POST

Can You Make a Wind Turbine Without Fossil Fuels?

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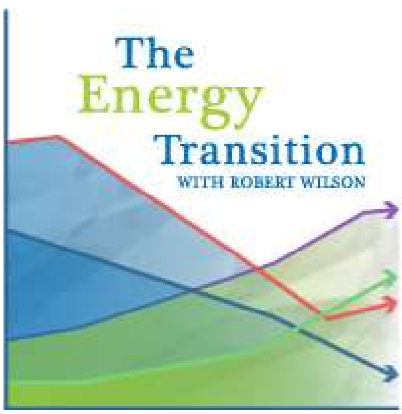

Wind Turbine and Energy Use

Various scenarios have been put forward showing that 100% renewable energy is achievable. Some of them even claim that we can move completely away from fossil fuels in only couple of decades. A world entirely without fossils might be desirable, but is it achievable?

The current feasibility of 100% renewable energy is easily tested by asking a simple question. Can you build a wind turbine without fossil fuels? If the machines that will deliver 100% renewable energy cannot be made without fossil fuels, then quite obviously we cannot get 100% renewable energy.

This is what a typical wind turbine looks like:

What is it made of? Lots of steel, concrete and advanced plastic. Material requirements of a modern wind turbine have been reviewed by the United States Geological Survey. On average 1 MW of wind capacity requires 103 tonnes of stainless steel, 402 tonnes of concrete, 6.8 tonnes of fiberglass, 3 tonnes of copper and 20 tonnes of cast iron. The elegant blades are made of fiberglass, the skyscraper sized tower of steel, and the base of concrete.

These requirements can be placed in context by considering how much we would need if we were to rapidly transition to 100% wind electricity over a 20 year period. Average global electricity demand is approximately 2.6 TW, therefore we need a total of around 10 TW of wind capacity to provide this electricity. So we would need about 50 million tonnes of steel, 200 million tonnes of concrete and 1.5 million tonnes of copper each year. These numbers sound high, but current global production of these materials is more than an order of magnitude higher than these requirements.

Fossil fuel requirements of cement and steel production

For the sake of brevity I will only consider whether this steel can be produced without fossil fuels, and whether the concrete can be made without the production of carbon dioxide. However I will note at the outset that the requirement for fiberglass means that a wind turbine cannot currently be made without the extraction of oil and natural gas, because fiberglass is without exception produced from petrochemicals.

Let's begin with steel. How do we make most of our steel globally?

There are two methods: recycle old steel, or make steel from iron ore. The vast majority of steel is made using the latter method for the simple reason that there is nowhere near enough old steel lying around to be re-melted to meet global demand.

Here then is a quick summary of how we make steel. First we take iron ore out of the ground, leaving a landscape looking like this:

This is done using powerful machines that need high energy density fuels, i.e. diesel:

And the machines that do all of this work are almost made entirely of steel:

After mining, the iron ore will need to be transported to a steel mill. If the iron ore comes from Australia or Brazil then it most likely will have to be put on a large bulk carrier and transported to another country.

What powers these ships? A diesel engine. And they are big:

Simple engineering realities mean that shipping requires high energy dense fuels, universally diesel. Because of wind and solar energy's intrinsic low power density putting solar panels, or perhaps a kite, on to one of these ships will not come close to meeting their energy requirements. We are likely stuck with diesel engines for generations.

We then convert this iron ore into steel. How is this done? There are only two widely used methods. The blast furnace or direct reduction routes, and these processes are fundamentally dependent on the provision of large amounts of coal or natural gas.

A modern blast furnace

The blast furnace route is used for the majority of steel production globally. Here coal is key. Iron ore is unusable, largely because it is mostly iron oxide. This must be purified by removing the oxygen, and we do this by reacting the iron ore with carbon monoxide produced using coke:

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

Production of carbon dioxide therefore is not simply a result of the energy requirements of steel production, but of the chemical requirements of iron ore smelting.

This steel can then be used to produce the tower for a wind turbine, but as you can see, each major step of the production chain for what we call primary steel is dependent on fossil fuels.

By weight cement is the most widely used material globally. We now produce over 3.5 billion tonnes of the stuff each year, with the majority of it being produced and consumed in China. And one of the most important uses of cement is in concrete production.

Cement only makes up between 10 and 20% of concrete's mass, depending on the specific concrete. However from an embodied energy and emissions point of view it makes up more than 80%. So, if we want to make emissions-free concrete we really need to figure out how to make emissions-free cement.

We make cement in a cement kiln, using a kiln fuel such as coal, natural gas, or quite often used tires. Provision of heat in cement production is an obvious source of greenhouse gases, and providing this heat with low carbon sources will face multiple challenges.

A modern cement kiln

These challenges may or may not be overcome, but here is a more challenging one. Approximately 50% of emissions from cement production come not from energy provision, but from chemical reactions in its production.

The key chemical reaction in cement production is the conversion of calcium carbonate (limestone) into calcium oxide (lime). The removal of carbon from calcium carbonate inevitably leads to the emission of carbon dioxide:

$$CaCO_3 \rightarrow CaO + CO_2$$

These chemical realities will make total de-carbonisation of cement production extremely difficult.

Total cement production currently represents about 5% of global carbon dioxide emissions, to go with the almost 7% from iron and steel production. Not loose change.

In conclusion we obviously cannot build wind turbines on a large scale without fossil fuels.

Now, none of this is to argue against wind turbines, it is simply arguing against over-promising what can be achieved. It also should be pointed out that we cannot build a nuclear power plant, or any piece of large infrastrtucture for that matter, without concrete or steel. A future entirely without fossil fuels may be desirable, but currently it is not achievable. Expectations must be set accordingly.

Recommended Reading

Sustainable Materials With Both Eyes Open – Allwood and Cullen

Making the Modern World: Materials and Dematerialization – Vaclav Smil

generation renewables