

Dear Professor Garnaut,

***Garnaut Climate Change Review Interim Report – February 2008***

The basis of my submission to you is about the use of the words **power** and **energy** and about how these physical quantities are measured. I am responding to the third point in your call for submissions:

*the role which Australia can play in the development and implementation of international policies*

The physical concepts of energy and power are essential to any understanding of the issues of greenhouse gases, global warming and climate change but they are little understood by many in the wider community and also among our politicians. The way in which power and energy are measured is also crucial to comparing different sources of energy.

My suggestion is that you add a few paragraphs to your preamble in which you define the words energy and power and specify which units you prefer for their measurement. I suggest something along the following lines:

## Energy and power

As we believe that an understanding of the physical concepts of energy and power is crucial to our understanding of the greenhouse effect, global warming, and climate change, we will define these words as we use them in this report.

### Energy

Energy is the ability to do work. Energy cannot be created (generated) or destroyed, but energy can be converted from one form to another. We use and recommend the joule, which is the sole energy unit in the International System of Units (SI). Large amounts of energy can be expressed as kilojoules, megajoules, gigajoules, terajoules, petajoules, exajoules, zettajoules, and yottajoules.

### Power

Power is the time rate of doing work or using energy. Power measures how quickly you do work or use energy. The sole power unit in the International System of Units (SI) is the watt that is equal to 1 joule per second (J/s). Large amounts of power can be expressed as

## Reasons for this recommendation

### Power

As I was reading your '*Garnaut Climate Change Review Interim Report – February 2008*', I had to stop every time I came to the word 'power', and pause to consider what might be meant by your current use of the word, as you used the word 'power' in a number of different ways. I have reviewed each use in this table.

Your use of the word 'power'	My interpretation
Page 4: Item 4.2 Using the power of the market to minimise mitigation costs	You probably mean 'ability of the market'.
Page 12: The range results from limitations in scientific understanding and in the computing power of the models.	You probably mean 'computing capability of the models'.
Page 16: using purchasing power parities (PPPs)	I don't know what you mean here (I was trained to be a farmer); is this economic jargon?
Page 45: Using the power of the market to minimise mitigation costs	You probably mean 'ability of the market'.

Page 46: with powers to investigate and respond to non-compliance.	You probably mean 'authority to investigate and to respond to non-compliance'.
Page 49: of loss provided to an independent authority with information discovery powers.	You probably mean 'of loss provided to an independent person authorised for information discovery'.
Page 51: some coal-mining and coal-based power-generating firms in Australia	One of the physical realities of energy (and hence power) is that it cannot be 'generated'. Energy can be converted from one form to another but this can only be done under the 'Law of conservation of energy' (as described by physicists in the 1870s).
Page 51: The power requirements of the sequestration process itself	You probably mean 'the energy requirements of the sequestration process itself'
Page 51: coalbased power-generating regions	You probably mean coal-based energy-converting regions
Page 55: they may lead to potential investors in low-emissions power generation	You probably mean ' they may lead to potential investors in low-emissions energy conversion.
Page 55: to bring together decisions on power generation	You probably mean 'to bring together decisions on energy conversion'
Page 57: for solar, geothermal and wind energy and possibly for tidal and wave power and biofuels	You probably mean 'for solar, geothermal and wind energy and possibly for tidal and wave energy and energy from biofuels'

Unfortunately, the words power and energy are constantly abused, misused, and confused in the media, and our politicians now seem to have little concept of any true physical meaning for either of these words when they are used in a technical sense. There is also the problem that many politicians, in my experience, often have only a slippery grasp on matters related to engineering, science, mathematics, and technology, so they need all the help you can give them with technical words like power and energy.

To demonstrate this point, I have constructed a paragraph with references to 'power' from recent media and political statements relevant to the greenhouse effect, climate change, and global warming:

*As we powered along the corridors of power, the politician, large and physically powerful, assured me that he did not have the power to reduce energy or power production from nuclear energy and hydroelectric power, but he could do something about wind energy and solar power if only his party could power up the Senate by winning power in the next election. He also assured me that the government might empower him by giving him the power to act on these energy and power issues using military power if his arguments were sufficiently powerful.*

## Energy

Using the same process, I reviewed each occasion that you used 'energy'. Physicists define energy as:

*'Energy is the ability to do work'.*

In all but two instances you used the word energy in accordance with this definition.

The first of the exceptions (on page 50) referred to something called 'stationary energy'; this is a concept with which I am unfamiliar but the phrase has the air of an oxymoron. You used it in the sentence:

*'Stationary energy is the dominant industry within this category'.*

The second example arose (on page 51) when you wrote:

*'The power requirements of the sequestration process itself would support a large expansion of electricity output to maintain established contributions into the national energy systems.'*

You probably intended (*I have stressed my suggestions for changes*):

*'The **energy** requirements of the sequestration process itself would support a large expansion of **the electrical energy** output to maintain established contributions into the national energy systems.'*

## Measuring energy and power

Measuring units are a real problem with respect to any discussion of the greenhouse effect, global warming, or climate change, as we have just lived through almost 150 years of energy descriptions that have been dominated by obfuscation (deliberate) and inadvertent (accidental) confusions. Since 1889, the internationally agreed unit for measuring energy has been the joule.

*In 1889, the year of Joule's death, the British Association for the Advancement of Science (BAAS) suggested a new name for the work and energy unit to honor the name of James Prescott Joule and his pioneering work on electricity and energy. The BAAS promoted this idea actively and the Second Congress of the International Electrical Conference (IEC) added the joule as the international unit of work and energy, the watt as a unit of power, and a unit of inductance that was later given the name henry. These units were adopted by the IEC as internationally agreed units. To see this in an historical context go to: <http://www.metricationmatters.com/docs/MetricationTimeline.pdf>*

The joule and the watt are now the sole units of the International System of Units (SI) for energy and power respectively.

However, in 2008, the nuclear industry still uses 'atomic energy units'; the oil industry still uses 'barrels of oil equivalents' or 'bboe's'; the nuclear research industry still uses 'billions of electron volts'; the diet industry still uses tens of different calories (and Calories), and there are many, many, others.

When I searched for the ways that amounts of energy are currently described in various places around the world, I found 199 different words and word combinations all purporting to be energy measures. These 199 energy words require 39 402 conversion factors to be fully understood by the public and by our political leaders. I have listed all 199 energy words in the right hand column of the table on the next page.

Although the unit, joule, has been internationally accepted by scientists as the sole unit for energy since 1889 our politicians have been bombarded with old pre-metric substitutes such as the 199 poor substitutes that I found. Notice how words like 'British thermal unit' and 'calorie' have different naming conventions and abbreviations in different places and they also vary in definition according to the ambient temperature and by the way they are spelled (e.g. 1 Calorie is 1000 times larger than 1 calorie because of the upper case C).

Many of these old pre-metric measuring words have only loose definitions and, since they are not coordinated by international agreement, they can and do vary quite remarkably from place to place, and from time to time.

Please note that these are all very poor substitutes for joule, the single energy unit of the International System of Units (SI) that is used by scientists all around the world.

Australia has been a signatory of the 'Treaty of the metre' that supports the International System of Units (SI) since 1948.

This profusion of energy related words has led the public to an almost complete misunderstanding of how energy is measured internationally by scientists using joules (with kilojoules, megajoules, gigajoules, petajoules, exajoules, zettajoules, and yottajoules for larger amounts).

Complete list of SI energy units	Some of the old pre-metric measuring words — there may be many others
<p style="text-align: center;">joule</p>	<p>Atomic energy unit, barrel oil equivalent, bboe, billion electron volts, Board of Trade unit, BOE, BOT, British thermal unit, British thermal unit (16 °C), British thermal unit (4 °C), British thermal unit (international), British thermal unit (ISO), British thermal unit (IT), British thermal unit (mean), British thermal unit (thermal), British thermal unit (thermochemical), British thermal unit-39, British thermal unit-59, British thermal unit-60, British thermal unit-IT, British thermal unit-mean, British thermal unit-th, BThU, BThU-39, BThU-59, BThU-60, BThU-IT, BThU-mean, BThU-th, Btu, Btu-39, Btu-59, Btu-60, Btu-IT, Btu-mean, Btu-th, cal, cal-15, cal-20, cal-mean, calorie, Calorie, calorie (16 °C), calorie (20 °C), calorie (4 °C), calorie (diet kilocalorie), calorie (int.), calorie (IT) (International Steam Table), calorie (mean), calorie (thermochemical), calorie-15, Calorie-15, calorie-20, Calorie-20, calorie-IT, Calorie-IT, calorie-mean, Calorie-mean, calorie-th, Calorie-th, cal-th, Celsius heat unit, Celsius heat unit (int.), Celsius heat unit-IT, Celsius heat unit-mean, Celsius heat unit-th, centigrade heat unit, centigrade heat unit-mean, centigrade heat unit-th, Chu, Chu-IT, Chu-mean, Chu-th, coulomb volt, cubic centimetre atmospheres, cubic foot atmospheres, cubic metre atmospheres, double Rydberg, duty, dutys, dyne centimetres, E-h, electron mass energy equivalent, electron volt, equivalent volt, erg, eV, foot grains, foot pound, foot pound force, foot poundal, ft-lb, ft-lbf, ft-pdl, gigaelectronvolt, gram calorie, gram calorie-15, gram calorie-20, gram calorie-IT, gram calorie-mean, gram calories (mean), gram calorie-th, grand calorie, grand calorie-15, grand calorie-20, grand calorie-IT, grand calorie-mean, grand calorie-th, hartree, Hartree energy, horsepower hours, horsepower hours (metric), inch pound force, Kayser, kcal, kcal-15, kcal-20, kcal-mean, kcal-th, kgfm, kilocalorie, kilocalorie (16 °C), kilocalorie (4 °C), kilocalorie (int.), kilocalorie-15, kilocalorie-20, kilocalorie-IT, kilocalorie-mean, kilocalorie-th, kiloelectronvolt, kilogram calorie, kilogram calorie-15, kilogram calorie-20, kilogram calorie-IT, kilogram calorie-mean, kilogram calories (int.), kilogram calorie-th, kilogram force metre, kiloton TNT equivalent, kilowatt hour, kilowatt hour, kilowatt minute, kilowatt second, kWh, large calorie, large calorie-15, large calorie-20, large calorie-IT, large calorie (mean), large calorie-th, Latm, latm, litre atmosphere, major calorie, major calorie-15, major calorie-20, major calorie-IT, major calorie-mean, major calorie-th, megaelectronvolt, megaton TNT equivalent, megawatt hours, metric ton oil, metric ton TNT, metric ton coal, micri-erg, natural unit of energy, newton metre, petit calorie, petit calorie-15, petit calorie-20, petit calorie-IT, petit calorie-mean, petit calorie-th, Q unit, quad, quadrillion, Rydberg, small calorie, small calorie-15, small calorie-20, small calorie-IT, small calorie-mean, small calorie-th, therm, therm (EC), therm (EU), therm (UK), therm (US), thermie (16 °C), ton coal equivalent, ton oil equivalent, ton TNT equivalent, tonne coal equivalent, tonne oil equivalent, tonne TNT equivalent, watt hour, watt minute, watt second ...</p>
<p>Larger amounts of energy can be measured using kilojoules, megajoules, gigajoules petajoules, exajoules, zettajoules, and yottajoules.</p>	<p style="text-align: center;">Note: this is not a complete list</p>

In your interim report you seem to have somewhat skirted around this issue. You twice mention the idea of measuring units but in neither case do you specify which measuring units you recommend. See:

*Page 33: All countries participating in trade would have to have: a similar definition of a carbon unit;*

*Page 57: Australia has large deposits of high quality (that is, low emissions per unit of energy) coal, which means that our share of global coal supply would increase in a world of comprehensive mitigation*

## An example of poor communication

Let me quote from the Australian Bureau of Statistics (ABS) web page as an example of how this diversity of measuring units fails to communicate effectively with either the public or with politicians.

In '*Detailed Energy Statistics, Australia*' I found that the choices of measuring units made by the ABS make it very difficult for me to compare energy from oil, with energy from black or brown coal, with hydroelectric energy, or with energy from petroleum. I quote from the ABS web page:

*... Non-renewable fuels used to generate electricity include black coal (53,576 kt), brown coal (65,075 kt), and natural gas (291,372 TJ). Hydro-electricity was the main renewable source of electricity, and in 2001-02, 15,567 GWh of hydro-electricity were produced ...*

Fortunately, there is an immediate solution to this communication problem and that is contained within the single (SI) metric unit, **joule**. As an example of its use, consider the Australian energy use figures, quoted above, lightly edited, sensibly rounded, and expressed in petajoules (PJ):

*... Non-renewable fuels used to generate electricity include 1600 PJ from black coal, 1000 PJ from brown coal, and 290 PJ from natural gas. Hydro-electricity was the main renewable source of electricity, and in 2001-02, 56 PJ of hydro-electricity were produced ...*

How can any citizen concerned about global warming begin to comprehend the various jargons incorporated in the ABS statistics? More importantly, how can national and world leaders sensibly discuss energy issues when the language of energy measurement is made so unnecessarily complex?

To reinforce this point here is the same ABS energy data in a table format.

Energy source	Diverse measures	(SI) metric units PJ = petajoules
Black coal	53,576 kt	1600 PJ
Brown coal	65,075 kt	1000 PJ
Natural gas	291,372 TJ	290 PJ
Hydro-electricity	15,567 GWh	56 PJ

Expressing energy in joules, whenever energy information is provided, means that conversions are no longer necessary, and all forms of energy are immediately comparable. You don't have to memorise, look up, or calculate with conversion factors because there aren't any.

This measurement muddle is even worse in the USA where they have yet to widely adopt the modern metric system more formally known as the International System of Units (SI). In the USA, there are some people still using things like:

toe's (for tons of oil equivalent measured in one or other of the British thermal units)

MMBtu/Mcf (for million million British Thermal Units per million cubic feet)

and using conversion factors like

1 short ton per cubic yard = 0.0330687831 long tons per cubic foot.

I wish the USA well with their inevitable metrication transition, but if anyone tells you that the USA will take a leadership role in the measurement components of the global warming discussion anytime soon — 'tell 'em they're dreamin'!

I believe that we need to understand the issues behind peak oil and global warming better than this, and so do our legislators and elected politicians.

## **Recommendation**

Given the long history of obfuscation in the matter of describing and measuring energy and power, this is an area that you might like to consider for special treatment as you prepare your final report.

If you choose to act on this issue, your final report could well become the world leader on the energy and power measurement issues related to the greenhouse effect, global warming, and climate change.

Yours faithfully,

Pat Naughtin

Pat Naughtin is a metric system consultant, writer, and speaker who has helped thousands of people and hundreds of companies upgrade to the modern metric system smoothly, quickly, and so economically that they now save thousands each year when buying, processing, or selling for their businesses. Pat provides services and resources for many different trades, crafts, and professions for commercial, industrial and government metrication leaders in Asia, Europe, and in the USA. Pat's clients include the Australian Government, Google, NASA, NIST, and the metric associations of Canada, the UK, and the USA. See <http://www.metricationmatters.com/> for more information.

## Not for publication

### Some editorial suggestions on your interim report

#### watts

On page 11, in the sentence: '*It is measured in Watts per square metre.*' the unit watts is misspelt; it should read: '*It is measured in **watts** per square metre.*' with a lower case w.

#### tonne (t)

On page 39, you misuse the word 'ton' (instead of tonne and its symbol t) in the footnote:

25 These numbers can be approximately replicated through the following simple computation: Global CO<sub>2</sub> emissions under the illustrative 450 ppm CO<sub>2</sub>-e scenario at 2050 are 14 GtCO<sub>2</sub>, with the global population projected at 9 billion, to yield emissions rights of 14/9=1.6 t/person in the world at 2050. Australia's population is conservatively projected at 30 million at 2050, giving total emissions rights of 1.6\*30=48 million tons for Australia. Compared to CO<sub>2</sub> emissions in Australia of around 400 million tons in 2000, this is an 88 per cent reduction. Higher population growth in Australia and higher global stabilisation concentrations will require a lower reduction.

As this is an extremely important concept it needs to be made as clear as possible so I suggest that you rewrite this to read (*I have stressed my suggestions for changes*):

25 These numbers can be approximately replicated through the following simple computation: Global CO<sub>2</sub> emissions under the illustrative 450 ppm CO<sub>2</sub>-**equivalent** scenario at 2050 are 14 **gigatonne CO<sub>2</sub>-equivalent**, with the global population projected at 9 billion, to yield emissions rights of 14/9=1.6 **tonne per** person in the world at 2050. Australia's population is conservatively projected at 30 million at 2050, giving total emissions rights of **1.6 x 30 = 48 million tonnes** for Australia. Compared to CO<sub>2</sub> emissions in Australia of around 400 million **tonnes** in 2000, this is an 88 per cent reduction. Higher population growth in Australia and higher global stabilisation concentrations will require a lower reduction.

#### measures

I suggest that you reconsider the use of the word, 'measure' on pages 4 and 44. You might like to replace 'measures' with (say) 'laws' or 'regulations' in each case so that you don't give the illusion that you actually mean to measure something. Here are the relevant sentences:

*Page 4: To achieve effective mitigation at the lowest possible cost, the ETS will need to be supported by measures to correct market failures or weaknesses related to innovation, research and development, to information, and to network infrastructure.*

*Page 44: and the need for complementary measures guided by a market failure framework.*

#### 'generation' of power and energy

Since 'energy can neither be created nor destroyed', it follows that neither energy nor power can be 'generated'. I suggest that you reconsider the 11 occasions that you have used this 'generation' idea (See page 48 paragraph 3 - twice, page 51 paragraph 2 - twice, page 51 paragraph 4, page 55 paragraph 1 - twice, page 55 paragraph 2 - three times, and page 56 paragraph 9).