi (u\$)/Kw	Cexp
1	0.00	5.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	0.800	48.90	0.24	2141.82	32000.00	68538240.00	769.50	\$24,623,971.36	0.0045	12.45%	\$3,065,339.53	\$	0.04	\$424,580.83		
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00	69350000.00	767.68	\$20,880,795.68	0.0045	12.45%	\$2,599,366.58	\$	0.04	\$424,580.83		
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00	69050213.33	768.35	\$15,981,632.57	0.0045	12.45%	\$1,989,489.40	\$	0.03	\$424,580.83		
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00	66951706.67	773.11	\$12,988,167.67	0.0045	12.45%	\$1,616,844.95	\$	0.02	\$424,580.83		
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00	63393200.00	781.40	\$10,627,083.89	0.0045	12.45%	\$1,322,923.09	\$	0.02	\$424,580.83		
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00	58919760.00	792.25	\$ 8,239,361.28	0.0045	12.45%	\$1,025,685.07	\$	0.02	\$424,580.83		
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00	54220506.67	804.13	\$ 7,076,347.21	0.0045	12.45%	\$ 880,906.11	\$	0.02	\$424,580.83		
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00	49056000.00	817.77	\$ 5,887,976.40	0.0045	12.45%	\$ 732,970.59	\$	0.01	\$424,580.83		
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00	44503603.20	830.31	\$ 5,048,273.50	0.0045	12.45%	\$ 628,439.34	\$	0.01	\$424,580.83		
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00	39921149.87	843.40	\$ 4,453,172.99	0.0045	12.45%	\$ 554,357.66	\$	0.01	\$424,580.83		
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00	34589619.20	859.25	\$ 3,849,421.75	0.0045	12.45%	\$ 479,199.09	\$	0.01	\$424,580.83		
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00	29754566.40	874.18	\$ 3,216,966.44	0.0045	12.45%	\$ 400,467.26	\$	0.01	\$424,580.83		
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00	25754400.00	886.93	\$ 2,838,183.09	0.0045	12.45%	\$ 353,314.04	\$	0.01	\$424,580.83		

14
Cexp
% CC Qi (u\$/d)
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83
\$ 424,580.83

Costo de Explotación = 6% Costo Construcción Qi40

Detalle de las Fórmulas y Cálculos:

Paso 15: Cálculo del Costo Unitario de la Energía por Explotación (CEU)

Calcular el costo unitario de la energía por gastos de explotación (CEU) en \$/kWh: $CEU = E_a C_{exp}$

	1						2			3	4	5	6	7	8	9	10	11		12	13	14	15		
Intervalo	Pi (%)	Pi+1 (%)	Qi (m³/s)	Qi+1 (m³/s)	ΔP (%)	Σ ΔP (%)	(Qi+Qi+1)/2 (m³/s)	ΔQm (m³/s * %)/100	SUMA(Δqm)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	8760*Fu (hs)	8*Hu*Qi (Kw)	Ni*Tu (kwh)	Ea	Cu	CC	a	r	r*CC (u\$d)	Sa/Ea (u\$d/kw)	% CC Qi (u\$d)	Cexp	CEU
1	0.00	200.00	170.00	5.00	5.00	185.00	9.25	61.13	48.90	0.800	48.90	0.24	2141.82	32000.00	68538240.00	769.50	\$24,623,971.36	0.0045	12.45%	\$3,065,339.53	\$	0.04	\$424,580.83	\$	0.006
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00	69350000.00	767.68	\$20,880,795.68	0.0045	12.45%	\$2,599,366.58	\$	0.04	\$424,580.83	\$	0.006
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00	69050213.33	768.35	\$15,981,632.57	0.0045	12.45%	\$1,989,489.40	\$	0.03	\$424,580.83	\$	0.006
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00	66951706.67	773.11	\$12,988,167.67	0.0045	12.45%	\$1,616,844.95	\$	0.02	\$424,580.83	\$	0.006
5	20.00	30.00	85.00	65.00	10.00	30.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00	63393200.00	781.40	\$10,627,083.89	0.0045	12.45%	\$1,322,923.09	\$	0.02	\$424,580.83	\$	0.007
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00	58919760.00	792.25	\$ 8,239,361.28	0.0045	12.45%	\$1,025,685.07	\$	0.02	\$424,580.83	\$	0.007
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00	54220506.67	804.13	\$ 7,076,347.21	0.0045	12.45%	\$ 880,906.11	\$	0.02	\$424,580.83	\$	0.008
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00	49056000.00	817.77	\$ 5,887,976.40	0.0045	12.45%	\$ 732,970.59	\$	0.01	\$424,580.83	\$	0.009
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00	44503603.20	830.31	\$ 5,048,273.50	0.0045	12.45%	\$ 628,439.34	\$	0.01	\$424,580.83	\$	0.010
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00	39921149.87	843.40	\$ 4,453,172.99	0.0045	12.45%	\$ 554,357.66	\$	0.01	\$424,580.83	\$	0.011
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00	34589619.20	859.25	\$ 3,849,421.75	0.0045	12.45%	\$ 479,199.09	\$	0.01	\$424,580.83	\$	0.012
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00	29754566.40	874.18	\$ 3,216,966.44	0.0045	12.45%	\$ 400,467.26	\$	0.01	\$424,580.83	\$	0.014
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00	25754400.00	886.93	\$ 2,838,183.09	0.0045	12.45%	\$ 353,314.04	\$	0.01	\$424,580.83	\$	0.016

15
CEU
Cexp/Ea (u\$d/Kwh)
\$ 0.006
\$ 0.006
\$ 0.006
\$ 0.006
\$ 0.007
\$ 0.007
\$ 0.008
\$ 0.009
\$ 0.010
\$ 0.011
\$ 0.012
\$ 0.014
\$ 0.016

Costo de Explotación = 6% Costo Construcción Qi40

Detalle de las Fórmulas y Cálculos:

Paso 16: Cálculo del Costo Total de la Energía Hidráulica (CEH)

Calcular el costo total de la energía hidráulica (CEH) en \$/kWh: $CEH = CCU + CEU$

	1						2			3	4	5	6	7	8	9	10	11			12	13	14	15	16		
	PI (%)	Qi (m³/s)	QI+1 (m³/s)	ΔP (%)	Σ ΔP (%)		QI (m³/s)	ΔQm (m³/s)*/100	SUMAΔ(qm)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	8760*Fu (hs)	8*Hu*Qi (Kw)	Ni*Tu (kwh)	Cu/Qt*Qi (u\$/d/kwh)	Cu*NI (u\$/d)	CC	a	r	CCU	CC Qi (u\$/d)	% CC Qi (u\$/d)	Cexp/Ea (u\$/d/kwh)	CEU	CEU+CU (u\$/d/kwh)	
Intervalo	0.00	5.00	200.00	170.00	5.00		QI+QI+1/2 (m³/s)	ΔQm (m³/s)*/100	SUMAΔ(qm)	α	α*Qmi (m³/s)	α*Qmi (m³/s) / Qi	8760*Fu (hs)	8*Hu*Qi (Kw)	Ni*Tu (kwh)	Cu/Qt*Qi (u\$/d/kwh)	Cu*NI (u\$/d)	CC	1/(1+1)*(n-1)	a+1	r	CCU	CC Qi (u\$/d)	% CC Qi (u\$/d)	Cexp/Ea (u\$/d/kwh)	CEU	CEU+CU (u\$/d/kwh)
1	0.00	5.00	200.00	170.00	5.00		185.00	9.25	61.13	0.800	48.90	0.24	2141.82	32000.00	68538240.00	769.50	\$24,623,971.36	0.0045	12.45%	\$3,065,339.53	\$	0.004	\$424,580.83	\$	0.006	\$	0.0509
2	5.00	10.00	170.00	130.00	5.00	10.00	150.00	7.50	59.38	0.833	49.48	0.29	2549.63	27200.00	69350000.00	767.68	\$20,880,795.68	0.0045	12.45%	\$2,599,366.58	\$	0.004	\$424,580.83	\$	0.006	\$	0.0436
3	10.00	15.00	130.00	105.00	5.00	15.00	117.50	5.88	56.13	0.878	49.27	0.38	3319.72	20800.00	69050213.33	768.35	\$15,981,632.57	0.0045	12.45%	\$1,989,489.40	\$	0.003	\$424,580.83	\$	0.006	\$	0.0350
4	15.00	20.00	105.00	85.00	5.00	20.00	95.00	4.75	52.75	0.906	47.77	0.45	3985.22	16800.00	66951706.67	773.11	\$12,988,167.67	0.0045	12.45%	\$1,616,844.95	\$	0.002	\$424,580.83	\$	0.006	\$	0.0305
5	20.00	30.00	85.00	65.00	10.00	25.00	75.00	7.50	48.75	0.928	45.23	0.53	4661.26	13600.00	63393200.00	781.40	\$10,627,083.89	0.0045	12.45%	\$1,322,923.09	\$	0.002	\$424,580.83	\$	0.007	\$	0.0276
6	30.00	40.00	65.00	55.00	10.00	40.00	60.00	6.00	44.25	0.950	42.04	0.65	5665.36	10400.00	58919760.00	792.25	\$8,239,361.28	0.0045	12.45%	\$1,025,685.07	\$	0.002	\$424,580.83	\$	0.007	\$	0.0246
7	40.00	50.00	55.00	45.00	10.00	50.00	50.00	5.00	40.25	0.961	38.68	0.70	6161.42	8800.00	54220506.67	804.13	\$7,076,347.21	0.0045	12.45%	\$880,906.11	\$	0.002	\$424,580.83	\$	0.008	\$	0.0241
8	50.00	60.00	45.00	38.00	10.00	60.00	41.50	4.15	36.00	0.972	35.00	0.78	6813.33	7200.00	49056000.00	817.77	\$5,887,976.40	0.0045	12.45%	\$732,970.59	\$	0.001	\$424,580.83	\$	0.009	\$	0.0236
9	60.00	70.00	38.00	33.00	10.00	70.00	35.50	3.55	32.40	0.980	31.75	0.84	7319.67	6080.00	44503603.20	830.31	\$5,048,273.50	0.0045	12.45%	\$628,439.34	\$	0.001	\$424,580.83	\$	0.010	\$	0.0237
10	70.00	80.00	33.00	28.00	10.00	80.00	30.50	3.05	28.90	0.986	28.48	0.86	7560.82	5280.00	39921149.87	843.40	\$4,453,172.99	0.0045	12.45%	\$554,357.66	\$	0.001	\$424,580.83	\$	0.011	\$	0.0245
11	80.00	90.00	28.00	23.00	10.00	90.00	25.50	2.55	24.90	0.991	24.68	0.88	7720.90	4480.00	34589619.20	859.25	\$3,849,421.75	0.0045	12.45%	\$479,199.09	\$	0.001	\$424,580.83	\$	0.012	\$	0.0261
12	90.00	95.00	23.00	20.00	5.00	95.00	21.50	1.08	21.30	0.997	21.23	0.92	8085.48	3680.00	29754566.40	874.18	\$3,216,966.44	0.0045	12.45%	\$400,467.26	\$	0.001	\$424,580.83	\$	0.014	\$	0.0277
13	95.00	100.00	20.00	15.00	5.00	100.00	17.50	0.88	18.38	1.000	18.38	0.92	8048.25	3200.00	25754400.00	886.93	\$2,838,183.09	0.0045	12.45%	\$353,314.04	\$	0.001	\$424,580.83	\$	0.016	\$	0.0302

16
CEH
CEU+CCU (u\$/kwh)
\$ 0.0509
\$ 0.0436
\$ 0.0350
\$ 0.0305
\$ 0.0276
\$ 0.0246
\$ 0.0241
\$ 0.0236
\$ 0.0237
\$ 0.0245
\$ 0.0261
\$ 0.0277
\$ 0.0302

