Renewable Energy Resources (RER)

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Small-Hydro Plants

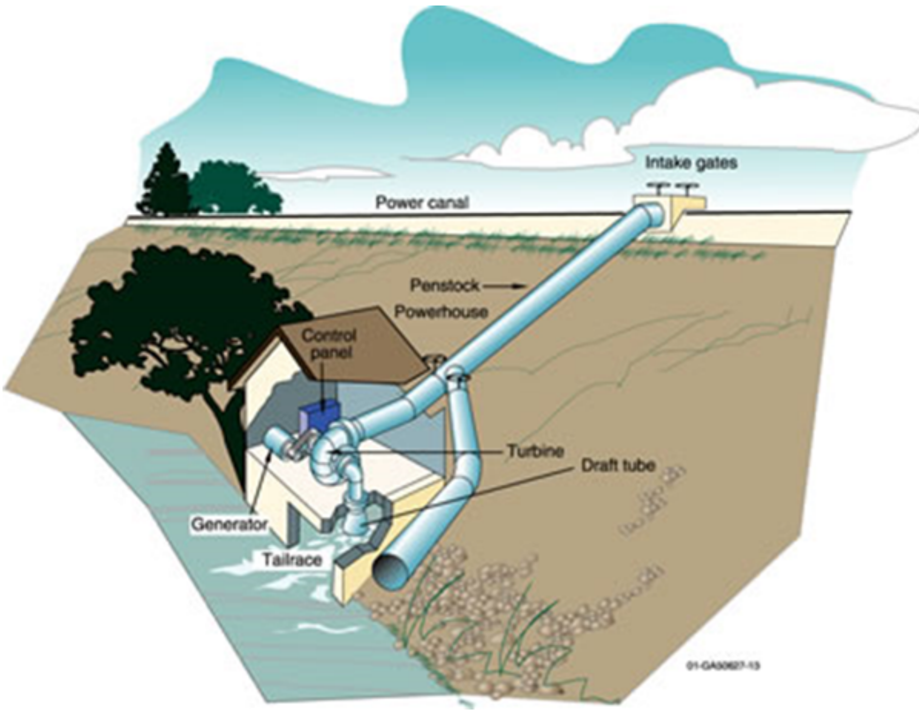
Chapter 5

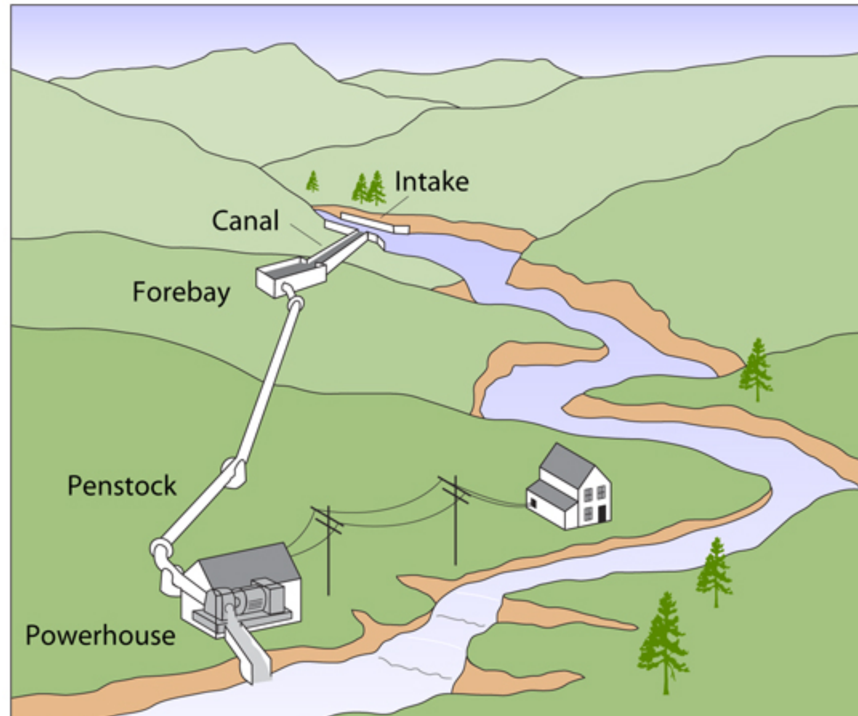
Definitions

	Capacity (MW)
Small hydro	<10
Mini hydro	<2
Micro hydro	<0.5

	Head (m)
Low	2 - 20
Medium	20 - 150
High	>150

A SHP



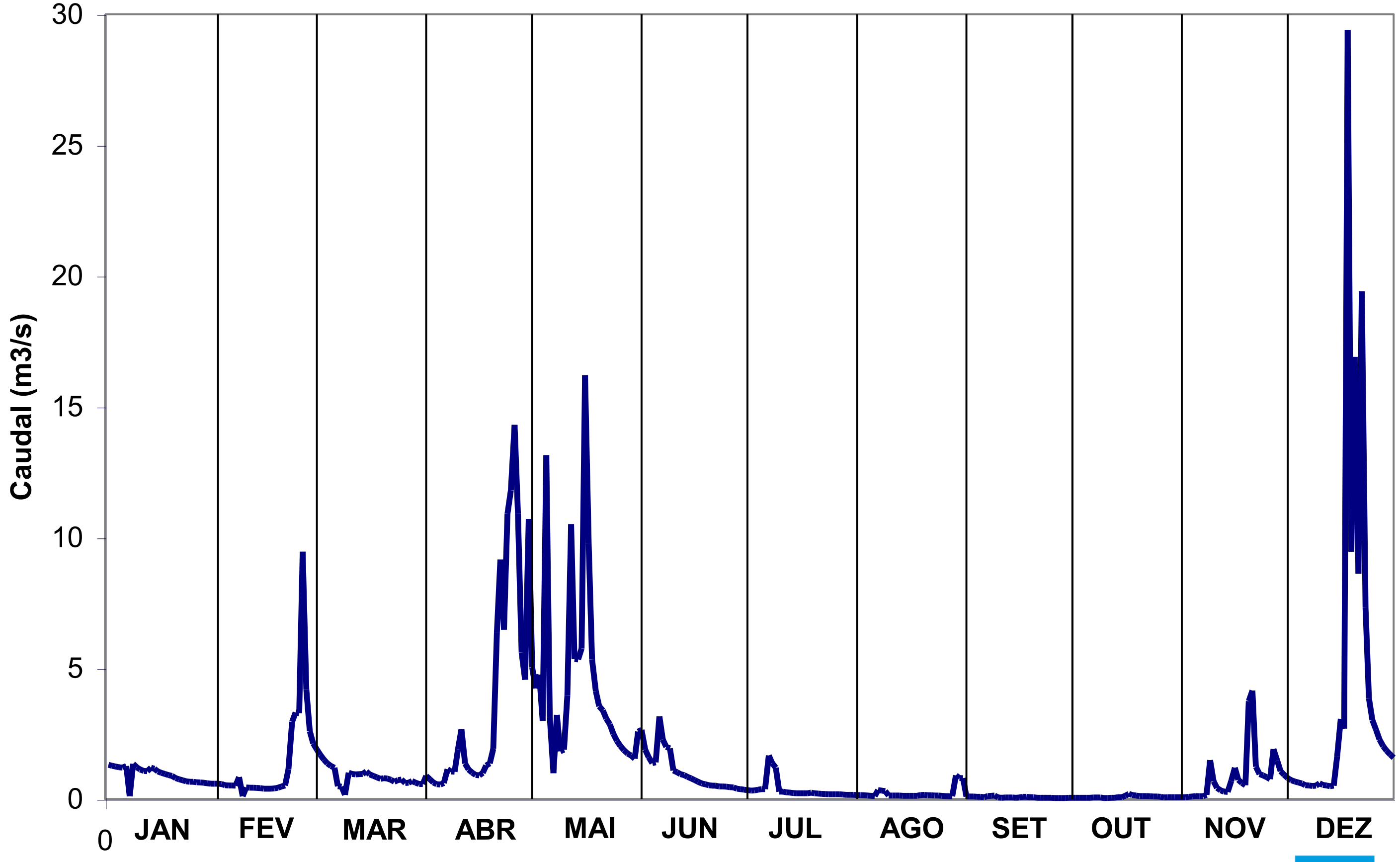


Albufeira (intake) e respetivo açude, Canal de adução (feeder canal), Câmara de carga (fore bay), Conduta forçada (penstock), Edifício da central (power house), Restituição (tail race), Caudal ecológico (reserve flow)

FLOW DURATION CURVE

Chronological flow time series

Flow (m3/s)



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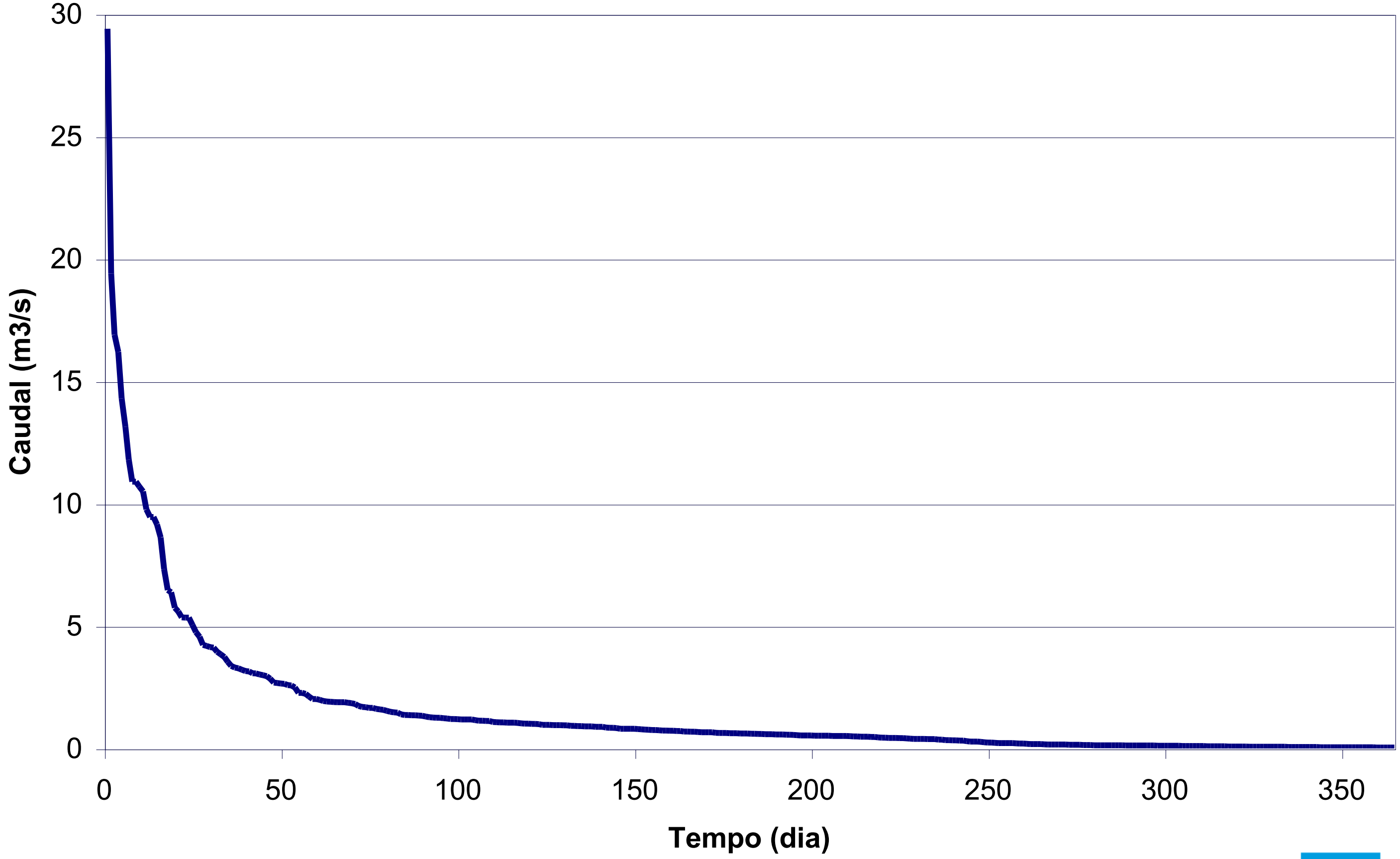
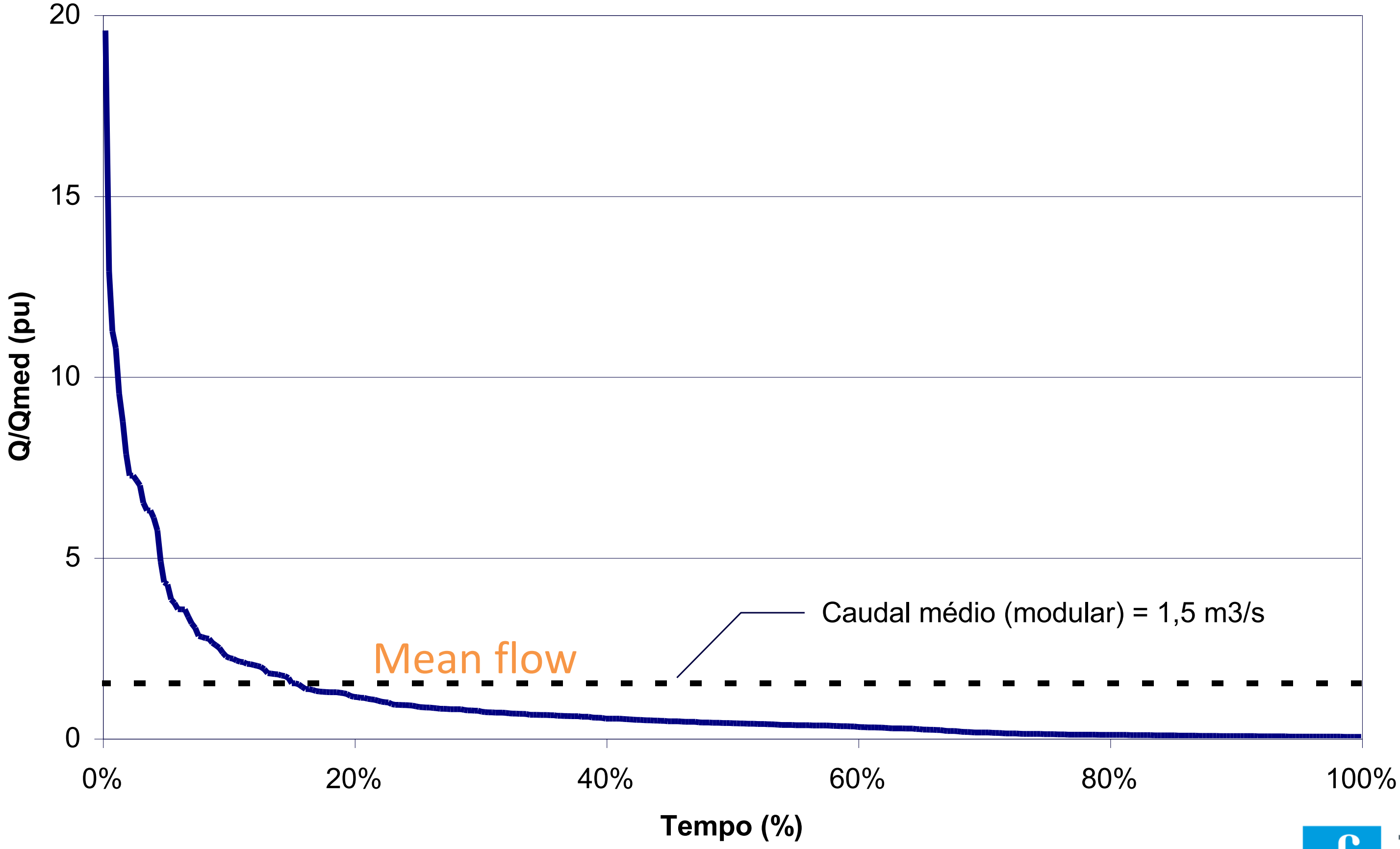
Flow Duration Curve (FDC)

Flow (m3/s)



Time (day)

FDC in pu


20
15
10
5
0
Q/Qmed (pu)
0%
20%
40%
60%
80%
100%
Tempo (%)
Caudal médio (modular) = 1,5 m3/s
Mean flow

TURBINE CHOICE

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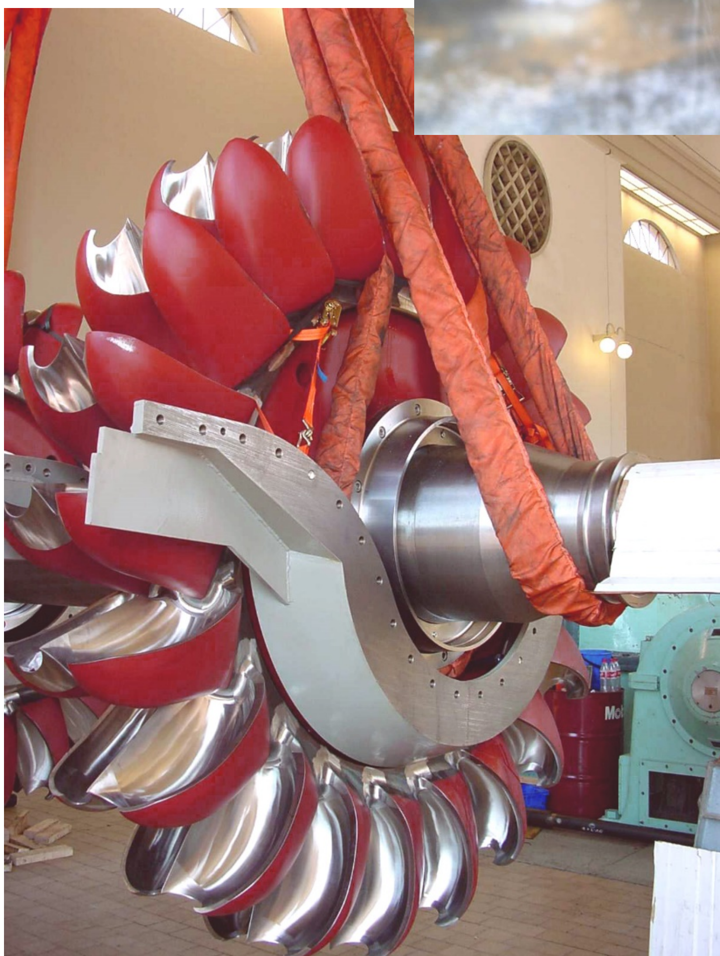
Turbine types

- Impulse turbines
  - Stator: nozzle jets; Rotor: wheel with spoon-shaped buckets (atmospheric pressure)
  - High heads, low flows
  - Pelton, Turgo, Banki-Mitchell
- Reaction turbines
  - Stator: distributor
  - Rotor: runner (pressure not constant water is accelerated)
  - Low and medium heads
  - Propeller (Fixed runner blades), Kaplan (double regulation – distributor guide vanes and blades regulated; single regulation – only blades regulated), Francis

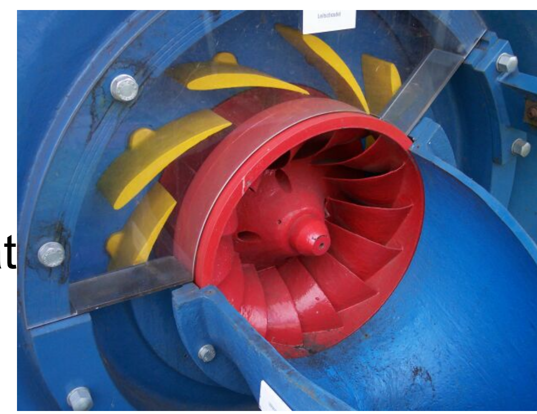
Pelton



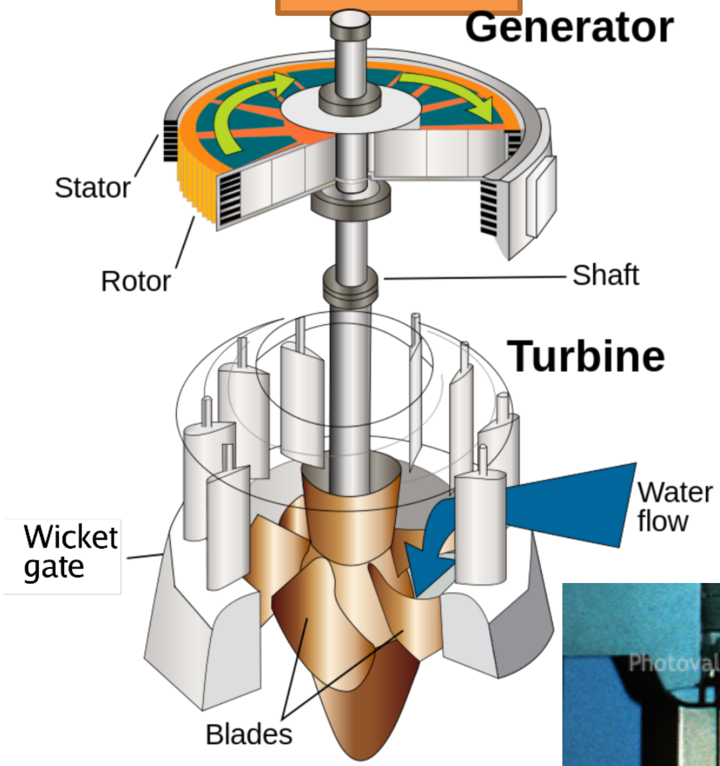
Francis

Wicket gates at minimum flow

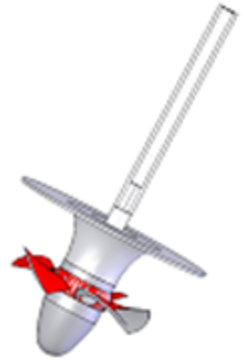
Wicket gates at full flow

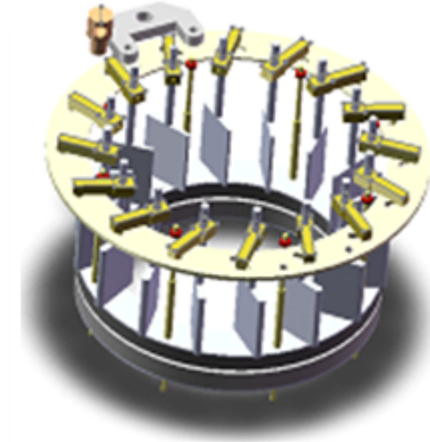


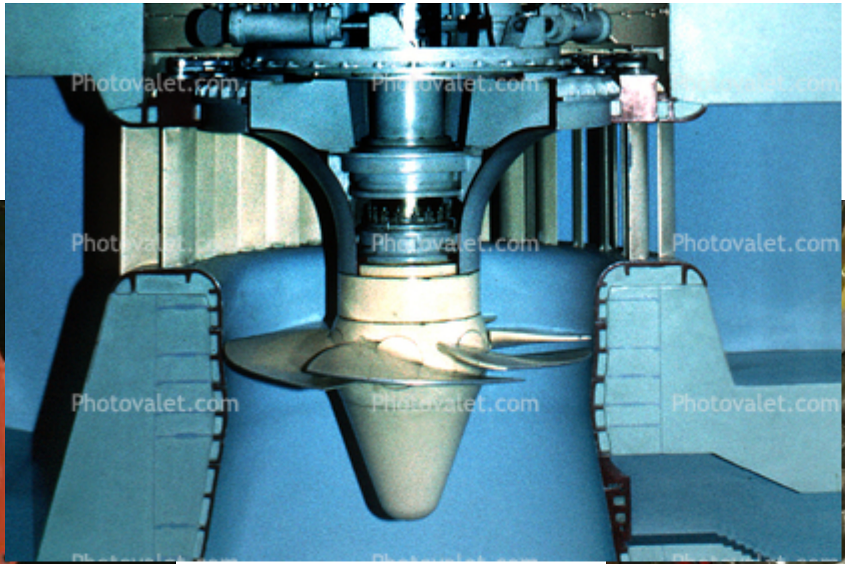
Kaplan



Generator
Stator
Rotor
Shaft
Turbine
Water flow
Wicket gate
Blades



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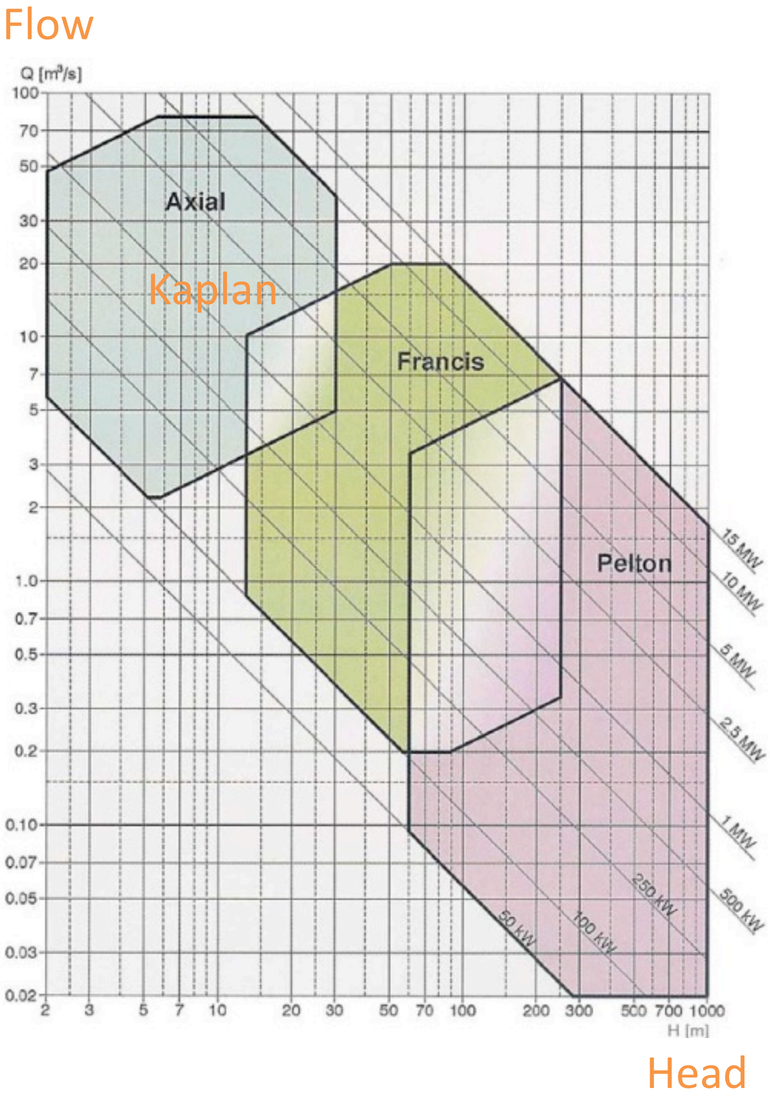
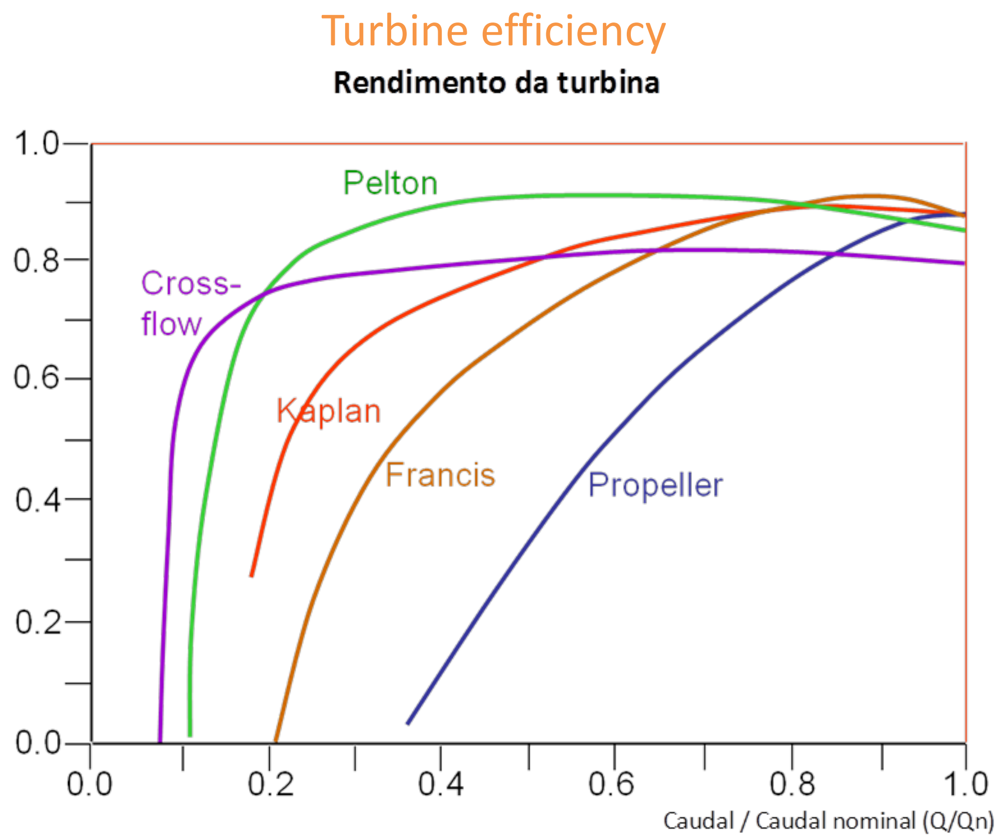
Turbine choice





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ELECTRICAL ENERGY COMPUTATION: SIMPLIFIED MODEL

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Rated capacity

Choice of Q_N: $0.15<Q_N<0.4$

1st approach: $Q_N = Q_{mean}$

$$P_N = \gamma \times Q_N \times H_b \times \eta_c$$

PN – rated capacity (W)
γ – specific weight (9810 N/m3)
QN – rated flow (m3/s)
Hb – gross head (m)
ηc – overall efficiency

Practical use equation

$$P_N = 7 \times Q_N \times H_b$$

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Energy produced: general formula

$$E_a = \int_0^{365} P(t)dt = 9.81 \int_0^{365} Q(t)h_u(t)\eta\,(t)dt$$

In preliminary studies, we make some simplifications

$$E_a = 9.81\eta_{avg}H_b \int_{t_{min}}^{t_{max}} Q(t)\,dt$$

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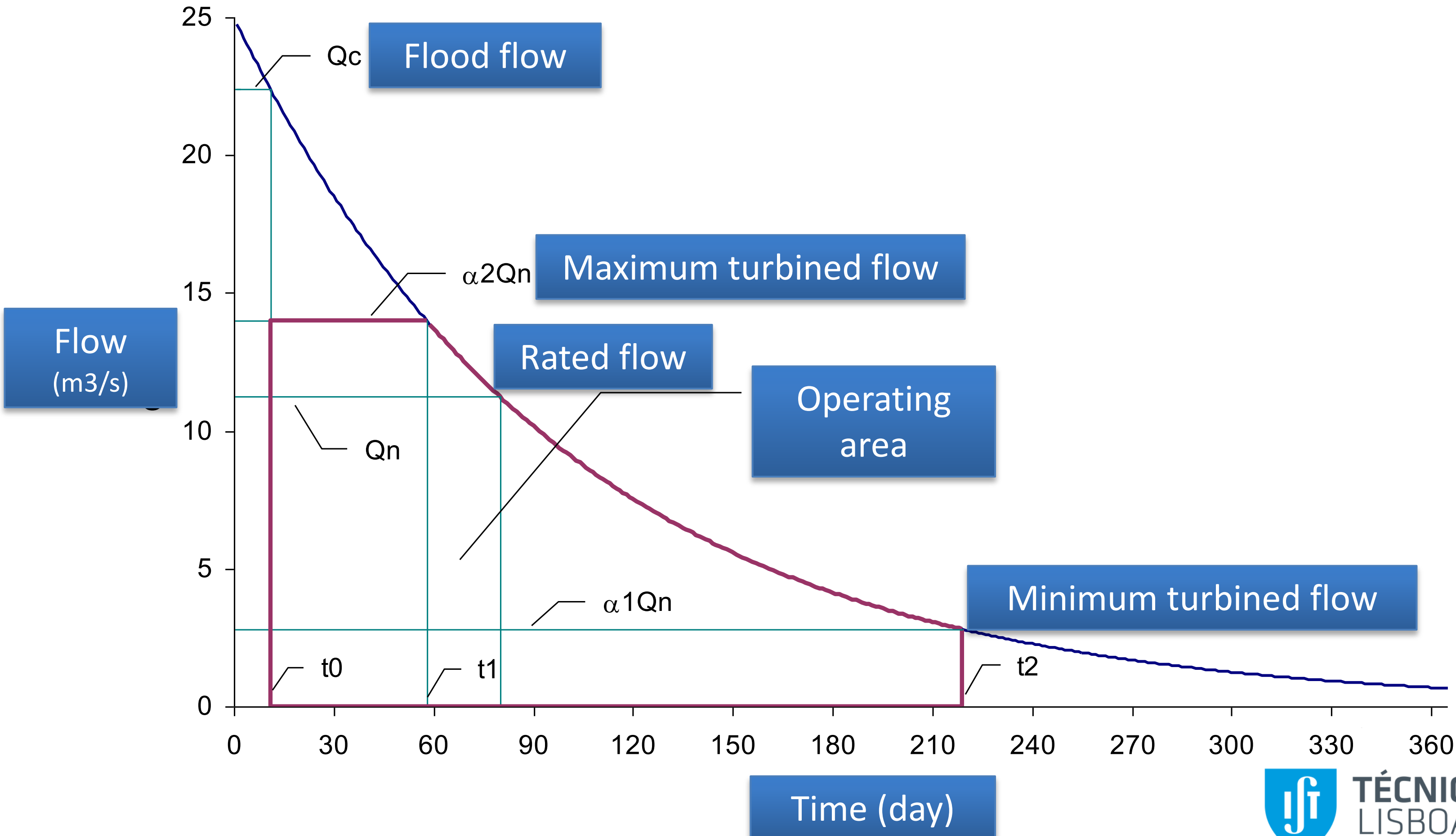
The relevant flows



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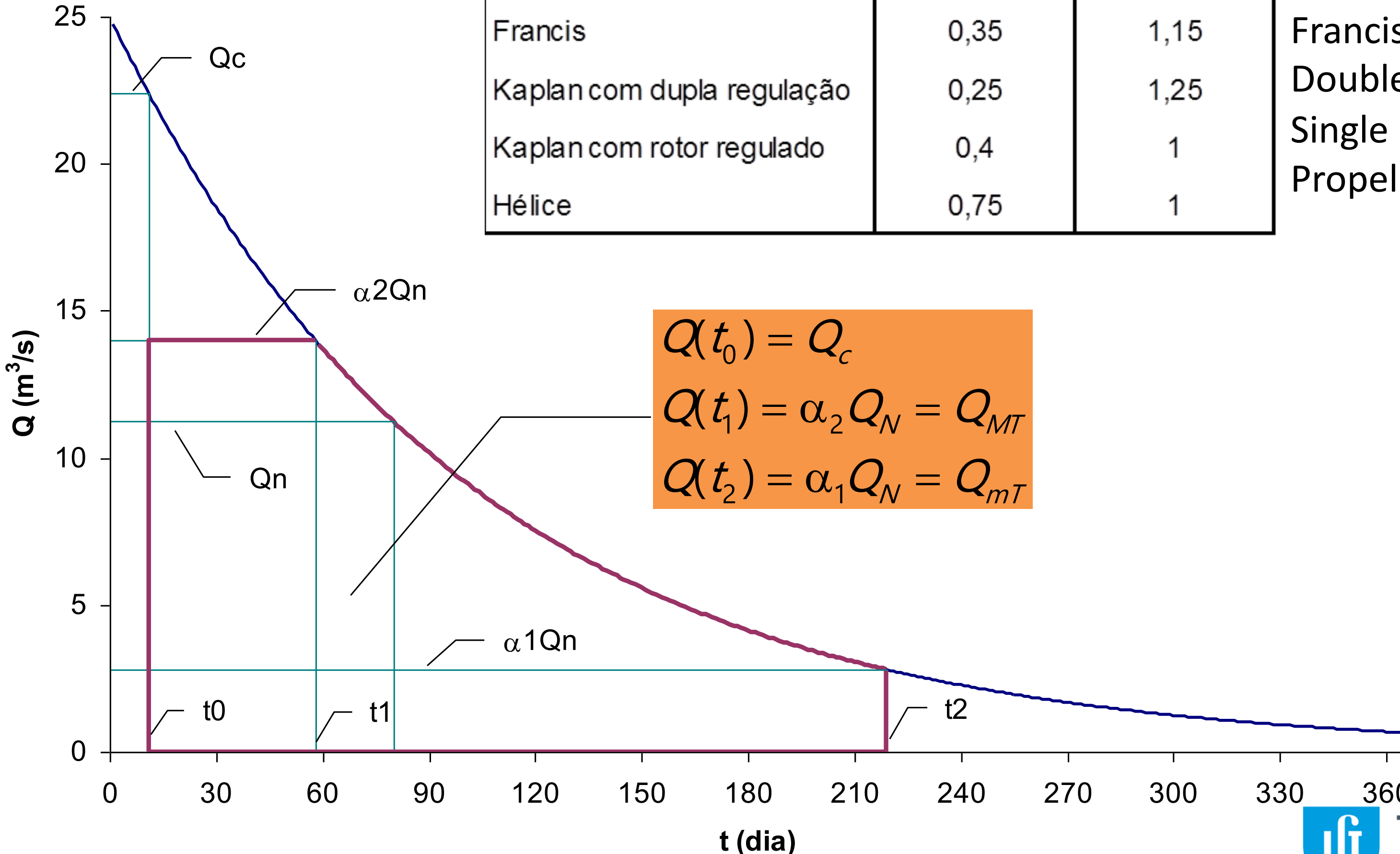
Maximum and minimum turbined flows

Turbina	$\alpha_1=Q_{min}/Q_N$	$\alpha_2=Q_{Max}/Q_N$
Pelton	0,15	1,15
Francis	0,35	1,15
Kaplan com dupla regulação	0,25	1,25
Kaplan com rotor regulado	0,4	1
Hélice	0,75	1

Pelton
Francis
Double reg. Kaplan
Single reg. Kaplan
Propeller



$$Q(t_0) = Q_c$$
$$Q(t_1) = \alpha_2 Q_N = Q_{MT}$$
$$Q(t_2) = \alpha_1 Q_N = Q_{mT}$$

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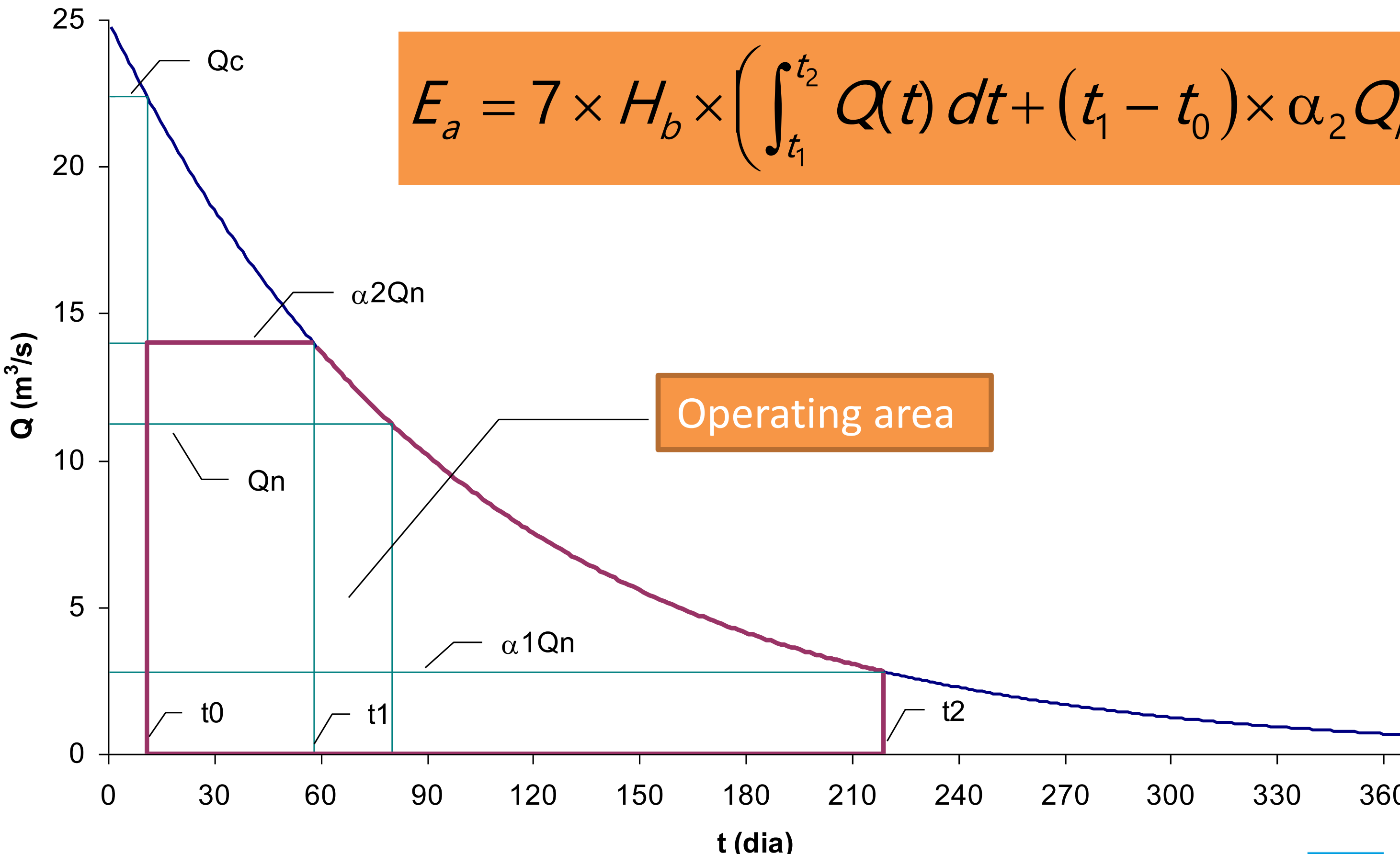
Electrical energy computation

$$E_a = 7 \times H_b \times \left(\int_{t_1}^{t_2} Q(t)\,dt + (t_1 - t_0) \times \alpha_2 Q_N \right) \times 24$$



Two turbine/generator groups

Q_j	Turbina 1	Turbina 2
$0 \le Qj \le QN/2$	Qj	0
$QN/2 \le Qj \le \alpha_2 QN$	Qj/2	Qj/2

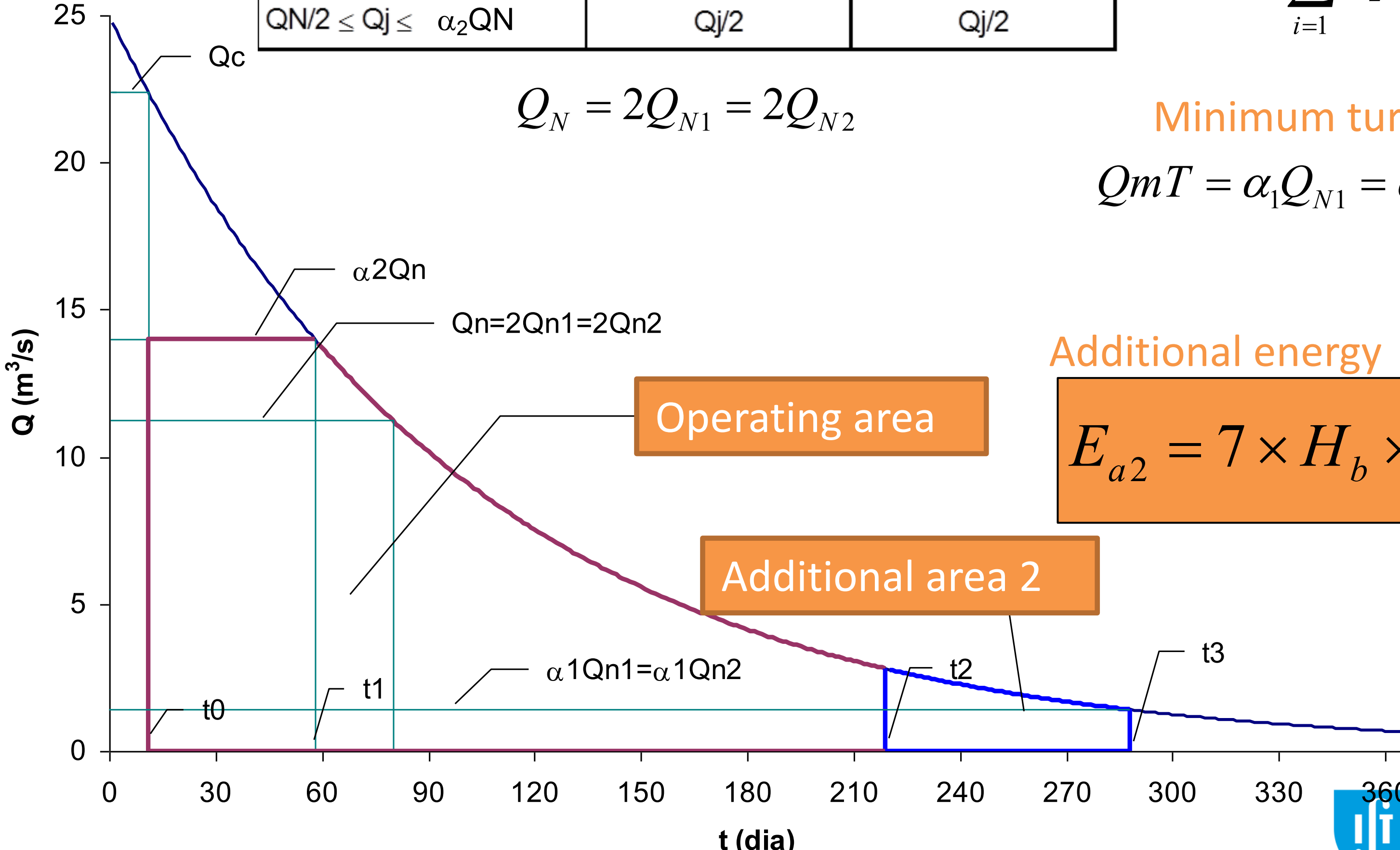
$$Q_N = 2Q_{N1} = 2Q_{N2}$$

Maximum turbined flow

$$QMT = \sum_{i=1}^{2} \alpha_2 Q_{Ni} = \alpha_2 Q_N$$

Minimum turbined flow

$$QmT = \alpha_1 Q_{N1} = \alpha_1 Q_{N2} < \alpha_1 Q_N$$



Additional energy

$$E_{a2} = 7 \times H_b \times \int_{t_2}^{t_3} Q(t)\,dt$$