Renewable Energy in San Rafael

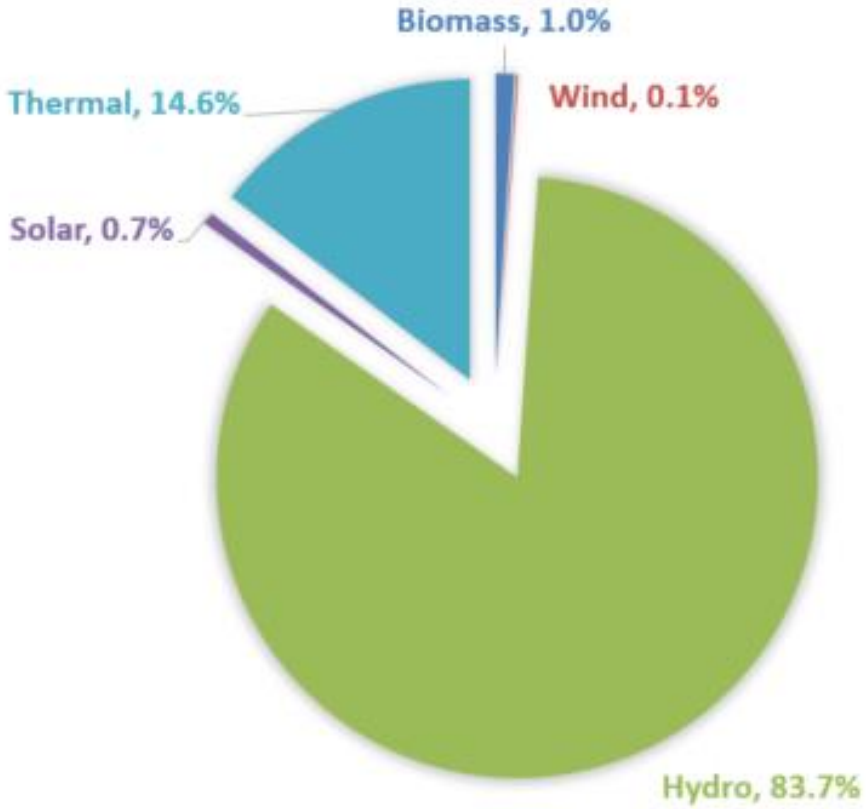
Technology and Potential

Mónica Gutiérrez

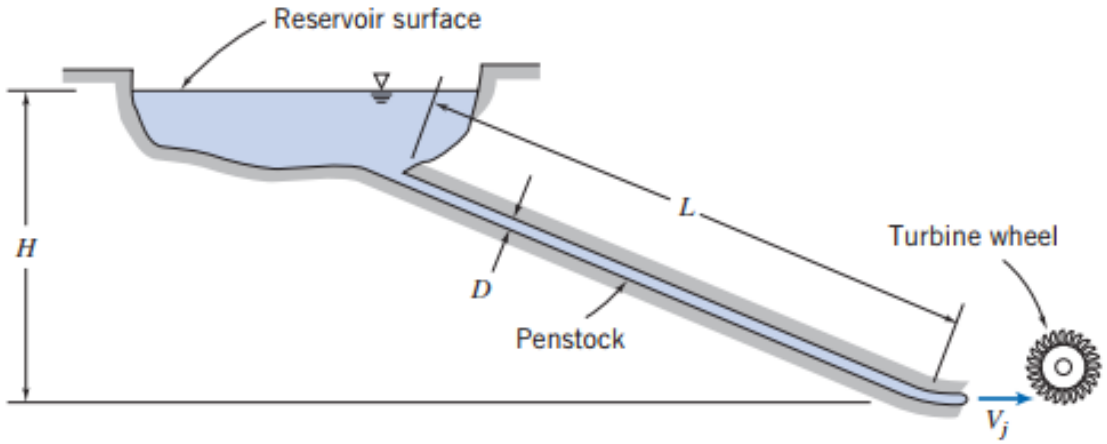
The general picture in Colombia

Source	2022 GWh	Share (%)
Biomass	771.36	1.0%
Wind	74.3	0.1%
Hydro	64337.26	83.7%
Solar	502.6	0.7%
Thermal	11219.8	14.6%

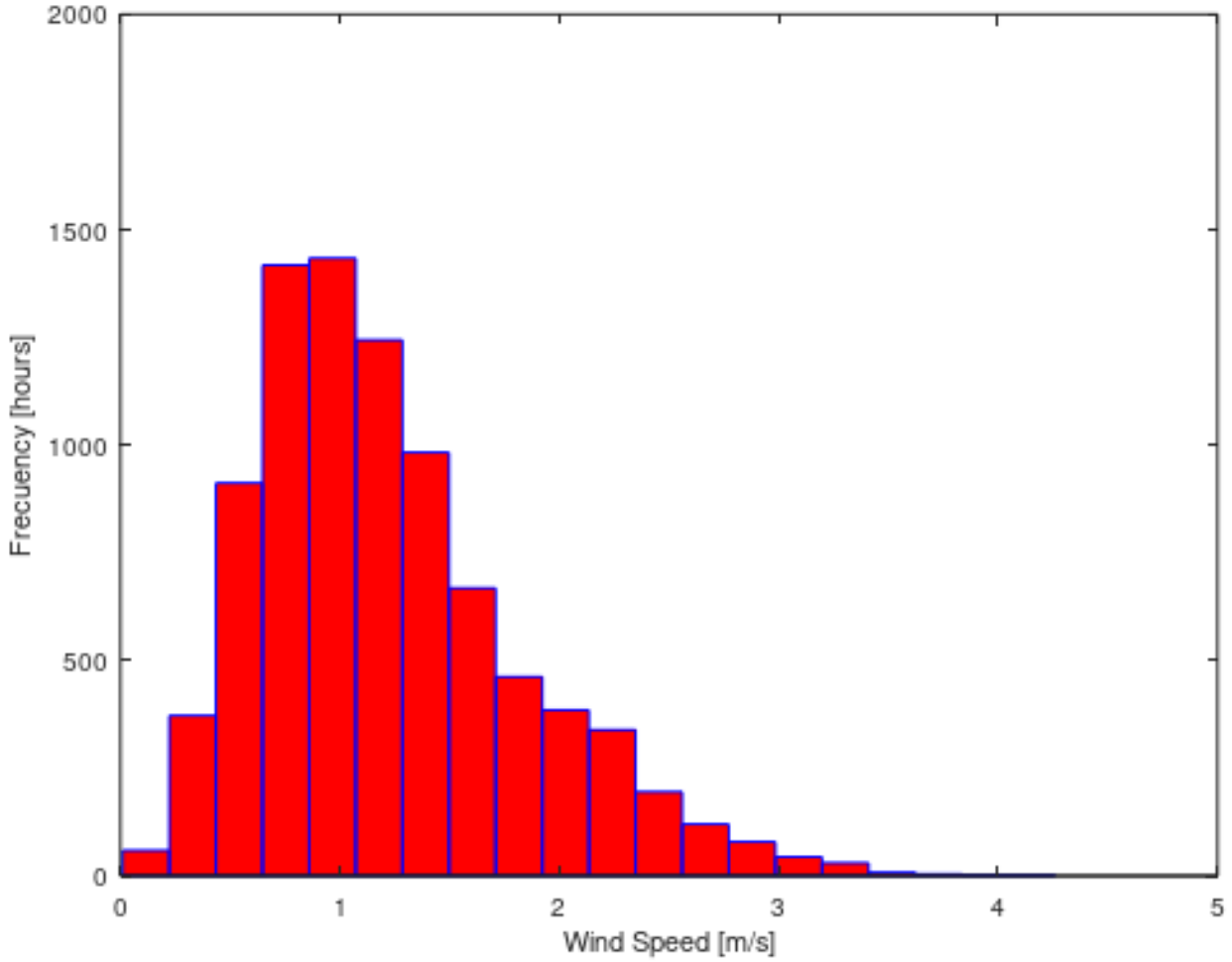
Source: XM S.A. Generación del SIN (2022)



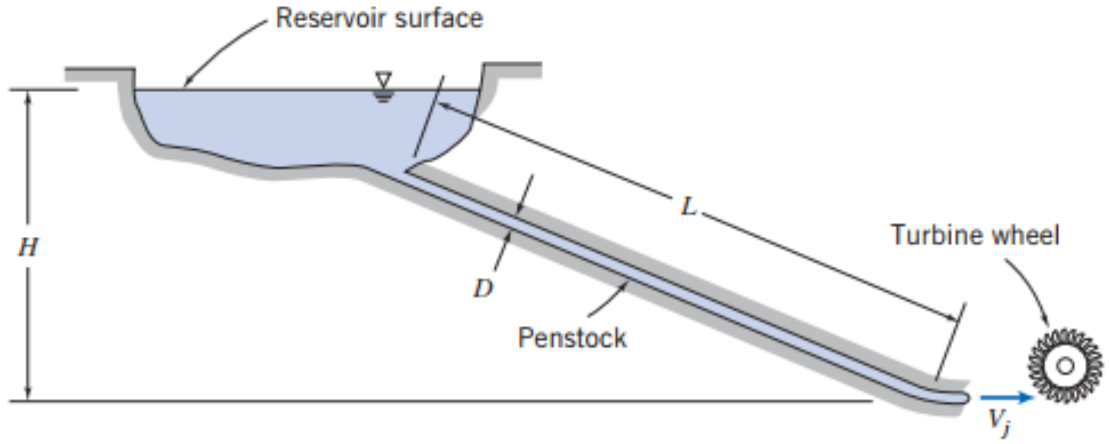
Energy potential in San Rafael



Wind potential



Hydro potential



Fuente: https://www.e-ray.eu/wasser/

River gauging

What variables do we need to measure from the river?

How can we measure these variables?

River gauging

What variables do we need to measure from the river?

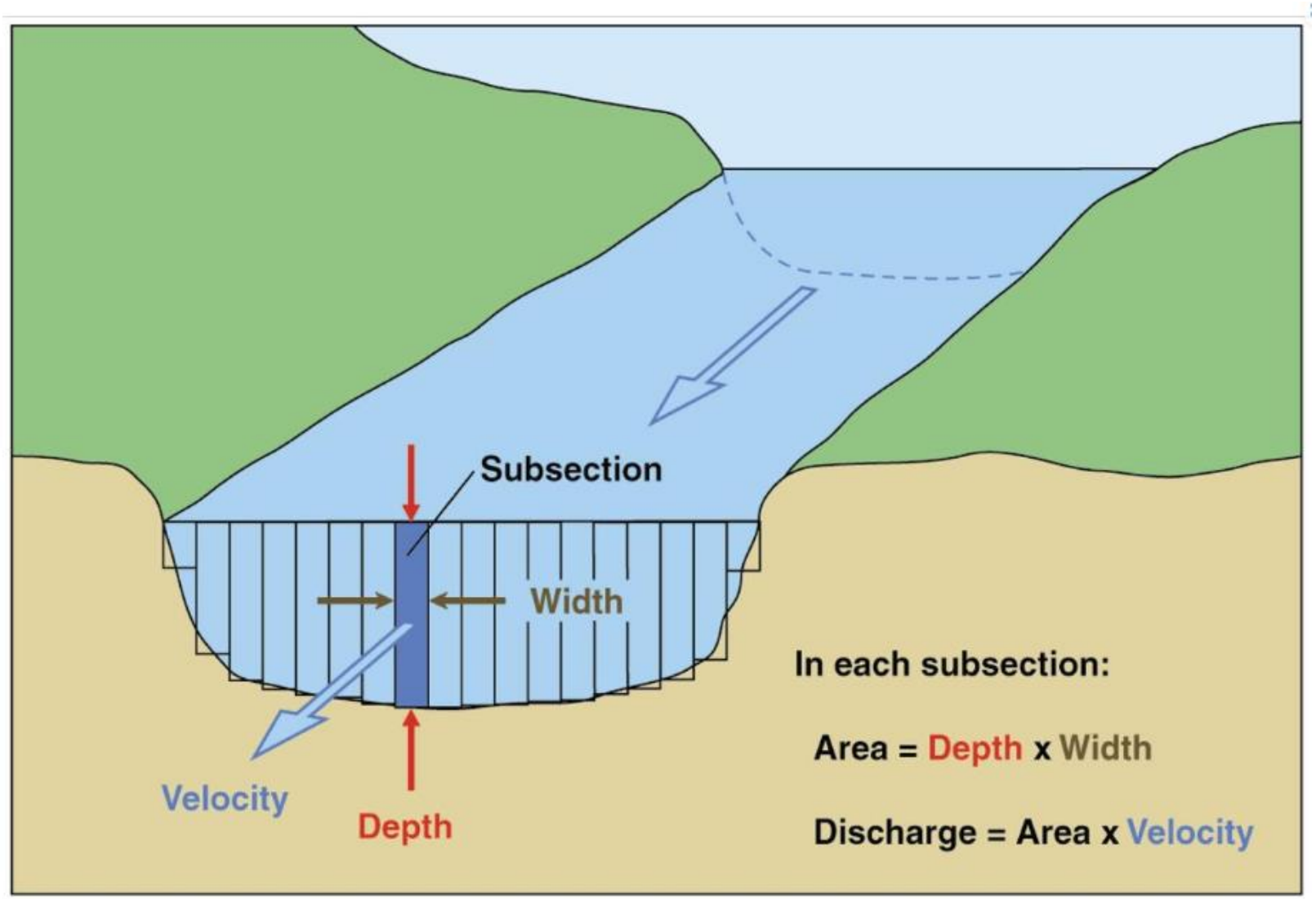
$$Q = A \times V$$

Q - Flow rate

A - Area

V - flow velocity

How can we measure these variables?

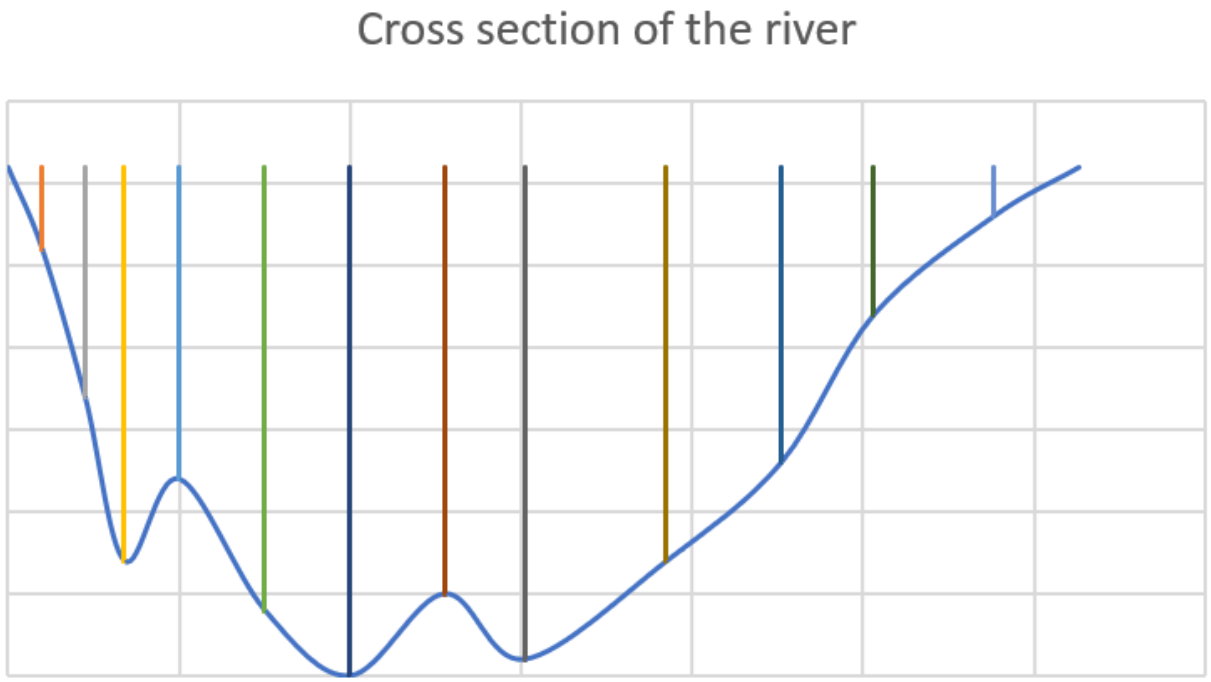


Source: USGS. *How streamflow is meassured.* Available at: www.usgs.com

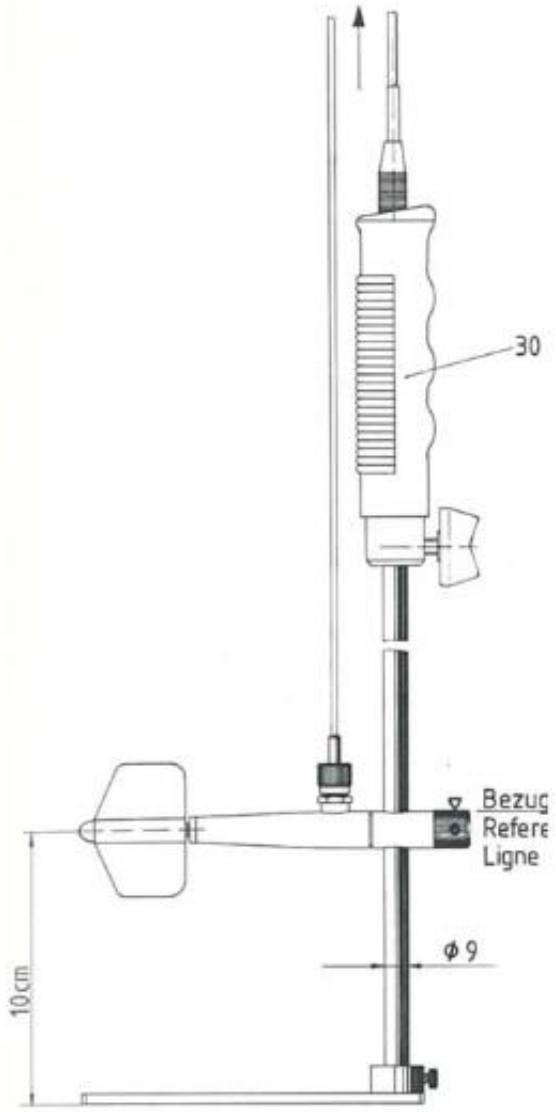
Spacing according with the river's width

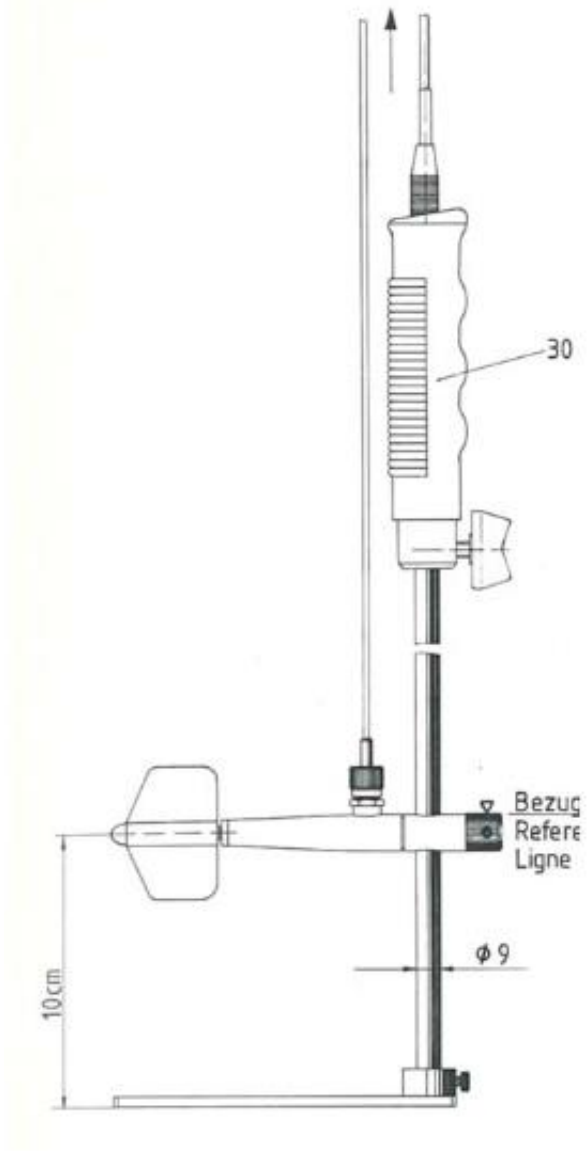
River's width range [m]		Spacing [m]
0	1	0.20
1	2	0.25
2	4	0.50
4	8	1.00
8	15	1.50
15	25	2.00
25	50	3.00
50	75	4.00
75	125	5.00

Measurement Nb	Distance from the origin [m]	Depth [m]
1	0	0
2	2	0.5
3	4.5	1.4
4	6.8	2.4
5	10	1.9
6	15	2.7
7	20	3.1
8	25.5	2.6
9	30.2	3
10	38.5	2.4
11	45.2	1.8
12	50.6	0.9
13	57.6	0.3
14	62.6	0



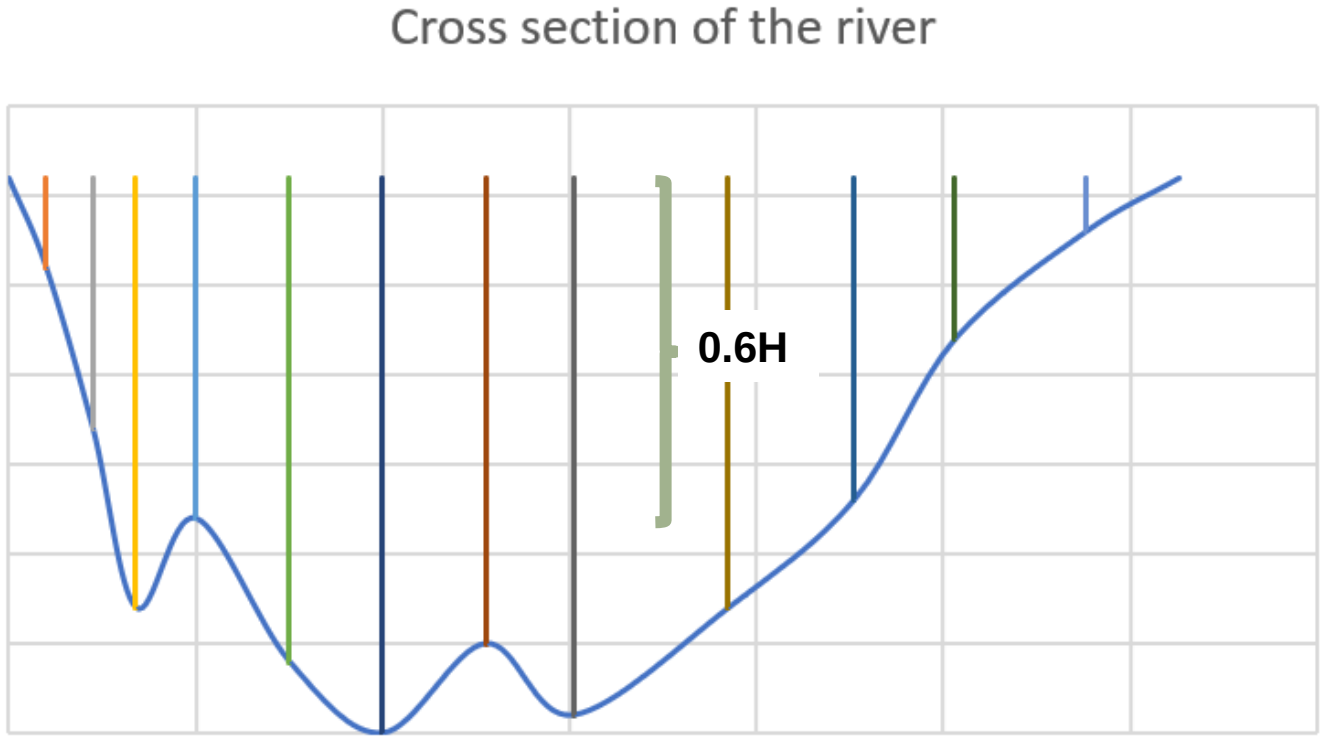
Flow probes/meters

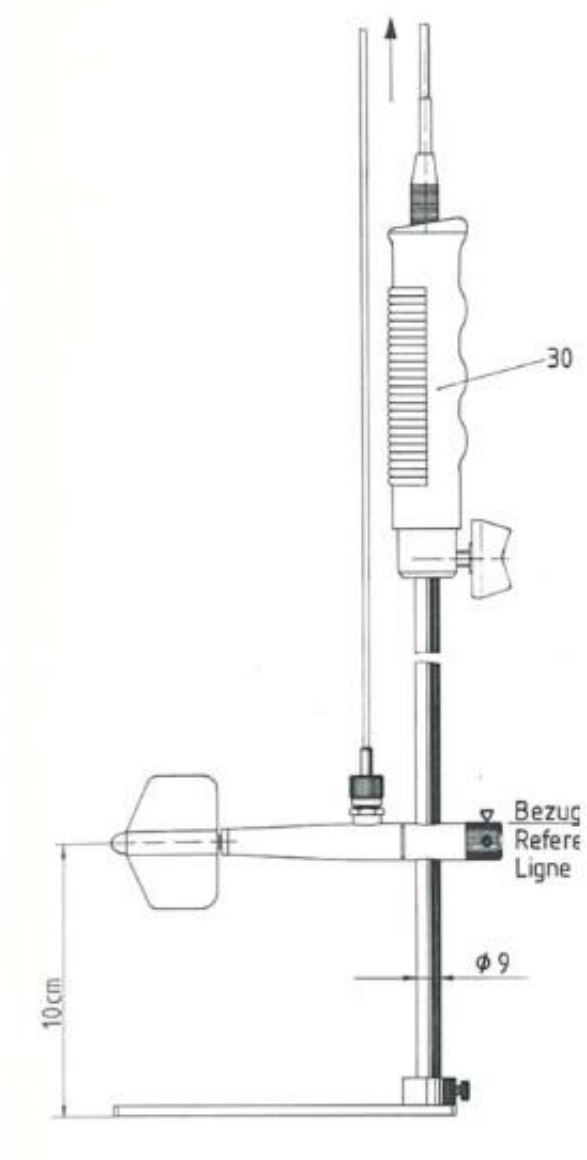




Method 6/10:

Put the Flow meter at 60% Depth from the Surface. It is assumed that the speed in that point approximates to the mean velocity of the vertical section.

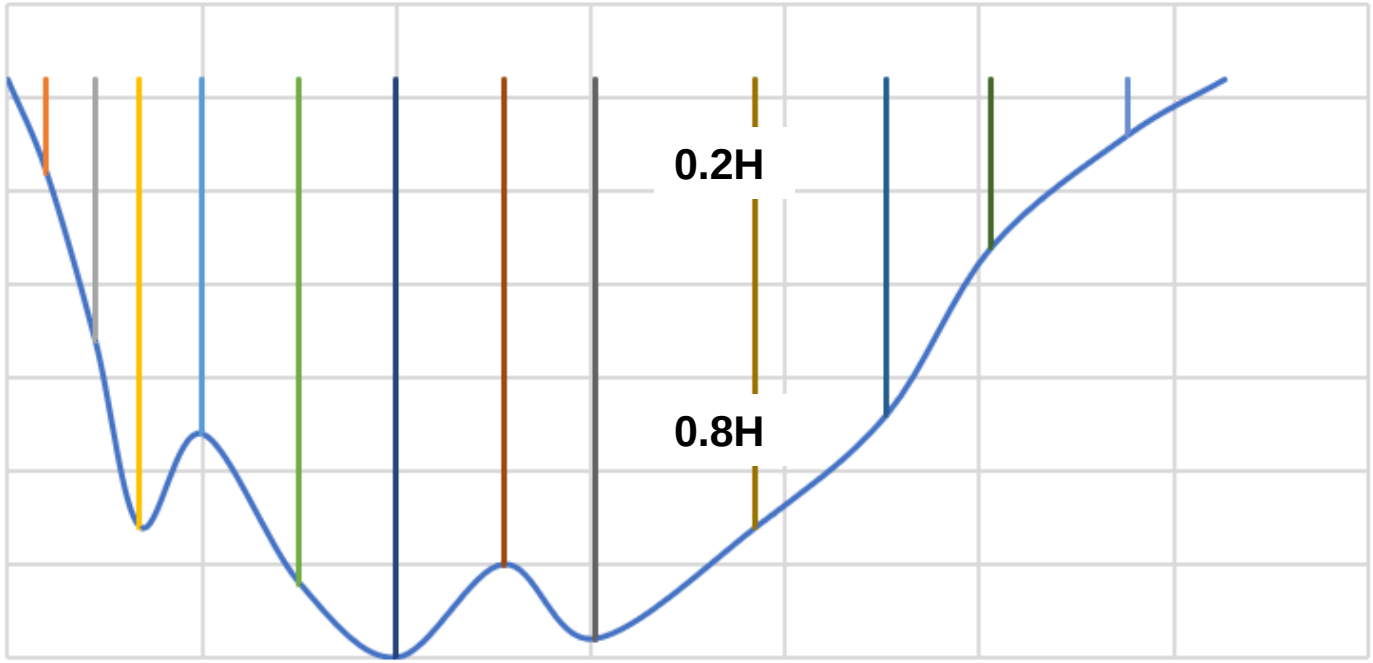


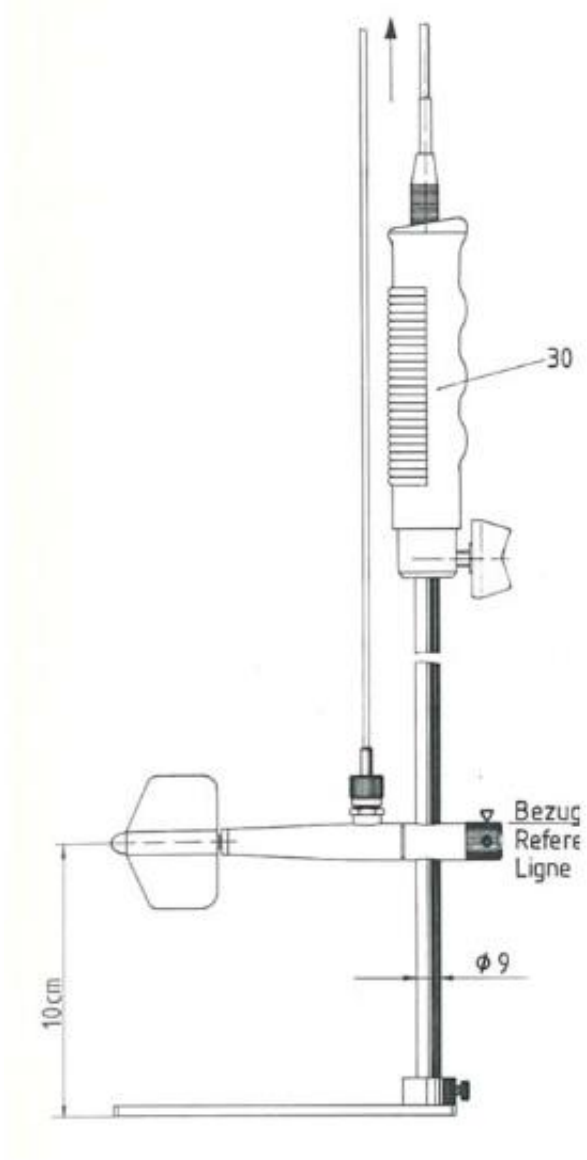


Method 2/10 y 8/10:

Measurements at 20% and 80% depth. The average is assumed to approximate to the mean velocity in the vertical section.

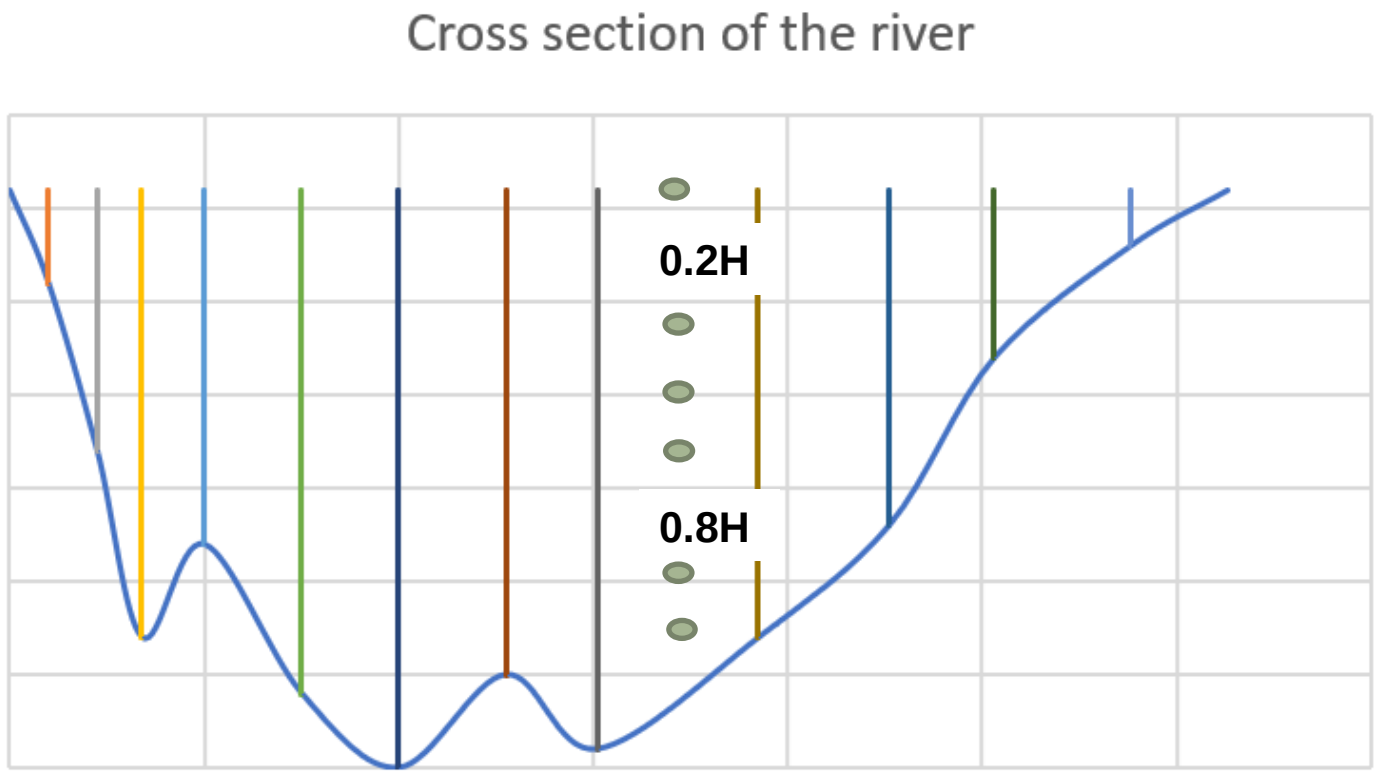
Cross section of the river

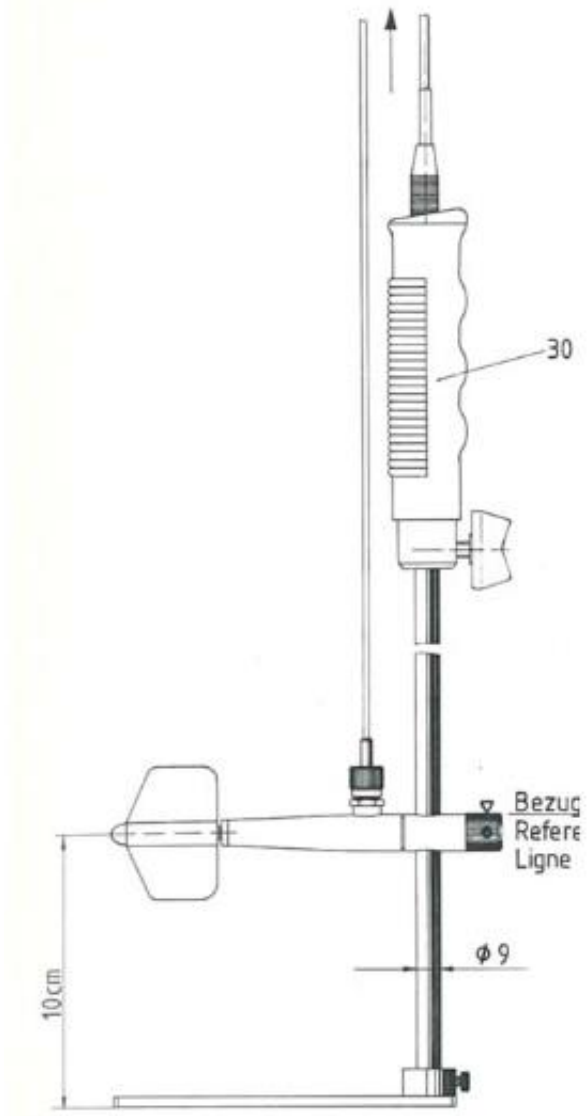




Various points measurement method:

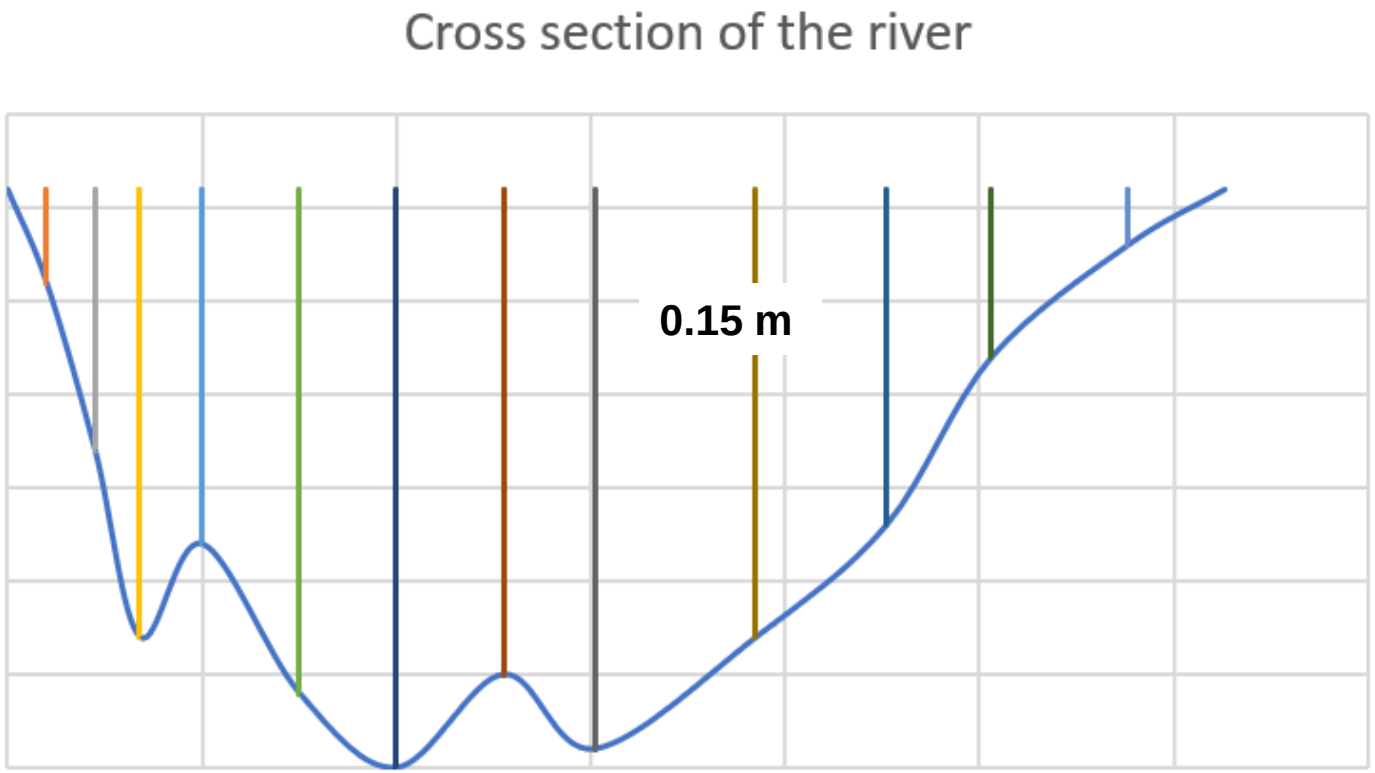
Highest accuracy.



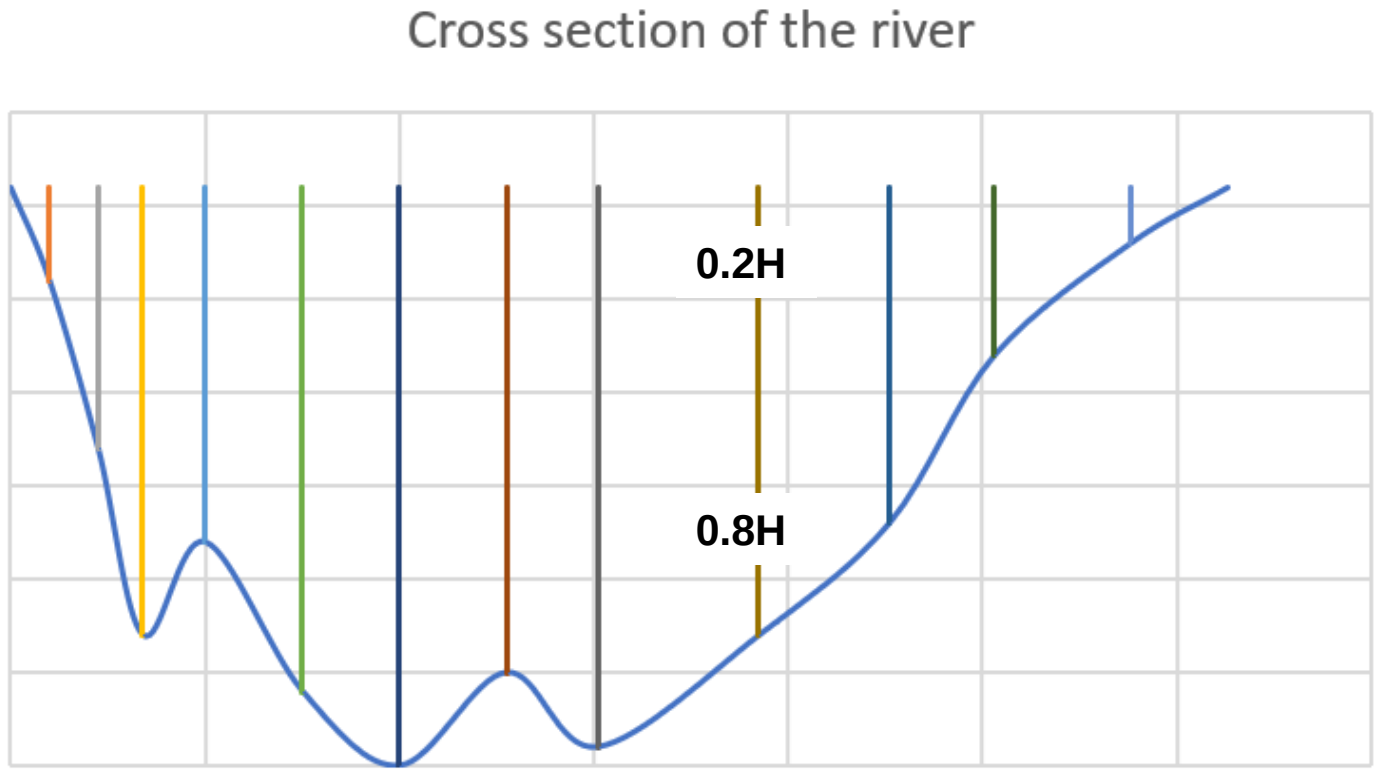


Surface method:

For strong currents, where you can not hold the Flow meter still.



Measurement Nb	Distance from the origin [m]	Depth [m]	Vel. 20% [m/s]	Vel.l 80% [m/s]
1	0	0	0	0
2	2	0.5	0.3	0.12
3	4.5	1.4	0.8	0.35
4	6.8	2.4	1.12	0.45
5	10	1.9	1.2	0.51
6	15	2.7	1.4	0.62
7	20	3.1	1.55	0.67
8	25.5	2.6	1.45	0.63
9	30.2	3	1.62	0.72
10	38.5	2.4	1.2	0.43
11	45.2	1.8	1.97	0.37
12	50.6	0.9	0.82	0.28
13	57.6	0.3	0.25	0.11
14	62.6	0	0	0

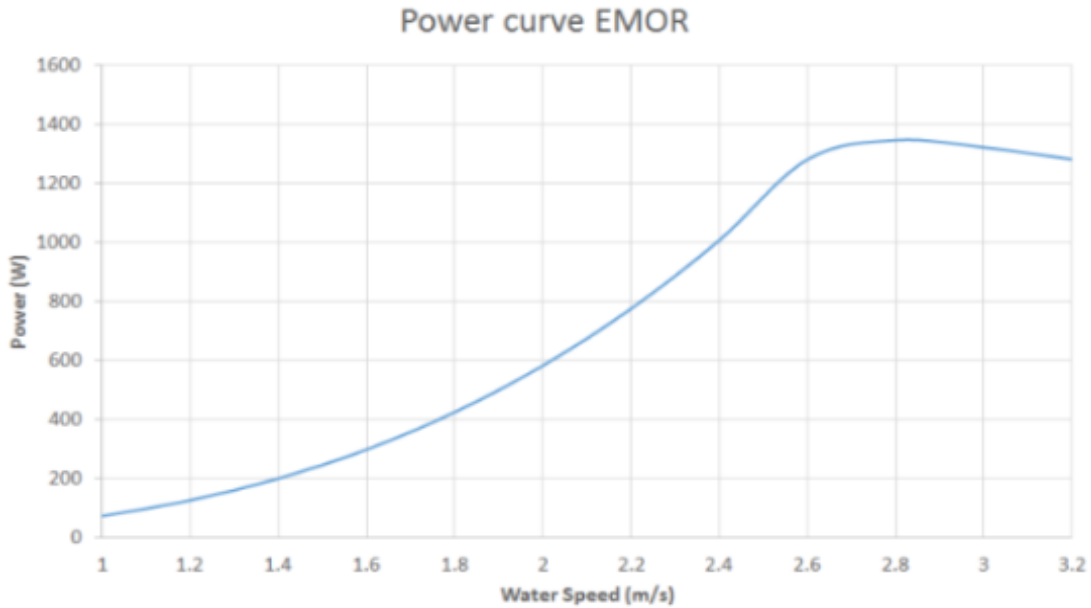


¿How could we calculate the area?

STREAMFLOW MEASUREMENTS								
Measurement Nb	Distance from the origin [m]	Depth [m]	Vel. 20% [m/s]	Vel.l 80% [m/s]	Width [m]	A [m2]	Vel. [m/s]	Flow rate [m3/s]
1	0	0	0	0				
2	2	0.5	0.3	0.12	2.00	0.50	0.21	0.11
3	4.5	1.4	0.8	0.35	2.50	2.38	0.58	1.37
4	6.8	2.4	1.12	0.45	2.30	4.37	0.79	3.43
5	10	1.9	1.2	0.51	3.20	6.88	0.86	5.88
6	15	2.7	1.4	0.62	5.00	11.50	1.01	11.62
7	20	3.1	1.55	0.67	5.00	14.50	1.11	16.10
8	25.5	2.6	1.45	0.63	5.50	15.68	1.04	16.30
9	30.2	3	1.62	0.72	4.70	13.16	1.17	15.40
10	38.5	2.4	1.2	0.43	8.30	22.41	0.82	18.26
11	45.2	1.8	1.97	0.37	6.70	14.07	1.17	16.46
12	50.6	0.9	0.82	0.28	5.40	7.29	0.55	4.01
13	57.6	0.3	0.25	0.11	7.00	4.20	0.18	0.76
14	62.6	0	0	0	5.00	0.75	0.00	0.00

And the total Flow rate?

Total	109.68



Source: https://www.e-ray.eu/wasser/

Width [m]	A [m2]	Vel. [m/s]	Flow rate [m3/s]
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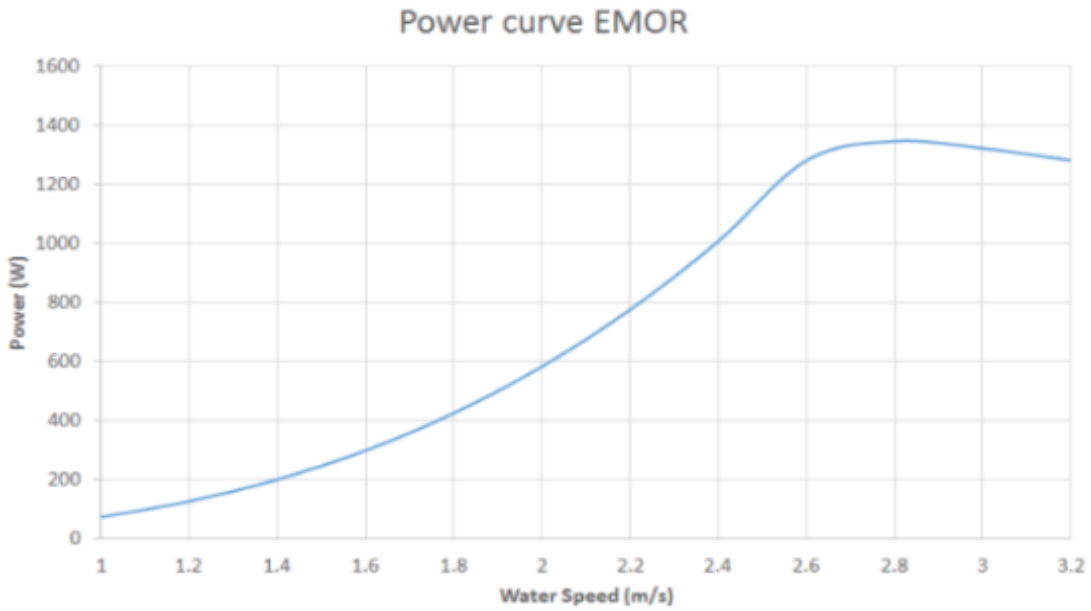

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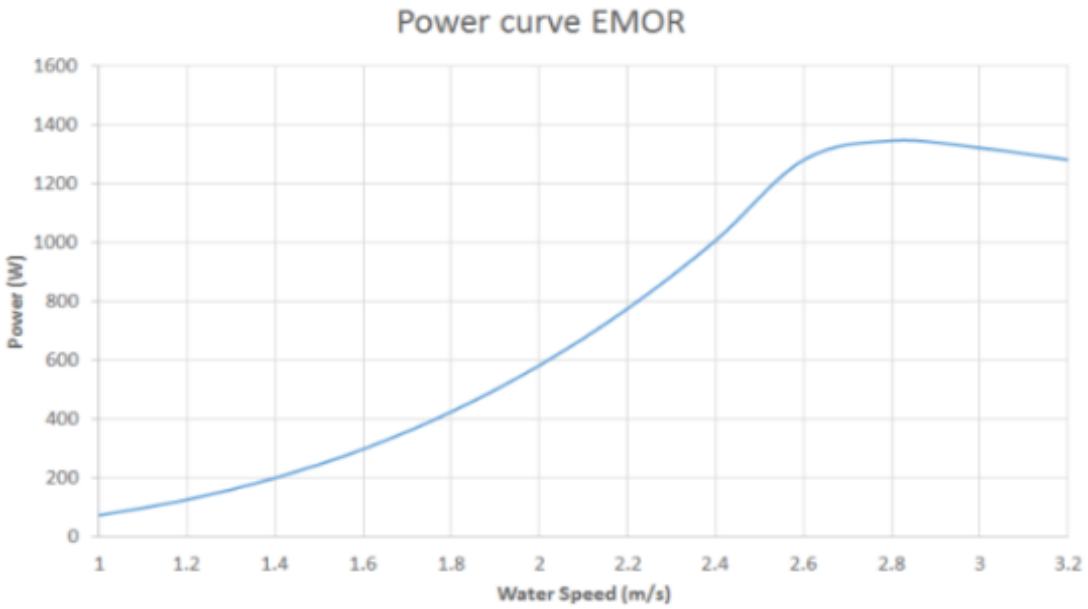
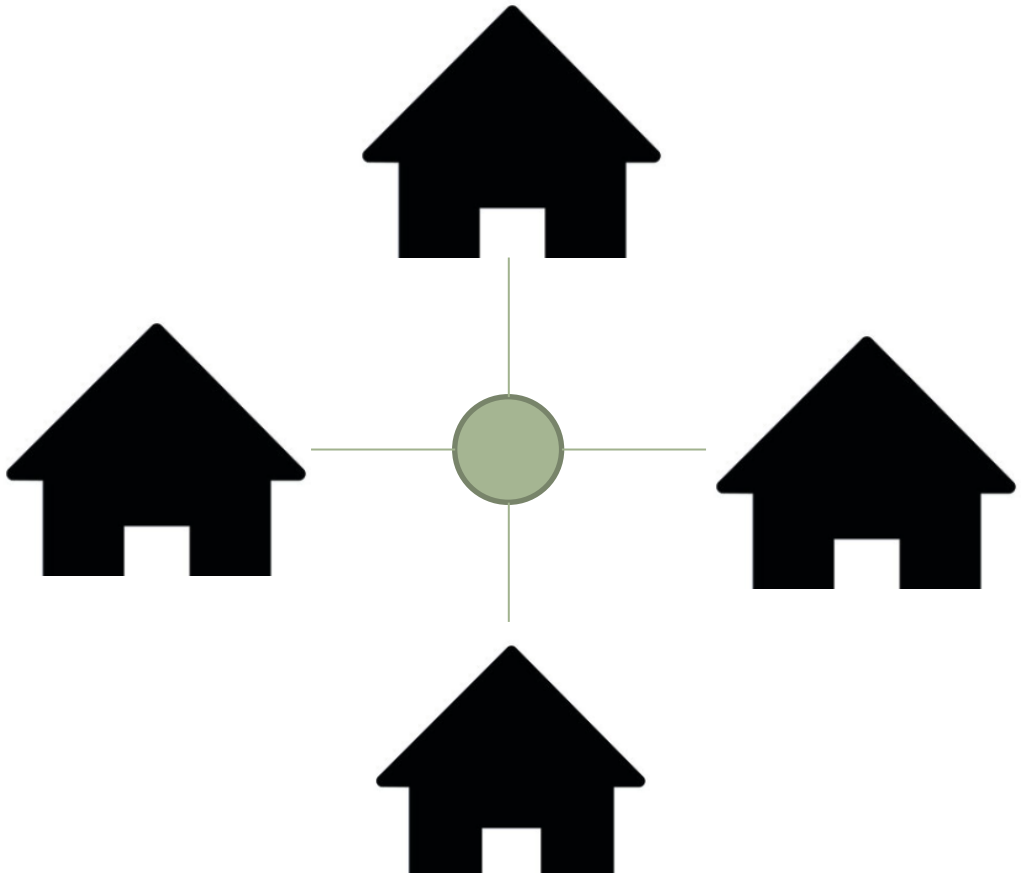


How can we calculate the energy that we could generate with this turbine?

Power at 1m/s – 90W

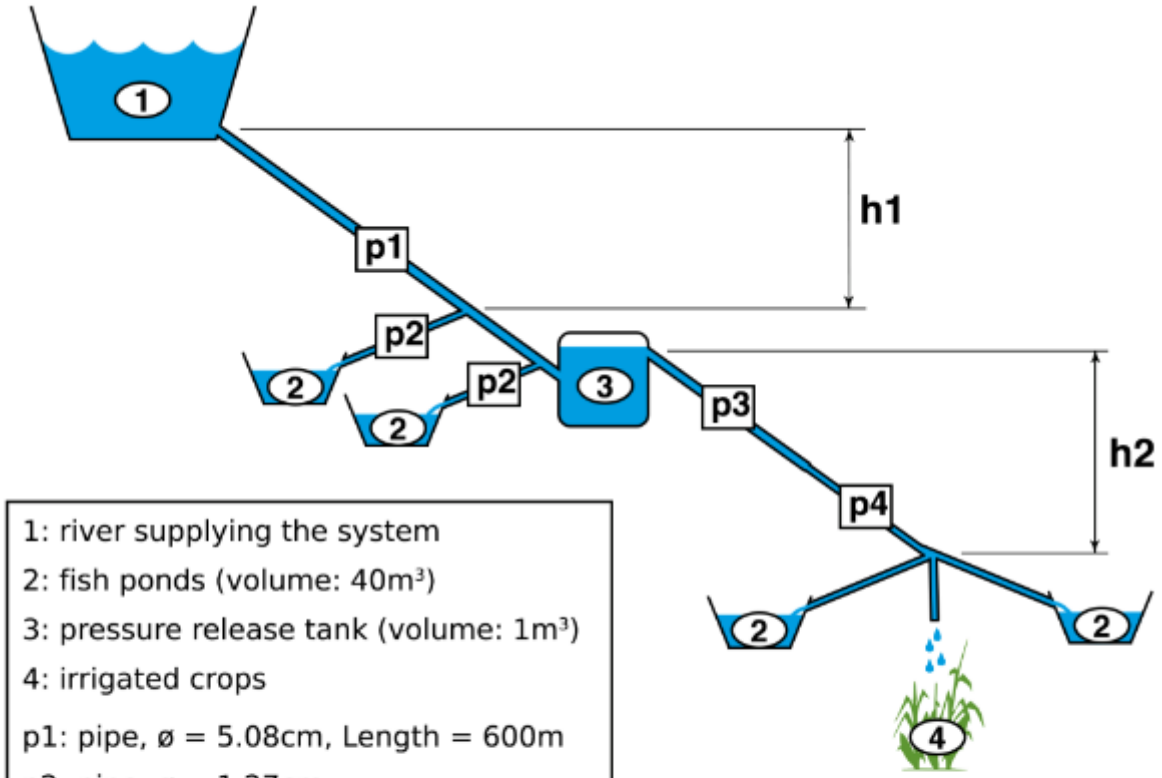
Energy assuming 24 hours of stream flow= 2.16 kWh/day



Time Period	Total Consumption [kWh]
28. August - 30. November	1072
30. November - 26. February	922
26. February - 27. May	993
27. May - 29. August	796

Total of 3783 kWh/year or 10.4 kWh/day

Is the kinetic turbine enough to supply the demand?



1: river supplying the system
2: fish ponds (volume: 40m³)
3: pressure release tank (volume: 1m³)
4: irrigated crops
p1: pipe, ø = 5.08cm, Length = 600m
p2: pipe, ø = 1.27cm
p3: pipe, ø = 3.81cm, Length = 100m
p4: pipe, ø = 2.54cm, Length = 100m
h1: head = 37m
h2: head = 36m

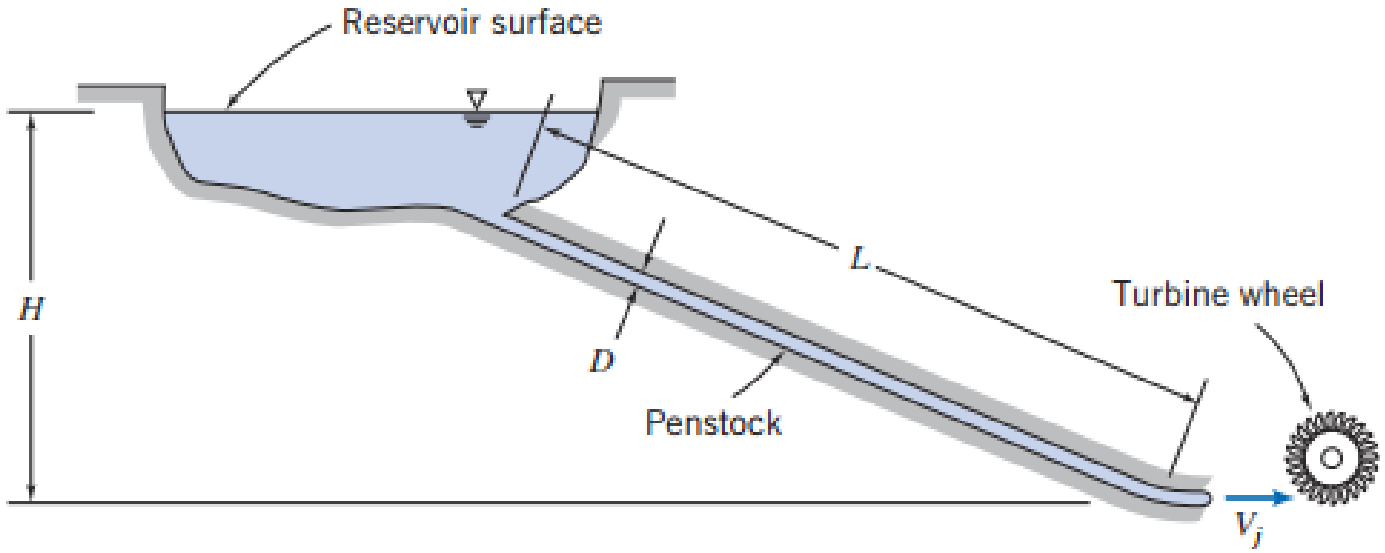
Source: Berhe, G. et al. *Assessment of hydropower potentian in the village of San Rafael in Colombia.* Case study report 2023.

Case studies

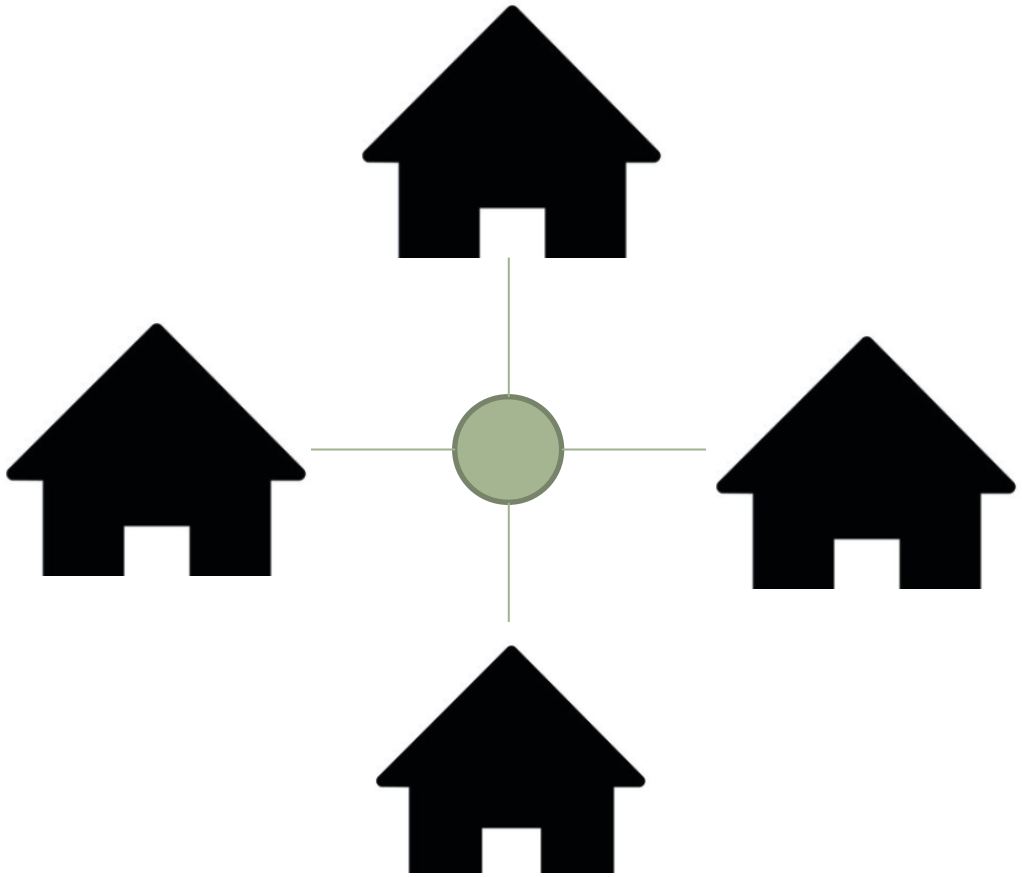
1) **Turbine just before the fishponds.**

2) **Turbine at the bottom of the system, ignoring the fishponds.**

Input data	
H [m]	37
L [m]	600
Pipe diameter [inches]	2
Nozzle diameter [inches]	1/2
Turbine efficiency	85%



Energy potential – 9.4 kWh/day



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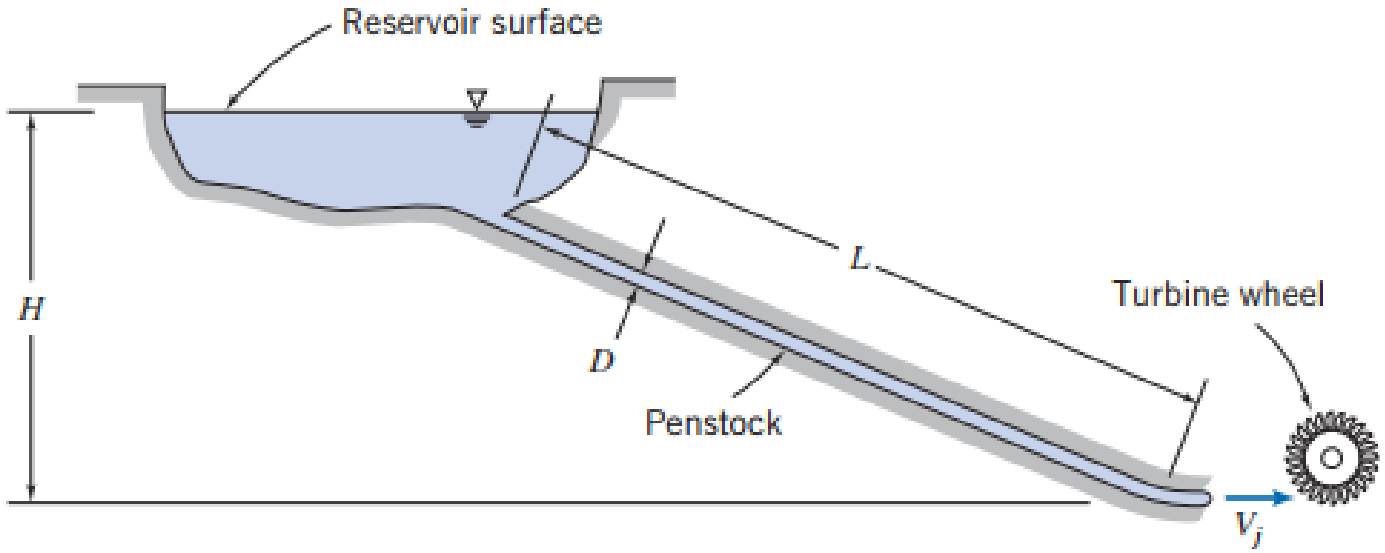
Total of 3783 kWh/year or 10.4 kWh/day

Is case 1 enough to supply the demand?

Input data	
H [m]	73
L [m]	800
Pipe diameter [inches]	2
Nozzle diameter [inches]	1/2
Turbine efficiency	85%

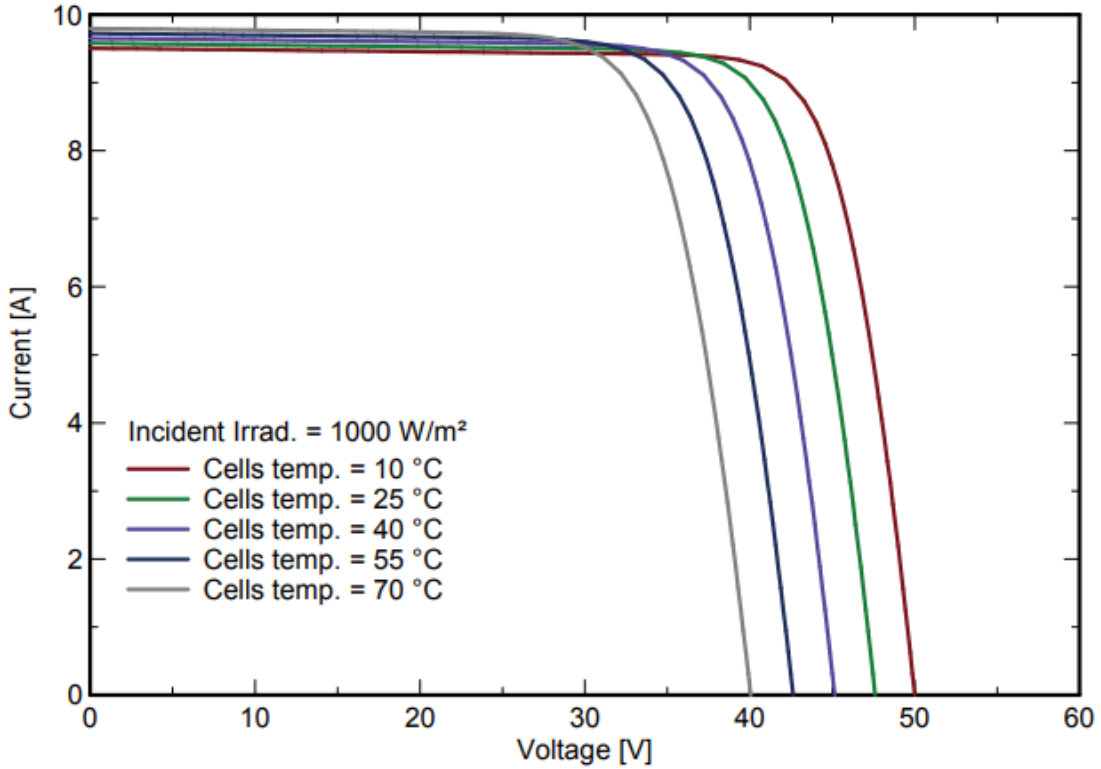


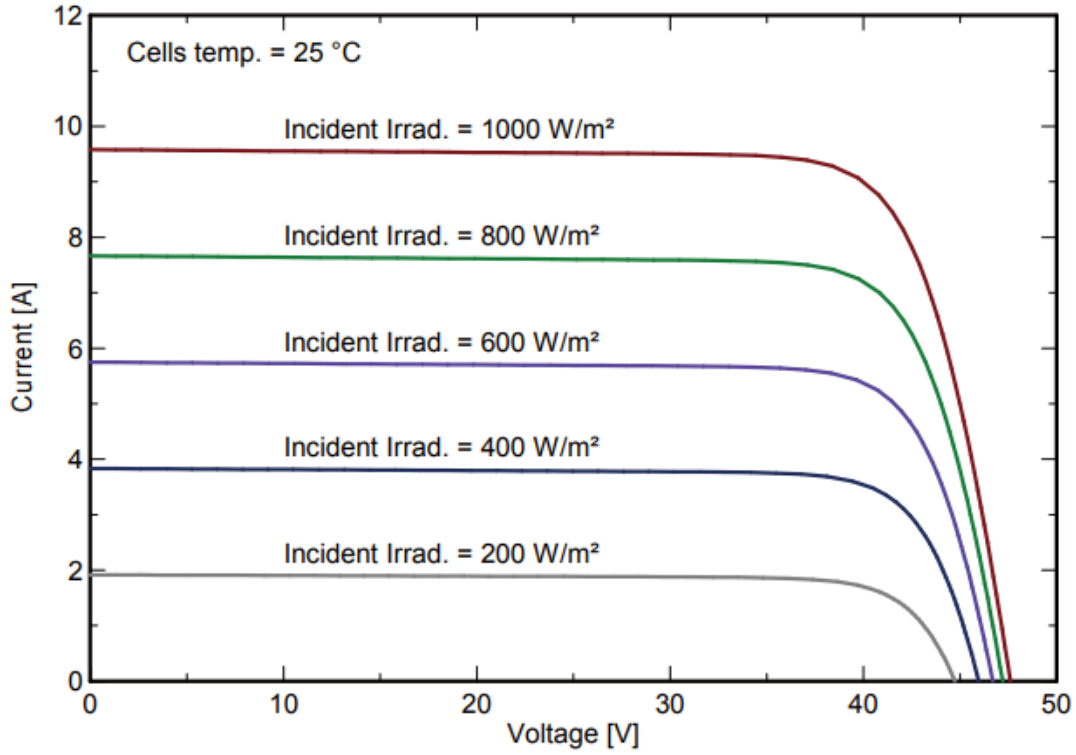
Energy potential – 21.9 kWh/day

Solar potential

$$P_{DC} = \eta(T_m, G_{AOI}) \cdot A \cdot G_{AOI}$$

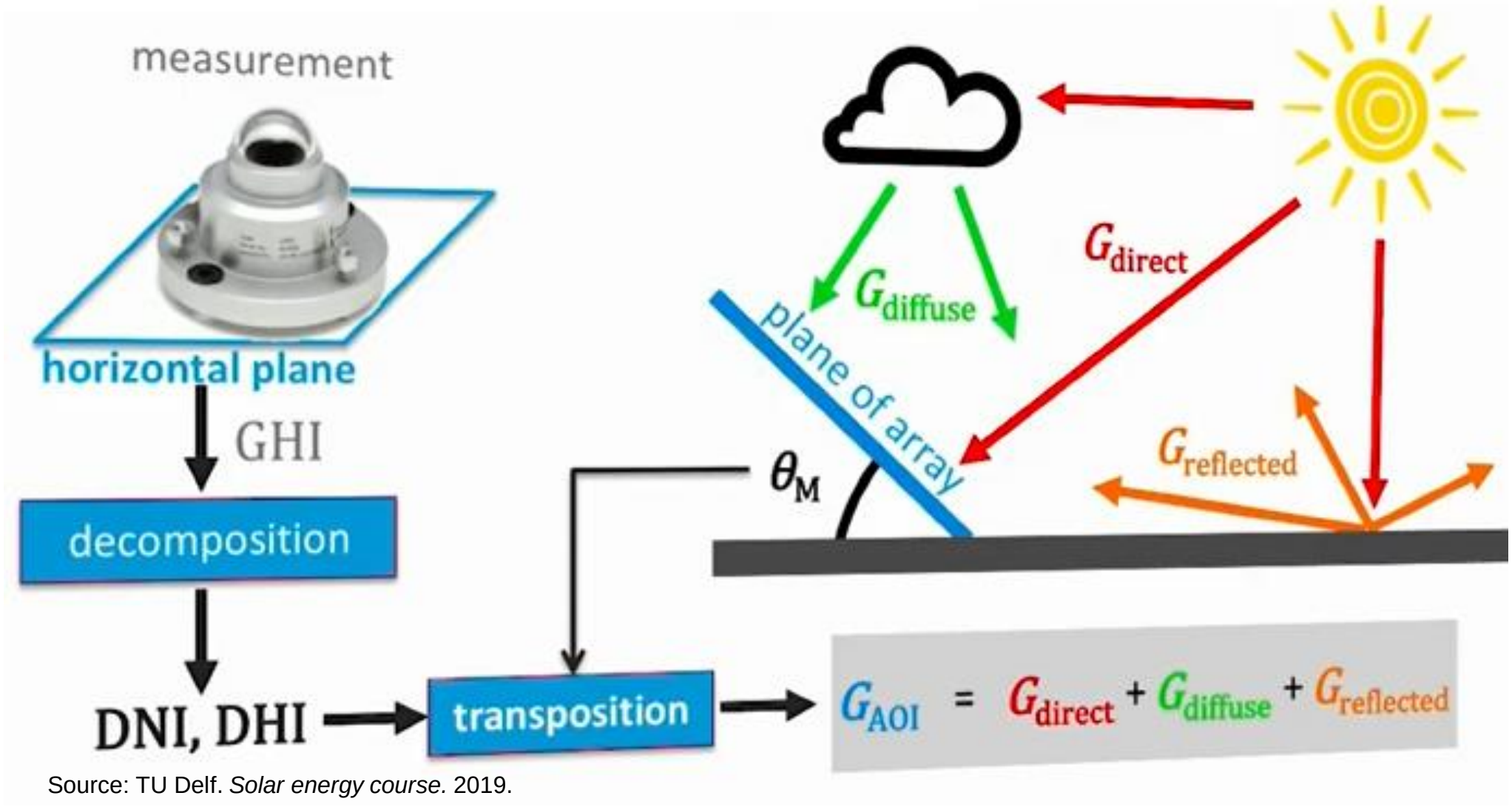
Source: TU Delf. *Solar energy course.* 2019.





TEMPERATURE RATINGS

NOCT (Nominal Operating Cell Temperature)	43°C (±2°C)
Temperature Coefficient of P_{MAX}	- 0.30%/°C
Temperature Coefficient of V_{OC}	- 0.25%/°C
Temperature Coefficient of I_{SC}	0.04%/°C



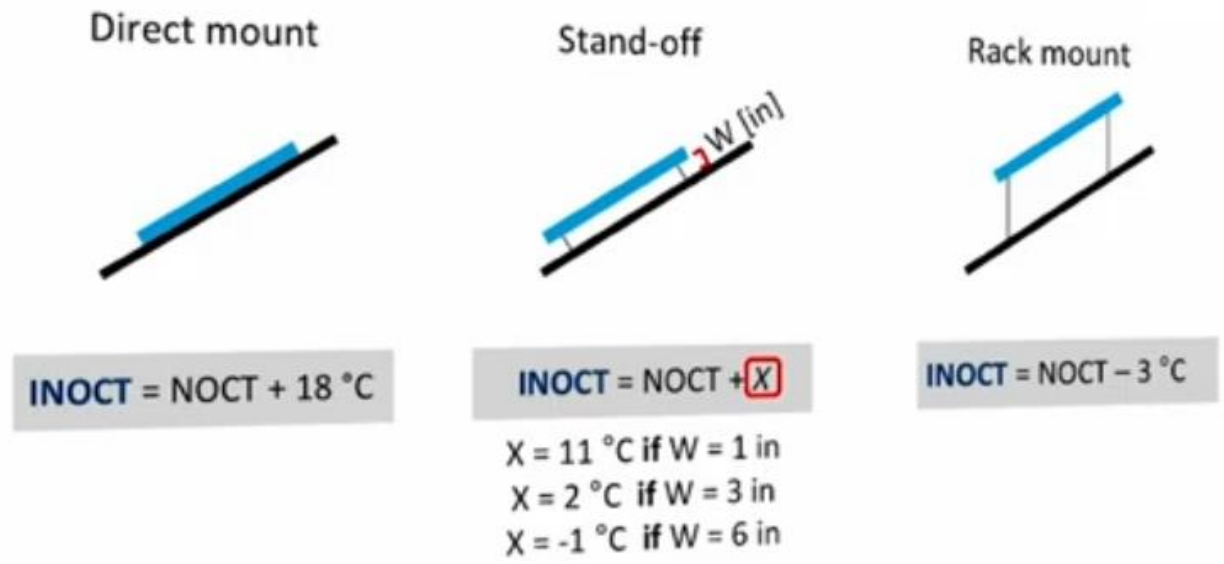
Source: TU Delf. *Solar energy course.* 2019.

Module temperature models:

- INOCT model
- Duffie – Beckman model
- Sandia National Laboratory model
- Fainman model
- Fluid Dynamic model

INOCT model

$$T_m = T_{amb} + \frac{G_{AOI}}{G_{NOCT}}\left(INOCT - 20\ ^\circ C\right)$$



NOCT – open circuited cell temperature at 800W/m2, Tamb=20°C y wind speed of 1m/s.

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Duffie-Beckman model

$$T_m = T_{amb} + \frac{G_{AOI}}{G_{NOCT}}\left(\mathrm{INOCT} - 20\,^{\circ}\mathrm{C}\right)\cdot\frac{9.5}{5.7+3.8\cdot w}\left(1-\frac{\eta_{STC}}{\tau\cdot\alpha}\right)$$

Module’s temperature depend on:

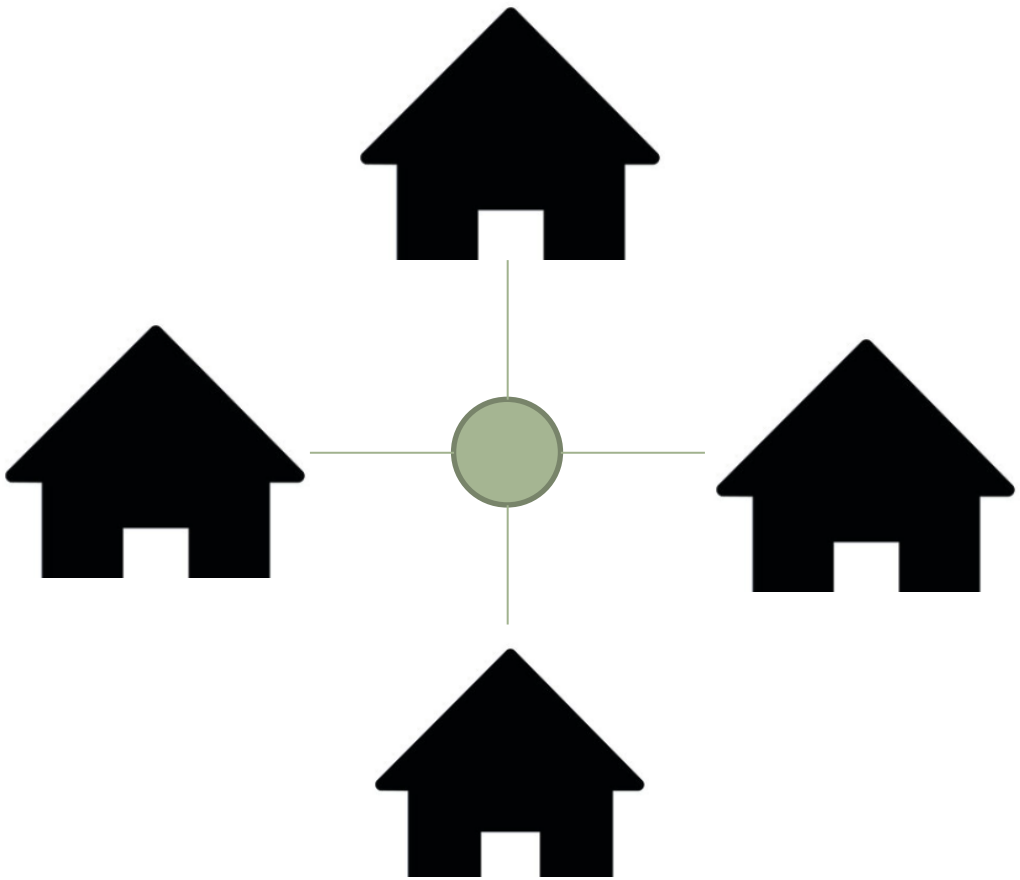
- Ambient temperature
- Wind speed
- Irradiation
- Mounting system
- Module features

Source: TU Delf. *Solar energy course.* 2019.

$$P_{DC} = \eta(T_m, G_{AOI}) \cdot A \cdot G_{AOI}$$

DC ENERGY YIELD		
Parameter		**Description**
E_{DCy} [kWh]	603.72	Annual DC-side energy yield
$E_{DCy,area}$ [kWh/m^2]	304.90	Annual DC-side energy yield per area

Trina solar TSM-DD14A – 345 W



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How many panels do we need to meet the demand?

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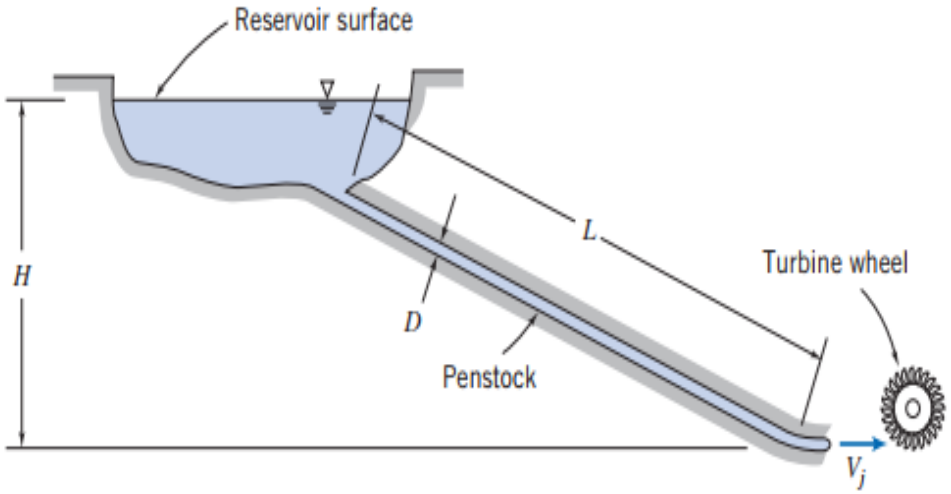

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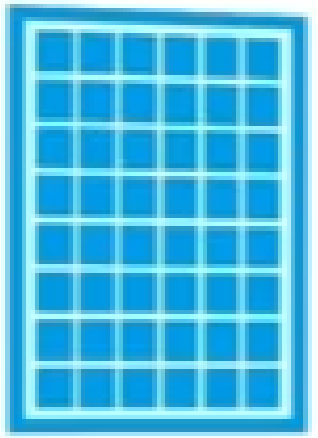

Energy potential – 9.4 kWh/day

Energy potential – 603.7 kWh/year
1.7 kWh/day

How many panels do we need to meet the demand?

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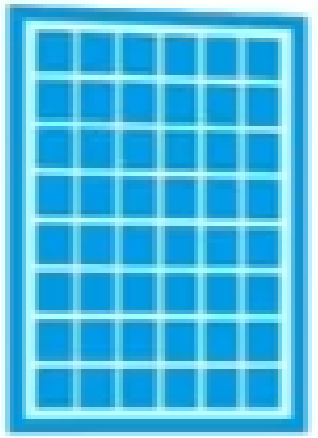

Energy potential – 2.16 kWh/day

Energy potential – 603.7 kWh/year
1.7 kWh/day

Many remaining open questions

- Grid connected or batteries
- Turbine easy to buy (Import necesary)?
- Economic capacity from the community (Funding options)?
- Technology social acceptance
- Sustainability plan
- Technical service near - technical capacity at the community?