The truth behind renewable energy

Can renewable energy sources supply the world with a large share of the energy it requires? While some environmentalists advocate the total replacement of fossil fuels by solar, wind and battery power, Dr Lars Schernikau explains why this is impossible.

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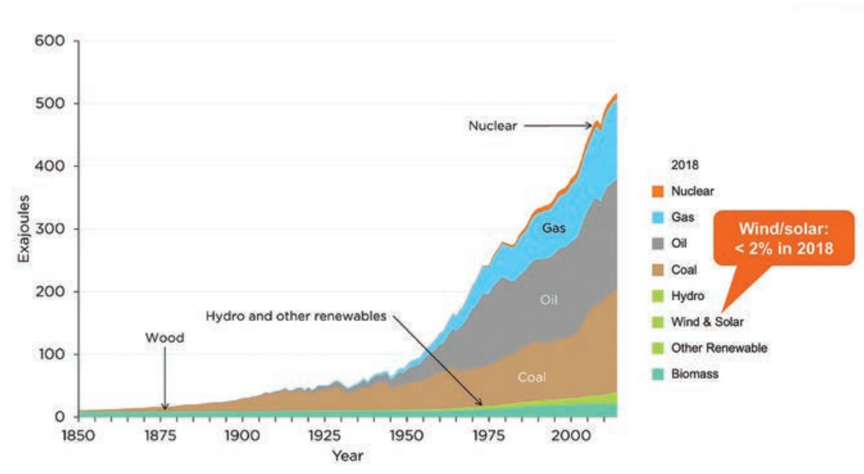
Today we hear and read about the climate crisis every day, driven by well-funded campaigns. But we hear little of the perils of switching from conventional energy to wind, solar and battery-powered vehicles. It appears that every second person has become an atmospheric physicist understanding that carbon dioxide is the main driver of global warming and switching to renewables will save us from devastating hurricanes and floods reaching the ceilings of our dream seaside properties. Every other person appears to be an energy specialist being certain that wind, solar and battery-powered vehicles will be a happy, safe and environmentally friendly way to power our everyday electricity and transportation needs. However, little could be farther from the truth.

The author is all for sensible use of renewable energy and for reducing everyday energy waste. Society needs to invest in additional filtering systems, cleaner transportation and mining operations that minimise the negative impact on the planet. Moreover, many trees should be planted. However, are current climate actions good for the environment? Are today's wind and solar technologies the solution to our energy problems? This article aims to take the reader on a journey away from current standard thinking.

Figure 1: a life without fossil fuels is decades away[1]



Current and future energy needs

Today, close to 8bn people live on Earth and they feed 80 per cent of their hunger for energy with hydrocarbons or fossil fuels (see Figure 1). Wind and solar make up an estimated two per cent of 2018 primary energy, the remainder largely comes from nuclear, hydropower and some biomass. This is in sharp contrast with the 2bn people that inhabited the Earth only a 100 years ago and had just learnt how to spell "oil and gas". Of today's world population, there are at least 3bn with no or only erratic access to power. In the next 50 years, a further +3bn people could be added, and as a result, the pure number of people plus the additional air conditioning equipment, new electronic gadgets, cars, aeroplanes and space travel, will increase the demand for energy dramatically.

Extrapolating the trends shown in Figure 1 to the future, it becomes questionable that non-hydro renewable sources such as wind and solar will provide the energy required in a sustainable and environmentally friendly way.

The media says the share of solar and wind will grow exponentially but does not mention the growth of electronic waste shipped to Africa that comes with it. And it certainly does not mention that solar and wind technology can literally *never* be the main source for the world's power generation due to their low energy density and the issues described below.

ERoEI, energy density and intermittency: en-masse deployment of wind and solar is detrimental

The now-famous documentary "Planet of the Humans" from Michael Moore, which has 9m views on YouTube, illustrates this problem very well.

Solar and wind power are not new energy sources – we had to "wean off" low-efficiency wind- and solar-based power to fuel humanities technological revolution. While there is nothing extraordinary or revolutionary about these power sources, their efficiency has greatly improved over recent decades. Moreover, these sources are getting close to their physical limits. The Schockley-Queisser Law states that a maximum of 33 per cent of incoming photons can be converted into electrons in silicon photovoltaic (PV) with modern PV reaching 26 per cent. In wind power, the Betz Law states that a blade can capture up to 60 per cent of kinetic energy in air. Modern wind turbines reached 45 per cent. The era of 10-fold gains is over.[2] There is no Moore's Law in energy and therefore, what is seen in the domain of computers, cannot be expected from energy. Costs will not continue dropping and it is time that a whole-system view is taken when looking at solar and wind or any form of power generation.

The three key problems of wind and solar generation are:

- their variability, or intermittency
- extraordinarily low energy return on energy invested (ERoEI)
- low energy density (see also Figure 2).

Virtually every solar panel and every windmill requires a back-up for times when the wind does not blow, or the sun does not shine. The German press proudly presented that at around 13.00h on 4 July 2020, 97 per cent of Germany's power demand was sourced from renewables for one hour (see Figure 3). However, it was not reported that:

- During the same hour, 22 per cent (~15GW) of power demand was waste energy that had to be exported or dumped across German borders, likely at negative prices.
- At around 21.00h on 18 July 2020, ~16 per cent of Germany's power demand was sourced from renewables for one hour (nil per cent from wind and solar, all from reliable biomass and hydro).
- During that hour on 18 July 2020, about nine per cent (~4GW) needed to be imported from surrounding countries at high prices because Germany did not produce enough power (see Figure 3).

There is no area practically large enough to ensure that there is always wind or sun. It happens every few years, probably at least once a decade, when a continent such as North America experiences a full day or two of no sun or wind anywhere.

The logical requirement for back-up capacity for all variable renewable energy (VRE) and all consequences that come with it need to be considered when costs are compared to fossil or nuclear power. However, virtually all cost comparisons published use the so-called levelised cost of electricity (LCOE) measure that only considers investment, operations and fuel costs. Fuel costs for wind and solar are of course virtually zero. However, LCOE fails to consider the other cost categories.

Figure 2: wind has very low energy density with density in Asia even lower than Europe[3]

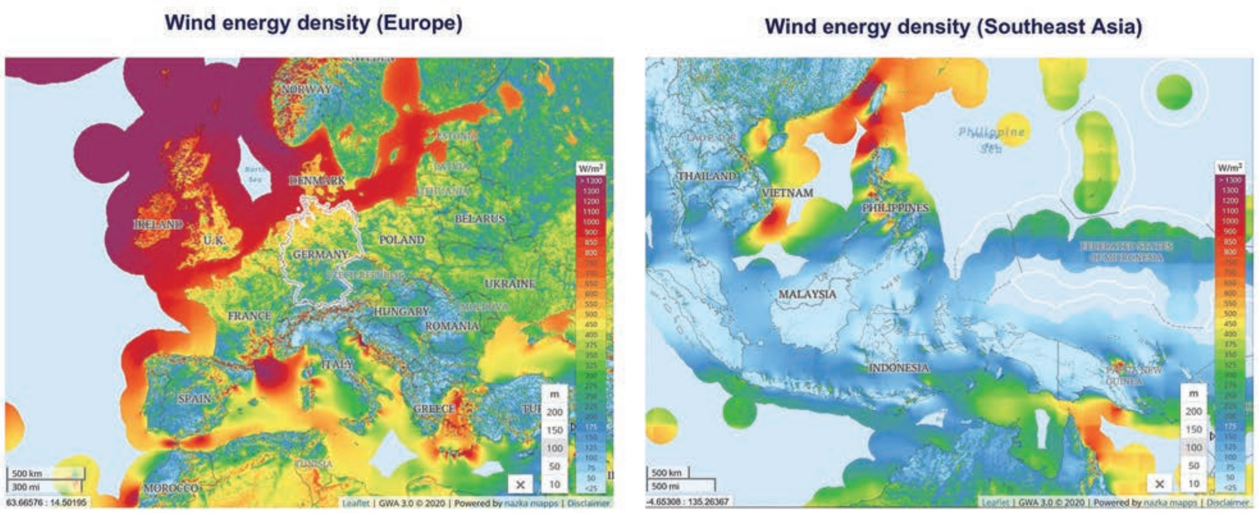


Figure 3: record 97.2 per cent renewable power in Germany on 4 July 2020 (left) vs a typical summer period in Germany in July 2020[4]

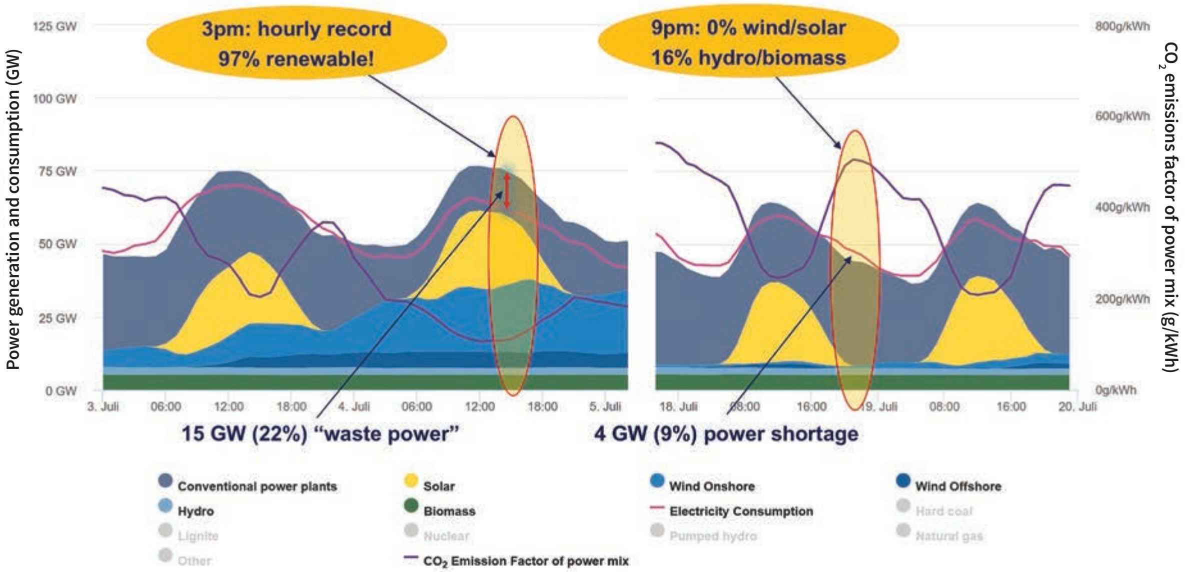
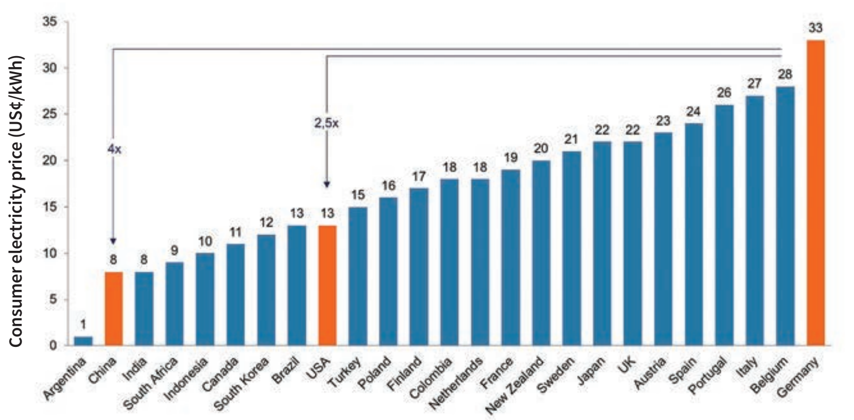
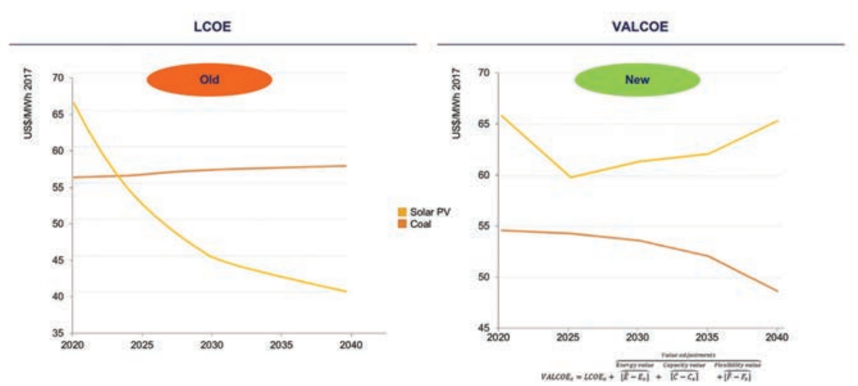


Figure 4: global prices for power – power in Germany is the most expensive[5]



This statistic shows electricity prices in selected countries worldwide excluding VAT.

Figure 5: levelised cost of electricity (LCOE) and value-adjusted LCOE (VALCOE) for solar PV and coal-fired power plants in India[6]



The true cost of solar and wind has to include:

1. Back-up costs (profile costs): cost originating from "temporal" deviation between generation and demand. Includes cost of batteries, decline in conventional power utilisation, increased ramping and cycling.
2. Interconnection costs: costs originating from "spatial" deviation between generation of variable renewable energy (VRE) and power demand, includes grid/interconnections management costs, and balancing costs.
3. Material and energy costs: costs for energy and materials to build solar and wind capacity (the EROEI is far too low for wind and solar).
4. Efficiency losses: costs associated with efficiency losses from underutilisation of conventional backup power.
5. Spatial costs: costs related to the space required for VRE (energy density is far too low), crop land, forests, effected bird and animal life, changing wind and local climate, noise pollution, etc.
6. Recycling costs: higher recycling costs of VRE and back-up capacity after its useful life.

Contrary to popular belief and press, costs for conventional energy as back-up and the resulting efficiency losses of conventional energy explain, amongst others, why the total cost of variable renewable energy always increases with more installed capacity beyond a certain point. This point varies by country and region, but one thing is sure: Germany is far beyond this point, which explains the country's high power prices (see Figure 4).

Figure 5 illustrates the misleading LCOE measure used in the popular press and by most governments, and compares it to the still incomplete but better value-adjusted LCOE (VALCOE) from the IEA, which was first published in 2019. In January 2020 the prestigious Institute of Energy Economics Japan (IEEJ) published its 280-page 'IEEJ Energy Outlook 2020' and raised concerns about renewables' rising unaccounted-for integration costs, concluding that LCOE is not capable of capturing the true cost of wind and solar.

Germany has become aware that it needs conventional power despite its large wind and solar capacity installed. However, Germany decided to exit coal power in addition to exiting nuclear power. Despite Germany's Environment Minister, Svenja Schultze, proudly claiming in July 2020 "We will solely rely on wind and solar for our country's power generation", Germany, very quietly, is building new gas-fired power plants as back-up. Gas is a legitimate fuel with many positive properties, but Germany does not have any itself. Despite gas' "clean" transportation and combustion, we know that gas is typically more expensive than coal, more difficult and expensive to transport than coal since it requires pipelines or LNG, and generally more difficult and sometimes dangerous to store. So, why is Germany shutting down its existing coal mines, coal-fired power and nuclear plants and is now building new, gas-fired ones? The response usually is greenhouse gas (GHG) emissions because gas emits about half the CO_2/kWh during combustion than coal, so the switch is supposed to save the climate.

If we adhere to the popular, but in the author's view, misinterpreted global warming theory, what appears to be a lesser known fact is that gas supply results in methane leakages during production, processing and transportation (methane is an 84 times more potent GHG gas than CO_2 over 20 years, and 28 times more potent over 100 years). This has been documented in several studies, including Poyry's 2016 German study on 'Comparison of greenhouse-gas emissions from coal-fired and gas-fired power plants'. It was also picked up by Bloomberg in a January 2020 article discussing methane leakages associated with LNG. Methane emissions vary widely, but there are many instances – as also documented by a Total Gas-sponsored study from 2016 – when GHG emissions are higher for gas than for coal. The study states that "with 95 per cent confidence, US shale gas may emit more GHGs than Colombian hard coal."

- Gas emits about half of CO_2 compared to coal during combustion.
- Gas emits more CO_2eq (mostly in form of methane) during production, processing and transportation. This includes, but is not limited to, leakages and energy requirements for LNG processing and transportation.

• Total gas CO_2eq emissions are on par with or higher than coal, depending on the turbine type, location and the source and type of gas.

Gas is a good and necessary fuel in the power mix, but if global warming theory is to be believed in, one must be consistent and not spend tax payers' money switching from coal and nuclear to gas when even by one's own admission it will have no positive impact on 'the climate'. Methane emissions are neither measured nor taxed. Is this fair for coal or for the environment or the everyday citizen that pays the taxes?

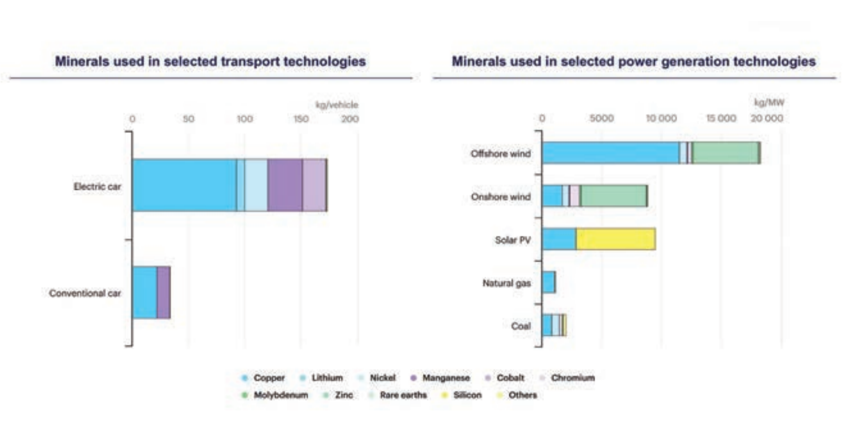
Battery technology is not capable of grid storage for power

If gas is not the solution, then what is? What about those great batteries? It is true that an affordable and sustainable storage system would be the solution to wind and solar's intermittency issue (but not to the issues of energy density or ERoEI). Over the years, batteries have become far more efficient and the recent move towards electrical vehicles has driven large investments in battery "gigafactories" around the world.

The largest known and discussed factory for batteries is Tesla's US$5bn Gigafactory in Nevada, which is expected to provide an annual battery production output of 50GWh in 2020. By 2021 CATL in China is expected to double that. Berlin's Gigafactory 4 will start producing electric vehicles in 2021-22. These factories will provide the batteries for our future cars and also provide back-up batteries for houses, but what about their environmental and economic impact? Figures 6 and 7 summarise the environmental challenges of today's battery technology. The three main issues with any known battery technology are:

- energy density
- material requirements
- recycling.

Figure 6: comparing mineral needs for renewable technology (IEA, 2019)[7]



Energy density

Hydrocarbons such as oil, gas and coal are one of nature's most efficient ways to store energy. Today's most advanced battery technology can only store 2.5 per cent of the energy that coal can store. The energy that a 540kg, 85kWh Tesla battery can store equals 30kg of coal energy after combustion. A Tesla battery must then still be charged with power (often through the grid) while coal is already 'charged', albeit only once.

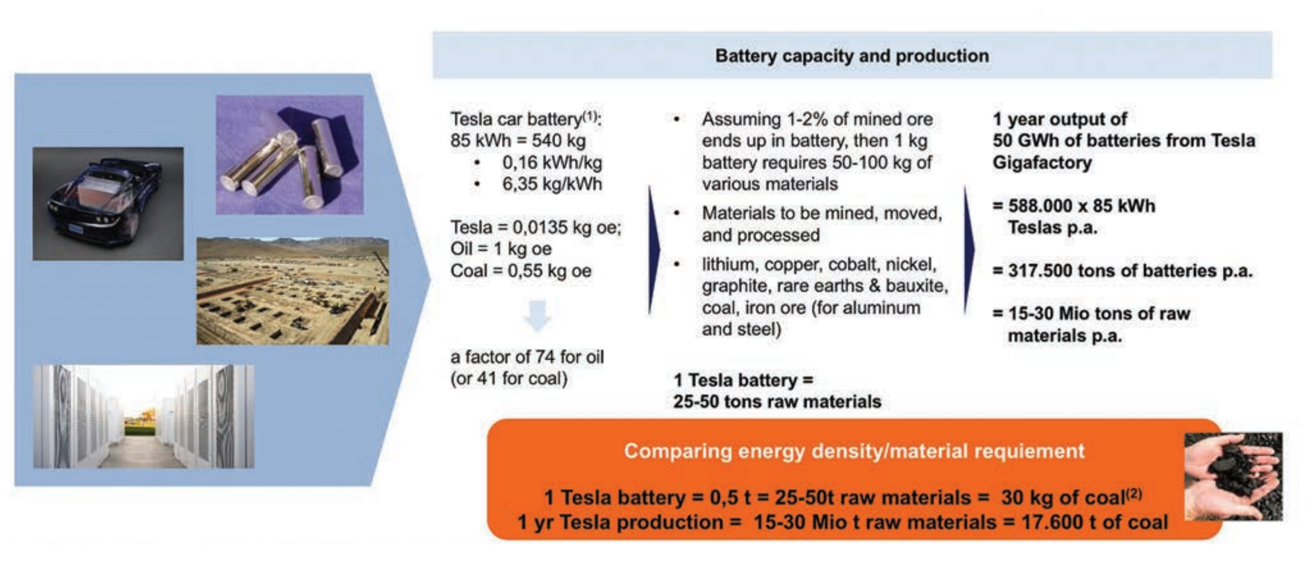
In addition, you can calculate that one annual gigafactory production of 50GWh of Tesla batteries would be enough to provide back-up for 6min for the entire US power consumption (and then no Teslas to drive). Today's battery technology cannot be the solution to intermittency.

Material and energy requirements

Next comes the question of the energy inputs and materials required to produce

Figure 7: case in point – energy density and environmental impact of Tesla batteries

Images from https://www.tesla.com



Note: 1 kWh = 860kcal = 0.086kg$_{oe}$ = 3600kJ. 1 kcal = 41868kJ. 50 GWh = 50mkWh = 317,500t batteries

1. Tesla's Powerwall has a usable capacity of 13.5kWh and weighs with frame 125kg. Assuming 100kg is net battery weight this means 0.135 kWh/kg, so even less effective than Tesla's battery

2. Tesla battery: 90 per cent efficient = 76.5kWh. Assuming 5.500kcal/kg for coal and 40 per cent power plant efficiency to generate 76.5kWh requires 191kWh or about 30kg of coal

Analysis and research by Lars Schernikau, based on Mills (2019)[2] and SHANER, MR, DAVIS, SJ, LEWIS, NS AND CALDEIRA, K (2018) 'Geophysical Constraints on the Reliability of Solar and Wind Power in the United States' in: Energy & Environmental Science, 11, (4 – February), p914-925.

a battery. The required materials include lithium, copper, cobalt, nickel, graphite, rare earths & bauxite, coal and iron ore (for aluminium and steel).

Additionally, energy of 10-18MWh is required to build one Tesla battery, resulting in 15-20t of CO_2 emissions assuming 50 per cent renewable power. Assuming conservatively that 1-2 per cent of mined ores end up in the battery in the form of metals, one Tesla battery requires 25-50t of raw materials to be mined, transported and processed (see Figure 7).[2]

Recycling

This is slowly hitting the main-stream media.[8] The first larger batches of retired and unusable wind farms and solar panels are hitting landfills and insufficient recycling plant capacities. There is not yet an affordable, large-scale way to recycle wind blades. The electronic waste we create is already a devastating problem for landfills outside Accra (Ghana), Nairobi (Kenya) and Mombasa (Mozambique).

A New Energy Revolution

"What do we do now? Are we all doomed?" A young engineer asked the author this question after one of the latter's presentations when he realised that currently there is simply no viable alternative to conventional energy from coal, oil, gas and nuclear. It is concerning that young people are taught in school to fear the slight warming of about 1˚C during the past 150 years. At least half of the past warming is natural, caused by the sun as we are coming out of the Little Ice Age that ended roughly 300 years ago. The other half, or less, may be 'human-caused', which includes the heat all consumed energy produces that is released into the biosphere plus the greenhouse-gas CO_2. The additional greening – and therefore biomass – created by this additional CO_2 is rarely spoken of. That the warming effect of CO_2 declines logarithmically with higher CO_2 levels is not published by mainstream media either. A catastrophe is not looming, but real pollutants to the environment and the waste created by humans are a concern – and this is where resources should be focussed.[9]

On global warming and the upcoming catastrophe, the IPCC confirms as follows:

- IPCC 2020 Climate Change and Land, p9, A2.3: "Satellite observations have shown vegetation greening over the last three decades .... Causes of greening include combinations of an extended growing season, nitrogen deposition, carbon dioxide (CO_2) fertilisation ..."
- IPCC 2013 Climate Change, Chapter 2, p235: "There is limited evidence of changes in extremes associated with other climate variables since the mid-20th century."
- IPCC 2018 Third Assessment Report 14, p771: "In climate research and modelling, we should recognise that we are dealing with a coupled non-linear chaotic system, and therefore that the long-term prediction of future climate states is not possible."
- On the tuning of climate models – that are the sole basis for today's energy policy – the Max Planck Institute, Germany, writes in April 2020: "When we were faced with a model system that was bound to fail at reproducing the instrumental record warming, we chose an explicit approach where the past temperature trend is a tuning target."

Moreover, Bjørn Lomborg, who runs the Copenhagen Consensus Center thinktank, explains in his recent book 'False Alarm' many interesting scientific facts. He states "Climate change is real, but it's not the apocalyptic threat that we've been told it is."

Either way, even if people believe that catastrophic predictions for global warming are the correct way to approach environmentalism, this article highlights that wind and solar – while certainly being appropriate for applications such as heating a pool, and thus earning a place in the energy mix – cannot and will not replace conventional power.

As Michael Shellenberger, Time Magazine Hero of the Environment 2008, said in an article published in Forbes in May 2019: "The reason renewables cannot power modern civilisation is because they were never meant to. One interesting question is why anybody ever thought they could". His recent book 'Apocalypse Never: Why Environmental Alarmism Hurts Us All' details his rationale.

What is needed in the next one or two centuries is a 'New Energy Revolution'. Future energy may be completely new, possibly more renewable, and fusion- or fission-based, but will have little to do with wind and photovoltaic. To reach this New Energy Revolution, more must be invested in education and base research (power generation, storage, supraconductors, etc) while simultaneously investing in conventional power to make it more efficient and environmentally friendly. There will be the need to invest *in* fossils to clean them up, not divest *from* them. This is the most sensible path to save the planet from the negative impact that human existence has on it. However, please consider, humankind has never been better off than today. Shouldn't we celebrate this fact? ■

A young man burning electrical wires to recover copper at Agbogbloshie, September 2019

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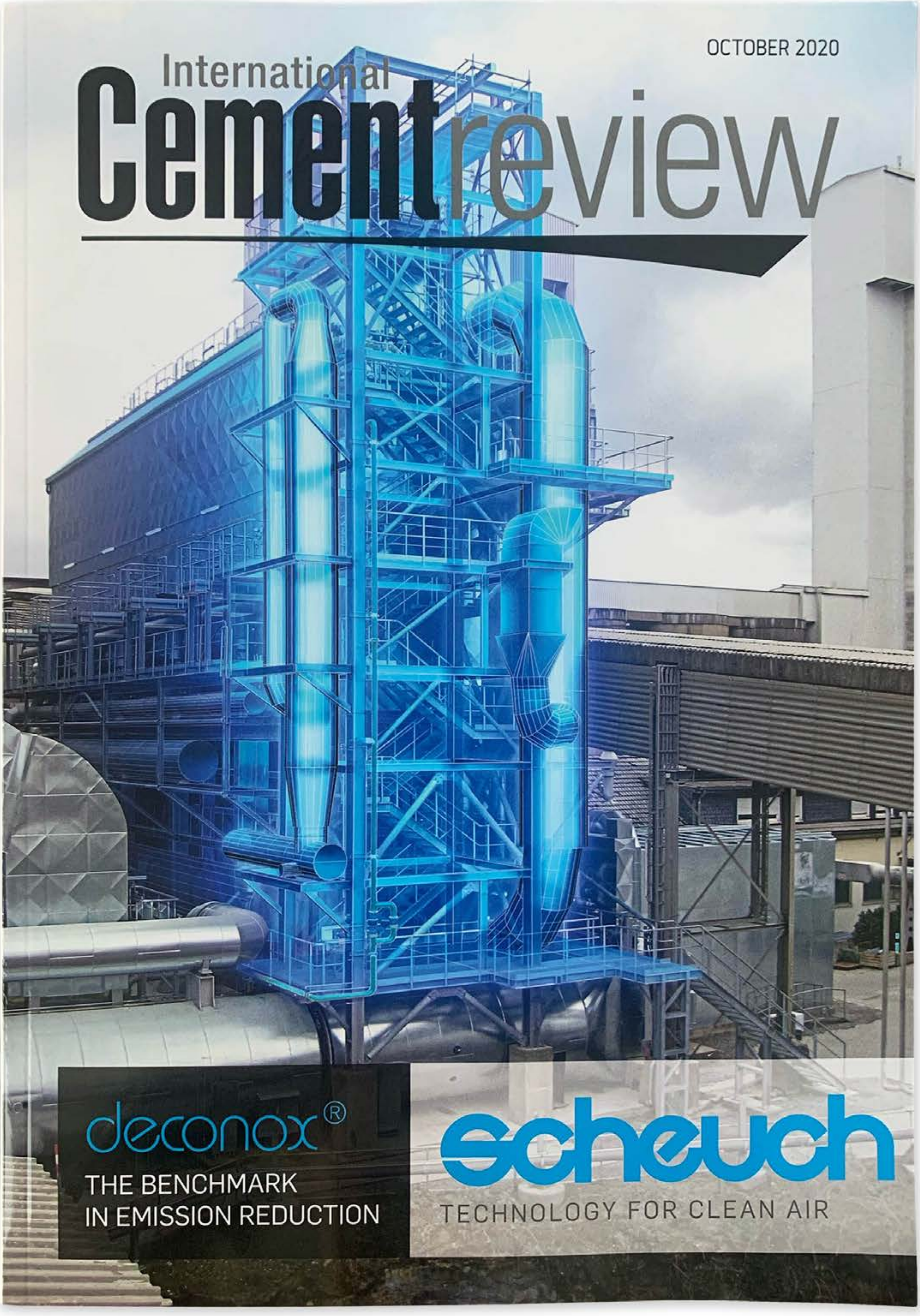
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