

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!

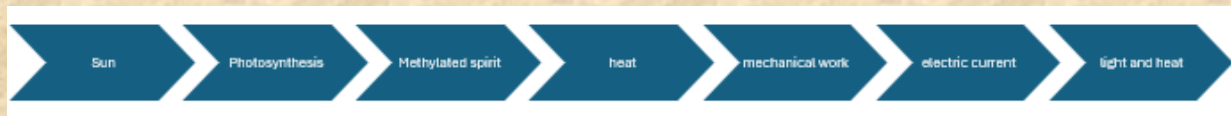
Pupils attending FutureWorld courses took part in what I suppose was conceived as a physics version of Earthkeepers, beginning with a “gerbil munch line”. The key idea was to understand energy flow:



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 6000 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, but it is our guide to what a killerwatt hour (1kWh) is, the equivalent of cycling continuously for ten hours. 1kWh is therefore a lot of munch line energy.

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 20 060 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?



After a great deal of thought, debate and trial, we came up with 190 as the number of sacks the hard-working labourer might load in an hour. That’s assuming that each one had to be lifted by one metre (mechanical work in physics) then carried a horizontal distance of five metres (does not count as mechanical work in physics) and finally shuffled around on the lorry (the distance and the shuffling are what set the limit of 190 sacks per hour). Now that is seriously hard work, for which we are going to pay the UK minimum wage £12.21. Each sack shifted represents about 500 Joules of useful work, so if 190 were loaded in an hour, the value in Joules is going to be $500 \times 190 = 95\,000$. Divide 1221 pence by this and we get just under 0.013 pence per Joule, which works out at roughly 12.85p per kJ (1000 Joules) or £12.56 per 100 000J (£125.60 per megajoule).

At this rate, munch line energy costs £462.70 per kWh, as opposed to the monster energy rate of just 0.26p per kWh. The other way of looking at it is to say that electricity is sold at a ludicrously cheap price. We can now ascribe monetary value to our currency of Joules.

Monster	NEWTOWN ENERGY BANK Promise to pay the bearer on demand	Munch Line
.0073p	1 000 Joules 1 000 James Watt chief cashier 	3.8p
.073p	10 000 Joules 10 000 James Watt Chief cashier 	£0.38
.73p	100 000 Joules 100 000 James Watt Chief cashier 	£3.38

The problem here is that human power is really very weak and feeble compared to what an electrically powered machine can do (approximately **7,340 weights of 50 kg** could be raised **1 metre** by **1 kWh** of energy, assuming 100% efficiency). **But it is what nature gave us** and we are now living with the legacy of free-riding nature ever since 1776 when James Watt began marketing the first practical steam engine. Of course, because we had brains, we could and did use animal power to do more work without offending the principle of munch line energy. We could travel further and faster by riding horses. We could put horses to work in other ways:



Beamish Museum – Wikimedia Commons

Taking 1 horsepower to be 750 watts a 100% efficient horse working at full power continuously for one hour could lift 5,500 eight stone girls or 50kg sacks by one metre in an hour. To put this more realistically, let us suppose the horse is plodding around on the ginn and raising 50kg sacks from a loading point 10m below the surface, an estimate taking count of friction, inefficient gears and the horse tiring would be something in the region of 180 sacks per hour. A long way short of electric monster energy, but a big improvement on a man climbing a ladder with a sack on his back.

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 10 000 000 000 000 000 000 kWh per annum (1.5×10^{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 on that!

The big remaining question

The attraction of nuclear power was, and is, that it can create monster energy levels without adding greenhouse gases to the atmosphere. All the electricity generated to date by nuclear power has used a not hazard-free process (nuclear fission) that will doubtless be considered primitive once the holy grail of nuclear fusion has been perfected as a commercial proposition, should humanity survive long enough to do that. This might serve to remind us that all the so-called “renewables” we use are in fact examples of nuclear fusion because that is what powers the Sun and it is the Sun that shines on solar panels, the Sun that creates the giant convection currents we call “wind” and the Sun that lifts water out of the oceans and drops it in the reservoirs that power our hydro schemes (not forgetting the photosynthesis that powers munch lines). Since 1997 we have got ever better at harnessing natural nuclear fusion in this way. It is entirely possible that we could in the not-too-distant future sustain monster energy without plundering any more fossil deposits, but ***has this possibility come too late?***



Nature can be unimaginatively powerful, as in this super-nova that released 10^{44} joules
(100,000,000,000,000,000,000,000,000,000,000 J)