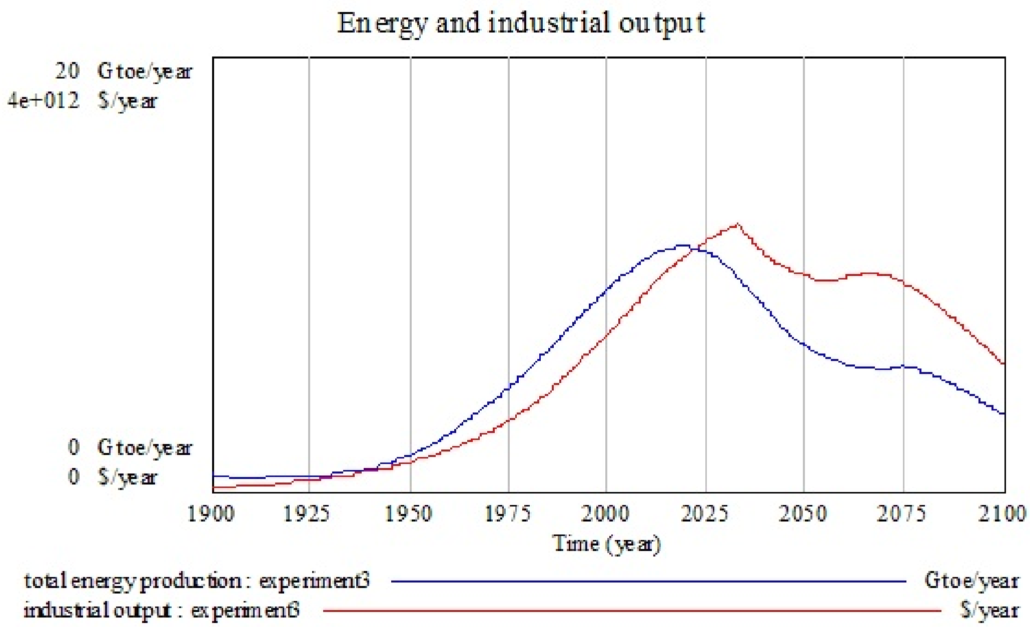
The Oil Drum: Europe
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

New World Model – EROEI issues

Posted by Chris Vernon on August 24, 2009 - 10:48am in The Oil Drum: Europe
Topic: Demand/Consumption
Tags: energy, eroei, limits to growth, modeling, population, resources [list all tags]

This is a guest post from Dolores García, an independent researcher based in Brighton, UK.

When I published the results on The Oil Drum of my New World Model, based on World3 (the "Limits to Growth" model) – see here, many of the questions and issues that people had were around EROEI. So I'm writing this article to clarify how the model uses EROEI and the results in some alternative scenarios where EROEI is changed in different ways.



Total energy production and industrial output in the New World Model.

Why are the results so different from the original World3 model? Is it because of EROEI?

The results are different because there are many changes from the World3 model. EROEI is only related indirectly to the difference in results.

In the World3 model, industrial output depends on the amount of non-renewable resources available. In the New World Model, there isn't a "non-renewable resources" variable, but instead there are different energy sources, including renewables, that are also essential to produce industrial output. In the same way that in World3 the amount of industrial output tracks quite closely the usage of non-renewable resources, in the New World Model the industrial output tracks the total energy.

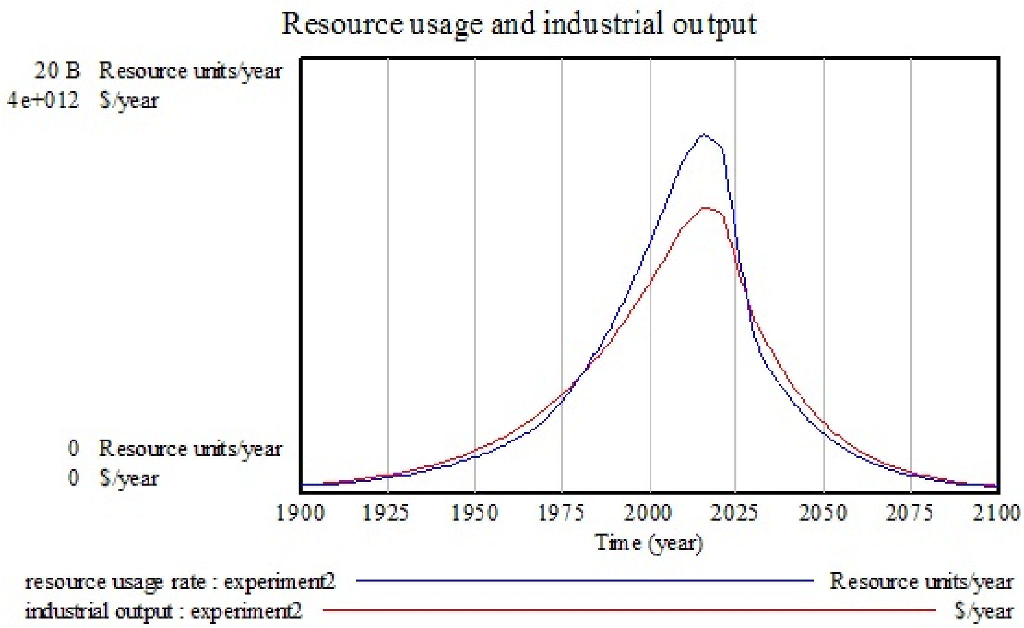


Fig. 1 *Resource usage and industrial output in the World3 model.*

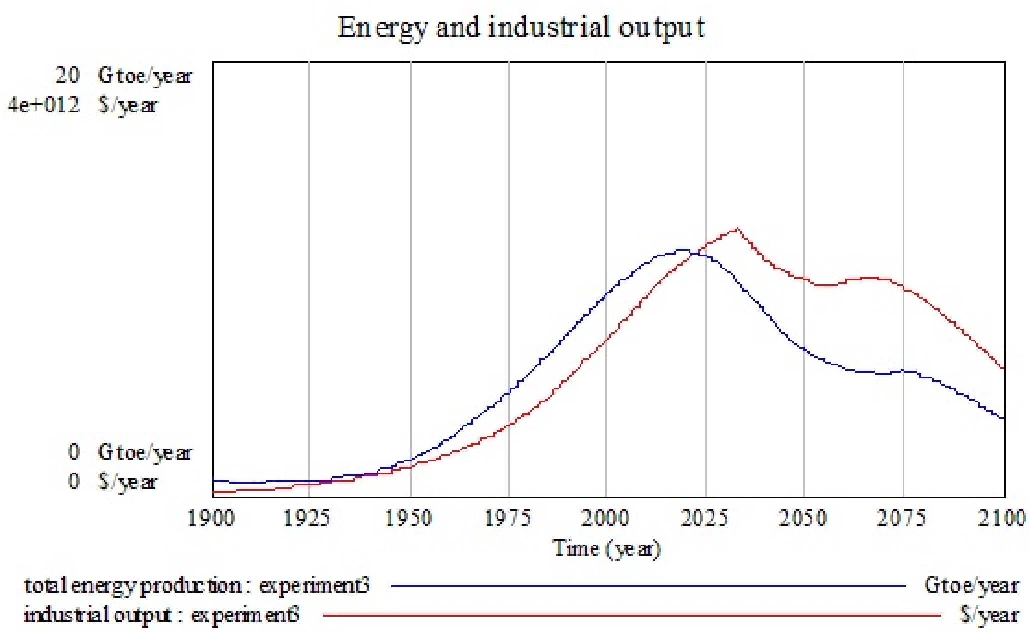


Fig. 2 *Total energy production and industrial output in the New World Model.*

As you can see in the graphs, total energy declines much less abruptly in my model than non-renewable resources decline in World3. There are several reasons for this:

1. Renewable energy sources
2. The decline of non-renewable energy sources follows a logistic curve. The exact equation is:

   Increase in production = 0.2*(fraction of fossil fuel remaining-0.5)*current production

   In the World3 model, the decline of non-renewable resources happens as fast as people can consume them. In other words, there isn't any limitation imposed to how fast non-renewable resources can be exploited, leading to a very abrupt decline when it happens. It could be said that one of the conclusions of the new model is that peak oil and peak fossil fuels is good news for civilization, because it gives a natural limit to how fast we can deplete our resources, preventing us from depleting them so fast that it would lead to a complete collapse.

3. Switching from some energy sources to others makes for a gentler, staged decline

EROEI has only an effect on this last point, in that it's the cause that drives the switching from one energy source to another.

How does the model estimate historical changes in use of different energy sources? Is it based on historical data or only EROEI?

The model uses only EROEI to decide whether to change the amount in the mix for any energy source and any type of demand (electricity, heat or transport). As I said in my previous article, there are two fundamental ideas that I have used:

1. Market forces follow EROEI: the most efficient sources of energy are also the most profitable. This seems to make sense intuitively but is disputed.
2. Energy companies are conservative: they will not start reducing the usage of an energy source until its EROEI falls below the average of all sources. Also, the reduction or increase in any energy source is gradual.

You can see below the graphs that represent energy usage for different types or energy and EROEI for the same types of energy, and see how they match.

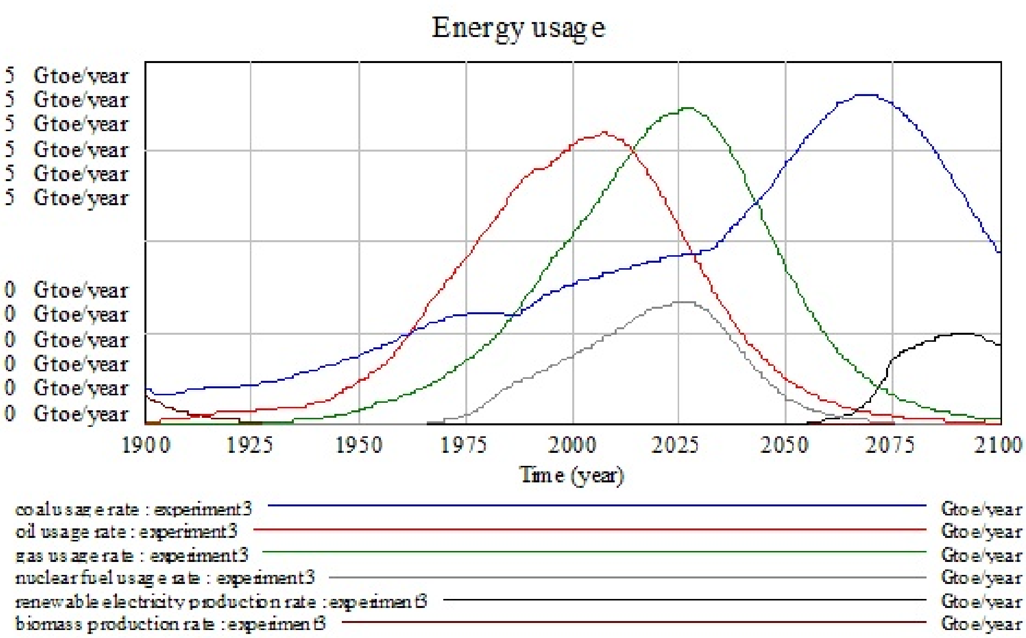


Fig. 3 *Energy usage in the New World Model.*

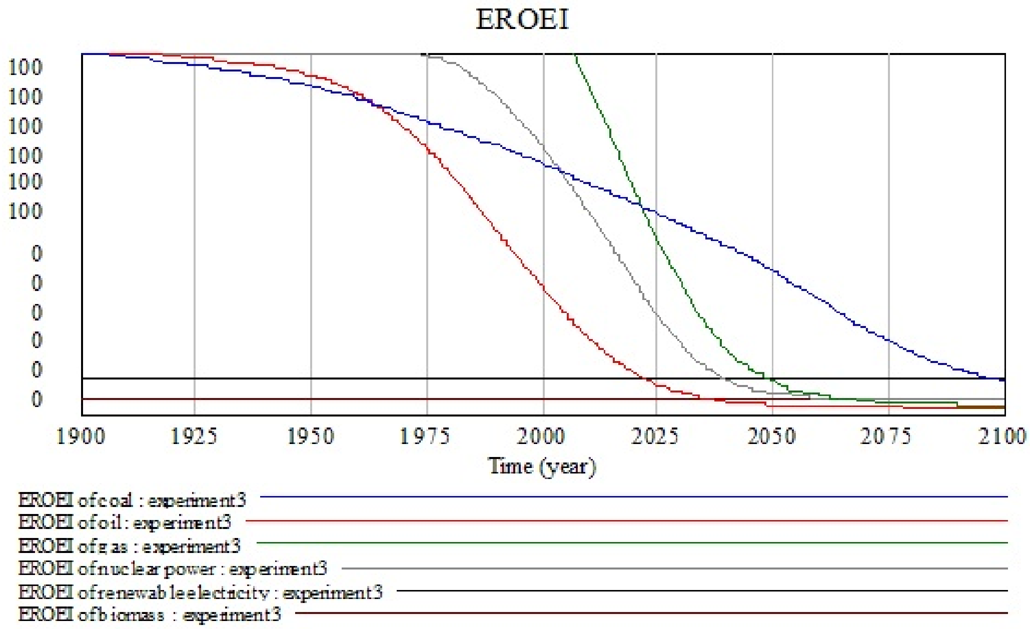


Fig. 4 *EROEI in the New World Model.*

Do the production profiles depend on EROEI?

No. The shape of the production curve for non-renewable energy sources depends on two factors:

1. Demand.
2. The maximum production, defined by the formula:

   Increase in production = 0.2*(fraction of fossil fuel remaining-0.5)*current production

If demand is lower than the maximum production, the production matches demand. If not, it matches maximum production. None of these things depend on EROEI.

Is there a clear point when EROEI has fallen so low that it causes a collapse?

If one had to give a date in the model for that, it would be sometime around 2030, around the time when the peak of industrial output is reached. The graph below shows industrial output, average EROEI and the amount of industrial capital needed to obtain energy, which indicates what happens.

Note: The reason there is a kink at the peak on industrial output is partly because of the sharp increase in the industrial capital needed to obtain energy, and partly because the table that estimates the industrial capital needed to obtain energy is a bit sparse on data points.

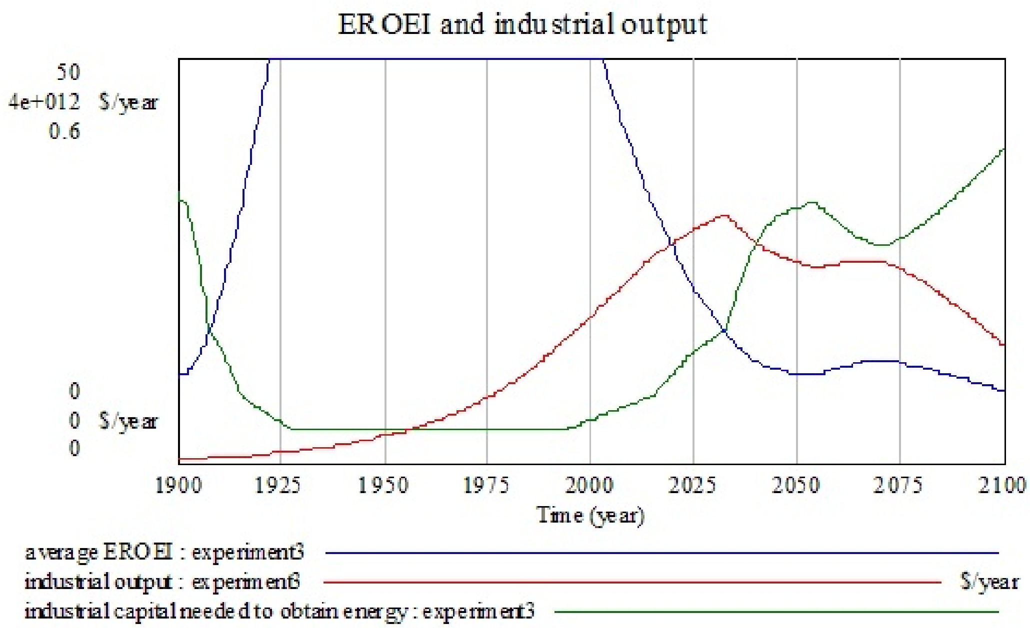


Fig. 5 *EROEI and industrial output in the New World Model.*

Where does your formula for EROEI come from?

The formula I've given for EROEI of oil (other fossil fuels are similar) is:

EROEI of oil = (fraction of oil remaining^2)*100

This comes from an approximate fit for the data points given by Charles Hall, 2008 for oil in the USA:

1930 – About 100:1
1970 – About 30:1
2000 – About 11-18:1

An additional reason to go for this simple relationship is because it has the following property: it takes the same amount of energy to extract the first half of the oil as it takes to extract half of the remainder (a quarter), and so on. This fits well with the intuitive idea of declining EROEI.

Clearly, the data is too limited to tell if this formula holds true with any certainty, so an obvious possible set of scenarios to try is changing it to other possible curves and see what happens in that case.

What happens if you choose EROEI curves that decline faster or slower?

One can change the curve for one that declines faster, such as a cubic. In this case, the world doesn't even have time to adapt to the first peak in production of a fossil fuel (peak oil), and industrial production collapses before there is time to switch to another source.

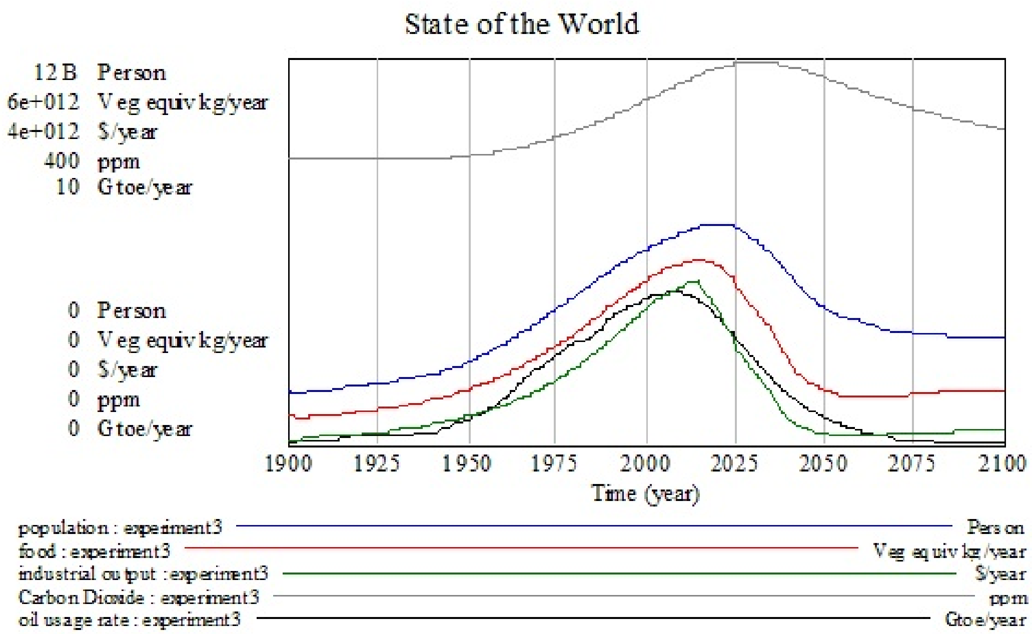


Fig. 6 *Key variables in the New World Model for a scenario with rapid decline for EROEI, following a cubic curve.*

If one changes to a curve that declines slower, such as a linear curve, an interesting thing happens: collapse happens later, but when it does, it's much faster and catastrophic. The world has time to adapt gradually to each of the peaks in each fossil fuel with not too much disruption, but when it reaches the final one, it affects food production in a catastrophic way. Climate change has been making it harder and harder to get adequate crop yields, and this world compensated by more and more industrial inputs to agriculture. When the final energy crisis hits, a significant portion of the world industrial base is dedicated to try to keep at bay the food crisis, and when that fails, everything else does.

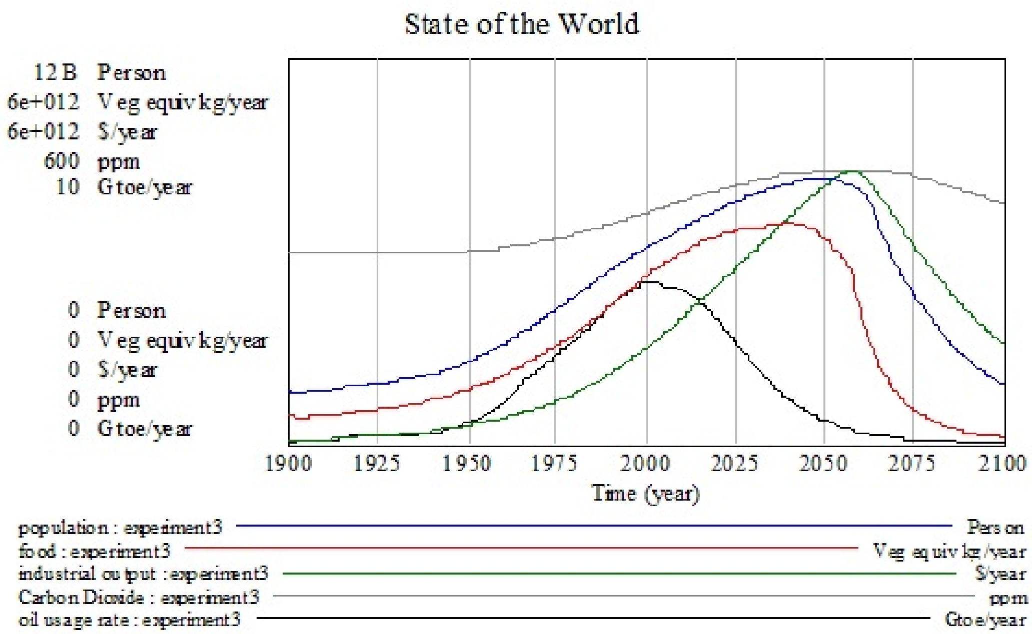


Fig. 7 *Key variables in the New World Model for a scenario with slow decline of EROEI, following a linear rate.*

What if the model underestimated EROEI for renewables and/or overestimated EROEI for fossil fuels?

There were several complaints that my estimate of EROEI for renewables was way too low and/or my estimate for fossil fuels was too high. I've ran a few scenarios with different values for EROEI to see what happens.

A scenario with a higher EROEI for renewables (30:1 for renewable electricity and 15:1 for renewable thermal) is similar, except that renewable energy sources start getting used sooner, and the final decline that comes with the decline of coal also happens sooner, because renewables helped this world live with a higher energy usage rate than the "business as usual" run.

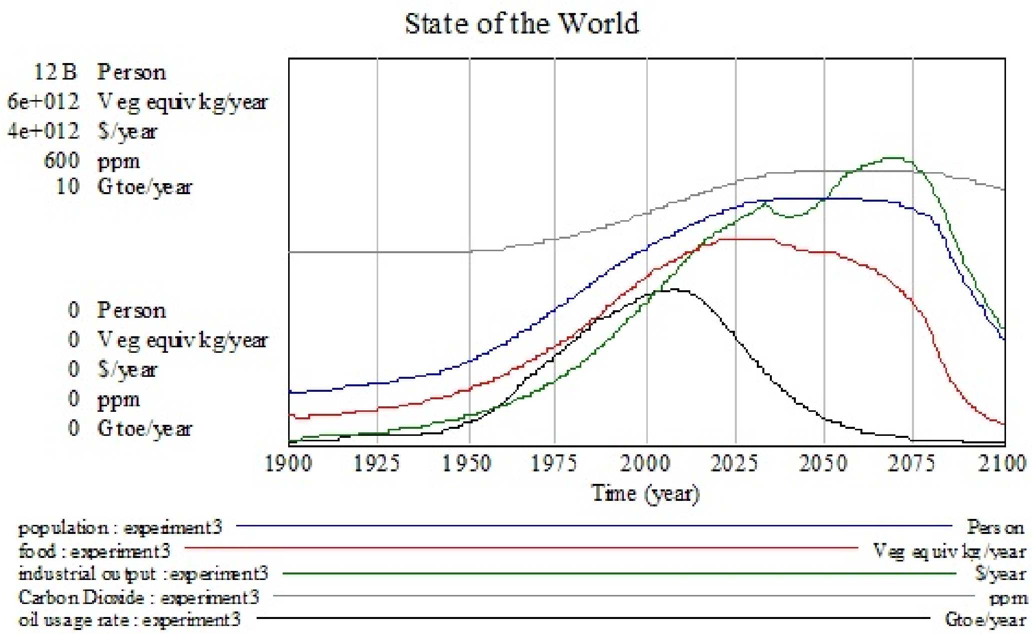


Fig. 8 *Key variables in the New World Model scenario with higher EROEI for renewables.*

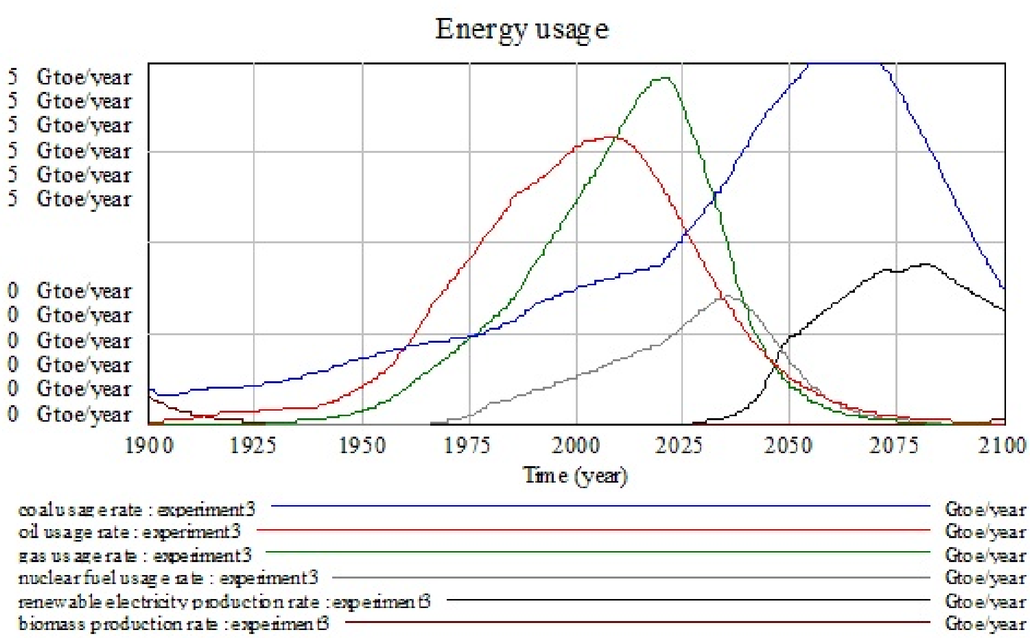


Fig. 9 *Energy usage in the New World Model scenario with higher EROEI for renewables.*

If one assumes both lower EROEI for fossil fuels and higher EROEI for renewables, we get a world where the energy crisis is a serious bump, but does a partial recovery eventually. The main reason that this world manages to recover is because usage of coal is kept at moderate levels, due to its relatively low EROEI, instead of being ramped up after oil and gas peak.

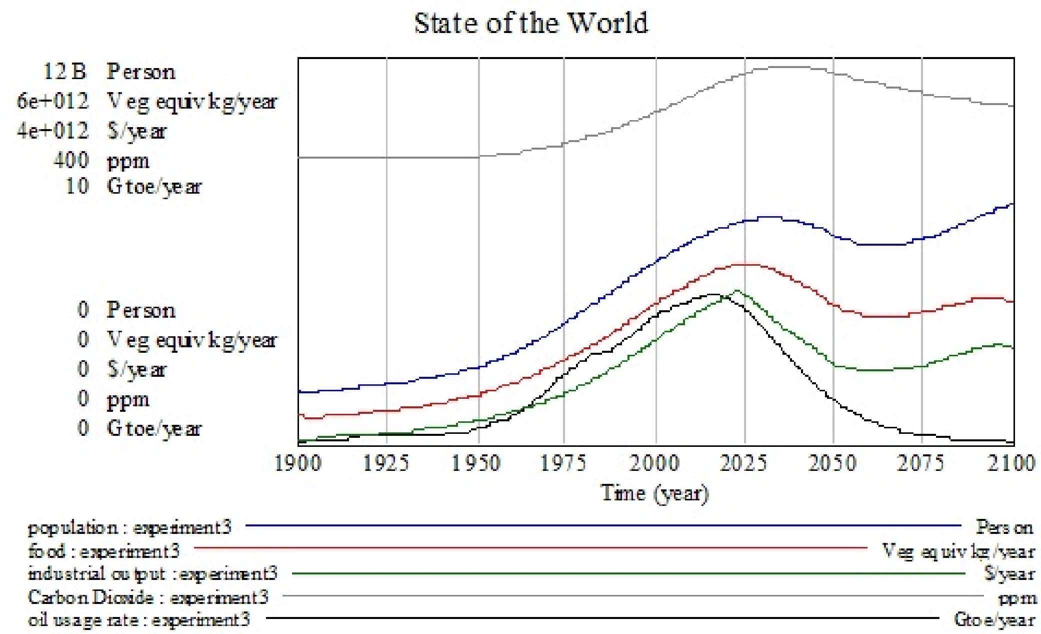


Fig. 10 *Key variables in a New World Model scenario with low EROEI for fossil fuels and high EROEI for renewables.*

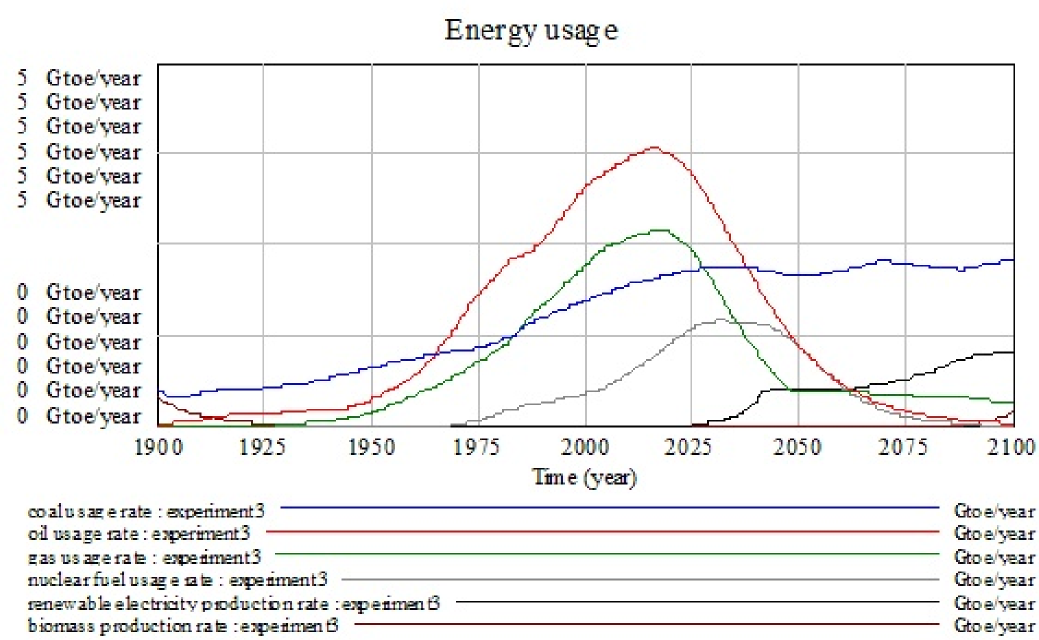


Fig. 11 *Energy usage in a New World Model scenario with low EROEI for fossil fuels and high EROEI for renewables.*

What if a new technology for renewable electricity is discovered that has very high EROEI?

It was suggested that some new technologies for renewable electricity, for example high altitude wind power, have extremely high EROEI. Wouldn't that resolve all our problems?

The answer, surprisingly, is "no". A scenario where a high EROEI (100:1) technology is discovered for renewable electricity on 2010 produces similar results to the scenario with high EROEI for renewables above. The fundamental problem is that just because there is a high EROEI technology available, market forces are still conservative, and the change to a higher

EROEI, more profitable technology only happens when the old technology has dropped below a certain level of EROEI. Market forces as simulated in this model eliminate the worst energy sources, but don't reduce the share of energy sources that are still able to operate a normal business. People still burn fossil fuels even when there are better alternatives available. This causes to climate change, a gradual decline in food production, and a final collapse when it's impossible to keep food production going.

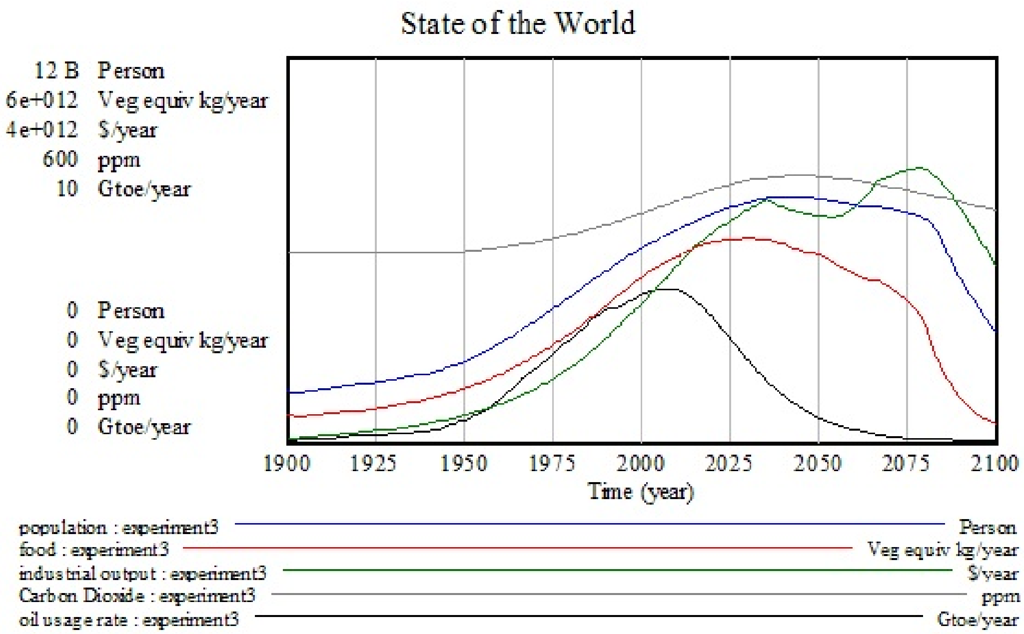


Fig. 12 *Key variables in the New World Model scenario with a very high EROEI renewable electricity technology.*

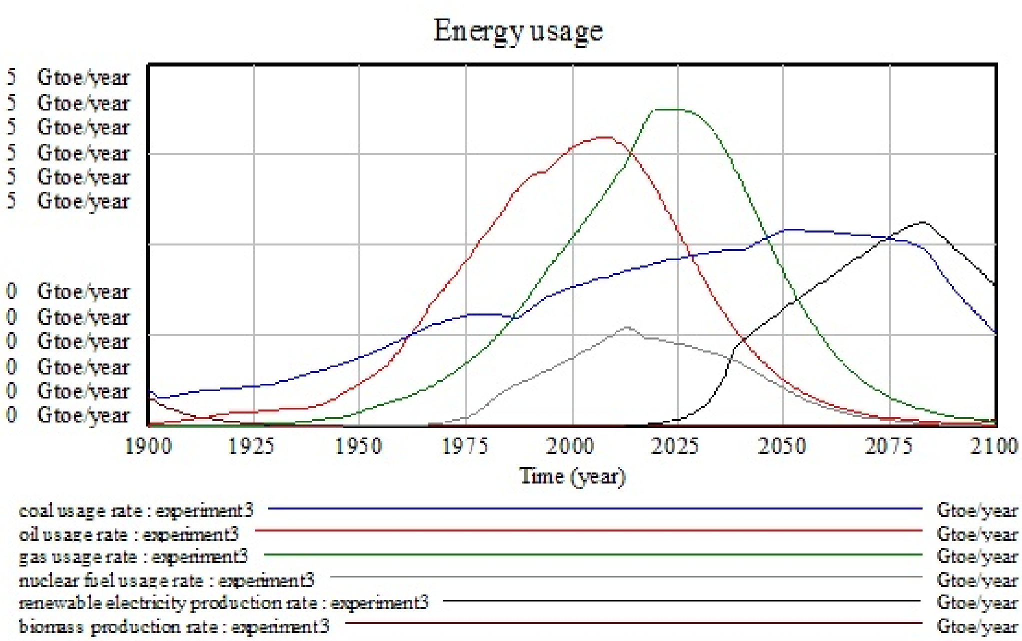


Fig. 13 *Energy usage in the New World Model scenario with a very high EROEI renewable electricity technology.*

What if things aren't left to market forces and/or EROEI, and there is a policy decision to ramp up renewables straight away, whether it makes sense financially or energetically or

not?

This is an interesting scenario to model, because it could be said it represents what seems to be happening currently. Policy decisions are being made to encourage renewables, often with little concern about practicality. Is this a good decision?

A run with a scenario that forces renewables to go online produces a definitely better result than the "business as usual", the energy crisis doesn't last as long it and has a higher standard of living for a longer period of time than the optimistic "high EROEI renewables / low EROEI fossil fuels" scenario described above. Problems start appearing towards the end of the run, but they are only the food crisis that this model will always show if there are no policies to take proper care of the soil.

It's important to note that there is no need to assume optimistic EROEIs for this scenario. There is no need to be hopeful if we can be smart.

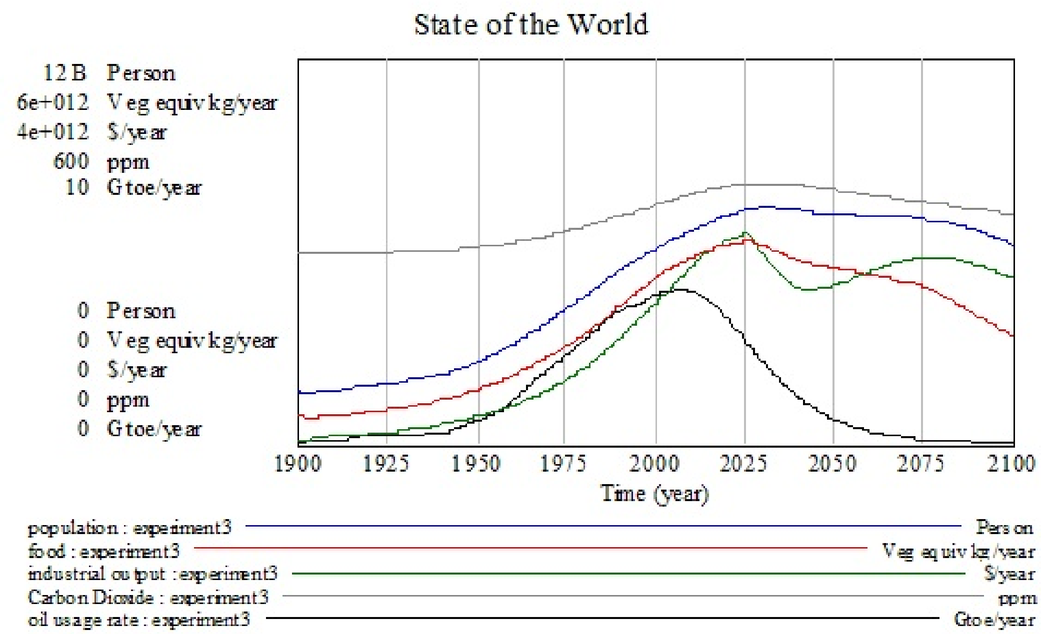


Fig. 14 *Key variables in the New World Model scenario where renewables are encouraged regardless of EROEI.*