Munch Lines and Monsters

I'm not sure whether it's still going, but the Institute for Earth Education, founded by Steve Van Matre in 1974 created an imaginative programme for 10–11-year-olds called Earthkeepers. We incorporated it into the Sustainable Millennium Project and during the 1990s we took several groups of Y5 and Y6 children to the local centre to learn the principles of ecology as set out by the Institute. A phrase which stuck was "munch line", used to describe the flow of energy from sunlight through to top predator.

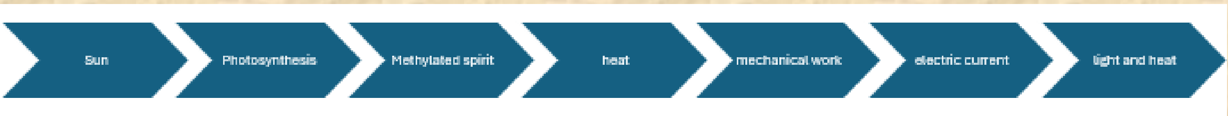
I'm not sure what I really think of language such as "munch line" but it must have stuck at the time because I incorporated the term into the idea of the Energy Monster that I devised for slightly older children (Y7 – 9, ages 11 – 14). At least some of those children would have been familiar with Earth Education munch lines. The principal aim of the Energy Monster was to put across the concept that the Energy Monster was a creature many, many times more powerful than any living creature on Earth. So big and strong was it that it required more food than all the Earth's agricultural systems could produce to feed it. Some monster!

Pupils attending FutureWorld courses took part in what I suppose was conceived as a physics version of Earthkeepers, beginning with a "gerbil munch line". The key idea was to understand energy flow:

Could the gerbil produce 0.25 watt? No, alas not! Maybe too much power was lost in friction and other inefficiencies!

But it was a memorable lesson.

The next step was to up the stakes and connect the dynamo to a toy steam engine which children, even by 1997 deprived of the joys of meths and Mamod, found quite "cool".



This time, success! We produced over a whole watt, enough to light the bulb.

At gerbil scale, we had created an energy monster!

Then we took things up to human scale. What power could be produced by the course participants themselves? After much fun running up the stairs, doing step-ups, and picking people up, the relationship between joules and watts and newtons and kilograms was becoming familiar and we came up with the concept of the **100-watt minute.** This power, or rate of energy conversion could be felt at an entirely practical level. *It was work at human, not monster scale*. We calculated that if it took a boy weighing 40kg one minute to pedal his 10 kg bike uphill by a vertical distance of 15m, he would be producing roughly 100 watts.

That boy then represented the **100-watt minute,** a convenient unit of munch line energy equivalent in total to about 7360 joules. At absolute flat-out maximum power, the boy might produce almost 200 watts, but no way could he sustain it for more than a short burst. The 100-watt minute is also equivalent to the power of a fit adult cycling comfortably for a sustained period. If that adult were going at 15mph it would take them 10 hours to reach 1kWh. Not many adults would do that.

It was time to put the kettle on. *The 2400-watt electric kettle to be precise*. We put it on twice. Once with enough water for one mug of tea measured out and once filled to the maximum mark. It took 82 seconds to boil enough for one mug. That worked out as 196 800 joules, which is 196 800 newtons acting over one metre. Convert newtons to kilograms by dividing by 9.81. That's 20 061 kg. Not a massively helpful figure, so let's convert it to something a bit more meaningful like a girl weighing 8 stone (just over 50 kg).

The energy needed for boiling one mug of water understood as human power is roughly the same as carrying the girl up a 10m staircase just over 39 times.

Surprisingly, there were no takers!

So, what if we wasted energy by carelessly filling the kettle?

The girl would then have to be carried up the stairs **130** times. Seems very hard to believe, but that's the point. It taught course participants not to overfill kettles (or tell their parents off for doing so). A small step towards sustainability. So, we are now working, not in **100 watt minutes** of boy power, but in **1000 watt hours**, more familiar as the **kWh**, the standard unit of electrical billing. In 1997, the price of a kWh was about 8.5p. Now, in 2026 it has gone up to the "outrageous, staggering, unaffordable, rip-off" price of about 26.1p.

We needed a more realistic task than carrying people up the stairs.

And one to which a monetary value could be assigned. Who would lift 50kg weights for a living? Before Health and Safety introduced a 25kg limit, heavy sacks of coal or cement weighed one hundredweight, i.e. 8 stone or 50kg. Problem solved. How much should we pay the labourer?

We performed the following calculation.

First, how many joules of energy in 1kWh? 1000 x 60 x 60 = 3 600 000. So, using our newly gained knowledge, we decided that must be a force of 3 600 000 newtons acting over 1 metre. We then converted that into cement sacks by the convenient approximation of the force acting on one cement sack being 500 newtons.

This gave us 3 600 000 / 500 = 7 200, which allowed us to conclude that to produce the equivalent of 1 kWh, a human labourer must raise 7200 sacks by one metre to load them. A strong, fit man, fresh from a break and working hard might load between 180 and 200 sacks in an hour (say 190). We assumed a wage of £6 per hour, so that gave us the cost of a human ("munch line energy") kWh as 7200/190 x 6 = **£227.37**

Today (2026) assuming a labour rate of £29 per hour: 7200/190 x 29 = **£1098.95**. Or at the minimum wage rate of £12.21, **£460.70** (against price of 1kWh electricity £0.26)

The whole point of this awareness raising exercise back in 1997 was to educate a generation that would cut back significantly on the use of fossil fuels. There was plenty of recognition at the time that this was necessary, but upcoming generations needed to be presented with alternatives. During the 1990s the debate centred on the future role to be played by renewables and nuclear power.

When we'd finished with gerbils and steam engines, we played with mini wind turbines and solar panels. Back in 1997, it wasn't generally believed that wind power, useful though it might be, could one day produce as much as 29.5% of the UK's electricity. Nuclear power was seen as the only real non-greenhouse alternative to fossil fuels, but it was rather more controversial then than it is now and was strongly opposed by green groups. So, we visited the energy monster in its lair! Hinkley Point B nuclear power station closed in 2022, but back in 1997, it was churning out 13 000 000 kWh per day or 4,802.18 Gigawatt hours per year. That's the equivalent of 2.18 million horses working a continuous 8 hour day.

So, had we found the energy monster?

The Sun emits 10 000 000 000 000 000 00 kWh per annum (1.5 x 10^{18} in standard form), which is more in one hour than humanity uses in a year. I'll leave you to make up your own minds!