Wind, water, solar and socialism

Electricity systems: building blocks of a socialist view. By Simon Pirani

Part 1: energy supply

Workers inspecting a wind farm in Inner Mongolia, China

Worldwide, thousands of socialists are active in movements demanding action on climate change; many more participate in co-ops and community energy projects. But our collective efforts to map the transition away from fossil fuels, and how it relates to the transition away from capitalism, have fallen short, in my view. In particular, we need some starting-points for understanding how electricity systems are changing.

In this article[1] – both this first part on energy supply, and a second part on electricity networks – I suggest what these starting-points might be. It aims at clarification, including self-clarification, and I invite responses.

I include some polemical comments on recent would-be socialist arguments, by Matt Huber and Fred Stafford, supporting nuclear power against decentralised renewables.[2]

Here are some assumptions I start with. First, in the transition away from fossil fuels, electricity's role will expand: not only will it be used to provide heat and light, for cooking and to drive appliances and machinery, but it will have to spread in transport and industry. This expansion is to be welcomed as a method of junking fossil fuels, but unless combined with measures to curb capital's cycles of overproduction and overconsumption – and thereby cut total throughput of energy through economies – it will fail.[3]

Second, I think renewable electricity generation is in principle better than nuclear or doubtful, borderline technologies such as hydrogen and biofuels,[4] in part because of its potential for underpinning a collectively owned and controlled energy system. However, all good (and all bad!) outcomes will most likely involve a combination of technologies; each has its pros and cons, and socially-determined potentials for good or bad uses.

Third, no technology is politically or socially neutral. Capitalism has shaped, and shapes, the technologies that have developed under its domination. Technological change rarely pushes social change in the way that some people hope, but as society changes, technological potentials that are constrained by capitalism may be unleashed.

Fourth, from a socialist standpoint, tackling dangerous climate change can not be separated from the struggle against capitalism and its hierarchies. Our actions with regard to the energy system must centre on fighting for forms of public and common ownership and control, and to turn energy into a public service, as opposed to a commodity.[5]

Fifth, my focus here is on what the labour movement and social movements internationally can do, now. Far too many socialists state their arguments in terms of state policy, despite their limited or non-existent means to influence it. I will not join them.

1.1. To what extent have renewables become a competitor to fossil fuels?

Renewable technologies' share of electricity generation worldwide is still dwarfed by that of fossil fuels, but is growing fast. Capital is pouring into wind farms and solar panels, attracted by costs that have plummeted in the last decade. In many countries, companies that manage electricity networks are considering how, not whether, to adapt to electricity supply dominated by renewables.

Hydro accounts for 15.7% of global electricity generation, other renewables for 10.8% – so, about a quarter

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[1] Thanks to Kolya Abramsky and David Camfield for commenting on a draft, and to friends I have discussed the issues with

[2] Matt Huber and Fred Stafford, "In Defense of the Tennessee Valley Authority", *Jacobin*, 4 April 2022, and "Socialist Politics and the Electricity Grid", *Catalyst* 6:4, 2023

[3] I have written about reducing throughput e.g. in "How to do away with fossil fuel consumption", People & Nature, August 2023 and *Burning Up: a global history of fossil fuel consumption* (Pluto Press, 2018), chapter 12

[4] I outlined the problems with hydrogen in "The hydrogen hoax", The Ecologist, December 2020. A good source on biofuels is the Biofuelwatch web site

[5] See: S. Pirani, "How energy was commodified, and how it could be decommodified", People & Nature, 2021

of the total all together. Nuclear's share is 10.4%, and the remaining 63.1% is fossil fuels (coal 36.7%, gas 23.6% and oil 2.8%). In 1973, when the total amount of electricity generated was less than a quarter of what it is now, hydro's share was 20.9% and other renewables', 0.6%.[6]

Remember that electricity generation only accounts for a small part – about a quarter, or less, depending on exactly how you count – of total primary energy supply, which measures all the inputs (or rather, the commercially-exchanged inputs) to energy systems. Almost all the rest is oil products for transport, and fossil fuels for industry and domestic use.

When considering the transition away from fossil fuels as a whole (see 1.2 and 1.3 below), the expansion of electricity supply to displace fossil fuels from these other uses is a huge issue.

Capital buying into renewables is a fairly new development. The International Energy Agency (IEA) reckons that this year, out of $2800 billion of energy investments, $1700 billion will be put into clean energy (counted broadly, including nuclear). More than $600 billion of that will be for renewable electricity; more money will go to solar than to upstream oil for the first time.[7]

These capital flows are reproducing the same rapacious relationships in supply chains as exist for fossil fuels and nuclear power. Raw materials are often mined in the global south and manufactured – mostly in China, which also continues rapidly to expand its climate-trashing coal-fired power sector – into solar panels, wind turbines, batteries and other equipment. Often harsh conditions of labour exploitation are the outcomes of financial chains that stretch from the markets of the global north.

The dynamics of those markets are working in favour of renewables. The cost of solar photovoltaic (PV) modules has fallen especially dramatically. A good indicator is the levelised cost of energy (LCOE), used by finance capital to measure the cost of electricity delivered to markets from different technologies. Lazard's, the investment bank, puts the LCOE of solar PV at $60 per megawatt hour ($/MWh), down from $359 in 2009; the LCOE of onshore wind at $50; combined cycle gas plants $70; coal $117; and nuclear at $180.[8]

For decades, solar technology development was funded by the state. And both solar and wind relied heavily on subsidies – for example, feed-in tariffs that fixed their prices in wholesale electricity markets – to compete with fossil fuels, that had all the advantages of incumbency, corporate political power and subsidies of their own.

This is now changing, partly because, as these technologies have been diffused more widely, they have benefited from learning-by-doing and economies of scale, as have other technologies of the "third industrial revolution" (i.e. semiconductors, small-scale computers and phones based on them, the internet, and so on).[9] The IEA says the disruption of energy markets caused by the Russian invasion of Ukraine and resulting sanctions accelerated the momentum to renewables investment "even as it also prompted a short-term scramble for oil and gas supply".

Matt Huber and Fred Stafford, arguing against socialists who welcome renewables, claim that these fuels are artificially cheap, because the cost estimates and prices do not reflect the investment required in networks to accommodate them. This is much less than half the truth. Finance capital is very good at estimating costs and while, naturally, companies want to avoid investing in infrastructure, and try to push that cost on to the state, this is unlikely to stop renewables expansion. (See *Note: Infrastructure costs*, at the end.)

The much greater dangers inherent in the renewables expansion under capitalism is that it will be used to supplement, rather than replace, fossil-fuel-intensive processes; that it will be used to delay, rather than hasten, decarbonisation; and that it will be undertaken in a manner every bit as exploitative and extractivist as the fossil fuel and nuclear industries.

1.2. What part could renewables really play in driving fossil fuel use down to zero?

Coal, gas and oil are consumed by and through technological systems that are embedded in the social and economic system we live under, capitalism. To drive down their use will require a transformation of all these systems. Renewable electricity generation, one way or another, will play a big part.

Before I sketch outlines of how this could happen, here are a couple of paragraphs to deconstruct "energy" and "energy demand", terms used in public discussion of these issues.

"Energy" is often assumed to be a commodity to be bought and sold, reflecting two centuries of history during which fossil fuels – and electricity, heat, vehicles' motive force and other forms of energy produced by them – have mostly been used under capital's control. There is a distinction between this commodified "energy", whose exchange value is measured in dollars or other currency, and energy as a physical phenomenon, measured in joules, kilowatt hours or other units.[10] A great deal of energy is used at the edges of the commodified system in a non-commodified form, e.g. in rural communities who rely on firewood that they collect themselves. And now, solar and other technologies carry the potential for new types of non-commodified energy use.

"Energy demand" has also been given a false meaning. Politicians and businessmen talk as though "energy demand" is fixed by populations, and companies producing oil, cars or electricity are merely serving that demand. But actually most energy (whether as fuel, electricity, motive power or heat) is consumed by industrial or transport systems, built

[6] IEA, Key World Energy Statistics 2021. The "non-hydro renewables" item covers "geothermal, solar, wind, tide/wave/ocean, biofuels, waste, heat and other"

[7] IEA, *World Energy Investments 2023*, page 9 and page 12

[8] Lazard's Levelized Cost of Energy Analysis 2023, page 9. LCOEs for all technologies are higher this year than in 2018-21, due to global inflation

[9] See: Max Roser, "Why did renewables become so cheap so fast?", Our World in Data, December 2020; Gregory Nemet, *How Solar Energy Became Cheap* (Routledge, 2019)

[10] At global level, energy may be measured in exajoules (a billion billion joules, or 10^{15} joules), as I do in this section. An exajoule is equal to 277.8 Terawatt hours, or 23.8 million tonnes of oil equivalent

environments, infrastructure or other facets of the economy controlled not by the population, but by capital.

Now I will look at likely upcoming trends in, first, energy use on a global scale, and, second, energy supply.

Final ***energy use***, whether by luxury jets, blast furnaces or poor rural families' cookstoves, is only one aspect of total energy use. It is more accurate to think of energy being used by and through big technological systems, with some of it reaching those final uses at the end.[11] In the rich countries, energy use is conditioned by endemic overproduction and overconsumption. Reducing total energy use is the single most effective way to reduce fossil fuel burning, which in turn is the single most effective way to tackle global heating.

To put some numbers on it: analysts reckon that total energy inputs to the world economy are somewhere above 600 exajoules; after losses in conversion and inefficiencies, somewhere above 400 exajoules per year are used, in the form of electricity, heat, light, motive power, and so on.[12] Most scenarios worked out for the international climate talks include estimates of total energy use in 2050: the widely-cited scenarios under which global heating is limited to 1.5° above pre-industrial levels put energy use in 2050 at, or a little above, the current level – so, 400+ exajoules. Scenarios in which global heating goes above that mostly expect higher total energy use.

The interesting scenarios from a socialist standpoint are those that highlight the potential gains from transforming energy use – (a) by sweeping changes in global north economies, e.g. shifting away from private car ownership, reducing meat consumption, reforming the built environment, dematerialising industrial processes and implementing energy conservation, and (b) by the provision of electricity to the 770 million people without it, and cleaner cooking fuels to more than 2 billion people without them.

We can compare two such scenarios, one by a research team led by Arnalf Grubler and one by Greenpeace, with other scenarios in which global heating is held to 1.5°. Grubler et al map a route to reducing total world energy use, by 2050, to 245 EJ/year; Greenpeace, to 314 EJ/year. By contrast, other scenarios included in the IPCC's fifth assessment report that keep to 1.5% predict total global energy use to rise to 424 EJ/year (SSP1-1.9) or 438 EJ/year (SSP2-1.9).[13]

Are the economic transformations that could reduce energy throughput possible? That is primarily a social and political question. If untrammelled capitalism is not constrained by "Green New Deals" or other social democratic measures, superceded by social movements against capital – or laid low, with the resulting social catastrophes, by its own crises – then clearly not. I remain hopeful that society can combat and even suppress capital, and prevent the worst climate outcomes – although I do not pretend to know how this will happen.

Grubler's team work in a mainstream academic context, and their paper does not consider prospects for a social and economic transition beyond capitalism. But nevertheless their thought experiment – which, whatever claims are made, is basically what all modelled scenarios are – is useful in considering how the coming decades will unfold.

Now I will suggest how ***energy supply*** might change in future. Scenarios promoted by oil companies and governments, which assume that vast quantities of greenhouse gases will be sucked from the atmosphere by unproven technologies, have long been denounced as greenwash, designed to allow fossil fuel burning to continue.[14]

The expansion of electricity networks, powered by renewables, is the main alternative. But among researchers who champion this, approaches differ. Most authors doing "100% renewables research" have a technocratic approach, accepting dominant assumptions about energy demand, and looking at technological means to meet it. By contrast, the Grubler team and others like them marry research on energy supply to interrogations of how energy is used, critiquing both overconsumption in the global north and extreme energy poverty in the global south.

Politically, the latter approach is more useful to socialists and all who believe in "climate justice". Furthermore – there is a noticeable difference between the two sides when it comes to the actual quantity of renewables that might be used.

The researchers led by Grubler reckoned that, of that 245 EJ of energy use in 2050 (down from 410 EJ in 2020), 132 EJ would be in the form of electricity (up from 78 EJ in 2020) and another 22 EJ from non-electric uses of solar. Their scenario provides for inputs (primary energy supply), by 2050, of 87 EJ from solar and 52.5 EJ from wind – compared to 2.45 EJ solar and 5.1 EJ wind in 2019.

Note that even in Grubler et al's scenario, which envisions far more radical social, economic and political change than the mainstream IPCC scenarios, electricity output would almost double over the next 30 years. This is because they, like most researchers, assume that many forms of energy use that currently involve coal, oil and gas (e.g. heating homes, various types of transport and industrial processes) would be electrified and decarbonised.[15]

The volumes of renewable electricity output targeted by 17 "100% renewables" papers reviewed recently are far higher than Grubler et al's: for solar, 33.8-375.4 EJ (average

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[11] On analysis of energy flows (primary energy supply, secondary energy, final energy, etc) see: "How to do away with fossil fuel consumption", People & Nature, August 2023

[12] In 2019, the IEA counted annual total primary energy supply (i.e. all the inputs) as 606 exajoules (EJ) and final energy consumption (i.e. all use) as 418 EJ. (IEA, *Key World Energy Statistics*, 2019.) About units of measurement, see note 10 above

[13] A. Grubler et al, "A low energy demand scenario for meeting the 1.5° target and sustainable development goals without negative emissions technologies", *Nature Energy* 3 (2018), pages 515-527; Greenpeace, Global Wind Energy Council and Solar Power Europe, *Energy [R]evolution: a sustainable world energy outlook 2015*

[14] See e.g. "Climate scientists: concept of net zero is a dangerous trap", *The Conversation*, April 2021; Kevin Anderson et al, "A Factor of Two: how the mitigation plans of 'climate progressive' nations fall far short, *Climate Policy* 20 (2020), pages 1290-1304

[15] Research such as Grubler et al's is a useful antidote to inflated claims of "electricity demand" in projections by energy corporations and their consultants. For example Hitachi Energy is cited by *The Economist*, asserting that "by 2050 the world will need four times as much electricity generation as it has today", begging questions about what "the world" is, what "need" means, etc. See "The ultimate supply chains", *The Economist*, 8 April 2023

137.5 EJ), and for wind 23-238.3 EJ (average 96.8 EJ).[16] The pessimist in me says the higher end of those ranges could never be achieved, but the analyst in me says that, assuming social change, they are anyway unnecessary.

To sum up. The range of forecasts of the amount of energy that the world economy might use in 2050 is vast. The most important determinants are how society changes, the extent to which capitalist overproduction and overconsumption can be constrained, and how total energy throughput can be reduced. Assuming progress in that direction, it would be possible, but not easy, to meet need using systems based on renewable electricity generation.

A worthwhile research task would be to develop a socialist critique of the disputes among academic researchers about "100% renewables" scenarios. Huber and Stafford state, wrongly, that the subject is "largely based on the models of one researcher, Mark Z. Jacobson", betraying their own lack of interest. When the nuclear advocate Ben Heard of the university of Adelaide, Australia, and his colleagues, reviewed and challenged the conclusions of significant "100% renewables" papers, they studied the work of 13 research teams.[17]

A final point about energy supply is that while hydropower, wind and solar PV are the significant technologies now, there are others that definitely work, but need scaling up. Some generate electricity, such as concentrated solar power; others provide heat, such as modern ways of burning biomass, and direct solar heat use via e.g. rooftop heat collectors or ground-mounted arrays; geothermal energy does both. Still others, such as wave power, ocean thermal devices and airborne wind power, are still at the experimental stage.[18]

1.3. What about materials?

Is it conceivable that solar and wind capacity could be multiplied dozens of times over in the coming decades? New technologies can spread fast: think mobile phones and personal computers. But solar panels and wind turbines, and the networks and storage systems needed to support them, are much bigger and heavier. The main constraint on their growth is surely the availability of materials.

Now, these materials are most often looted from countries in the global south by mining corporations. The heavy price paid by millions of people in those countries – for example the Democratic Republic of Congo, which holds an estimated 56% of cobalt reserves, or Guinea, which holds 28% of bauxite and alumina reserves (for aluminium production) – has been documented by left-leaning NGOs.[19]

Of course, measured by the human misery they cause, as much as by other criteria, these supply chains are far smaller than those for fossil fuels and nuclear power. But, together with the state power that protects them and the exploitative social relations on which they depend, they are underwritten by different ideologies. Whereas fossil fuel extractivism was often legitimised in the name of colonialism, nationalism or "energy security", "'green' extractive projects are often justified in the name of universal climate salvation, including for the very populations most likely to bear their costs", as the researcher Meredith DeBoom argued recently.[20]

Socialists in the global north can not just reassure ourselves that "green" extractivism confirms what we know about capitalism, and carry on. Politically, we need to pay far more attention to the great social struggles across the global south, not only against the fossil fuel corporations, but also those resisting the mining and metals corporations and their allies. We need to develop long-term alliances between social movements north and south.[21]

Another important task, in my view, is to challenge mainstream approaches to energy consumption in the global north. Without this, it is impossible to get a real understanding of whether and how renewable energy systems can be developed at scale. Some central issues are raised in a report by War on Want and the London Mining Network, which challenges the assumptions on which many studies of the energy transition are based.[22] The authors write:

> None of these studies question the assumption that total economic activity and overall energy demand will continue to increase. It is particularly concerning that they do not consider the possibility of a reduction in the disproportionate consumption of the global north.

The reports shows that critical metals[23] are used in more varied ways than mining companies suggest. First, demand

[16] Grubler et al, op. cit.; C. Breyer et al, "On the history and future of 100% renewable energy systems research", *IEEE Access*, vol. 10 (2022), 78176-78218

[17] B.P. Heard et al, "Burden of proof: a comprehensive review of the feasibility of 100% renewable-electricity systems", *Renewable and Sustainable Energy Reviews* 76 (2017), pp. 1122-1133; and the response, T.W. Brown et al, "Response to 'Burden of proof'", *Renewable and Sustainable Energy Reviews* 92 (2018), pp. 834-847. If you are finding your way into the debate, I would suggest starting with: David Roberts, "A beginner's guide to the debate over 100% renewable energy", *Vox* (2017), and S. Pirani, "We need social change, not miracles", *The Ecologist*, July 2023

[18] There is a useful survey in: Elliott, *Renewable Energy: can it deliver?*, pages 17-64

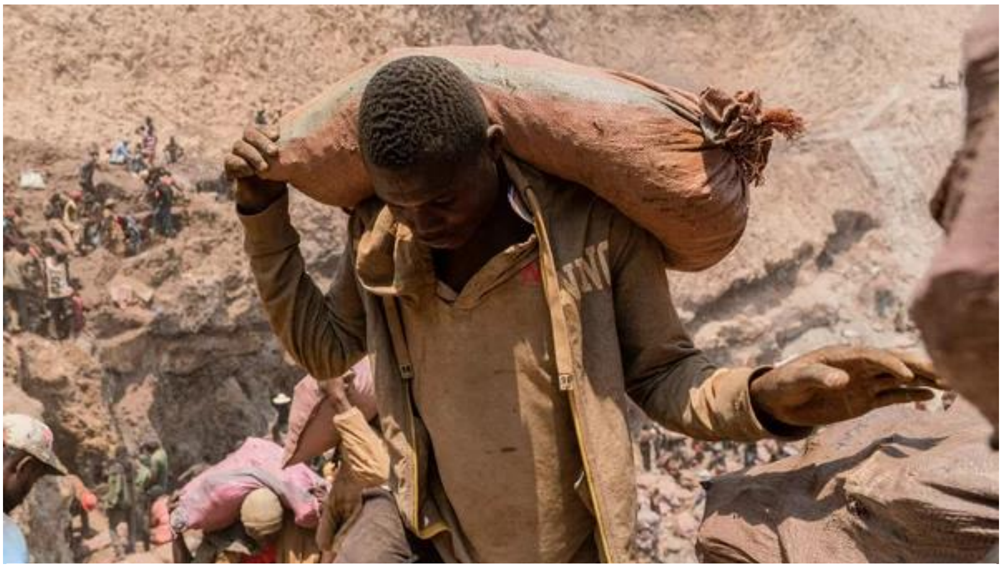
[19] Clare Church and Alec Crawford, *Green Conflict Minerals: the fuels of conflict in the transition to a low-carbon economy* (IISD, 2018) provides a summary. In addition to Congo and Guinea, they highlight China (rare earths), Guatemala (nickel) and Zimbabwe (lithium)

[20] Extractivism has been defined as "a mechanism of colonial and neocolonial plunder and appropriation", that was "forged in the exploitation of the raw materials essential for the industrial development and prosperity of the global North" (Alberto Acosta, "Extractivism and neoextractivism: two sides of the same curse", in *Beyond Development: alternative visions from Latin America* (Transnational Institute, 2013). Meredith DeBoom, "Climate Necropolitics: ecological civilization and the distributive geographies of extractive violence in the Anthropocene", *Annals of the American Association of Geographers* (2021) 111:3, pages 900-912. The general comments on extractivism are made along with a study of Chinese uranium mining in Namibia. On energy-related aspects of extractivism, see: Joshua Kirshner et al, "Energy landscapes in Mozambique: the role of extractive industries in a post-conflict environment", *Economy and Space* (2020) 52:6, pages 1051-1071

[21] A good place to start, politically, would be with the Manifesto for an Ecosocial Energy Transition from the Peoples of the Global South (February 2023)

[22] War on Want and London Mining Network, *A Just(ice) Transition is a Post-Extractive Transition* (2019)

[23] The International Resource Panel defines critical metals as those of "high economic importance that faces supply risks" and that have no commercially viable substitute. The term is used in the



An artisanal miner carrying a sack of ore at the Shabara mine near Kolwezi in the Democratic Republic of Congo, October 2022

for them is not primarily from renewable energy producers; a “diverse, and often destructive” array of uses include construction, aviation, nuclear technology, electronics and the arms industry, which can and should be questioned.

Second, in the case of demand forecasts for e.g. cobalt and lithium, batteries for electric vehicles (EVs) play an outsize role. The potential for reducing lithium demand by economic transformations in the global north was highlighted recently by a US-based research group, which concluded that greenhouse gas emissions from the US transportation system could be reduced to zero while sharply cutting the amount of lithium used, “by reducing the car dependence of the transportation system, decreasing the size of EV batteries and maximising lithium recycling”. Merely limiting the size of EV batteries would cut 42% of the lithium demand in a baseline projection.[24]

War on Want and the London Mining Network call for projected demand to be further disaggregated, to “critically evaluate which of these end-uses most contributes to meeting the demands of energy justice and access”, rather than the imperatives of overproduction and overconsumption in the global north. Another recent report, by the university-based Institute for Sustainable Futures in Australia, points to the importance of recycling and efficiency measures, which it shows are desperately underused, and of substituting critical metals with alternative materials.[25]

All such changes will of course meet the resistance of profit-based corporations; technological potentials can not be realised without confronting and weakening their power.

1.4. What about energy return on energy invested?

Might the transition to a new, all-renewables energy system itself so drastically push up demand for energy that the economy would strain, or even collapse, under the burden? Such possibilities are discussed in a good article by Michael J. Albert – who also (I think, quite rightly) criticises “ecosocialists” collectively for saying far too little about the transition from where we are now to the utopian ends they envision.[26]

Albert raises the issue of energy demand in his critique of various versions of the Green New Deal (GND):

> GNDs (particularly moderate GNDs, which are more likely to emerge in the near-term) would likely result in a prolonged trajectory of stagnation and crisis for global capitalism.

Rather than stabilising global capitalism in a new regime of accumulation, Albert writes, GNDs may “give way to an era of political-economic turbulence”, that would produce opportunities, but also dangers – and one of the reasons for this is the possibility of “net energy decline”.

People can read Albert’s broader argument themselves. Here I focus on the issue of “net energy decline”. Here are some definitions. It takes energy to produce energy; the energy inputs, minus the energy used in the energy system, is “net energy” or useful energy. Researchers have over decades developed another measure, “energy return on energy invested” (usually abbreviated EROI), which is the ratio of energy inputs to useful energy.[27]

There are a mountain of ways to work this out, and an even bigger mountain of uncertainties, but most researchers agree that since the mid 20th century, when the world economy gorged on high-EROI coal and oil, EROI has been going down. There is general agreement that corn-based ethanol, for example, has such a low EROI that there’s no point in producing it (aside from ecological reasons). But debates continue to rage about the EROI of wind and solar power, partly because the implications of intermittency and how electricity networks will adapt to them are not fully understood. Albert writes:

> As we increasingly shift to renewable energy sources with a lower EROI, more energy will be required to collect and

Just(ice) Transition report, with the caveat that the author does not favour the geopolitical values it reflects

[24] Thea Riofrancos et al, *Achieving Zero Emissions with More Mobility and Less Mining* (Climate and Community Project, January 2023)

[25] Institute for Sustainable Futures, *Responsible minerals sourcing for renewable energy* (2019). A much more technical briefing paper on potential substitutions is: Aidan Rhodes et al, *Materials for Energy* (Energy Futures Lab, Imperial College London, 2022)

[26] Michael J. Albert, “Ecosocialism for realists: transitions, trade-offs and authoritarian dangers”, Capitalism Nature Socialism 34:1 (2023), pages 11-30. (Albert is not to be confused with the US-based economist Michael Albert, who writes on participatory economics (parecon).)

[27] The concept of “net energy” owes much to the pioneering work of Howard Odum; see e.g. H. Odum, *Environment, Power and Society* (Wiley, 1971). On EROI, see numerous articles by Charles Hall, the first to use the concept. An explanation for beginners is in: Richard Heinberg and David Fridley, *Our Renewable Future: laying the path for one hundred percent clean energy* (Island Press, 2016), pages 18-21 and 117-121

store these diffuse energy sources, which means less energy may be available for the global economy overall.

Albert gives four reasons why EROI may fall during a transition to renewables: (1) the need for large-scale storage, which itself imposes energy costs; (2) the burden placed on land use by large-scale wind and solar, and the possibility that wind and solar farms might have to be placed further away from electricity users, incurring transportation costs; (3) the fact that renewables infrastructure currently being manufactured with fossil-fuel-produced energy will eventually be produced with renewably-produced energy; and (4) the amount of metals needed for renewables infrastructure.

To cut a long and fiendishly complex story short, my take on this is: yes, the storage, land, infrastructure and metals requirements for renewables systems are substantial, and will impose economic burdens, some of which I touched on above with respect to metals; but, no, researchers' attempts to capture these complexities meaningfully in EROI models can not yield definite conclusions. There are just too many variables, including, above all, the effect of social conflict and social change.

A paper by Iñigo Capellán-Pérez and his colleagues, that Albert cites, questions the "green growth" paradigm promoted by the international financial institutions and western governments: they say its "consistence and soundness" is put into question by their results, and that the difficulties with renewables reflected in their computer models have not been accounted for in mainstream economic thinking.[28] In particular they say that their approach, of working out "dynamic EROI", more realistically captures the up-front costs, and delayed returns (in energy terms) of a fossil-to-renewables transition. All that I can believe – but I note that Capellán-Pérez et al list the uncertainties in their calculations and call for further research.

In my view, the important political conclusion from this is that it dovetails with socialist critiques of "green growth" discourse. Assumptions about renewable technologies being a means to continue capitalist economic expansion, combined with greenwash-laden technofixes (carbon capture etc), not only need to be challenged for their perpetuation of hierarchy and social injustice, but they also fly in the face of what researchers understand about the physical constraints on energy systems.

1.5. Is it not more realistic to include nuclear in our perspectives?

Nuclear power is a low-carbon way of generating electricity, and it uses a much smaller land area than wind or solar. Most of France's electricity (69%) is generated by nuclear, but in other big nuclear nations it supplements gas (e.g. Russia, where 19% of electricity is nuclear), coal (e.g. China, 4.7%) or hydro and renewables (e.g. Sweden, 30%).[29] The true costs of decommissioning a reactor, which can easily take a decade or more, are still poorly understood, but the much bigger unsolved problem is of burying nuclear waste.

Huber and Stafford, who strongly advocate investment in nuclear, say the waste problem has been "overstated", and that "we have proven methods for storing it safely on-site, or the long-term solution of underground". Again these are less-than-half-truths. Dave Cullen, a socialist writer on nuclear issues, points out that the "long-term solution" does not yet exist: there is "no working deep repository for high level waste anywhere in the world", despite limited progress in Finland and Sweden. Claire Corkhill, who advises the UK government on nuclear, has said that plans for new nuclear should be put on hold "until we have a geological disposal facility": officially, that is timetabled for the 2040s, but is far likelier to take longer.[30]

Huber and Stafford also write that, in electricity market terms, "nuclear power struggles to compete with natural gas and subsidised renewables". That's understatement on stilts. Nuclear electricity costs have risen constantly over time – notwithstanding state support for construction, decommissioning and other aspects of the industry – while costs of electricity generated from renewables costs continue to fall (see 1.1 above).

In the 1970s, nuclear was seen by much of the ruling class, certainly in the US and UK, as the most promising future energy source. But despite strong support from capital, governments and above all the military, nuclear went into long-term decline. In 2021 its share of global electricity generation was the lowest for four decades, at 9.8%; over the two decades 2002-2021, there were 98 nuclear start-ups and 105 closures. Fifty of the start-ups were in China, meaning that the rest of the world saw a net decline of 57 reactors.[31]

Nuclear is so expensive that it is not only shunned by capital seeking rapid returns, but is also increasingly untenable even with state funding and policy support from the military. Specialist researchers Andy Stirling and Phil Johnstone argued recently that the question is not why nuclear is in overall decline, but rather: why is it proving, in a limited group of countries, "so surprisingly resistant" to changing market conditions? Their answer is its interdependence with the military, evidence of which is strong in military studies but "typically neglected" in energy policy analysis.[32]

Huber and Stafford are among those who neglect the connection between civil and military nuclear. They do not write a word about it. With the largest nuclear plant in Europe, Zaporizhzhia, occupied by the Russian army – which has ignored UN calls to cease military action near the plant,

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[28] Iñigo Capellán-Pérez et al, "Dynamic Energy Return on Energy Investment (EROI) and material requirements in scenarios of global transition to renewable energies", *Energy Strategy Reviews* 26 (2019), 100399. In another paper (C. de Castro and I. Capellán-Pérez, Standard, Point of Use and Extended EROI from comprehensive material requirements of present global wind, solar and hydro power technologies", *Energies* 2020 (13), 3036), the same research team, expanding the boundaries of what they include in the energy system, find levels of EROI for wind and solar power, all below 3:1, and substantially lower than other researchers' results. I learned a bit about the methodological issues from: D. Murphy et al, "Comparing Apples to Apples: "Why the Net Energy Analysis Community Needs to Adopt the Life-Cycle Analysis Framework", *Energies* 2016 (9), 917.

[29] Energy Institute Statistical Review of World Energy

[30] Dave Cullen, "Stop Trying to Make Nuclear Power Happen", *New Socialist*, 16 October 2021; "Push for new UK nuclear plants lacks facility for toxic waste", *Guardian*, 28 March 2022

[31] Mycle Schneider et al, *The World Nuclear Industry Status Report* 2022

[32] Andy Stirling and Phil Johnstone, *A Global Picture of Industrial Interdependencies between civil and mlitary nuclear infrastructures*, SPRU Working Paper 2018-13

and which bears responsibility for the collapse of the nearby Kakhovka hydro plant[33] – it is a bizarre silence.

This is typical of Huber and Stafford's approach: they pick and choose parts of technologies' social and economic contexts to suit their argument. They one-sidedly portray renewables as playthings of US tech giants and merchant electricity generators, ignoring the broader picture of state support for renewables research during the 1970s energy crisis; renewables development as community energy in Denmark, and by a Social Democratic-Green alliance in Germany from the 1980s; the Chinese government's role; and the widespread social support for them in the global north and south. When it comes to nuclear, the role of governments and the military does not rate a mention, to say nothing of decades of social opposition, not only in post-Hiroshima Japan but in Europe and the US. This is not Marxist analysis.

What about nuclear's future? Again, broader social and economic dynamics matter. If our sole aim is to produce as much electricity as possible, as far into the future as possible, nuclear might be a good choice. But if our aims are to avert dangerous climate change, to move society away from social injustice and the rule of capital, to challenge capital's endless expansion, and to heal humanity's rift with its natural environment opened up by capital, the calculations are different. Then, the logical policy is to reduce total throughput of energy through technological systems (see 1.2 above). Renewables are suited to this; nuclear is not. Assuming the speed of technological transition matters – an issue that Huber and Stafford do not directly address – renewables have another great advantage: they can expand rapidly. A nuclear power station typically takes a decade to build.

Furthermore, there is the issue of where social, economic and political power lie in society. If our vision of the future assumes a strong state and a reinforced military, nuclear power might work. Such assumptions are antithetical to anything I understand by the word socialism. If socialism assumes people taking more direct control over their own lives and developing forms of collective power and democracy, then renewable power – and especially decentralised renewables – has potential. Nuclear does not.

What about the workplaces in which electricity is produced? Huber and Stafford write that renewables companies are fiercely anti-union (true, no doubt), but do not explain US nuclear companies' attitude to, or relationship with, the unions. In the UK, union officials representing nuclear sector workers often ignore the labour movement's wider concerns, to focus on maintaining bargaining rights for those relatively well-off members.

So, while I agree with Huber and Stafford that we should "listen to what these workers and unions say" about electricity, their point that energy sector unions favour a "broad-based approach to decarbonisation", including nuclear, carries less weight than they give it. They do not probe the extent to which these union officials really speak for these workers. Nor do they confront the harsh reality that here, as so often, there are tensions between some workers' sectional interests and the aims of the wider workers' movement. I doubt there are simple answers to that – but the longer we avoid discussing it, the further we will be from resolving it.

Finally, what about actual policy proposals? Huber's and Stafford's are for state investment in a capitalist context. In an earlier article, Stafford suggested a "return to the New Deal politics of public power" and argued for funds released under the US Inflation Reduction Act to be funnelled to the nuclear industry via the publicly-owned Tennessee Valley Authority.[34] This is effectively a call to divert funds from renewables to nuclear.

In their *Catalyst* article, Huber and Stafford claim that, because nuclear has proven so expensive:

> [N]uclear power needs socialism to grow – or at least a form of public investment that socialises the costs of construction and does not privatise the gains.

But in reality, most nuclear power plants have not needed socialism; they have been constructed by an alliance of capitalist governments and private capital. The exceptions are those built in the Soviet bloc which, whatever it was, was not "socialist".

A more compelling question is: does socialism need nuclear power? I can not suggest a better answer to this than Dave Cullen's. On the back of a working life spent studying nuclear power, he writes:

> Nuclear power is antithetical to the world we want to see. From its origin as a figleaf to distract us from the grim truth of mutually assured destruction, to its recent resurrection as a bogus solution to climate change, it is inherently bound up with violent state forms and paranoid and secretive hierarchies. [...]
>
> Climate change mitigation measures need to be prefigurative of other changes we want to see in the world. Technology will never be the solution to climate change, but any viable solution will need to deploy it alongside social change. Nuclear can not deliver on even the limited grounds where it claims to make a difference, and is a distracting dead end. In political circumstances where social change is not immediately realisable, we need to be advocating for technologies which are in harmony with the changes we want to see, not providing free PR for an industry which should have been left to die decades ago.

Note. Infrastructure costs

Matt Huber and Fred Stafford suggest that renewables are not "the cheap option" because:

> The cheap prices of renewable energy don't include the transmission lines to their remote locales or the costly back-up required when the weather isn't favourable. In other words, it is the limited use value of solar and wind that leads to broader system costs of integrating backup

[33] The most recent IAEA report on Nuclear safety, Security and Safeguards in Ukraine notes Russia's failure to heed the agency's calls "to immediately cease all actions against and at nuclear facilities in Ukraine". The agency continues to report military activity near the plant. See also e.g. "Inside the Ukrainian city threatened with nuclear sabotage", *OpenDemocracy*, 6 July 2023. On Kakhovka, see "Why the evidence suggests Russia blew up the Kakhovka dam", *New York Times*, 16 June 2023

[34] Fred Stafford, "We Need a Nuclear New Deal", Breakthrough Institute web site, 6 December 2022

power plants (usually natural gas) and storage technologies.[35]

This is much less than half the truth. Firstly, because, by every conceivable measure, state support for renewables has for decades been dwarfed by that for fossil fuels and nuclear.

So the implication, that renewable technologies are free-riding on good ol' coal and gas – which can be heard whenever a bunch of oil company managers sit together in a bar – is out of place in any serious analysis.

Secondly, electrical engineers and researchers have been thinking for years about how to adapt to large-scale renewable generation (see 2.1 and 2.2 below). For sure, investment in interconnection, storage and flexibility lags far behind. As with all infrastructure investment under capitalism, companies are desperate to avoid paying for it and anxious to secure state funding.

But there is a mountain of research showing that (i) there will be substantial network costs, whichever technological directions systems go in, and (ii) these costs are expected to be higher, but not dramatically higher, in systems dominated by renewables. The energy researcher David Elliott reflects the consensus opinion that the extra cost of grid balancing to adapt to renewable supply may be 10-15%.[36]

Thirdly, to support their argument, Huber and Stafford misrepresent work by Robert Idel, a researcher who constructs market models, to claim that "if systems costs were added" to LCOE estimates, the costs for solar and wind in Texas, USA, would be more than 11 and 7 times higher respectively. But Idel only modelled a theoretical situation, which could not and will not happen in real life, in which the given technology supplies 100% of the electricity.[37]

Had Huber and Stafford been seriously interested in network costs, they could have looked at the research. A paper by economists at Imperial College, London, summarising current views, concluded, among other things, that variable renewables can take high shares of total generation with "relatively" low costs, provided there is attention to flexibility. They say they can not be sure that renewables will always be cheaper than nuclear, but "it is important to avoid simplistic claims that system integration costs are large".[38] Sound advice.

Worth looking at too is a report published by the IEA and the Nuclear Energy Authority, who developed a "value-adjust levelised cost of electricity" designed to take account of system costs.[39] It concludes that in 2025 gas plants would be far more competitive if system costs were taken into account; nuclear and coal plants would mostly have "zero or minimal value adjustments"; and wind and solar would be "somewhat less competitive" than the LCOE methodology shows.

In my view, socialists should embrace a technology that can help to avert dangerous climate change, even if it is "somewhat less competitive" in the market. If someone has a legitimate reason to dispute that, fine. Point-scoring, supported by cherry-picking bits of research, is insufficient.

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Part 2: electricity networks

The first part of this article dealt with the supply of energy by renewable electricity generation or by nuclear power. This second part focuses on how electricity networks are changing.

2.1. Is it really technologically possible to base electricity networks on renewables, since they produce electricity intermittently? Could there even be advantages?

There are *already* big electricity networks based on renewables, and more are on their way. Denmark generates 61% of its electricity from wind and solar, and a further 23% from modern biofuel use. Three of the largest European economies – Germany, the UK and Spain – generate 41%, 40% and 35% of their electricity from wind and solar, respectively, and that share will surely keep rising. Within these countries, variable renewables' share of electricity generation is much greater in some places: in Scotland, a nation of 5.5 million people, it averaged 60% in 2019-21 and is growing.

While variable renewables only contributes 16% of the USA's electricity, their share in the state of California (which uses more electricity than most countries) is 43%, balanced with another 24% from hydro, 10.5% from nuclear and 22.5% from gas. And then there are nations such as Norway and Paraguay, where hydro power, a non-variable renewable resource, accounts for 88% and 99.5% of electricity generation respectively.[1]

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[35] Huber and Stafford, "Socialist Politics and the Electricity Grid", *Catalyst* 6:4, pages 71-72

[36] David Elliott, Renewable energy: can it deliver? (Polity Press, 2020), pages 7-9

[37] Robert Idel, "Levelized Full System Costs of Electricity", *Energy* journal 259 (2022), 124905. Yuhji Matsuo in a recent survey of methods of calculating system costs ("Re-Defining System LCOE: Costs and Values of Power Sources", *Energies* 2022(15), 6845), comments on Idel's methodology: "LFSCOE by Idel is different from other metrics in that it calculates the cost of VRE [variable renewable energies] when the market is occupied only by one power generating technology. For this reason, this metric is not discussed much in this article, which aims to capture the economics of real power systems." In other words, Idel's work does not address what actually happens in real power systems

[38] Philip Heptonstall and Robert Gross, "A systematic review of the costs and impacts of integrating variable renewables into power grids", *Nature Energy* 6 (2021), pages 72-83

[39] IEA/NEA, Projected Costs of Generating Electricity 2020, page 80

[1] Data from Our World in Data (Denmark, Norway and Paraguay); the Energy Institute (formerly BP) Statistical Review of World

A dispatch centre in Beijing that controls most of China's ultra-high-voltage lines and monitors renewable electricity inputs. Photo from State Grid Corp of China

The growth of renewables is forcing two big changes to electricity networks: they are becoming less centralised, and bi- or multi-directional. The networks installed in rich countries in the first half of the 20th century, and across much of the global south in the second half, were designed to carry electricity in one direction: mostly from big coal, gas and nuclear power stations, to users. Peak centralisation was in the 1970s; combined heat and power plants, and power stations using combined-cycle gas turbines (CCGT) built in the 1980s and 90s, were smaller. As for wind farms, only the largest, with 100 or more turbines, are comparable in scale to coal-fired plants. Solar power mostly operates at still smaller scales: only about half of the world's supply is from utility-scale solar farms; the rest is from rooftop panels. In China and Europe, the leading installers in recent years, more solar is being added as rooftop panels than as solar farms.[2]

The *physical decentralisation* of electricity generation is accompanied by *growth of centralised operational coordination*. As the number and type of electricity generators increases, networks – i.e. the "grid" of transmission lines, storage facilities and the computers that regulate flows – adapt to manage their inputs. This is part of the "third industrial revolution", analogous in some respects e.g. with changes made by a committee that uses video conferencing (geographically disparate people using centralised operational technology to work), or a newspaper (geographically disparate reporters, editors and managers who in the last century produced a physical product distributed from one physical location, and now coordinate digitally to produce multiple digital products).

Another consequence of physical decentralisation of generation is *disruption of markets* through which electricity is sold. The number of sellers rises. Typically, owners of solar panels (mostly, richer households, public entities or co-ops in rich countries) not only supply most of their own electricity, but have some to spare. Fierce battles are raging over the terms on which they sell it back to electricity companies.

In the global south, a different shake-up is underway: off-grid systems are being set up in areas that previously had no electricity access. The IEA estimated that by 2019, 39 million people's homes had been electrified this way. Capital is turning even this provision of electricity to some of the poorest people in the world into a market. While some projects are managed by NGOs and development agencies, it is private sector monopolies, including mobile network operators, mobile banking platforms and first-generation utilities, that are consolidating their power in this market.[3]

Struggles over who controls what, and who pays who, will continue, but the technological trend towards decentralised generation and multidirectional grids can only accelerate, in my view.

Network development has trailed behind renewables expansion. More than a decade ago, the *Global Energy Assessment*'s authors noted the "supreme irony that computers, sensors and computational ability have transformed every major industry except power generation".[4] The underinvestment characteristic of capital's treatment of socially vital infrastructure continues. One sign of this is regular curtailment, e.g. some wind farms are compelled to stop operating when it is very windy, because the network operator is unable to deal with the sudden increase in electricity flow. In the US, UK and Germany this is cutting wind power generation by 2-5%; in the mid 2010s, China was curtailing almost one-fifth of its wind power but by 2019 had brought curtailment down to similar levels.[5]

Energy (UK, Germany, Spain); the UK government web site; and the US Energy Information Administration web site

[2] Walt Patterson, *Transforming Electricity* (Earthscan, 1999), pages 68-70, 72-75 and 114-116; IRENA, *Renewables 2023 Global Status report: Energy Supply module*, pages 17-18 and 64-66; Solar Power Europe web site

[3] On off-grid solar in the global south, see: Lucy Baker, "New frontiers of electricity capital: energy access in sub-Saharan Africa", *New Political Economy* 28:2 (2023), pages 206-222; Kirsten Ulsrud, "Access to electricity for all and the role of decentralised solar power in sub-Saharan Africa", *Norwegian Journal of Geography* 74:1 (2020), pages 54-63; and Eberhard Rothfuss and Festus Boamah, "Politics and (Self)-Organisation of Electricity System Transitions in a Global North-South Perspective", *Politics and Governance* 8:3 (2020), pp. 162-172

[4] Thomas Johansson et al (eds.), *Global Energy Assessment* (IIASA/Cambridge University Press, 2012), pages 1159-61, and S. Pirani, *Burning Up*, page 36

[5] REN21, *Renewables 2023 Global Status Report: Renewable Energy Systems & Infrastructure*, pages 11-12; Hao Chen et al, "Winding

Still more serious, though, are the long delays facing new wind and solar generators that want to provide electricity to the grid. In the US, waiting times for the four largest electricity grid operators grew on average from 2.1 years in the 2000s to 3.7 years in the 2010s; in the UK, projects connected in 2022 were doing so four years after the date they had requested, and a supplier asking for a connection in 2023 can expect to be offered one between 2030 and 2038. An investigation by *The Economist* concluded that a key factor in the delays is speculation, i.e. companies filing paper projects with a view to selling their place in the queue. Planning and permitting procedures are also alarmingly slow – 3-9 years for onshore wind projects in the EU.[6]

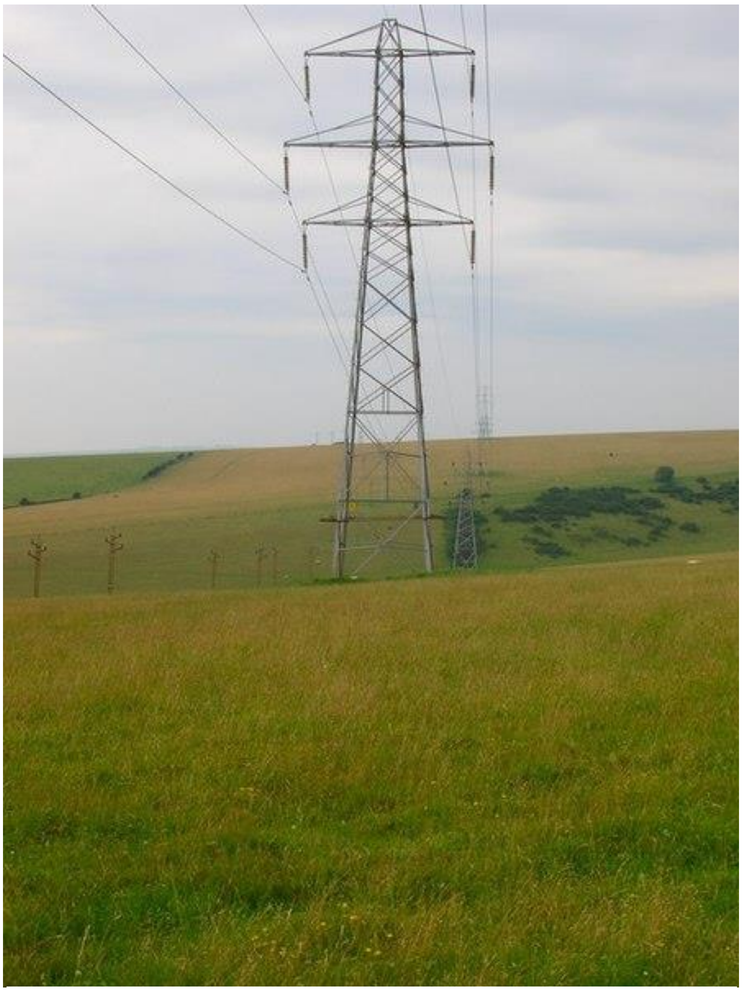
2.2. Can the technological challenges be overcome?

Re-making electricity grids to cope with high levels of renewable generation is a challenge on which electrical engineers have been working for years. In 2015, a US government research group listed the key problems renewables would create for networks as: (1) variability (i.e. the sun doesn't always shine and the wind doesn't always blow); (2) uncertainty (it's difficult to predict exactly how much electricity they will produce and when); (3) location specificity (sun and wind are not necessarily strongest where electricity networks are now); (4) nonsynchronous generation (i.e., roughly, lack of alternating current (AC) generation, particularly for inertia); and (5) capacity factors (how often a generator can run at maximum capacity – which is far lower for solar (about 25%) and wind (about 36%) than for combined cycle gas plants (about 56%) or nuclear (about 93%)).[7]

The solutions include:[8]

Storage. Electricity grids are complex systems, in which inputs and outputs have to be the same at all times. Storage is a key to regulating flow, but is also very tricky: electricity has to be turned into another form of energy to be stored – either chemical energy in a battery, heat energy or motive power. Much mainstream, technology-centred commentary assumes that lithium batteries, particularly in electric cars, will play a huge role in storage – which brings us back to the constraints on lithium mentioned above. There are large-scale storage methods such as pumped hydro (use the energy to pump water up a hill, and drive a turbine with it as it comes down), or heat storage. Other options involve turning the electricity into an energy-intensive gas, e.g. compressed air or hydrogen, for reconversion later.[9]

Flexibility. Apart from storage, grids can be balanced by adjusting the level of inputs or outputs. Most wind-heavy systems now use gas plants to balance supply; as gas is phased out this can be done by hydro and other non-variable renewables. Adjusting outputs is potentially a much greater



Electricity pylons in West Sussex, UK. Photo from Geograph/ Wikimedia Commons

source of savings, in the first place by "peak shaving", i.e. moving demand away from the busiest times. Environmentalists have long argued that electricity corporations calculated peak demand too generously, resulting in over-construction of power stations. Now, "smart" grid technology makes "peak shaving" technologically straightforward. Where electricity is delivered as a paid-for commodity, this is a market adjustment.

The UK National Grid recently tested price incentives to customers to use appliances at non-peak times: a basic approach secured a 12% reduction of peak demand, a more ambitious "Big Turn Down" offer, 64%. You do not have to buy into the corporate rhetoric about "empowering customers" to understand the potential for flexibility. Nor do you have to be a hard-line anti-capitalist to see that household flexibility would be dwarfed by that achievable in industry: *The Economist*, pointing to the example of industrial freezers, says much industrial demand is "not particularly time sensitive" and will respond to price signals; and the Energy Transition Commission, a corporate-backed

down the wind power curtailment in China", *Renewable and Sustainable Energy Reviews* 167 (2022), 112725

6 "Hurry up and wait", *The Economist*, 8 April 2023; "Carbon-Free Energy: how much, how soon?", *IEEE Power & Energy Magazine*, November-December 2021, pages 67-76; Lawrence Berkeley National Laboratory, *Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection*, April 2022; REN21, *Renewables 2023 Global Status Report: Global Overview*, page 18

7 National Renewable Energy Laboratory, *Flexibility in 21st Century Power Systems* (2015); David Roberts, "Why wind and solar power are such a challenge for energy crids", *Vox*, 19 June 2015. The capacity factors are for the US in 2022, from the Energy Information Administration web site

8 This is my non-engineer's summary, based on my reading of industry publications and academic research

9 David Elliott, *Renewable Energy: can it deliver*, pages 65-73; and *Energy Storage Systems* (IOP Publishing, 2017)

"green" think tank, points to the "great potential" of flexibility from big industrial consumers such as aluminium smelters.[10]

Changes to system stability provision. A big engineering challenge in the transition to renewables-dominated grids is that fossil-fuelled, nuclear and hydro plants have historically provided inertia, which is essential to protect the system from failure. The specialists' take on this is, first, that as grids shift towards renewables, the amount of inertia available will go down, but so will the amount needed; and, second, that inverters (which convert DC to AC and are used to supply renewable power to the grid) can be developed to take on a "grid forming" function and replace the old "spinning reserve".[11]

Information technology. Improved weather forecasting and data analysis, made possible by developments in information technology, address the uncertainty issue.[12]

Integration. The more supply options available, the more effectively variability can be dealt with. Greater interconnection between regional grids helps, and high-voltage direct current (HVDC) transmission lines, a relatively new technology, can do that with lower losses in transit. More significant in the long term is, first, integration between electricity, heating/cooling and transport (via electric vehicles), and, second, the spread of decentralised renewables, which reduces the need both for utility-scale generation and for transmission. The International Renewable Energy Agency recently published a study of the potential for such sectoral integration together with hydrogen storage and decentralised renewable energy resources with "self consumption" (i.e. the household or community that produces the energy also uses it). A corporate consultancy in the US recently published a report projecting very hefty reductions in total throughput if decentralised renewables are used widely.[13]

New combinations of direct current and alternating current. Continuing the theme of reducing throughput, some engineers see potential for this in microgrids, using direct current (DC) electricity.[14]

The direction of technological change is clear. Where renewables already dominate the grid, gas-fired power stations (where output levels can be moved up and down quite easily) are usually used for balancing. As time goes by, larger, varied ranges of generators, greater interconnection and integration, and storage, will replace them; managing the multiple changes in flows is already much easier thanks to the revolution in information technology. Decentralised generation (firstly, rooftop solar) will surely always be combined with larger generators, be they solar and wind farms, hydro or other non-fossil-fuel plants.

2.3. What are the starting points for a socialist view of this?

Not only is the shift to renewables well underway, but electricity corporations and their political allies are putting together narratives to guide it. In an interview given the best part of a decade ago – representative of these narratives, in my view – Steve Holliday, then chief executive of the UK National Grid, commented that "the world is clearly moving towards much more distributed [i.e. decentralised] electricity production and towards microgrids", and that "the idea of baseload power is already outdated". In future, the market would be "turned on its head"; a consumer's solar and heat pump would be the baseload; the electricity industry "based on meeting demand" would be superceded by one balancing supply and demand.[15]

A socialist response to such narratives must be based not on a rejection of renewables or of decentralisation, but on a rejection of corporate power and of the dictates of capitalist expansion and capitalist markets; and on an assertion of the need to decommodify energy, to take energy infrastructure into public ownership and to make energy provision a public, or common good.

The technological changes to which we need to respond have been outlined above (2.1): the more decentralised generation supercedes large-scale generation, the more electricity flow will be multidirectional, and the more the grid will function to match flexible use with flexible supply. In my view, this is no less welcome to socialists than the growth of the internet or mobile telephony: we don't have to accept the form of ownership to acknowledge the technology's potential. In the case of the internet, that potential has been choked and smothered, but not yet extinguished, by the corporations that control so much of it. In the case of decentralised renewables, the potential for new forms of common or public ownership and control of energy supply stares us in the face.

This potential has as yet only been realised in a limited way, in co-ops and municipal projects that operate, at best, as islands of common ownership and control in a sea dominated by corporations. Perhaps the most important issue is whether, and how, such small islands can join together and become part of a generalised challenge to capital; whether, and how, they can be brought together with political change at national level – social democratic footholds in the capitalist state, or other more far-reaching changes that can push back capital.

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[10] National Grid ESO, CrowdFlex – Phase 1 Report (November 2021); ETC, *Making Mission Possible: delivering a net-zero economy* (September 2020), page 22; "Defying Dunkelflaute", *The Economist*, 8 April 2023

[11] Paul Denholm et al, *Inertia and the Power Grid: a guide without the spin* (Natioanl Renewable Energy Laboratory, 2020); B. Kroposki et al, "Achieving a 100% renewable grid", *IEEE Power & Energy magazine*, March-April 2017, pages 61-73; Elliott, *Renewable Energy*, page 87

[12] REN21, *Renewables 2023 Global Status Report: Renewable Energy Systems & Infrastructure*, page 13

[13] IRENA, *Sector Coupling in Facilitating Integration of Variable Renewable Energy in Cities* (2021); C. Clack et al, *Why Local Solar For All Costs Less* (Vibrant Clean Energy, 2020); David Roberts, "Rooftop solar and home batteries make a clean grid vastly more affordable", *Volts*, May 2021. See also Unlocking the potential of Energy Systems Integration (Imperial College, 2018), and my comments on it, "Memo to Labour: let's have energy system integration for the many", People & Nature, May 2018

[14] See e.g. D. Magdefrau et al, *Analysis and Review of DC Microgrid Implementations* (iSemantic / IEEE Explore), 2016; K. Shenai and K. Shah, "Smart DC migro-grid for efficient utilisation of distributed renewable energy", *IEEE Energy Tech* (2011); Brock Glasgo et al, "How much electricity can we save by using direct current circuits in homes?", *Applied Energy* 180 (2016), pages 66-75

[15] "Steve Holliday, CEO National Grid: 'The idea of large power stations for baseload is outdated'", *Energy Post*, 11 September 2015

Struggles for common forms of ownership will always be limited without linked struggles to decommodify energy and supercede markets by public provision – that is, for public control of networks, not just nationalisation of them to serve corporations. A group of academic researchers in Europe have over the last several years developed proposals for *commons-based peer production*, under which "smart" technology is used not to trade electricity as a commodity, but to share it as a common good.

The group have analysed the technical requirements for commons-based peer production, which are broadly divided into digital technologies to manage energy flows on one hand, and raw material and physical components on the other. The two main software technologies are software-defined energy networks (SDEN) and packetised energy management (PEM). These "align with the existing liberalised market with ancillary and balancing services", the group wrote in a 2020 paper.[16] "However they also open up the possibility for democratising electricity if governed as a commons."

Here I quote from a paper published by the group last year, of which Chris Giotitsas of the university of Tallinn, Estonia is the lead author:[17]

> Our proposed commons-oriented Energy Internet builds on the concept of microgrids. In a software defined energy network, multiple microgrids (small local, often independent, grids) connect with each other to share electricity as a commons. These interactions are optimised and managed through packetised energy management via a communications network infrastructure, based on similar principles as the Internet. The technological expertise for the digital infrastructure is already largely available, albeit with primary attempts to be applied in market-based relations whereby energy is treated as a commodity amongst distributed producers and consumers.
>
> Applying this infrastructure in a commons framework, i.e. treating energy and energy infrastructure as a communal resource rather than a commodity, simplifies several structural difficulties associated with current proposals around distributed energy production. The commons framework removes the complex financial considerations that sit on top of an, already, complex network of decentralised energy transfer. It also makes the value of energy sharing more transparent and accountable for citizens, avoiding an overwhelming complexity of market dynamics and equilibria that shallowly represent citizens as rational selfish agents.

For those fighting to expand those commons islands, accessing hardware elements of energy systems is harder than developing software. Sharing knowledge of design and construction techniques is one avenue. Giotitsas et al discuss the experience of two projects – a micro-hydropower plant in Nepal and an electricity microgrid in Brazil – in getting their hands on equipment. It is a work in progress. They conclude that the two projects are currently "reliant upon infrastructure produced in this [capitalist] world economy" – but also show how these existing material components and infrastructure can be "used, repaired or reshaped" to form the basis of commons-based peer production.

These valuable papers do not map a path for the transition to a commonly owned and controlled energy system. That is not a criticism of the papers: mapping that path is a huge common task, synonymous with challenging and superceding capitalism, that faces all of us, and in my view recent decades of struggle have shown that we are collectively, inevitably, uncertain about which routes we will take.[18] However, I suggest that these proposals are a good starting-point for discussion about the transition towards a socialist energy system.

2.4. Are decentralisation and public ownership mutually exclusive?

Matt Huber and Fred Stafford claim that decentralisation and public ownership are mutually exclusive for two reasons. First, they construct a false opposition, that does not exist in the real world, between public/centralised electricity and private/decentralised/renewable electricity. Second, they claim that their imagined public/centralised system is threatened by variable renewables.

The *false opposition* is underpinned by what Huber and Stafford call a "deep materialist understanding" of electricity networks. This points toward

> [T]he importance of centralised, large-scale reliable power generation like hydroelectric dams and nuclear power, as opposed to decentralised, small-scale and intermittent forms of power like rooftop solar panels.

Firstly, not all small-scale power generation is intermittent (e.g. small dams, geothermal, modern biofuel plants and small gas plants are not) and, while large-scale generation is not intermittent, over longer periods it also comes and goes (e.g. for repairs and maintenance, or if fuels supply is disrupted).

But secondly and more substantially, the whole function of centralised electricity networks is to manage the endless changes in levels of supply, along with the changes in levels of use. Right now, centralised operational coordination of networks is necessarily expanding, as electricity generation tends towards decentralisation, and is being revolutionised by the changes in communication technologies (see 2.1, above).

Any materialist understanding of the electricity system, "deep" or otherwise, surely needs to grasp the dynamics between the decentralising trend in generation and the changes in centralised operational coordination. Huber and Stafford never even acknowledge the distinction between the two.

Huber and Stafford also present a completely distorted picture of how decentralised generation is developing in reality, focusing on off-grid solar in the global north, which is a tiny part of the whole picture:

> While the Elon Musks of the world hawk the benefits of "delinking" from the grid through the individual purchases of rooftop solar equipment and battery storage,

[16] Chris Giotitsas et al, "From private to public governance: the case for reconfiguring energy systems as a commons", *Energy Research & Social Science* 70 (2020), 101737

[17] Chris Giotitsas et al, "Energy governance as a commons: engineering alternative socio-technical configurations", *Energy Research & Social Science* 84 (2022), 102354

[18] Vasily Kostakis et al, "From private to public governance: the case for reconfiguring energy systems as a commons", *Energy Research & Social Science* 70 (2020); and Pirani, *How energy was commodified, and how it could be decommodified*, pages 9-11

we must fight for the expansion of electricity as universal public infrastructure.

Yes, Elon Musk is a dangerous clown, and, yes, a small number of rich households in e.g. the US and Australia surely see rooftop solar as the road to a reactionary, isolationist, off-grid existence. But in the big picture, they are irrelevant. The overwhelming majority of rooftop solar, whether household, municipal or corporate, is connected to the grid.The boom in rooftop solar installations in recent years has been led by Chinese state-owned or state-supported companies, followed by European electricity companies, often with state support. All these solar panels are already part of a universal infrastructure; the barriers to that infrastructure being public is not that the panels are decentralised, but that they – and some networks too – are not publicly or commonly owned and controlled.

Huber and Stafford's article is full of warnings about *the supposed threat presented to centralised electricity systems* by decentralised renewables. Intermittency gives renewable energy "limited use value" that "creates unavoidable problems for grid planning", they write; when there is too much wind and solar power, that leads to curtailment, and when there is too little wind, electricity prices go up.

They make no reference to the centralised operational coordination by electricity networks – not only in Scotland, Denmark and California with majority-renewables supply, but in many other countries with significant electricity generation by variable renewables – and no mention of how this coordination has been transformed by computer technology over the last two decades.

The cause of curtailment, as detailed by the Renewable Energy Policy Network and a bundle of research articles, is the shortage of transmission and storage capacity;[19] that in turn is caused by underinivestment, which in turn is rooted in neoliberalism.

As for electricity prices rising when less power than expected comes from wind – well, that's how (pending improved weather forecasting) markets regulate supply and demand. The problem is not intermittency, it is markets. (Note that the example used, of too little wind in Europe in December 2022, is factually incorrect, pointing to a problem with Huber and Stafford's research methods.[20])

On these shaky foundations, Huber and Stafford base a claim that it is "still not clear how [renewables] can provide reliable power for the entire grid the way centralised power plants do today", passing over all real-world experience and research (see 2.2. above). They highlight the dangers of blackouts to "the very survival of the system", ignoring the reality that blackouts historically have occurred in fossil-fuel-dominated systems for reasons that have nothing to do with renewable generation.

Huber and Stafford summarise their view of intermittency by quoting Mark Nelson, who said: "claiming cheap renewables are a viable solution for our grid system is like claiming flimsy tents are a viable solution for the housing crisis". Absurdly, they describe Nelson, a consultant and vociferous public advocate of nuclear,[21] as an "energy analyst". This is symptomatic of an unsatisfactory approach: in support of polemical goals, they present a distorted view of electricity systems, strewn with errors of fact and illustrated with sound-bites such as Nelson's that have no place in a discussion which, given climate change, may legitimately be called a matter of life and death.

2.5. Are there principled (rather than pragmatic) grounds to oppose decentralisation?

There are two reasons to *welcome* decentralised renewables, in my view – one basically technological, the other basically social and political.

The growth of decentralised renewables, and the corresponding development of centralised network coordination, is best understood as part of the "third industrial revolution" of the 1980s-90s that started with the transformative development of the micro-processor. This is not only because of the importance of post-Einstein physics for the development of solar panels (to understand the photovoltaic effect and the p-n junction in silicon chips), but more because of the crucial role of the latest generations of computing in electricity network development. All this has produced the potential for renewables, including but not only decentralised ones – notwithstanding the serious problems with their use at scale (see 1.3, 1.4 and 2.2 above) – to play a part in decarbonising the economy and thus tackling the threat of dangerous climate change.

Given the conditions of 21st century capitalism, and capital's extreme corrosion and misuse of technologies, does it mean anything to define the "third industrial revolution" in a Marxist sense as a "development of the forces of production"? I think it does, although with major qualifications – not least because of the terrifying speed at which new forms of labour exploitation are spreading, enhanced by these new technologies.[22] (In his book *Climate Change as Class War*, Huber suggests that "centralisation" is inherent in the development of the productive forces, and that Marx thought it was somehow inherently progressive. Perhaps this misunderstanding informs his one-sided view of

[19] REN21, *Renewables Global Status Report 2023: Energy Systems and Infrastructure module*, pages 11-14

[20] Huber and Stafford write that in autumn of 2022, low wind speeds "plagued the European grid precisely at the time they needed wind power most". Actually, European onshore wind electricity generation was 7% higher year-on-year in the third quarter of 2022 and 10% higher in the fourth quarter. In July, there was a day of negative wholesale prices (i.e. generators paid traders to take electricity off their hands) because of high wind speeds combined with weak demand. Soaring wholesale prices in the third quarter were attributed by Brussels analysts mainly to disruption of gas supply by Russia; they judged that a further price hike in December was due to "increased demand due to low temperatures, supported by outages of Norwegian gas assets", not lower wind. Instead of looking at analysis based on an appropriate selection of information and statistics, Huber and Stafford seem to have based their wrong assertion on a report in the *Wall Street Journal*. But even medium-term market trends can not be understood from a single newspaper report. It is good enough if you are looking for a headline to support your already-decided argument. European Commission, *Quarterly reports on European electricity markets* 15:3 and 15:4 (3rd and 4th quarters of 2022); IEA, *Electricity Market Report* 2023, pages 75-82

[21] See Mark Nelson's twitter profile

[22] See: Ursula Huws, *Labour in Contemporary Capitalism* (Palgrave 2019)

electricity networks. See *Note. Marx and centralisation* at the end.)

Socialism surely mean seeing past the corrosive effect of capitalism on technologies, and on labour, and on the human relationship with nature, and fixing our sights on the potentials of technologies, renewables included, for human cooperation and democracy, and for new social relations of production, not only of electricity but of much else. It is these unrealised but visible potentials that, in my view, constitute a reason for socialists to welcome the spread of decentralised renewables.

The second reason to welcome decentralised renewables is the social and political one mentioned above (see 2.3 above): they open up possibilities for public and collective forms of ownership; they have a prefigurative function (showing us how post-capitalist society can be different), and can play a part in broader movements around climate policy.

Huber and Stafford are opposed to this vision of public power in principle, dismissing it as "localist utopia". They claim that there is a "split within the capitalist class" between "historically embedded investor-owned utilities" who claim a commitment to reliability, and "industrial consumers of electricity" who seek flexible supply contracts and "emphasise their green credentials". This split, they say, is replicated in "the Left": "traditional labour unions" are siding with utilities, and therefore with centralised generation, while "environmentalists and ecosocialists" are with "renewable energy producers, Google and increased marketisation of electricity".

This is a contrived argument. The division between US utilities and industrial electricity consumers is not one of principle, it is simply sellers vs buyers. And the identification of more renewables with "increased marketisation" is a myth: the fastest expansion of renewable generation is in China, one of the most heavily regulated electricity markets on earth. As for the supposed alliance between "environmentalists and ecosocialists" with "increased marketisation", "Google", and so on, this is simply a declaration of guilt by association.

For Huber, opposing the "localist path" is a matter of principle: it is "deeply at odds with the traditional Marxist vision of transforming social production", he writes. And to drive the point home: "Duke Energy does not care if you set up a locally owned micro-grid."[23]

This betrays a very narrow view of socialist politics. Huber and Stafford appear to believe that the only forums worth fighting in are the national political space associated with the capitalist state, and the traditional workplace. But in real life, the class struggle is much bigger and more complicated than this, and – without exaggerating the potential of co-ops – it is hard to see what is "Marxist" about dismissing them with such bitter invective.[24]

In a practical sense, dismissing co-ops and community projects in the energy sector can only obstruct a real assessment of their progress and limitations. A vital contribution to such an assessment was published in 2020 by Trade Unions for Energy Democracy. The authors reviewed the experience of such organisations in Europe over the last quarter of a century. While they vigorously question those community energy advocates who bought in to market liberalisation narratives, they concentrate their main fire – rightly in my view – on pro-business EU market regulation, designed to reinforce capital's role, and call for "a comprehensive reclaiming of energy systems, anchored in a public goods approach".[25]

Co-ops and community projects, for all their importance, particularly in pioneering renewables in Denmark, are only one type of owner of decentralised renewable generation. Much of it is owned by corporations.

Another significant form of ownership is by municipal government, where, together with insulation and heat pumps, decentralised renewables will surely figure more and more in battles over working people's housing. This is another arena of struggle that Huber and Stafford seem to think is a waste of time – while in New York, legislation directing the public power company to plan, build and operate renewables projects has just been passed, thanks to a lengthy campaign by socialists and trade unionists.[26]

Probably the most significant expansion of renewable generation, though, is at the household level. In the US, for example, the number of households with rooftop solar passed 2 million in 2019. Controversies over "net metering" – the terms on which these households should sell excess electricity back to the grid – rage in many states.[27]

Research has shown that it is the most well-off households that invest in panels. They end up saving their owners money on electricity bills, although under current rules in many places the payback time can be many years. Surely the socialist political response should be not to oppose the expansion of solar power, but to demand that municipal and central government supply panels for free, and tightly regulate bills to households' advantage. Such demands would continue naturally from campaigns already in progress to curb electricity companies' profiteering from retail price hikes.

Conclusions

In the first part of the article, I asked whether renewables could play a role in pushing fossil fuels out of the economy.

[23] Huber, *Climate Change as Class War*, page 250

[24] If Marx's own attitude is relevant, it is worth re-reading the classic text, *Socialism Utopian and Scientific,* by Marx's close comrade Friedrich Engels. While he lambasts the "eclectic, average socialism" that sees its principles of economic organisation as "the expression of absolute truth, reason and justice", and shows the origin of those views among "utopian socialists" such as Robert Owen, Engels's characterisation of those utopians was full of warm admiration for their theoretical insights and practice. Owen, "banished from official society" and hated by the bourgeoisie, was linked by his activity to "every social movement, every real advance in England [the UK and above all Scotland, actually!] on behalf of the workers". The co-ops he formed, envisaged as "transition measures to the complete communistic organisation of society", had throughout the early 19th century "given practical proof that the merchant and the manufacturer are socially quite unnecessary"

[25] Sean Sweeney et al, *Transition in Trouble? The rise and fall of "community energy" in Europe* (TUED, 2020)

[26] Ashley Dawson, "How to win a Green New Deal in your state", *The Nation*, 11 May 2023

[27] Fereidoon Sioshansi (ed.), *The Future of Decentralized Electricity Distribution Networks* (Elsevier 2023), chapter 1. On "net metering", see Leah Cardamore Stokes, *Short Circuiting Policy: interest groups and the battle over clean energy and climate policy in the American states* (Oxford 2020)

One important conclusion is that, while they definitely could, the really decisive issues are the resistance to capital, and in particular to its regime of overproduction and overconsumption in the global north. Progress in such a struggle would result in a reduction in the total throughput of energy through big technological systems. Further, I made the case against those who claim that labour movement support for nuclear power would help in some way.

I also discussed the constraints on renewables development, the most serious of which is the problem of materials that are currently accessed in unjust, extractivist relations inherent in 21st century capitalism. The challenge here will be to bring together fights against that extractivism with initiatives that tackle dangerous climate change.

In this second part of the article, I have discussed the developments needed in electricity networks to accommodate renewables, including decentralised renewables, and argued against the false claim that decentralised generation is somehow inherently antithetical to public and common forms of ownership.

I have offered a view of technologies that are conditioned by capitalism, and suggested that we need to hold together an awareness not only of the way that capital corrodes technologies, but also of their potential to support common ownership and democracy.

Under capitalism, dangers are written into these technologies: dangers that they will be used to supplement, instead of to supplant, fossil fuels; dangers that the supply chains will be every bit as exploitative and extractive as those for fossil fuels and nuclear; dangers associated with corporate control and greenwash. But every solar panel or wind turbine, even if installed under private ownership, has the potential be assimilated into publicly or collectively owned systems, and the potential to play a role in decarbonisation.

September 2023

Note. Marx and centralisation

Karl Marx's ideas about the tension between the development of the productive forces and the social relations of production are among his most important, but also most misunderstood, insights, in my view. The momentous struggles of the early 20th century, when the Russian revolution brought into government Marxists who faced unenviable decisions about rapid industrialisation, had a distorting effect on these ideas. On one hand, Marxists wrote about the "productive forces" not as the ensemble of humanity's productive interaction with nature, with labour at its centre, but as a purely quantitative expansion of machines and techniques – which, with regard to the Soviet Union, looked like a super-urgent task. On the other hand, some Marxists adopted a mechanical understanding of how the tension that Marx had written about would be resolved, hoping – against the mounting evidence – that the progress of machinery and technique would be a fundamental force pushing society past capitalism. (I have written more about this elsewhere.[28])

Matt Huber is influenced, I think, by this mechanical understanding. Polemicising, as usual, against "the localist path to social change", he writes:[29]

> From Marx's perspective, capitalism produces the material basis for emancipation through the development of large-scale and ever-more centralised industry. He explained how capitalism tends to centralise capital through the "expropriation of many capitalists by a few". But through this centralisation process, production itself becomes more and more socialised.

But when Marx wrote about the "expropriation of many capitalists by a few", he was referring to the centralising effect of money capital and the development of corporations. Marx also wrote at length about the bringing-together of workers, previously dispersed in small workshops or home working, in factories. But in Marx's view, what laid the basis for social ownership and control (socialism) was the increasingly *socialised* nature of production under capitalism, not *centralisation*.

Huber's claim that Marx's descriptions of the physical bringing-together of workers in factories, or of the development of financial capital, implied some sort of principled approval of "centralisation" makes no sense. To then transpose this to a 21st century context, and claim that Marxism embraces a third type of centralisation – the physical centralisation of electricity generation – makes even less sense.

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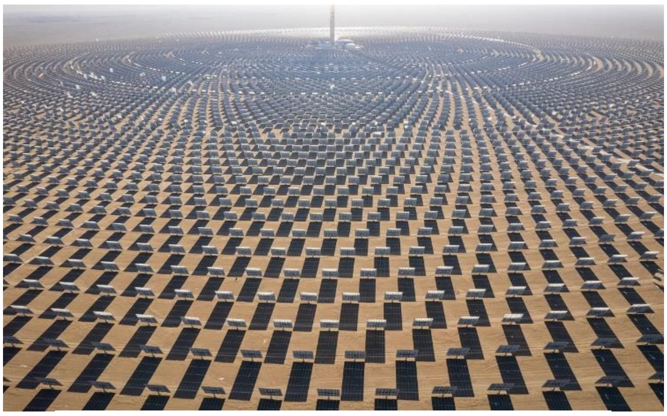

Solar panels in the Gobi desert, China

[28] "Technology and socialism. Do they fit together THAT easily?" (People & Nature, August 2013); "'The instrument of labour strikes down the labourer.' Marx on machinery is worth reading" (People & Nature, June 2015)

[29] Huber, *Climate Change as Class War,* page 250