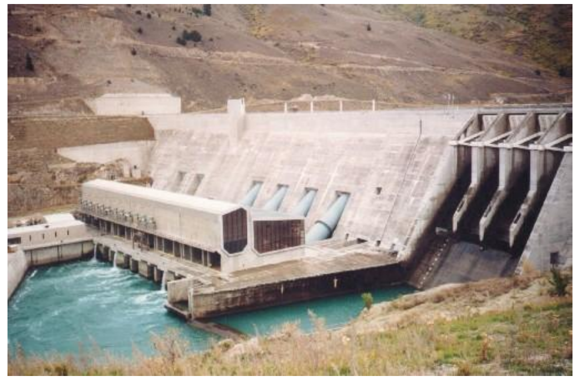
Efficiencies of Hydro-electric Generators

Clyde

The water behind the Clyde dam has greater gravitational potential energy, GPE, compared to the water downstream.



The height of the Clyde dam is 58 m.

The maximum output from each generator is about 108 MW, and it takes 206 m^3 of water passing each second through the turbine to produce this power.

GPE = mass × g × height.

A cubic metre of water has a mass of 1000 kg.

The potential energy of each cubic metre of water at the top of the dam is therefore GPE = 1000 kg × g(9.8 Nkg^{-1}) × 58 m = 568,980 J

Power (watts) = joules per second = joules per cubic metre of water × number of cubic metres of water per second, $W = \frac{J}{s} = \frac{J}{m^3} \times \frac{m^3}{s}$.

Power = 568,400 × 206 = 1.17 × 10^8 watts = **117 MW**.

But the maximum output of a Clyde generator is **108 MW**.

Why is it less?

Some energy is lost as heat and sound in the energy conversion process in the turbine and generator.

Efficiency = electrical power out / water power in = 108 MW / 117 MW = 0.92 = **92%.**

A Clyde generator is therefore about 92% efficient.

Waipoua
Flow rate 2 litres per second = 2 kgs^{-1}
Head 60 m

Input power = GPE lost per second
= (mass × g × height fallen) per second
= mass per second × g × height fallen
= water flow rate × *g* × head

$$\Rightarrow \quad P_{in} = 2 \text{ kgs}^{-1} \times 60 \text{ m} \times 10 \text{ ms}^{-2} = 1200 \text{ W}$$

Output power = electrical energy generated per second
= "…6 to 7 kilowatt-hours per day…"

A kilowatt-hour kWh is the amount of energy delivered in 1 hour at the rate of 1 kW or 1000 J per second.
There are 60 × 60 or 3600 seconds in 1 hour,
so 1 kWh is 1000 J per second × 3600 seconds
= 3 600 000 J
= 3.6×10^6 J or 3.6 MJ
Therefore, 6 kWh per day is 6 × 3.6 M J = 21.6 MJ delivered in 24 hours which is 86400 s.
(seconds per day = 24 hours per day × 60 minutes per hour × 60 seconds per minute)

$\Rightarrow$ Output power = 21.6×10^6 J / 86400 s = 250 W
Similarly, 7 kWh per day converts to 290 W.
Say 270 W on average.

$$\text{Efficiency} = \frac{P_{out}}{P_{in}} \times 100\%$$

$$= \frac{270 \text{ W}}{1200 \text{ W}} \times 100\%$$

$$= 23\%$$

The Waipoua generator is about **20** to **25 %** efficient.

VUW model

Water flow rate 0.3 litres per second = 0.3 kgs^{-1}

Head 1.2 m

Input power = GPE lost per second

= (mass × g × height fallen) per second

= mass per second × g × height fallen

= water flow rate × *g* × head

QuickTime™ and a None decompressor are needed to see this picture.

$$\Rightarrow \quad P_{in} = 0.3 \text{ kgs}^{-1} \times 1.2 \text{ m} \times 10 \text{ ms}^{-2} = 3.5 \text{ watts}$$

Output power = electrical energy generated per second

= voltmeter reading × ammeter reading

$$\Rightarrow \quad P_{out} = V \times I$$
$$= 2 \text{ V} \times 0.05 \text{ A}$$
$$= 0.1 \text{ W}$$

$$\text{Efficiency} = \frac{P_{out}}{P_{in}} \times 100\%$$
$$= \frac{0.1 \text{ W}}{3.5 \text{ W}} \times 100\%$$
$$= 3\%$$

The VUW model generator is only **3%** efficient.