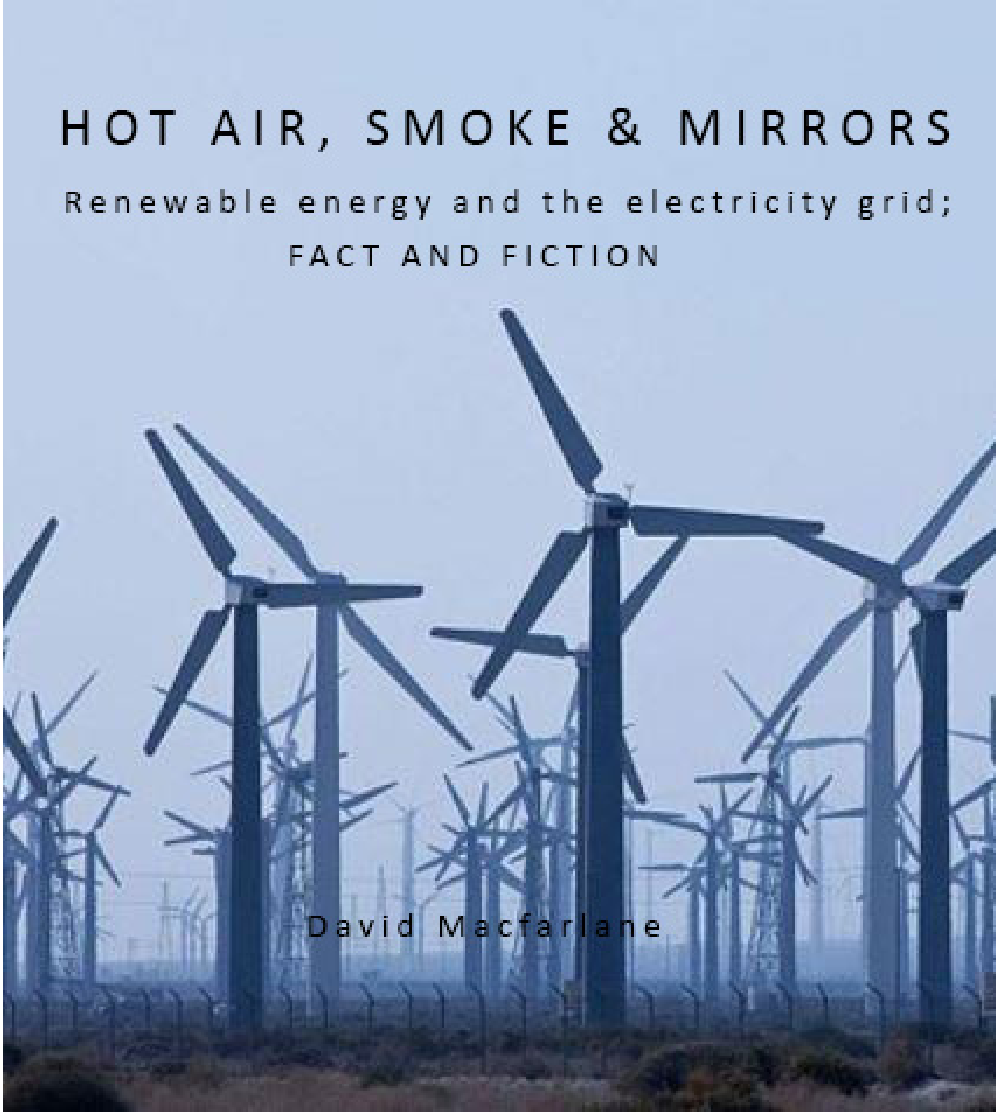

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CONTENTS

1. SUMMARY

This paper analyses information from government and industry reports and websites, academic research journals, and more than a dozen recently-published books to get as broad a view as possible of the way wind turbines and photovoltaics interact with the electricity grid – and combines this information with the author's practical experience of micro-grid design, implementation and management in order to understand and explain the likely effect of grid-connected intermittent renewable energy sources on the world's carbon emissions.

After evaluating a wide variety of surprisingly conflicting statistics and opinions from organizations and individuals with different beliefs and agendas, plus atmospheric CO_2 readings, the conclusion is drawn that not only is there no evidence to indicate that grid-connected wind turbines and photovoltaics actually lower 'real-world' carbon emissions, but with an understanding of the way an electricity grid works, there is no logical reason why they would; unless some form of mass electricity storage can be built into the grid system. At present, the only significant form of grid storage is pumped hydro, which accommodates only a tiny fraction of the storage required and has limited potential for expansion in most countries.

The world should eventually be able to be powered predominantly by solar-generated electricity, but not without major advances in battery technology for storage, and probably not if we rely solely on large interconnected electricity grids, which tend to be inefficient, unwieldy, wasteful, and unreliable. The most likely outcome will be a move to decentralized (off-grid) solar-generated electricity supply systems consisting of smaller autonomous units that include battery storage. Like computers for the past two decades, solar PV and battery storage are technologies with enormous potential for exponential advancement in performance and cost reduction. Solar (PV) panels, which unlike wind turbines and all other known sources of electricity generation, have no moving parts, are robust, silent, emission free, and maintenance free.

2. INTRODUCTION

We know that – even if you don't 'believe in' human-induced global warming – we can't keep consuming resources at a steadily increasing rate forever. We also know that atmospheric CO_2 has been constantly increasing for the past hundred years and is now close to 400 parts per million (ppm), and there is a connection between CO_2 levels, global temperatures, and sea levels. For the previous 800,000 years CO_2 levels never exceeded 300 ppm. The level was about 280 ppm at the beginning of the Industrial Revolution around 1750, when large-scale burning of fossil fuels began in earnest. The last time Earth's atmosphere contained 400 ppm was more than two-and-a-half million years ago, during which time the temperature was as much as 10°C higher, and sea levels were at least 6 metres higher than current levels (National Climatic Data Center, 2013).

One problem with our current response to this information appears to be the proliferation of decisions made on the basis of short-term public opinion, which is often ill-informed or deliberately misled by corporate interests (Gore, 2013) or well-intentioned political groups blinded by ideology, emotion, and wishful thinking (Lovelock, 2007). The reason this is relevant is because to believe this paper's hypothesis – that in the past few decades, billions of dollars' worth of public funds might have been spent on developing, promoting, manufacturing, installing, and subsidising a system that doesn't actually work (i.e. it doesn't, and probably never will solve the problem it's purported to; which is to significantly reduce carbon emissions) – you'd have to be open to the possibility that not only can governments and bureaucrats get things completely wrong, that corporations would act for no other reason than their own self-interest and short-term profit; but that it's also possible for a large majority of the public to be ill-informed and misled by idealism and wishful thinking.

Recent events might sway many into believing this not only could happen, but most probably is happening, in many different spheres of the modern world – such as the invasion of Iraq to prevent it from deploying its (supposed) secret cache of weapons of mass destruction (Wikipedia: invasion of Iraq, 2013); the way an unstable and unsustainable global financial system has been allowed to develop, resulting in the collapse of several major banks which were given 'triple-A' credit-ratings by authorities only days before their demise (Preston, 2012); and a modern food industry that has been allowed to chemically engineer products not to make us healthy, but to make us hungry and eat more, at the expense of our health – while telling us (with billions of dollars' worth of marketing) that it's good for us (Gillespie, 2012).

So this paper explores the notion that the (grid-connected wind turbine and photovoltaic) renewable energy industry could be based on a false premise – the premise that not only is it actually reducing carbon emissions, but if implemented on a large enough scale, it will be able to reduce carbon emissions significantly enough to prevent global warming. It's quite possible that the industry could have been allowed to develop because governments make decisions based on their ability to attract votes from a misinformed public who desperately want to believe that grid-connected wind turbines and solar panels will ‘save the world’, encouraged by an amoral corporate sector which is quite happy to go along for the ride, profiting all the way – at the expense of doing something genuinely effective to reduce global carbon emissions.

3. RESEARCH METHOD

Although most of us can tell opinion from fact, under a barrage of information, combined with an ever-increasing tendency towards political and corporate 'spin', it's getting harder and harder to tell the difference. The deeper one looks, the more one tends to find that many things presented as 'facts' aren't really facts at all – they're opinions, agendas, prejudices, and predictions, dressed up as statistics, scientific evidence, and academic reports (Goldacre, 2009). This is the sort of information that forms people's beliefs, and sets public opinion, corporate policy, and political agenda. When it comes to the environmental challenges the world currently faces, it can be difficult finding actual facts. For virtually every claim, it's possible to find research, statistics, and reports (by apparently equally well qualified authors) that indicate just the opposite.

As Ben Goldacre (2009) demonstrates in his best-selling book *Bad Science*, it's quite possible (and frighteningly common) to manipulate statistics and even supposedly legitimate, peer-reviewed scientific research, into telling any story one likes. And a common distraction is to present facts that, while undoubtedly true, are irrelevant to the argument. For example, the fact that wind and sun are free natural resources does little to prove that they can help reduce an electricity grid's carbon emissions. Most facts are distorted and sifted through the filter of the interpreter's background, experience, and personal agenda.

Another problem is the (apparently widening) gap between scientists/academics/industry-specialists and reality. The sophistication, complexity, and apparent accuracy of computer programs can be an alluring trap for those without regular contact with the 'real world' – to what is actually happening. And James Lovelock (2008) eludes to yet other issues with modern science: *"Younger scientists cannot freely express their opinions without risking their ability to apply for grants or publish papers. Much worse than this, few of them can now follow that strange and serendipitous path that leads to deep discovery. They are not constrained by political or theological tyrannies, but by the ever-clinging hands of the jobsworths that form the vast tribe of the qualified but hampering middle management and the safety officials that surround them"* (Lovelock, 2008. p.119). Lovelock seems to be suggesting that a tendency of modern scientists towards political correctness – for fear of damaging their career prospects by challenging the status quo – could be holding back genuine inquiry. On top of this, just about everyone and every organization has an agenda – to sell a service or product, or simply to defend a belief system that many have invested a lifetime (or at least their career, and perhaps their self-identity) into developing. Ideological blindness – one of the greatest impediments to real progress – is rampant in the environmental/sustainability/climate-change 'community'.

And it's not a good idea to allow ourselves to be convinced by those who are too certain of their opinions. It's a complex, ever-changing world, and we only see a tiny part of it, from our own perspective and background. In fact recent research has indicated that the more certain we are in our opinions, the more likely we are to be wrong. In what philosopher Nassim Nicholas Taleb (Taleb, 2007) refers to as "black swan events", we're often like turkeys – each day the farmer comes out to feed them they become more and more certain that he cares only for their well-being; until the fateful day he arrives with an axe. As James Lovelock (2007, p.118) says, *"a good scientist knows that nothing is certain; everything is a matter of probability".*

Many of the conclusions I've come to in this paper may be particularly challenging to those who already 'know' what is environmentally/morally good and what is bad – the ones who 'believe' in global warming, the evilness of the fossil-fuel industry, and the virtues of wind farms and grid-connected photovoltaics. The trouble is, when people start believing, they usually stop looking and thinking, even when circumstances change and new evidence is unearthed. And what people believe may have little to do with truth or reality. The fact that a few centuries ago most people believed the earth was flat didn't make it any less round. It just made it hard to open people's minds to what was actually quite obvious if they looked closely at the evidence.

So perhaps the most important phrase to apply to any conclusion is, 'it depends'. When someone declares that of course wind turbines and solar panels are good for the environment … well, it depends. It depends on how they're manufactured and installed, how and where they're applied, how long they'll last, and most importantly – as this dissertation explores – how the electricity they generate is used, stored, or otherwise (perhaps completely wasted). Can a house be entirely powered by solar-charged batteries? That depends also – on whether the occupants use one 20 watt laptop computer or three 400 watt desktop computers and a 1000 watt home entertainment system, amongst hundreds of other things. And this applies to just about everything.

My research method for this paper includes a literature review, predominantly recently-published books to obtain the views and conclusions of environmental scientists such as James Lovelock and Tim Flannery, and scientific and economic investigative journalists like Ben Goldacre, Robert Preston, Chris Martenson, and Richard Heinberg; mainly because they are experienced in their fields, very well researched, and have no obvious corporate or political agenda. They also tend to offer a logical, holistic view of the issues, written in an understandable format without excessive jargon or technical detail. A broad, well-considered perspective is invaluable in avoiding the dangers of being technically and theoretically correct, but realistically wrong or irrelevant. Most of the writers reviewed express the opinion that individual issues cannot be considered on their own. Martenson (2011) talks about "the three Es" (p.5), referring to the interplay between the economy, energy, and the environment; which all work together in forming our world, and our future; while more specifically, Lovelock (2007) does some simple calculations to show that (regardless of the electricity storage issue) it's physically and economically impossible for the UK to convert a significant amount of its electricity generation to photovoltaics and wind turbines. The room (offshore or onshore), money, and resources simply aren't available.

Industry, government, privately funded 'think-tank', and 'interest group' publications and websites are also analysed, although this information is viewed with a healthy dose of scepticism, as they all have obvious agendas. However, much of it is valuable – along with newspaper articles – in gauging public perception and the sort of information government and industry policy decisions are often based on. Relevant academic research journals were also reviewed, although in general they were found to be too limited in their scope – and too technically detailed/complex – for the holistic view aspired to in this dissertation; and perhaps, as James Lovelock (2007) suggests, too constrained by political correctness to challenge the status quo. Information and opinion which could be considered a primary source is from my own experience designing, installing, and managing an off-grid power system for a small commercial resort which I owned and operated for 14 years, plus a separate installation of a residential grid-connected photovoltaic system. While I have not documented the details, I've used this invaluable and quite unique practical experience carefully (keeping in mind the scale and technology I was working with) in trying to understand and explain how a large electricity grid might work.

Throughout this paper I'm guided, in general, by the following research principle, as used by Wikipedia, who define it as 'the duck test': *"If it looks like a duck, swims like a duck, and quacks like a duck, then it probably is a duck."* As explained on Wikipedia: *"The duck test is a humorous term for a form of inductive reasoning. The test implies that a person can identify an unknown subject by observing that subject's habitual characteristics. It is sometimes used to counter abstruse arguments that something is not what it appears to be."* (Wikipedia: The duck test, 2013) During my research, I have asked the following questions of each finding: 1. What are the vested interests of those involved in the research? 2. What are the qualifications, practical experience, and information sources of the 'experts'? 3. Does it make sense/seem logical? 4. Does it coincide with my observations, experience, and instincts; keeping in mind my own limitations and prejudices? 5. What is the most likely/probable scenario/truth, and under what circumstances?

4. WHY PHOTOVOLTAICS & WIND TURBINES?

The five main reasons given for switching electricity generation from fossil fuels to wind turbines and photovoltaics appear to be: 1. To reduce CO_2 emissions, which have been increasing significantly since the industrial revolution and are thought to be responsible for global warming. 2. To reduce other airborne, water, and soil pollutants caused by mining, refining, transporting, and burning fossil fuels. 3. To reduce dependence on non-renewable fuel sources that will inevitably run out and/or become prohibitively difficult and expensive to extract. 4. To improve national energy security; with the assumption that wind and photovoltaic generated electricity will be locally produced. 5. If implemented on a large enough scale, wind turbines and photovoltaics will inevitably be cheaper to operate in the long term than fossil-fuel generators.

This paper focuses on the effect of grid-connected wind turbines and photovoltaics on CO_2 emissions because, of all the reasons above, it is usually considered the most important. In fact the whole 'sustainability industry' is based on the concept of reducing carbon emissions. The level of CO_2 in the atmosphere also happens to be the simplest and most measurable of these issues, and as such, is the least susceptible to misinterpretation, manipulation, and opinion.

Of course to many people, wind and sun are the obvious answer to the carbon problem. They are abundantly free and clean sources of energy that just need to be economically converted into electricity to save the Earth from human-induced climate change – what Americans would call a 'no brainer'; by definition, something requiring little or no thought; which perhaps nicely sums up the problem with the implementation of wind turbines and photovoltaics at present. The comments below from environmental website Mother Nature Network (www.mnn.com) sums up many of the commonly held beliefs and attitudes towards renewable energy sources such as wind turbines:

"What's not to love? I'm an unabashed fan of wind turbines. I took a tour of a wind farm a few years ago and was blown away by the beauty of the towering, majestic monoliths spread out over the Wyoming hills. The slowly turning blades reminded me with every revolution that a little bit less coal would be burned to power our way of life …Wind power is environmentally friendly for numerous reasons. Emissions are negligible because no fuels are combusted, nor do turbines produce any substantial amount of solid waste while creating electricity" (Gunther, 2013).

In recent years, wind turbines have been favoured for large installations (predominantly rural and offshore wind farms) rather than photovoltaics because the bigger the turbines are, the more efficient they tend to be (as wind tends to be stronger and steadier higher off the ground), and the land under and around onshore wind farms can still be used for farming. Small wind turbines in urban environments tend to be ineffective (due to wind turbulence and interference from surrounding buildings), are sometimes noisy, and often unpopular with neighbours and local planning authorities (Boxwell, 2013). Wind farms are the preferred option of power companies in many countries to provide the percentage of 'renewable' energy they require to satisfy government legislation because they are considerably cheaper per kW than photovoltaics (EPA, 2013).

Photovoltaics tend to be favoured for smaller private installations because they can be made in small panels which are easily mounted on rooftops; plus they are silent, can be relatively unobtrusive, have no moving parts, and require little maintenance. They are usually sold to customers on the premise/promise that it will save them a lot of money on future electricity bills. The 'payback period' (the time it takes to recover the capital cost of the panels and installation) is very dependent on the government legislated 'feed-in tariff' (the amount the power company has to pay to buy back the electricity from the customer's solar system) (Boxwell, 2013). The underlying – but generally unstated – premise is that by installing grid-connected photovoltaic panels, people are also 'doing their bit' to save the planet from global warming; although some solar-system advocates and designers are surprisingly frank about the real environmental benefits of small-scale grid-connected systems:

"If you have grid-tie solar but sell most of your energy to the utility companies during the day in summer and then buy it back to consume in the evenings and in the winter, you are making little or no difference to the overall carbon footprint of your home. In effect, you are selling your electricity when there is a surplus and buying it back when there is a high demand and all the power stations are working at full load. Do not assume that because you have solar panels on the roof of your house, you are automatically helping the environment" (Boxwell, 2013, p.13).

5. WHAT THE RENEWABLE ENERGY INDUSTRY TELLS US

Most people in the renewable energy industry, along with most environmentalists, appear to be positive and optimistic about the role played by grid-connected wind turbines and photovoltaics in reducing the grid's carbon emissions. Al Gore, in his latest book, *The Future* (Gore, 2013), makes the following claims, which are mirrored by most supporters of renewable energy:

"The "fuel" for solar and wind is effectively limitless. More potentially usable energy is received by the Earth from sunlight each and every hour than would be needed for all of the world's total energy consumption in a full year. The potential for wind energy also exceeds the world's total energy demand several times over. Globally, renewables will be the second-largest source of power generation by 2015. Almost half of the world's additional electricity generation will come from PV by midway through the next decade. In the summer of 2012, there were periods when Germany received more than half its electricity from renewable energy sources. In 2010, for the first time in history, global investments in renewable energy exceeded those in fossil fuels ($187 billion, compared to $157 billion). During the previous decade, 166 proposed new U.S. coal-fired generating plants were cancelled" (Gore 2013, p.282).

The International Renewable Energy Agency (IRENA) *"aims to become … a powerful force in advancing the agenda of the widespread adoption and use of renewable energy, with the ultimate goal of safeguarding a sustainable future."* (IRENA, 2013a). Information on their website includes the following: *"With over 100 gigawatts of renewable power generation capacity added in 2011 alone, renewables have gone mainstream and are being supported by a "virtuous circle" of increasing deployment, fast learning rates and significant, often rapid, declines in costs"* (IRENA, 2013b). In fact the renewable energy industry makes it abundantly clear that not only are grid-connected wind turbines and photovoltaics an imminently sensible option, but they are well on the way to successfully transforming the world's electricity grids to carbon-free systems (which assumedly is what a sustainable energy future would require) within the next few decades. According to them, some countries are halfway there already. This is undoubtedly heart-warming news for anyone who cares about the environment and is concerned about human-induced climate change.

But amongst all the wonderful rhetoric, there is no attempt to address the issue of whether or not grid-connected wind turbines and photovoltaics are actually reducing carbon emissions. The IRENA website contains hundreds of pages of information and over fifty published papers and journals; none of which make any attempt to examine or explain how or why grid-connected wind turbines and photovoltaics would reduce carbon emissions. There seems to be an assumption that the more wind turbines and photovoltaics that are installed, the less carbon is being emitted. It's as though the original reason for doing something has been forgotten in the excitement of the implementation – surely a dangerous distraction in any endeavour.

It’s probably fair to say that most environmentalists (and much of the public) share the belief that unlike the people in the fossil fuel industry – who are only interested in profit and growth – the renewable energy industry is owned and operated by people who care, and are only interested in the well-being of our children and our planet; helping to facilitate a transition to a ‘sustainable energy future’. So of course they can be trusted to tell us the truth. In reality, despite the veneer of social responsibility, the renewable energy industry is a multi-billion-dollar industry (Gore, 2013), and undoubtedly subject to the same pressures to maximize growth and profit as any other big industry. But environmentalists such as Al Gore obviously believe that anyone who isn’t a supporter of renewable energy is an ill-informed conservative with a vested interest in the fossil fuel industry. With this sort of prevailing image, it certainly wouldn’t be very politically correct or career-sensible for a company CEO or politician to question the environmental credentials of the renewable energy industry.

6. WHAT THE POLITICIANS TELL US

The Annual Energy Statement (DECC, 2012) presented to the UK parliament in November 2012 states that:

"The Climate Change Act 2008 established a legally binding target to reduce the UK's greenhouse gas emissions to at least 80% below 1990 base levels by 2050, and to achieve a 50% reduction in emissions over the 2023-27 period" (DECC, 2012.p.6). "Renewables contribution increased to 3.8% of energy consumed in 2011 from 3.2% in 2010, with electricity generation capacity from renewables having increased by 33%" (DECC, 2012.p.10).

In the 43-page statement, the UK government seems to accept the fact that electricity consumption will increase significantly (possibly double) in the next forty years, and that fossil fuel- and nuclear-powered generators will continue to provide the large majority (more than 95%) of the country's electricity. While they predict around £12.7 billion *"confirmed and planned investments in the renewables sector"* (p.10) in the next year, they also offer funding and support for carbon capture and storage (CCS) research, expanded domestic oil and gas production, and additional coal, gas, and nuclear generators. But a large part of the statement is dedicated to establishing the government's 'green' credentials and its commitment *"to prevent dangerous climate change"* (p.6). It's as though they're backing every horse in the race, for fear of disappointing someone, and losing votes, while actually making no significant changes or concrete commitments.

About the only thing that is clear about the UK government's energy strategy is that, after signing an international agreement to drastically reduce carbon emissions, they must take this into consideration with all their decisions, or at least appear to be taking action. But they are not clear about how to reach their (very ambitious) targets. This remains completely unexplained. Even more interestingly, while the renewable energy industry and environmentalists talk of a world rapidly approaching an electricity grid powered by close to 50% wind and photovoltaics, the government admits to a figure closer to 4%. It's as though they're living on different planets, with completely different realities.

7. WHAT THE COAL INDUSTRY TELLS US

Coal is by far the most widely used fuel for electricity generation on a worldwide scale, producing over 40%, with gas next at around 20%, and oil at 5%; which means that almost 70% of the world's electricity supply is currently dependent on fossil fuel (Wikipedia: Electricity generation, 2013). The following statements from an article by Dr Robert Peltier (Peltier, 2013), editor-in-chief of Coal Power an online industry magazine, give an indication of the current situation from the coal industry perspective, specifically in regards to Germany, one of the world's leading proponents of renewable energy:

"Germany is building more coal-fired power plants than at any time in the past 20 years for one very practical reason: They cost less to operate than the other options. … The new coal plants were part of Germany's race to renewables. There is one useful lesson to be learned from Germany's ruinous resource planning choices. Germany is building new ultrasupercritical coal plants designed to ramp up and down at 30 MW/minute and 500 MW within 15 minutes and shutting down older, less-efficient, and less-nimble plants. In other words, Germany's new coal fleet is designed to operate in a symbiotic relationship with renewables. The downside for Germany is that carbon emissions rose 1.6% last year as more coal was burned" (Peltier, 2013).

If nothing else, much of the information from Peltier is quite alarming to anyone who's spent years immersed in (and believing) green political rhetoric. He paints a very different picture to that depicted by environmentalists and the renewable energy industry. In fact according to Peltier, the only thing that grid-connected photovoltaics and wind turbines have achieved is a massive increase in consumer electricity prices and an increased demand for coal-fired generators to back up the intermittent renewable energy sources. And the coal industry is quite happy to benefit from these consequences, regardless of the effect on carbon emissions. Of course, just like many of the claims made by environmentalists, the renewable energy industry, and politicians, the statements on a coal industry website could be either fabricated or selectively distorted to portray an optimistic future for the industry's shareholders. However, claims about the construction of coal-fired generators in Germany are easily verified from other sources with less obvious vested interests, such as www.wattsupwiththat.com which claims to be *"The world's most viewed site on global warming and climate change*". Their information is from BDEW, the German Energy Producers Association:

"Germany's dash for coal continues apace. Following on the opening of two new coal power stations in 2012, six more are due to open this year, with a combined capacity of 5800MW, enough to provide 7% of Germany's electricity needs. Including the plants coming on stream this year, there are 12 coal fired stations due to open by 2020. Along with the two opened last year in Neurath and Boxberg, they will be capable of supplying 19% of the country's power" (Homewood, 2013).

So the question could be asked: If grid-connected renewables were working in Germany, why would they be building so many large fossil fuel-powered generators? If the answer was that they need to quickly replace their recently and soon-to-be decommissioned nuclear power plants; that excuse could be countered by noting that most of the new generators were commissioned well before the government's populist political decision (soon after the Fukushima disaster of 2011) to phase out all nuclear power, and that coal-fired generators take many more years to build than wind turbines and photovoltaics (Peltier, 2013). So why couldn't they replace the nuclear generators with renewables? It could be simple economics. Coal just might be the cheapest option. Or it could be that renewables simply add no (or very little) additional useable power to the grid, destabilise supply, and don't reduce carbon emissions anyway. Or, as the coal industry claims, it could be a combination of all these factors.

The one significant difference with claims made by the coal industry in relation to other interest groups is that they are quoting statistics and opinions from people working within the power industry, whereas environmentalists' and politicians' (and many renewable-energy-industry advocates) claims often sound like vague statements, wishful thinking, and political spin from people on the fringe of the industry, who are perhaps not as well informed (or ultimately responsible for designing and managing a reliable electricity grid) as they themselves believe, or would like us to believe.

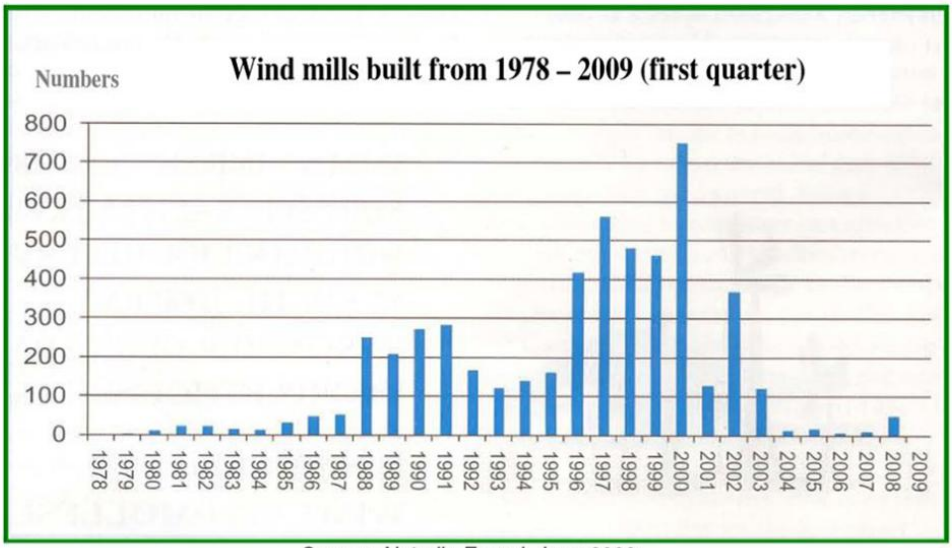
8. WHAT THE SCEPTICS TELL US

With a modicum of knowledge about how the grid, wind turbines, and photovoltaic systems work, it's hard not to be a little sceptical when proponents of this technology insist on quoting maximum installed capacity rather than the electricity actually usefully deployed by the grid. And according to the following article in www.forbes.com there's good reason to be sceptical:

"While the rapid growth in China's wind power capacity looks impressive on paper, it is less so in reality. China's total electricity production capacity reached 792.4 gW at the end of 2008; the 12 gW of wind capacity accounted for about 1.5% of that. However, in terms of actual power production, wind turbines generated 13 million megawatt-hours of electricity last year, only about 0.4% of China's total energy supply. China's wind turbine installation boom kicked off in 2006 as a result of a law that required power companies with over 5 gW of production capacity to build enough non-hydro renewable power sources to make up at least 3% of their installed capacity by 2010, and at least 8% by 2020. However, the regulations do not stipulate how much energy must actually be generated from renewable power sources" (Wai-yin Kwok, 2009).

According to a report titled *Wind Energy – The Case of Denmark by the Center for Political Studies* (CEPOS, 2009), an independent Danish research institution, a similar situation exists in Denmark, which is the world's leading proponent of wind energy, producing around 90% of the world's offshore wind turbines (The Official Website of Denmark, 2013). Denmark has a policy of building no new carbon-emitting power plants (in Denmark), and a firm commitment to increase their wind-generated capacity to 50% of the country's electricity demand (CEPOS, 2009, p.3). It is currently claimed to be over 20%. But that is not to say that wind power contributes 20% of the nation's electricity demand. The claim that Denmark derives about 20% of its electricity from wind overstates matters. Being highly intermittent, wind power has recently (2006) met as little as 5% of Denmark's annual electricity consumption with an average over the last five years of 9.7% (CEPOS, 2009, p.2).

It's not coincidental that the Danes also happen to pay the highest residential electricity rates in Europe (CEPOS, 2009, p.2). In the previous section the question of why Germany would be building more coal-fired power stations was asked. A similar question could be asked about Denmark when observing their wind-turbine construction statistics. The following graph could make a hardened sceptic suspect that Denmark discovered a serious problem with their wind-based power strategy as far back as 2001. Of course the flaw with this graph is that it's measuring the number of turbines, not the generating capacity, so a massive increase in the size of each turbine would coincide with a dramatic drop of individual numbers. But a check of Denmark's total wind generating capacity does in fact confirm the pattern indicated below; capacity has not increased since 2004 (CEPOS, 2009, p.9).



Source: *Naturlig Energi, June 2009*

Apart from pointing out the grossly exaggerated input of renewable energy sources, sceptics also claim that since photovoltaics and wind turbines are intermittent, feed-in systems do virtually nothing to reduce carbon emissions because the fossil fuel generators have to remain operating to provide a consistent base load. They claim that for every megawatt of renewable energy added to the grid, the equivalent is needed as backup, or what is known as 'spinning reserve'. A full capacity of 'other' electricity must be available at all times in case the wind stops blowing or the sky suddenly clouds over. According to sceptics, the 'wind and solar revolution' has done nothing more than appease the green vote, waste enormous amounts of money, increase energy bills, and destabilise the electricity grid.

And it may actually increase overall carbon emissions (Rosenbloom, 2012). In "Wind Report 2005," E.ON Netz, the German grid manager for about a third of Germany, hosting 7,050 MW of wind-generating capacity at the end of 2004, states, *"traditional power stations with capacities equal to 90% of the installed wind power capacity [a little over the maximum historical wind power infeed] must be permanently online in order to guarantee power supply at all times. The consequence is that wind power construction must be accompanied by corresponding construction of new conventional power plants. … The result is that, while wind-generated power itself is CO2-free, the saving to the whole power system is not proportional to the amount of fossil-fuelled power that it displaces.*" Richard S. Courtney similarly explains in *"Windfarms provide no useful electricity,*" a presentation to the 2004 Groups Opposed to Windfarms in the UK conference, that windfarms only force power stations to switch more often between generation and spinning reserve, or standby. *"They provide no useful electricity and make no reduction to emissions from power generation. Indeed, the windfarm is the cause of emissions from a power station operating spinning standby in support of the windfarm."* (Rosenbloom, 2012)

Some academic research journal articles express a similar opinion: *"Frequent ramp ups and downs of coal-fired plants lead to lower energy efficiency and higher emissions"*. (Li, et al, 2012) Most people understand that their car achieves more miles per gallon at a steady speed on a highway than at variable speeds in the city, where their engines are less efficient. It seems that grid generators may be similar. Germany is leading the world in its innovation and implementation of renewable energy, with a claimed input of 25% of total grid demand by 2012 (Wikipedia: Renewable energy in Germany, 2013). But the following article from the Institute of Energy Research (2013) points out some of the consequences for Germany's electricity grid:

"The government's transition to these intermittent green energy technologies is causing havoc with its electric grid and that of its neighbours – countries that are now building switches to turn off their connection with Germany at their borders. The intermittent power is causing destabilization of the electric grids causing potential blackouts, weakening voltage and causing damage to industrial equipment. These short interruptions to the German electric grid increased by 29 percent and the number of service failures increased 31 percent over a 3-year period, with about half of those failures leading to production stoppages causing damages ranging from ten thousand to hundreds of thousands of Euros. These power grid fluctuations in Germany are causing major damage to a number of industrial companies, who have responded by getting their own power generators and regulators to help minimize the risks" (Institute of Energy Research, 2013).

Smaller gas- and coal-fired generators, that can be turned on and off relatively quickly, are apparently being built to facilitate the integration of intermittent renewables, but according to the following report, they might not be helping to reduce carbon emissions:

"Meeting wind integration requirements with fossil generation will result in added emissions associated with part-load operation of thermal plants when they are placed into the duty cycles needed to support renewables integration … wind generation is expected to present a challenge to grid operators at increasing penetrations. Wind generation is difficult to forecast accurately and peaks at night in many regions, when system loads are at their lowest. … With the grid already scrambling, it's hard to imagine adding more renewables, like wind and solar power, because they are intermittent sources of power. We know customers are unpredictable, but now, so is the electricity. When the wind dies unexpectedly, a wind farm can lose 1,000 megawatts in minutes and must then quickly buy and import electricity for its customers. The alternative then is to use a peaker-style fossil-fuel plant, but that adds air pollution to clean electricity. These expensive fossil-fuel plants sit idle all year and can emit more air pollution than a large coal-fired plant. "If the peaker plants fall short, utilities pay large customers like aluminium smelters to use less electricity. If nothing works, you have brownouts and rolling outages," says Imre Gyuk, who manages the Energy Storage Research Program at the U.S. Department of Energy" (Nasr, 2009).

A website by an organization called *The Energy Collective*, *"an independent, moderated forum of the world's best commentary & analysis on energy policy, climate change, energy technologies and fuels, and energy innovation"*, whose members *"are our content contributors, and include leading scientists, activists, policy makers, executives and entrepreneurs"* looks to be a reliable source. An article posted by research scientist Schalk Cloete (Cloete, 2013) claims that renewable energy other than hydro will contribute only about 5% of the global energy mix by 2035. This paints a very different picture to that depicted by the renewable energy industry:

Some more extreme comments from wind-farm opponents make interesting reading:

"Enron invented the modern wind industry by buying the support of environmental groups for large-scale "alternative" energy and all that makes it profitable: tax avoidance schemes, public grants and loan guarantees, artificial markets for "green credits", and laws requiring its purchase. … Wind energy is just one more extractive industry, and with the collaboration of Enron's environmentalists it opens up land normally off limits to such development. … Industrial wind development may not be the worst scourge on the planet, but that does not excuse it. … It is, however, particularly evil because it presents itself as the opposite of what it is" (Rosenbloom, 2012).

Although it wouldn't be the first time in history that large corporations have manipulated government legislation and public opinion for their own benefit, the interpretation above does sound a bit like a conspiracy theory, and may or may not be true. But such extreme rhetoric shouldn't be used as an excuse to dismiss all of the sceptics' arguments, many of which are logical and backed up with sound research and references to legitimate government and industry reports. In fact the sceptics appear to be the only ones looking critically at the issue.

All of the detailed information about how renewables integrate with the grid is provided by critics – it is not even mentioned by supporters. On close examination, the 'feel-good' rhetoric from environmentalists and the renewable energy industry is mostly based on mistruths, exaggerations, and the dubious argument that because more and more money is being spent on renewables each year they must be lowering carbon emissions. Al Gore (Gore, 2013) boasts that *"In 2010, for the first time in history, global investments in renewable energy exceeded those in fossil fuels ($187 billion, compared to $157 billion)"* (Gore, 2013, p.282). On the same page he also claims that *"Globally, renewables will be the second-largest source of power generation by 2015"*, which is clearly so far from the truth it makes it hard to believe anything he says.

Sceptics and opponents of renewable energy technology are often dismissed as either fossil-fuel-loving conservatives or self-centred NIMBY (Not In My Backyard) activists who aren't prepared to make even a small personal sacrifice (in lifestyle, taxes, convenience, or aesthetics) for the common good. But NIMBYs generally focus on selfish, subjective, and sometimes exaggerated issues such as noise, land values, aesthetics, personal health, and birdlife. It should also be pointed out that most of the academic research journals reviewed for this dissertation that purportedly analyse the pros and cons of wind generation focus only on these issues too, while making no mention of the broader (and perhaps far more important) issues of grid-integration, storage, and overall carbon emissions.

As windfarm proponents usually point out, large, slow-moving turbines can look beautiful, depending on your attitude. And there are probably infinitely more birds killed flying into windows and hit by vehicles each year than are ever likely to be killed by the blades of wind turbines, no matter how many are built. But these issues have little to do with the problem being assessed in this dissertation. More to the point is that the sceptics who aren't NIMBYs are the only group publicly asking the critical questions. And unlike the renewable energy industry, politicians, the fossil fuel industry, and environmentalists, appear to be the only ones without a clear agenda of self-interest or political dogma. They occasionally sound frustrated and angry, but in general appear to have more integrity than other groups, and are at least thinking and observing; not dreaming, blindly believing, and manipulating public opinion through fear and ridicule with emotive arguments.

9. THE ELECTRICITY GRID & STORAGE

As identified by critics of grid-connected photovoltaics and wind turbines in the previous chapter, the main reason that this technology may not be actually reducing carbon emissions is that the electricity it generates is unreliable, intermittent, and stochastic (randomly variable). The wind might not blow for weeks on end; the sun might shine brightly one minute, but not the next. The electricity it generates can't be supplied 'on demand', when it is needed. And when it isn't needed, and can't be stored, the electricity is wasted. Plus sudden variations (when a cloud passes across the sun for instance with photovoltaics) can cause havoc with the grid voltage, which makes it difficult to manage and can damage electrical equipment. Without storage, conventional generators have to remain running in the background ('spinning reserve') to maintain a steady and even supply of electricity. If this is indeed the case, then the only thing achieved by connecting wind turbines and photovoltaics to the grid is a vastly more complex, unstable, and unreliable electricity grid, at an enormous cost – with little or no reduction in carbon emissions.

Although the power industry is well aware of this fundamental problem – that mass storage is required in order to integrate a large proportion of intermittent renewables into the grid – and is working towards finding solutions (discussed later in this chapter), it is rarely acknowledged or openly addressed by environmentalists or the retail side of the renewable energy industry. In fact, the current lack of grid storage could be described as 'the elephant in the room' of the renewable energy industry. So while grid parity (when the cost of renewable-energy-generated electricity is reduced to that of conventional grid electricity) has been the Holy Grail of the renewable energy industry for many years, and supposedly the only thing really holding back a wholesale transformation of the world's electricity grids (Wikipedia: Grid parity, 2013), it may not be the real problem after all. Energy storage is the key enabling technology for renewables. Until you can make [energy storage] reliable and affordable, it doesn't matter how cheap and efficient you can make wind and solar, because our grid can't handle the intermittency of those renewable technologies (Buie, 2013).

The uptake of household roof-mounted photovoltaic panels took off in many countries in recent years with the advent of the grid-connected system with a generous (usually heavily subsidised) feed-in tariff, which forced energy companies to buy back electricity from their customers at a government-legislated price usually higher or equal to the retail selling price. Although not popular with electricity suppliers (it is obviously not sustainable from a business perspective – no business would be profitable if forced to buy too much of its own produce off its customers), this not only made it a financially viable option for customers, who theoretically would receive free electricity for the next twenty years and could payback the installation cost within a few years, but it apparently overcame the problem of intermittent-renewable-energy storage; because households could draw off the grid at night when their solar panels weren't producing any electricity (Boxwell, 2013). This is often referred to as 'grid storage'.

But grid storage is a rather deceptive play on words when used in this context. The grid is just a system of wires, poles, transformers, and generators. The best it can do is shuffle electricity around to even out supply and demand (what is now being promoted as a 'smart grid'), but the grid itself, even a 'smart' one, cannot store or create electricity (Smart Grid, 2013). In fact a grid will never be able to absorb or 'store' a large amount of solar- or wind-generated electricity unless some sort of genuine storage is built into it. And this, apparently, is the limiting factor for grid-connected intermittent renewable energy.

At present, renewable variability is handled almost exclusively by ramping conventional reserves up or down on the basis of forecasts. However, as renewable penetration grows, storage and transmission will likely become more cost effective and necessary. … *Energy storage on a utility-scale basis is very uncommon and, except for pumped hydroelectric storage, is relegated to pilot projects or site-specific projects* (APS Physics, 2013). Water pumped to a height and stored in large reservoirs, then released through generating turbines when electricity is required, is a method of 'storing' electricity. It is the only method currently used in any significant amount to provide grid storage. Pumped storage is the largest-capacity form of grid energy storage available, and, as of March 2012, the Electric Power Research Institute (EPRI) reports that PSH accounts for more than 99% of bulk storage capacity worldwide, representing around 127,000 MW (Wikipedia, 2013: Pumped-storage hydroelectricity).

Pumped Storage Hydropower (PSH) is the only conventional, mature commercial gridscale electricity storage option available today (National Hydropower Association, et al, 2010). Hydropower, which is a form of renewable energy in itself, provides around 16% of the world's electricity (Wikipedia: Hydroelectricity, 2013). But not all hydroelectric schemes have the ability to pump water back up to their reservoirs, which are filled naturally from rainfall in catchment areas. So although they are effectively storing energy, and can help even-out supply provided by wind turbines and photovoltaics by generating 'on demand' as part of a smart grid, the majority of hydroelectric schemes cannot actually store the electricity generated by wind turbines and photovoltaics. As a result, most countries in the world have only a very small capacity, if any, for pumped storage – with limited potential for expansion.

And hydroelectric schemes are built at significant ecological expense (EPA, 2013a). Drier countries often need the water downstream, and most developed countries have already fully exploited their river systems. Australia, for instance, already has 502 major dams, has only built a few in the last couple of decades, and is unlikely to build any more (The Earthmover & Civil Contractor, 2010). According to the following extract from the US Energy Information Administration:

"There are 40 pumped storage plants operating in the United States … totalling more than 22 gigawatts (GW) of storage capacity, roughly 2% of U.S. generating capacity. There has been increased interest in building new pumped storage plants, although construction has not yet been authorized. According to the National Hydropower Association, as of January 2012, the Federal Energy Regulatory Commission had granted preliminary permits for 34 GW of pumped storage capacity over a total of 22 states, which would more than double existing capacity. There are, however, significant challenges to building new pumped storage plants, including licensing, environmental regulations, and uncertainty in long-term electric markets" (EIA, 2013: Pumped storage).

Although pumped hydro storage (PHS) will probably be increased by a few per cent each year in many countries over the next few years (National Hydropower Association, 2010), at this rate of expansion (which obviously cannot continue indefinitely) it is unlikely to ever provide anywhere near enough storage to enable the integration of a large percentage of photovoltaic- and wind turbine-generated electricity into the grid.

As for other storage options, a 2010 paper titled *Electricity Energy Storage Technology Options* by the Electric Power Research Institute of California (EPRI, 2010) concludes that compressed-air and advanced-battery technology are the two most practical and affordable options with the best potential to significantly increase grid storage. But these are still in the development phase and have yet to be commercially implemented on any significant scale. As with all electricity storage options, their feasibility seems improbable (in terms of money and resources) when the enormous scale of the storage required is realistically considered. To demonstrate the size of the problem; one of the world's largest battery storage facilities – a $35 million, 40 megawatt, 1300 tonne battery bank the size of a football field, built in 2003 to prevent weather-induced blackouts in the Alaskan city of Fairbanks – can provide the city's 12,000 residents with electricity ***for only seven minutes***. Replacing one large coal-fired power station with a wind turbine/photovoltaic array with adequate storage would require hundreds of battery banks the size of the Fairbanks facility (Luoma, 2009).

10. SOME OBSERVATIONS FROM PRACTICAL EXPERIENCE

The following section contains observations and opinions from the author's personal experience with an off-grid power system.

Anyone who has designed a small off-grid power system has generally had to make a choice between two different types of systems. Until about thirty years ago, before the advent of commercially available photovoltaics and small wind turbines, the most popular option for a continuous supply of electricity in a remote location was a continuously running diesel-powered generator. And anyone who's had to live with this type of system knows that it doesn't matter how many lights or appliances you turn off, it makes very little, if any, difference to the amount of fuel being consumed (the system's carbon emissions) by the generator; it's either running, and you have electricity, or it's not, and you don't. Even if no appliances are turned on, the generator must remain running so that electricity is instantly available when something is turned on.

This is a fact that is misunderstood by many people; carbon dioxide is produced when electricity is generated (by fossil fuels), not when it is consumed. And diesel generators (and apparently, most other fossil fuel-powered generators, according to information quoted earlier in this paper) are more efficient and generally have a longer service life and require less maintenance if they are kept operating under a steady constant load. So it's actually better to keep a certain number of appliances on all the time or have a 'dummy load' built into the system for when demand is low. Keeping this in mind, it would be of no benefit to feed extra electricity into the system from solar panels or wind turbines, which essentially would be no different from turning off a few appliances. All it would achieve is to make the whole system difficult to manage, highly unstable, and possibly damaging to some appliances. With wild fluctuations already possible on the demand side (perhaps a 1200 watt hairdryer, a 1500 watt iron, and a 2400 watt vacuum cleaner all suddenly turned on at exactly the same time), introducing wild fluctuations on the supply side for no actual benefit would be ridiculous – which is what would happen when, say, the 5000 watts from a photovoltaic system suddenly drops to 100 watts as a dark cloud passes across the sun.

For a small domestic power system (micro grid), if your maximum continuous demand was say, 10,000 watts, you would probably install a 15kW diesel generator, which allows a bit up your sleeve to handle extra surges from some appliances (electric motors in particular) which initially draw more power than their continuous rating for a few seconds when turned on. In theory, you could instead install a 10kW diesel generator plus a 5kW wind turbine and photovoltaic array to handle the total 15kW demand. But of course you would also have to install another 5kW diesel generator, and keep it running continuously, because the input from the renewable energy sources is going to be fluctuating from zero to 5kW on a minute by minute basis, and considerably less than 5kW most of the time (especially at night). Theoretically, if you could accurately predict that the total demand was going to be less than 10kW for certain periods of the day, you could turn the 5kW generator off for a while. But what then would you do with the extra power feeding into the grid from the wind turbines and photovoltaics? And what if the demand suddenly increased above 10kW due to an unpredicted demand?

In reality, by adding the wind turbines and photovoltaics, you've just created a very complex, difficult to manage system – at enormous additional cost – for no apparent benefit, and little if any reduction in carbon emissions; in fact probably more, if embodied energy is taken into account. And the more wind turbines and photovoltaics added, the worse it gets. Of course a large municipal electricity grid is vastly different to a simple micro grid, but it's worth noting that the problems identified above seem to be exactly what is happening to main grids which have tried to integrate wind turbines and photovoltaics.

These days, the other type of micro off-grid electricity system that could be installed is one that continuously draws electricity from large deep-cycle batteries (usually lead-acid 24V or 48V for a household-size system) with an inverter which transforms the voltage up to 240V (or 110V in the US). The batteries are kept charged by one of, or a combination of, photovoltaic panels, wind turbines, and a small petrol- or diesel-powered generator/charger (for when there's no wind or sun for extended periods). The generator doesn't power the micro-grid or any appliances directly, so only needs to be large enough to power the battery charger. If the battery/photovoltaic system is sufficiently large, adequately designed, and in a suitable climate, the whole system can operate without the need of a fossil-fuel-powered generator, and would thus be completely (and genuinely) emission free. This is a much simpler, more robust power system than any other, with no moving parts, little maintenance, and no fuel consumption. However, to be practical and affordable, it would require a massive reduction in maximum and overall electricity demand in comparison to a continuously-run diesel generator, which could quite happily operate under full load 24 hours a day.

Apart from the importance of the batteries in order to provide a continuous electricity supply from intermittent renewable energy sources, the other significant factor is that batteries act as a buffer between the wildly fluctuating input of renewables and the consumption demand. In practice, it makes no difference to the battery state-of-charge or inverter output if the input from the photovoltaics suddenly drops (say from 5000 watts to 100 watts) for a few minutes many times during the day, as long as the average daily input is sufficient to cover the total daily electricity consumption of the whole system. In many ways it's a more efficient, stable system than the continuously-running generator system, with virtually no chance of sudden voltage spikes.

Another observation from the author's experience is that a larger centralized power system is, overall, considerably more fragile than a collection of smaller autonomous systems. Although a single photovoltaic/battery/generator power system for a ten-cabin resort was the simplest and most economical to install, it would have been a far more robust, easier to manage (and cheaper in the long run) system if it had been broken up into ten small autonomous systems – one for each cabin – with no generator. Most of the problems with the system were related to operating, refuelling, and servicing the petrol generator and battery charger. And if something went wrong (often as a result of an appliance or pump left on) it generally brought the whole system down, instead of just one small sector.

11. CARBON EMISSIONS

There are four apparent ways in which carbon emissions can be measured or considered. They are listed below in increasing order of significance, accuracy, and connection to reality:

A. THEORETICAL CARBON EMISSION REDUCTIONS

Statements such as *"replacing one regular light bulb with a compact fluorescent light bulb will save 150 pounds [68kg] of carbon dioxide a year"* (UNESCO, 2013) are commonly made on environmental websites. Obviously these estimated reductions are just to give people a way of comparing how different activities and appliances might affect carbon emissions. But they can be misleading. As pointed out earlier in this dissertation, CO_2 is emitted when electricity is generated by fossil fuel, not when it is used by the consumer. So turning off a light doesn't actually lower your carbon emissions. This is different from the fuel in your car. If you decide to walk instead of drive, you have not burnt that fuel, so you have actually lowered your carbon emissions.

B. CARBON EMISSION ESTIMATES

These figures are also estimates, not actual emissions, so they are not necessarily real, or accurate, and can vary quite significantly depending on the parameters, methodology, and assumptions used. An article by Zeke Hausefather (2013) on a website called The Yale Forum on Climate Change & The Media gives an indication of just some of the assumptions made in these calculations: *"Wind generation … often cannot be used to directly displace coal baseload generation. Instead, wind often displaces generation sources like natural gas and oil. So assume here that increases in wind generation result in carbon reductions that reflect the average 2005 grid mix (which was a bit over 50 percent coal). So comparing a scenario in which wind power remained at its 2005 percent of generation with what has actually occurred, one can estimate the carbon reductions attributable to the expansion of wind power"* (Hausfather, 2013). Hausfather claims that recent carbon reductions in the U.S. were brought about by a combination of factors, including; driving less, improved fuel efficiency, flying less and more efficiently, switching from coal to natural gas, overall energy efficiency, and wind generation. He makes no mention of photovoltaics.

As an overall assessment, Hausfather surmises that: U.S. carbon emissions have declined at an impressive rate given the absence of any cohesive federal climate change policy. The U.S. has actually managed to make significant progress toward its long-abandoned Kyoto Protocol target to reduce emissions 7 per cent below 1990 levels (Hausfather, 2013). On the other hand, the United States Environmental Protection Agency (EPA, 2013b) states that US carbon emissions increased by just over 8% from 1990 to 2011, although they did decrease by around 1% from 2011 to 2012. They attribute this reduction mainly to the switch from coal to natural gas combined with an overall decrease in electricity demand resulting from a warmer than usual winter.

There are several other reasons listed as possible influences on carbon emissions. “Non-fossil alternatives” gets a mention as a minor influence. An article on The Energy Collective website only partially agrees with the EPA’s assessment, claiming that the vast majority of any carbon emission savings that were achieved were driven by energy efficiency and unusual weather conditions, but makes no mention of any contribution from grid-connected renewables: *"Contrary to popular perception, 2012 data shows that the increased use of natural gas in the electric power sector is not the largest contributor of energy related CO_2 reductions in the US over the past year. Nearly 75% of the CO_2 savings are attributable to economy-wide demand reduction driven by energy efficiency, conservation and the mild winter of the first quarter of 2012"* (Afsah, 2013). While in Europe: *"The main reasons for the favorable trend in Germany were increasing efficiency in power and heating plants, and the economic restructuring of the five new Länder after German reunification. In relative terms, emissions decreased strongly in the EU-27 between 1990 and 2000, mainly due to the introduction of market economies and the consequent restructuring or closure of heavily polluting and energy-intensive industries"* (European Environment Agency, 2013).

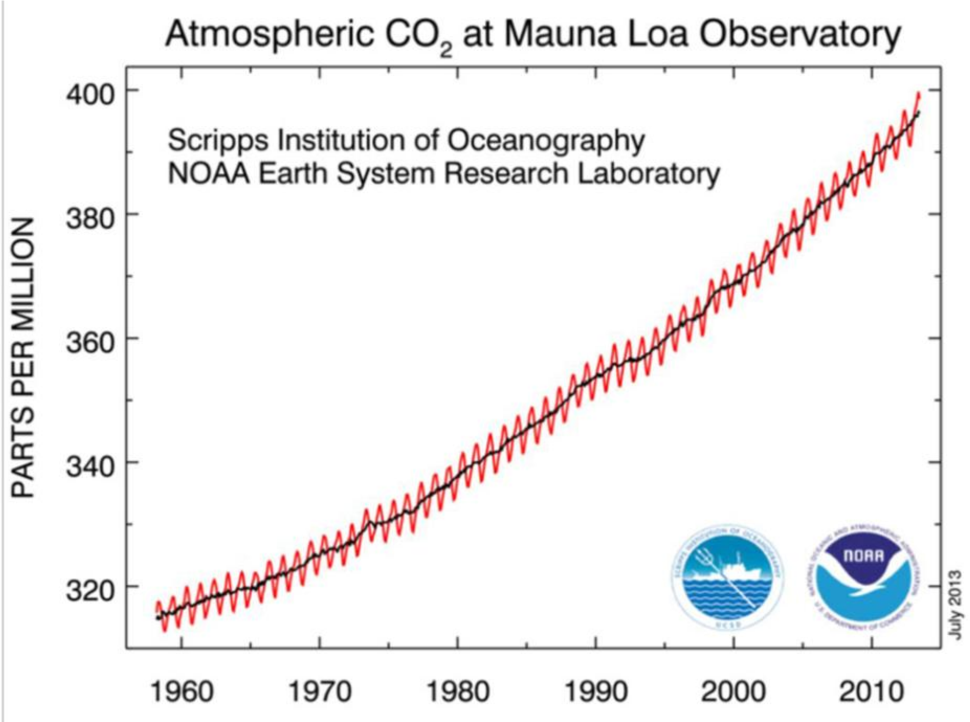
It seems that although there are some claims that carbon emissions in the U.S. and Europe have been reduced in recent years, no one is claiming that the introduction of grid-connected wind turbines and photovoltaics have contributed to this in any significant way.

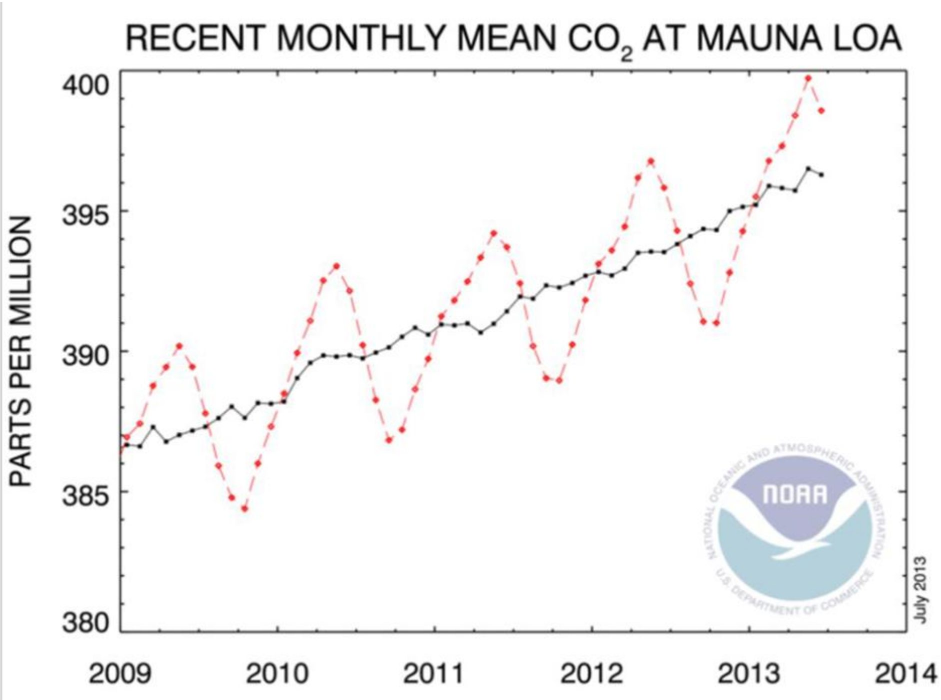
C. ACTUAL FOSSIL FUEL CONSUMPTION

According to climate scientists there’s a direct relationship between how much fossil fuel is consumed each year and atmospheric CO_2. In fact *“fossil fuel use is the primary source of CO_2”* (EPA, 2013b). So even though it’s not a direct measure of carbon emissions, a reduction of fossil fuel consumption might lead to, or indicate, a reduction of carbon emissions. And if grid-connected wind turbines and photovoltaics were replacing fossil fuel-powered generators by any significant degree, then we could expect to see some reduction in fossil fuel consumption. But according to the BP Statistical Review of World Energy (June 2012): *"World primary energy consumption grew by 2.5% in 2011, roughly in line with the 10-year average. Consumption in OECD countries fell by 0.8%, the third decline in the past four years. Non-OECD consumption grew by 5.3%, in line with the 10-year average"* (BP, 2012). The only time growth in world energy consumption has slowed in recent years was in 2008, most probably caused by a downturn in economic activity during the global financial crisis.

D. ATMOSPHERIC CARBON MONITORING

The one vital statistic likely to indicate if anything we are doing is leading to a reduction in carbon emissions is a regular measurement of actual CO_2 levels in the atmosphere. This also happens to be the simplest and most measurable way of considering carbon emissions, and as such, is the least susceptible to misinterpretation, manipulation, and opinion. According to a Canadian carbon-emission monitoring and information website: There is no single indicator as complete and current as the monthly updates for atmospheric CO_2 from the Mauna Loa Observatory … CO_2 is well mixed in the atmosphere, so observations of concentrations from a single site like the Mauna Loa Observatory are an adequate indicator of world trends (CO2 Now, 2013). As can be seen in the graphs below, CO_2 has been steadily increasing since monitoring began in 1958. For the past ten years, the average annual rate of increase is 2.07 parts per million (ppm). This rate of increase is more than double the rate of increase in the 1960s. In the graphs, the red line represents the monthly mean values. The black line represents the same, after correction for the average seasonal cycle. As can be seen from these graphs, there has been no change in the rate of increase of atmospheric CO_2 in the past decade. The Carbon Dioxide Information Analysis Center (CDIAC), which *"has served as the primary climate-change data and information analysis center of the U.S. Department of Energy (DOE) since 1982"* (CDIAC, 2013), monitors CO_2 levels at eleven sites around the world (including Mauna Loa). All of them show a similar pattern. This seems to be the one statistic that isn't disputed.




RECENT MONTHLY MEAN CO2 AT MAUNA LOA
PARTS PER MILLION
400
395
390
385
380
2009
2010
2011
2012
2013
2014
July 2013

12. CONCLUSIONS

Despite several hundred-billion dollars (and quite possibly trillions) invested globally in the past two decades on grid-connected renewables, the two most authentic indicators of actual carbon emissions – the measured global atmospheric CO_2 and the volume of fossil fuels being consumed – show no indication of the slightest reduction. A fact which is even more significant when all the other influences which might have helped reduce world carbon emissions in recent years are taken into account: including a major world financial crisis causing decreased production in many countries, a significant switch from coal and oil to natural gas, billions spent promoting and implementing energy efficiency in buildings, and improvements to vehicle efficiency and emissions.

But perhaps even more importantly, there is no logical reason why carbon emissions would be reduced by grid-connected renewables with the current grid infrastructure. All intermittent power sources like photovoltaics and wind turbines must be backed up with 'spinning reserve' (which still emits carbon unless it's nuclear or hydro) if the electricity generated cannot be stored. Since electricity from intermittent-renewable-energy generators can't be ramped-up on demand, they can always only be duplicating, not replacing other types of generators unless some form of storage can be built into the electricity grid. And despite recent efforts to address this problem with investment in compressed-air and advanced-battery technologies and increased pumped-hydro storage, it looks as though economic and resource limitations will prevent its implementation on a large enough scale (at current levels of electricity demand) to significantly reduce world carbon emissions.

Renewable energy optimists apparently believe that with time, technology will solve these problems. But although technology may be able to improve the efficiency in which energy can be transformed, it cannot create energy, or money (Martenson, 2011). Experienced scientists such as Lovelock (2007) and Flannery (2005) believe that we need to reduce the world's carbon emissions by at least 80% to prevent catastrophic global warming. So the notion that we just need everyone to 'do a little' to turn things around is a bit like being aboard the Titanic and believing that if everyone drags their finger in the water a disaster will be averted; as the ship heads full-steam towards an iceberg. And wasting time and effort on insignificant and ineffective action, just to satisfy people's desire to feel as though they are doing something, could be just what is happening with grid-connected intermittent renewables.

Could it really be possible that a whole multi-billion-dollar industry has been built on little more than generous government subsidies and fanciful legislation from politicians keen to win votes by appearing 'green' to an idealistic, well-intentioned, but grossly deceived public? That otherwise intelligent people can so easily be sold an idea that clearly doesn't work; simply because we so desperately want to believe that it does, that it will save the planet, without us actually having to curtail our own energy-consuming lifestyles.

A recent article in The Times (UK) sums it up perfectly:

"Through age, belief and disposition, I'm the sort of guy who sees a wind turbine and feels a tingle in his spine. It's something to do with the glorious meeting of natural beauty and human ingenuity, audibly subdued and at the scale of a cathedral. There's a set I pass often, heading out of Edinburgh on the A68, dotted along the horizon of the Lammermuirs. They make me want to park the car, and start singing hymns. And probably because of that I get quite upset when people start arguing that they don't work terribly well. I can just about cope with an economic criticism; that we have the incentives wrong and wind farms are actually subsidy farms, rewarding technological box-ticking rather than the actual generation of power. But start advancing the notion that the whole concept is just not a very good idea – that, like hybrid cars or most solar panels, wind turbines are all for show – and I start feeling edgy. Never mind, for now, whether such claims are true. The important thing is how badly I want them not to be" (Rifkind, 2013, p.23).

Or as James Lovelock claims:

"Enthusiasm for renewable energy coupled with a politics in which each nation tries to gain brownie points for its diligence in meeting the Kyoto limits is an unhappy mixture. It will fail and bring discredit both to the greens and to the politicians … the responsibility for the wrong advice given to the government came from well-meaning city dwellers with a romantic, impractical dream of clean renewable energy … it is a consequence of the vulnerability of people to the astonishing power to deceive of an endlessly repeated falsehood". (Lovelock, 2007, p.107).

If storage is the 'elephant in the room' of grid-connected renewables, then 'the dinosaur in the house' of the electricity grid is its unwieldy interconnectedness, which gives each household an apparently unlimited supply of electricity. A large grid has significant transmission losses, inefficiencies, and wastage – and contains many 'loose cannons'. For example, although they might get a nasty shock when their quarterly bill arrives, there's nothing to prevent a householder accidentally leaving a couple of 2000 watt electric heaters on for two months while away on an extended holiday. There's no immediate feedback and virtually no limit to the amount of power a household can draw from the grid. In fact consumers can just about have as much as they like, provided they can afford it. So with millions of consumers, it's difficult to manage a grid system that, in reality isn't unlimited at all – it only appears that way to each consumer. But there is a limit, that's why blackouts occur. If a million households each started continuously consuming 1000 watts extra, suddenly the grid needs another couple of 500 megawatt coal-fired power stations. Imagine if every household's pantry was automatically restocked from a large central supply, so that no matter how much was taken out each day it was always full of food. It would seem like a limitless supply. And it's fair to assume that consumption would increase considerably, and no one could be held responsible if the main supply ran low, no matter how much the government nagged people to eat responsibly.

Huge, centralised, interconnected, interdependent systems offer economies of scale, plus wealth and power to a minority of people. They give the impression of stability and robustness. But recent problems with the European Union, the world banking system, and large electricity grids, have made many people realise that such systems are in fact dangerously fragile – and often disguise massive inefficiencies, waste, and fundamental structural flaws. One way to address this problem and reduce consumption significantly would be an electricity grid that is broken up into smaller autonomous components where consumers become very aware of, and responsible for, the limited supply of electricity they have available to them each day. Off-grid photovoltaic/battery systems for detached houses in suitable climates (there are millions of them in the world) could be encouraged. Other households could be set up with individual batteries charged from a renewables-only grid. In essence, using electricity would become similar to the way people use petrol in their car – they have to keep an eye on the gauge. And they would only use what they could afford, soon finding ways to live within their electricity means. Overall consumption would be dramatically reduced.

Economic/environmental analysts such as Martenson (2007) and Heinberg (2011) believe that the world is about to reach "peak everything", and we're facing a predicament that will have to be adjusted to, not a problem that has to be (or can be) solved. An analogy is that of someone's poor health, which in many cases is a problem that can be 'fixed' with diet, exercise, and medicine; as distinct from ageing, which is a predicament of life that has to be accepted, accommodated, and planned for, not a problem that can be solved. As many have discovered, trying to fix the 'problem' of growing old inevitably leads to a life of frustration, disappointment, and ultimate failure (which sounds a little like the environmental movement of the last thirty years).

The predicament facing us today is that for the first time in human history, the inevitable outcome of exponential population and economic growth, is becoming not only obvious, but a looming reality – a confluence of resource depletion (especially oil and other sources of energy), unsustainable financial debt brought about by an economic system which requires continuous growth to be 'sustainable', and a natural environment being destroyed by exploitation and pollution at a rate well beyond its capacity to regenerate. Martenson and Heinberg believe that even nuclear power – which could never be implemented on a large enough scale quickly enough anyway, and still requires a finite resource – wouldn't solve the economic, energy, and environmental problems we're being confronted with. And de-carbonising the world's electricity grid doesn't solve the problem of a transport and food-production system almost totally reliant on oil (with no viable alternative in sight apart from the electrification of a small part of the transport system), while focusing on the electricity grid's carbon emissions, as though it's an issue independent of environmental and economic problems, is the sort of thing that can lead to vicarious outcomes such as converting electricity generation to natural gas because it emits less CO_2 than coal or oil, despite the fact that its extraction may ultimately cause more environmental damage and release more global warming gases than the fuels it's replacing (Lovelock, 2007).

In a world of uncertainties, it's impossible, and perhaps foolish, to make predictions, but equally foolish to ignore trends and probabilities. And probabilities based on fundamental truths, not wishful thinking, are likely to be the most useful to take into account. In relation to the world's population and resource consumption, a fundamental truth is that infinite growth in a finite physical world is, by definition, impossible. The question is not if, but when growth will cease. According to analysts like Martenson and Heinberg, the most likely outcome of the world's predicament is an end to the continuous economic growth (which appears to have begun in earnest with the global financial crisis of 2008) we've come to expect ever since humans began exploiting cheap and abundant fossil fuels almost three hundred years ago; combined with a massive reduction in consumption as resources gradually become too difficult and expensive (in terms of cost and energy) to extract.

The problem with fossil fuels and minerals is not that there will be none left, but that the proportion of energy required to extract and process them from increasingly inaccessible and remote locations – in relation to the energy or benefits they can provide – is steadily increasing; a trend that shows no sign of abating, despite constantly improving technology and efficiencies. It seems that the next century is likely to be vastly different from the one we've just experienced, with consumption and conventionally-measured living standards (and subsequently, carbon emissions) in developed countries gradually, but significantly, decreasing, whether we like it or not – a process that has already begun in Greece, Italy, Spain, and Portugal; plus many non-European countries, possibly even the USA.

But with acceptance and adequate planning, this won't necessarily lead to social chaos or a reduction in quality of life – in fact perhaps just the opposite. It may not be the future dreamed of by most modern economists and industrialists; a world of never-ending economic growth driven by ever-improving technology, populated predominantly by educated middle-class-consumers. But the unavoidable reality may be a healthier, more enjoyable, more fulfilling, and more sustainable life for a larger proportion of the world's population, for many generations to come.

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