8. Pivoting toward Energy Transition 2.0: learning from electricity

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According to the UN Intergovernmental Panel on Climate Change's (IPCC) 2018 report, humankind had 12 years to reduce radically fossil fuel use if we hope to avoid catastrophic environmental breakdown (Taylor et al., 2018). The report's language is intentionally strong. Fossil fuel use and extraction continues to rise worldwide, and the markets for these products show little sign of slacking, except in situations of crises and collapse (Stone, 2020). Though the energy transition towards renewables in the electricity sector is well underway, this has not led to lower greenhouse gas emissions even where renewable energy development and integration is prioritised (Temple, 2019). Indeed, since the UN's 2018 report, global CO_2 emissions have risen at the rate we might expect if humanity in the present were ignorant of the ways in which oil, coal and natural gas create anthropogenic climate change (Marin, 2019). Or, more prosaically, as a lead author of that report put it: 'The *wolf* is coming closer. It's not that it's not coming. It's coming. It's coming' (Joyeeta Gupta, lead author of the IPCC[1]).

The present is *not*, however, a time of ignorance or of stagnation as both culture and climate are changing rapidly in reaction to continued fossil fuel use and attendant intensification of atmospheric carbon dioxide. An awareness of the harms caused by fossil fuels is altering the ways humans live and think about living (Crate and Nuttall, 2009; Whitington, 2016). Conversations unfold differently, protests mobilise unusual consortia, people and other species move inland, toward the poles, or to higher ground. Tensions emerge between what is known, felt and understood to be at risk. Replacing fossil fuels, however, is not a process with a single silver bullet; there is no non-petrochemical with the same remarkable energetic densities as fossil fuels. Instead, what we see is the emergence of a great unruly tangle of solutions (attempting) to do what hydrocarbons have long done so well alone.

This lack of a singular solution magnifies problems for infrastructure and mobility, operability and inter-operability, short-term and long-term governance. It complicates the transition and fragments the present. The internal combustion engine may well be replaced by five or more different kinds of mobility: small electric vehicles, large hydrogen-powered vehicles; ocean-going methanol- or ammonia-powered cargo ships, (homemade) ethanol-powered farm vehicles with, as of yet, no viable solution for airplanes. The problem is the same in the electricity sector where not only do wind and solar power not work like fossil fuels, but they don't work like each other. Add tidal and wave power and it gets even stranger (EIA, n.d.). Each replacement for fossil fuels follows its own rhythm (no solar power at night, little wave power in calm waters); each is tied to specifics of their environment (no tidal power in the desert; little wind power in a swamp); each has limitations and strengths; and each holds different appeal to social and legislative communities. When taken together these factors force an extreme reimagination of infrastructural systems upon specialists and an unprecedented revision of business models upon industries that would prefer no change.

Despite this, the transformation of electricity systems to run on renewables is well underway, and this, in its specifics, can serve as a harbinger for the post fossil-fuelled world to come, guaranteed as it is to raise new questions, cause new problems, determine new relations, rely upon new expertise and develop according to novel epistemologies. We are working toward all of this newness now, individual by individual, community by community, country by country, sector by sector, even as we fail globally to reduce the extraction, trade and use of fossil fuels in any notable way.

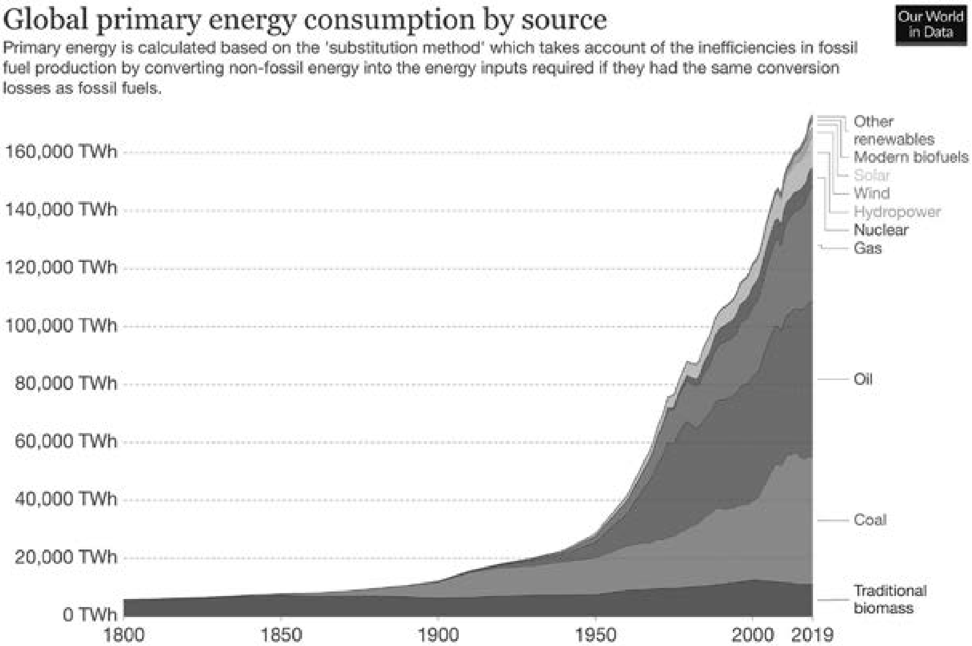
In this chapter I argue in Section 8.1 that the very nature of an energy transition away from fossil fuels is that of shattering singular solutions; in Section 8.2 that the details of how this shattering has reformed electricity systems offers lessons for the larger transition to come; and in Section 8.3 that the particular hardships attendant on the total phase-out of fossil fuels – no extraction, no transit, no markets, no use – will radically reform life as we know it – energetically, economically, and epistemologically. Section 8.4 concludes.

8.1 THERE IS NO ENERGY TRANSITION: TOWARD FUNCTIONAL DIVERSITY

The first decades of the twenty-first century saw a massive increase in electricity made renewably (Figure 8.1). The presumption attendant to this meteoric rise of new modes of power generation was that we were witnessing, and engineering, a global energy transition, understood as both the addition of renewables and the subtraction of fossil fuels from the energy mix. Transition gives this feel of replacement, of movement across regimes, of substitution. Though shifts have happened in the mix of fuels in certain industries or locations, the overall effect of the renewables revolution has been addition, not transition. Renewables make more energy available to human use. In this, they follow a 200-year-old pattern in the energy sector in which the term 'transition' is used to characterise increase: phase-in but not phase-out. Rather than phasing out non-renewable fuels globally, new modes of making power have long been added to those already in use: coal layered onto wood, natural gas layered onto oil, solar a tiny golden slice at the top. Energy in the present may be made differently, but mostly more of it is being made, while nothing (except possibly nuclear) is going away (see Pearson, Chapter 2). If 'transition' is taken to mean the *replacement* of one mode of making power with another, then globally *there is no energy transition* underway (see Figure 8.1).

Rather, what looks like transition is increase, whereby an older source of energy is quantitatively drowned in the abundance of a newer one. Thus, though it may seem that far less wood and coal are in use today than a century ago, this impression is false. In absolute numbers wood use has been flat globally since 1800, and coal consumption has grown astronomically since 1950s. A much lauded recent dip in the use of coal globally barely sets us back to levels from the early 2000s.

If transition is the wrong word with which to approach global primary energy production, it can be descriptive of energy systems transformation at the local level. Energy provision, despite the global trade in petroleum, remains unexpectedly local and often quixotic. Global increase can thus be felt as transition when looking at particular industries or geographies. Such local shifts are honest transitions, whereby one energy source is phased out in favour of another because of cost, availability, preference, ease of transport, or energy density. Water power in early English mills was replaced by coal, thus allowing factories to be moved away



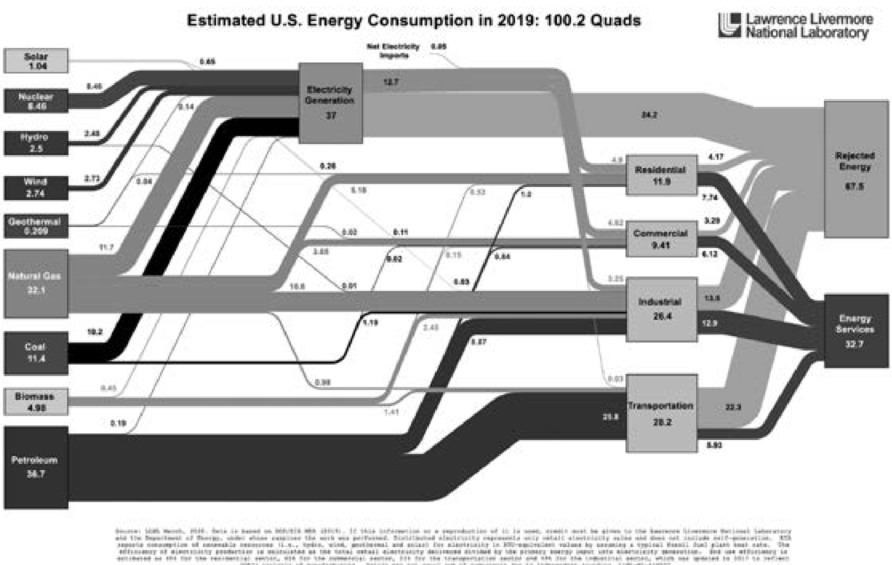
Note: Note that fossil fuels account for all significant increases in available energy since 1880.
Source: Smil (2017).

Figure 8.1 Global primary energy production

from swiftly flowing rivers and toward larger populations of potential workers (Malm, 2016); the British navy famously transitioned from coal to oil (see McCrone, Chapter 3) a shift credited for a number of victories before other navies followed suit (Dahl, 2001). Mississippi riverboats, which ran on wood and the occasional barrel of lard (in a race) were rendered irrelevant by the rise of the railroad; this shift to coal happened not so much in their own boilers (though there too) but in the engines of a different technology altogether (Martin, 1982; Brockmann, 2018). More recently, the much-lauded switches from oil to wind power in Denmark (Rüdiger, 2014) and from oil to solar power in Hawaii (Lee et al., 2020) have greatly increased regional interdependence in the first case and infrastructural splintering in the second as electricity generation flipped from single source and location to tens of thousands of networked rooftop solar systems.

None of these transitions was easily accomplished, or even particularly logical from the outset; each involved marshalling significant, often antagonistic, socio-political forces to the cause; each required the development of new technologies for managing the ways in which fuels organise systems differently, and each produced social, political and economic effects that spiralled almost immediately beyond predictability. Individuals go off-grid, municipalities aggregate and defect from utilities, political alliances emerge between left and right across vast differences in ideology. There is, then, nothing 'natural' or even straightforwardly logical about the effects of an energy transition at the local level. And though orchestrated in an open battle of interests, much of what appears rational about them has arisen only through detailed excavation after the fact. Despite their specificity, studious attentiveness to local cases in which a principal fuel source is replaced by another does offer guidance in understanding the unprecedented transition away from fossil fuels that we now face, and also largely ignore.

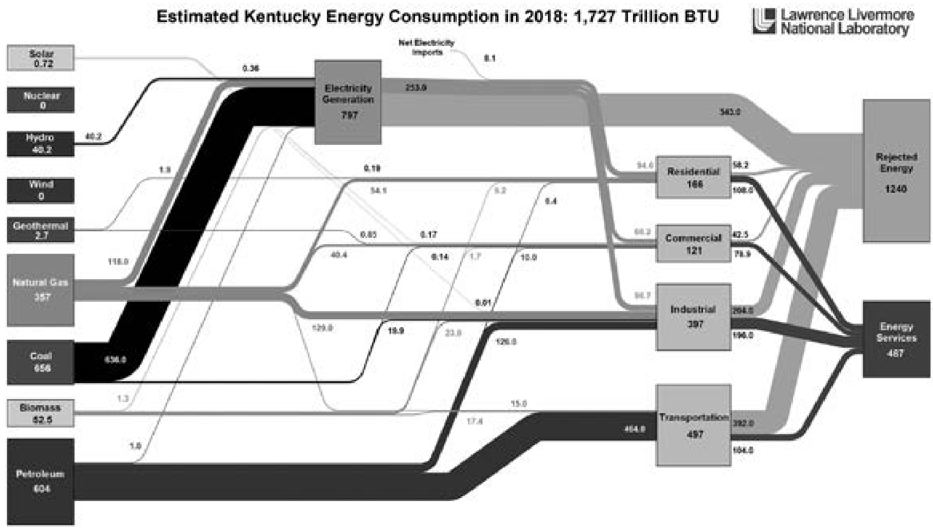
Thus, though it is true that globally there is no energy transition, this need not necessarily lead to alarm. Locally there have been many such transitions and we know a great deal about them. This knowledge reveals an interesting trend: when phased-in, fossil fuels – even when replacing other fossil fuels – tend to manifest as a singular solution. Coal replaces water, rather than tempering it, until the mills don't need the rivers anymore. Oil replaces coal rather than sidling up to run side by side, splitting the combustive burden; machinery and systems of supply are switched from supporting one to enabling the other. In contrast, to date it appears that transitioning to renewables does not work in this way. Rather, what emerges is a diverse panoply of partial solutions welded together in order to produce reliability. Identifying sectoral shatter, whereby single solutions are abandoned, coupled with a learned capacity to make diversity interoperable, is a second means by which one can identify an energy transition. When approached in this way a transition is not just about the fuel, but about the habitual ideas, or imaginaries, that subtend the fuel (Jasanoff and Kim, 2013; Wenzel, 2014).



Source: Sankey diagrams of energy consumption by source from the Laurence Livermore National Laboratory in Berkeley, California.

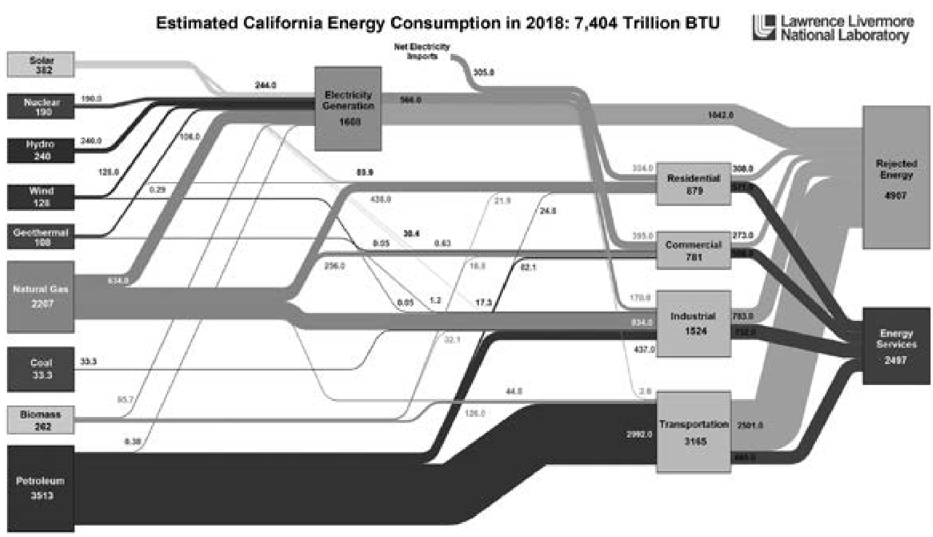
Figure 8.2 US energy consumption, 2019

In Figure 8.2 notice that in the USA electricity sector, where renewables have been most successfully integrated *without* necessarily replacing fossil fuels, mixed modes of power generation proliferate: solar, nuclear, hydro, wind, geothermal, natural gas, coal and petroleum are all used to make electricity. Compare this with the transport sector, which is comprised almost entirely of petroleum. In 1970, for which no comparable chart exists, the electricity sector in



Source: Sankey diagrams of energy consumption by source from the Laurence Livermore National Laboratory in Berkeley, California.

Figure 8.3 Energy consumption in Kentucky, 2018



Source: Sankey diagrams of energy consumption by source from the Laurence Livermore National Laboratory in Berkeley, California.

Figure 8.4 Energy consumption in California, 2018 the US would have been one bold, fat, black line for coal, with minor lines for natural gas and petroleum (EIA, n.d.). In this it bears some resemblance to Figure 8.3, where almost all electricity in the state of Kentucky continues to be made with coal. This reliance is due in part to the local prevalence of coal and is seen in other coal-producing regions globally.

Lack of diversity, in other words, points both to (a) the localness of electricity systems and (b) *a lack of* an energy transition. American states like Washington and Oregon or the Canadian Province of Québec, which rely on hydroelectric power; Iceland, which is geothermally powered; and France, which is nuclear powered, also each show a singular, fat line in the energy 'in' to electricity production. Though all rely on carbon-neutral sources of power, none have gone through an energy transition: they are 'carbon-neutrally' powered because they always have been. *Transition* is marked instead, first, by integrated diversity, and second, by the careful balancing of multiple sources of energy. Evidence of this balancing can be seen in Figure 8.4 where seven of the nine means for producing electricity in California are roughly equal (and the outliers are coal and oil). Imagine now, how that fat petroleum line feeding 'transportation' in every diagram might be broken up into six or more forms of energy consumed. Electricity will be one of them (a minor hint of this can be seen in Figure 8.4). Petroleum will be one; what will the other four be? And when might petroleum disappear from the chart entirely, as coal has all but disappeared from California's energy mix?

There is more at stake than how we make power in the current shift away from fossil fuels, and more needs to be overcome than just a cross-sector reliance on a particularly useful set of molecular arrangements. The very idea of singular solutions to complex problems is an artefact of the twentieth century fossil fuel era. Regional availability of resources might have governed this development at the beginning (e.g. coal in Kentucky, water in Québec, geothermal in Iceland), but once in place the development of those same resources – *as if* only one path toward the future were possible – has remained.

This tendency to continue down a trench of the known is what Hal Foster has termed 'the mimeses of the hardened' (personal conversation 2010). The 'hardened' is what feels right (e.g. coal power in Kentucky; hydropower in Québec). When speaking of infrastructure, this 'right feeling', as it is selected for again and again, is etched into landscape in the most literal of ways regardless of how the surrounding world – the environment – has transformed in the meantime (Warde et al., 2019; Benson, 2020). There is a magical wilfulness to this procedure (Gmelch, 1992) as if context could be held in place merely by doing the same thing over and over again. The changing climate system, born of a repetition of exactly this sort, puts the lie to this procedure, while doing little to slow its seductive capacities.

Actor and playwright Christine Beaulieu provides a magisterial demonstration of the 'mimeses of the hardened' in her tour de force *J'aime Hydro* (Beaulieu, 2017), a one-woman play that chronicles her quest to understand why the utility Hydro-Québec, a beloved entity in province, is building yet another dam. Of Québec's electricity, 95.2 percent comes from hydroelectric power, yet rather than exploring alternatives (e.g. wind, microgrids, storage) the monopoly proposes more large dams. Because hydroelectricity is carbon-neutral and because the utility is both a monopoly and monopsony, a situation which disallows competition in production, purchase and sale, there is no need to veer from the single solution. This failure, Beaulieu points out, subsists in the utility's dependence on *an idea*: that the same way of making power in the past should and will characterise the future, despite the fact that the cultural context, technological know-how, climate systems, and political and legislative constraints have changed; building big dams is no longer about francophone sovereignty (as it was in the 1970s) but is now about maintaining carbon neutrality. The excuse for the same path has changed, but the path itself has not. This situation makes it possible to avoid both adaptation and innovation that changing (cultural, economic, political, climate, etc.) environments demand. Or to put it most plainly, there are many ways to make carbon-neutral power today; all of them except the big dams and their singular solution threaten the existing hegemony of Hydro-Québec, and as such these are excluded from consideration. Carbon emissions are not the arbiter of sameness, they are lip service; what matters is the preservation of power (broadly conceived) in its existing form.

8.2 ENERGY TRANSITION 1.0: LEARNING FROM ELECTRICITY

If the goal is to *replace* fossil fuels – or decarbonise energy systems – then the word 'transition' fails to describe the present, just as diversification fails to characterise it. In most of the world, petroleum, natural gas and even coal remain the principle means of producing power across sectors, including transportation, manufacturing, and heating (see Figure 8.1). Transition is, however, a good way of describing what is happening to electricity networks today. How can this be? It turns out that integrating renewables like wind and solar power require that electricity systems be structured and managed differently than when based on fossil fuels alone. This is true of any system transitioning from a single solution model (*pace* Hydro-Québec) to a multiple solutions model. Electricity systems, however, push this general truism to its extreme. Because electricity can't be stored (batteries perpetuate a myth in this regard) and because electricity is very fast (a force *not* a substance) a system designed for its provision must be kept in careful, near-to-instantaneous balance (Bakke, 2016b).

Anywhere with universal electrification generation must be tuned to use across thousands of miles of interconnected landscapes, encompassing tens to hundreds of power plants and thousands to millions of users. Turn on the bathroom light at 3am somewhere and that tiny extra draw on the grid must be met and matched immediately, a bit more coal flash-combusted, a drip more water passing through a dam, a wisp of natural gas set afire (Bakke, 2016a). Solar power doesn't help here, not at 3am. Wind power doesn't help if it's a still night. The power we use must come from somewhere and immediately, but with renewables where precisely it comes from is less easily managed.

Thus, even if the same quantity of electricity is entering a grid, it makes a difference to this grid's good functioning if power is made in a centralised, utility-run, coal-fired power plant, or by radically dispersed, privately owned photovoltaics (solar) or even big wind farms. Devices that capture the sun or the wind guarantee that power is gathered in different locations, at different times of day, and with all kinds of jitters and kinks. Something as minor as a puffy white cloud can wreak havoc in a solar-powered community. These differences are far from trivial and, structurally speaking, distinguish renewables from coal. A stable and predictable fuel, coal is important mostly because it is something that humans can control. When cared for properly, coal doesn't burn of its own volition, which means we can burn it when we want power or store it when we don't. So too with natural gas and oil.

The capacity to hold the fossil fuels on reserve means that throughout the twentieth century our energy system was organised around the idea that someone could decide the output of a power plant. The same cannot be said of the sun and wind, the energy output of which is decided by the natural rhythm of day and season, climate and weather. Likewise, with coal, oil and natural gas, people could decide where to build electricity factories; they could build systems to transport the fuels there, and then stockpile these until needed. In contrast with solar, wind, tidal, wave, hydro or geothermal power generation has to be constructed where these resources are in plentiful supply. This reverses the effects detailed by Malm (2016), whereby with coal, factories could move away from rivers. Without coal, electricity factories (at least) have to move back to the natural environments that support them – wind where it is windy, solar where it is sunny and tidal by the sea.

Solar panels, thus, scattered across a thousand suburban rooftops might create the same amount of electricity as a coal-fired powerplant, but that is the only thing they have in common. The rest – ownership, governance, the physics of systems integration, time of day of power production, the very idea of command-and-control, air pollution, network stressors, and so on – all differ. These differences have *not* been easy to integrate into a functioning electricity system, causing a rocky if exciting couple of decades for the industry. More than this, each of these differences opens new avenues for social organisation (see, especially, Pinker, Chapter 20). Microgrids, that link communities infrastructurally and that can function as ‘electrical islands’ when the larger grid is under stress, have become almost mainstream. Nanogrids, grids the size of individual homes, begin to reform notions of network toward those of foam wherein each tiny grid is an island of self-sufficiency that, when aggregated, create a ‘grid effect’. Also called swarm electrification this congregation of small grids feels the same to the end user as the ‘big grid’ familiar from the twentieth century. What is different is that in moments of stress it can disaggregate, turning back into a jumble of tiny bubbles of self-sufficiency. In the age of resilience, such flexibility is lauded, as climatic changes so often bring larger infrastructures to their knees. It goes further. Even micro- and nanogrids have now begun to disperse, as the generation of electricity, its storage and its use remain privately held, but no single owner controls them all. Groups, rather like condo associations, form to govern the interoperability of shared bits of infrastructure. Scaled up, virtual power plants (VPP) manage these resources – and most especially the willingness of larger consumers to turn consumption up or down on call – to avoid the construction of new power plants. Cities and towns are using these technological solutions as excuses to abandon their utility and manage their power production themselves (Klein and Coffey, 2016). Utilities are likewise using these solutions as a means to unbuild existing infrastructure; Australia is dismantling long feeder-lines to isolated communities because microgrids do the job better (ARENA, 2018). Oregon is unbuilding small electrical dams because wind and solar are less disruptive of fragile river ecosystems. Change magnifies, becoming magnificent.

Here one begins to see why imagination is essential to Energy Transition 1.0 – the transition that integrates renewables into existing power grids. As command-and-control is overridden as an organisational means for creating ‘balance’ between supply and demand, new modes of balancing better suited to the complexities of renewables are being developed. These might be intimate and small scale, like pooled distributed energy resources (DERs) – home solar systems, home battery systems and building-level capacity to ‘turn down’ electricity demand – that can be used to stabilise the system as a whole. Or, on a far vaster scale, the development of cross-regional renewables balancing that marries sun power in the south with wind power in the sea and hydropower from the north can provide a strong renewably powered grid via procedures more like juggling than top-down planning. And, though large-scale modes of storing potential energy can help make this system more robust, they will likely be less essential to the future of electric power systems than artificial intelligence, which can 'think' at the speed that electricity systems function.

If success were to be measured by addition, adaptation and the capacity for balance under stress, then Transition 1.0 is a triumph, not perfect, not complete but fast moving, dynamic, and impressive in its embrace of the new and the integration of difference into functionality. In the first quarter of 2020, Germany produced more than half of its electricity renewably. In the last quarter of 2019, England produced more electricity with renewables than with fossil fuels for the first time since the turn of the last century (Ambrose, 2019). Hawaii and Arizona, Denmark and the tiny Scottish Isle of Eigg (among others) are all regularly producing *more* electricity than they can use with variable and distributed renewable forms of generation. And, globally, about a third of all electricity is now made renewably (IREA, 2019). There is little doubt that, were we not under Damocles' sword of climate pressure, much of the world would within a hundred years be running on radically distributed renewable forms of energy. Policy incentives would certainly facilitate this, but as the United States has amply proven, coherent (or any) energy policy is not necessary to the mass integration of renewables into an existing electricity system. Largely, this is because renewably made power is lucrative, asymptoting – after installation costs – down toward 0 cents a kWh, a price fossil fuels can never hope to beat. There is little doubt that with sufficient time we could transition even the most electricity-dependent elements of contemporary societies into similar societies differently fuelled with all the shatter and functional adaptation this implies.

8.3 PIVOTING TOWARD ENERGY TRANSITION 2.0: CROSS-SECTOR DECARBONISATION

We do not have sufficient time. The IPCC's doomsday-with-a-date report is, as I write this, already three years old, leaving nine years for a dramatic, world-wide reduction in the use of carbon-intensive fuels, materials and processes. Excluding the short-lived emissions reduction associated with the coronavirus, no quantitative progress has been made to date. This includes emissions from the extraction and combustion of fossil fuels and the manufacture and use of unthinkably common materials, like cement, steel, aluminium and fertiliser. The vision afforded by Energy Transition 1.0 is of a fossil-designed modernity maintained, indeed increased, without those fuels. And though social, political and economic relations are changing with Energy Transition 1.0, what is principally under revision is infrastructural. Thus does the future retain its promise as a dream-fantasy space in which nothing is lost, nothing given up, nothing abandoned (Günel, 2019). 'Everything the same, but now renewably' retains abundance as the centre piece of a transformed energetic regime. At issue is that this abundance (still) flows from fossil fuels; eliminate them and it grows diaphanous, conceptual, dubitable. Equally important is that abundance in some locations is buoyed up by extraction, privation and extreme poverty in many others (see Tomei and To, Chapter 10). There is thus good cause to question 'everything the same, but now renewably' on the grounds that it perpetuates massively exploitative global relations of power (Boyer, 2019; Howe, 2019). These too are rightly up for revision in Transition 2.0.

The transformation of abundance from promise to problem in Energy Transition 2.0 is because, in pointed contrast to 1.0, this energy transition is premised on reduction. Discussions centre on cross-sector decarbonisation strategies designed to reduce CO_2 emissions to zero globally (or in more politic terms, to achieve 'carbon neutrality'). If Energy Transition 1.0 is still about addition – getting renewables into the electricity system – then 2.0 is about subtraction: removing fossil fuels as a primary energy source across sectors. Even in the electricity sector, where the term 'transition' seems apt enough, this flip from addition (more renewables) to subtraction (no more natural gas) has not been made. Energy Transition 1.0's successes are additive – we now have *and use* more ways of making power, not fewer. And though this newfound capacity to make electrical power renewably should in theory facilitate the total phase-out of certain fossil resources (like natural gas) from electricity systems, it has not had this effect. Phase-in remains golden; phase-out, now theoretically easier, is a next step never taken.

Were we to phase-out fossil fuels from our current energy-intensive socioeconomic system, by subtracting them from the energy we use, then within a decade we would be using 90 percent less energy overall (see Figure 8.1). This sort of reduction is not something for which modernity has prepared us, as we have spent the age of fossil fuels becoming experts in increase not reduction; growth not decline. Indeed, addition is what modern economies not only excel at but were designed for (Appel, 2017); an excellence mirrored by and grounded in the continued expansion of energies available to harness. Because fossil capitalism is premised upon increase (more, better, bigger, faster, further), accumulation and expansion (Tsing, 2012), it is hard to reframe success in terms of reduction, dissipation, or contraction. The opposite of growth under fossil capitalism is collapse, not *de*growth, not small is beautiful, not even maintenance of the status quo. Companies go out of business, fortunes are lost, empires implode, failure is part and parcel of capitalism's boom-and-bust cycle (Marx, 1992). It is an exciting economic system to live in, but one in which great efforts are expended toward maximisation, and few toward functional minimisation. Consequently, collapse haunts the problem of subtraction, of 'phase-out' rather than 'phase-in', not because collapse is necessary but because subtraction as a mode of orchestrating success is so foreign. In the words of polymath Leopold Kohr, writing in the middle of the last century: 'The principal problem of our time is not how to grow, but how to stop growing' (1978, p. 79). The same is truer today as China, India, Nigeria and much of the rest of the world learns the singularly impressive lesson of fossil fuels: with them fantastic cross-sectoral growth is more than simply possible, it is easy. Without them, abundance remains elusive.

How then to become adept at what we are bad at (subtraction without collapse)? Or, how to flip the situation into one premised upon what we are now good at (addition rather than subtraction)? How much of that 90 percent can be replaced by non-fossil-fuelled energy sources? And how much can be sliced away, the fat from the happy pork of contemporary life, leading to leaner methods, habits and machineries? How might we go about doing this, globally and very fast? And how can we adjust the extractive, waste-laying practices of global capitalism toward the humane? Lastly, what sort of governance is needed to unmake fossil-fuel concerns that are often inextricable from the nations that hold them (China, Saudi Arabia, Russia, Venezuela, Holland, Canada and tens of others (Riley, 2017))? Seventy percent of the global CO_2 emissions can be traced to just 100 companies, more than half to only 25, almost all are Petrostates – companies and nations inextricably intertangled. We can name them, but there is no effective method (to date) to influence their behaviour and no way to shut them down.

This, then, is what is at stake: (1) Subtracting the internal combustion engine from the bazillions of machines it now powers; cars are the merest tip of this iceberg. How might this be done with care for the many industries attendant to and deeply dependent upon this engine?

(2) Subtracting fossil fuel extraction and trade from spreadsheets of global finance. How might this be done with care for the many nations singularly reliant upon this revenue? (3) Subtracting the unique molecular flexibility of fossil fuels from industries of advance chemical craft. Plastics, paints, fertilisers and other synthetics defined the twentieth century every bit as much as much as engines. How might these be abandoned without losing the colours that saturate the present; without forcing starvation upon us all? These subtractions stand at the beginning of Transition 2.0, not its end. They are worries for the immediate and the future. One can see why thoughtfulness behoves us. Subtracting well will take not just laws but imagination; not just inventiveness but grit coupled with profound motivation and an amplified capacity for care. We are entering uncharted and turbulent waters without ever really having learned how to swim.

Energy Transition 1.0 has nevertheless been instructive. We know from that process and from history (Mitchell, 2013) that even minor shifts in how, from what, where, by whom and in what quantities we make power cause major shifts in how we organise energy systems *and* social worlds (the two are, in fact, one and the same). And we know that people and organisations that have power do not give up that power lightly. As we have seen in the case of Hydro-Québec change is regarded with great suspicion. And rightly so; change is risky and haunted with failure. Many a company was toppled in Transition 1.0, but those that did the worst were those that clung most tightly to the mimeses of the hardened, refusing to see that the norms of the near future would be different from those in the present, continuing to build coal-fired power plants when the tide had already turned toward wind and sun; continuing to maintain fossil-fuelled investment portfolios when investments tuned to renewables were already outperforming oil, gas and coal; continuing to permit large coal mines while climate-driven fires burn great swathes of their own nation to ash. Not only do corporate entities balk at change, but governments, too, watch as national politics heave and grow uncertain, as even the most minor of modifications in energy policy yield structural and social developments that immediately escape the confines of power systems engineering. In Germany, for example, extreme right-wing voters have appeared most forcefully in former coal-producing regions; their once distinct political presence is newly echoed in communities dependent on a threatened auto industry. Contemporary fascism is feared everywhere, because it is emergent everywhere.

Neither doom nor gloom can colour the whole of the sky, however. There is a front on which Energy Transition 1.0 offers cause for hope. In 2010, when I began researching the restructuring of the United States' electric grid to accommodate renewables, solar power was dismissed out of hand. It was an implausible technology that would never become cost competitive to remain forever on the fringes of large power systems – the sort of thing that hippy ideologues invest in and the rest of the world could rightly ignore. Today, solar is beating all fossil fuels on cost per kilowatt hour and is the fastest growing renewable energy technology globally. Even in Germany, one of the worst rated countries in terms of solar potential, solar produces almost 7 percent of the nation's electricity annually. When it is hot and dry that number rises to about 15 percent (Wehrmann, 2018). The United Kingdom, where any electricity systems engineer would have once scoffed at the possibility of generating power with sunlight, is now the world's sixth largest producer of solar power (*The Switch*, 2020). In the tiny grey state of Vermont, 18–20 percent of electricity in an average year comes from distributed solar. In sunny places, like Arizona, Algeria, Egypt and Yemen, it is easy to generate more than 100 percent of midday electricity use through solar power alone (see also Parnell, 2018). The growth of off-grid systems, most especially in places of abundant sunshine and little existing electrical infrastructure, is more remarkable still (Cross, 2013; 2016). Impressive in all cases is the speed and scale of adoption of a technology so recently deemed 'impossible'.

As of 2019, 120,000 homes and businesses in Germany have opted for solar-plus-battery systems that do something surprising: they not only produce power for their owners, but their batteries make them resources for a common grid (Hockenos, 2019). This is the most exciting twist that 'energy independence' has taken in the developed world: yes, you can make a buck selling homemade power back to the grid, but the true value of these systems is their ability to go off-grid on demand. When the balance of power comes up short, small solar-plus-battery systems contribute to the common good via a dispatchable *withdrawal* from a large-scale power system. Rather than relying upon a 'great acceleration' logic making ever more (power) to meet demand, demand is reduced. Balance is achieved by the recently unthinkable means of consuming according to availability coupled with modest self-sufficiency; here the kitchen garden meets twenty-first-century electricity provision. Subtraction is, in other words, already part of a reimagined but still shared energy infrastructure.

8.4 CONCLUSION

Over the last decade or so, as renewables have become increasingly mainstream, we have substantively transformed not just an energy infrastructure, but also ways of thinking about fundamentals, like the relationship between supply and demand. Like the fact that a grid might be balanced by deployable *reduction* in demand rather than by a deployable increase in generation. Ten years. We can change systems fast. We just did it without most folks being much the wiser, such that when some say 'ten years for the phase out of fossil fuels is impossible', remind them that ten years ago solar was a 'weirdo' thing for hippies and Germans, but of no real value to anyone else. How wrong we were, and how wrong perhaps we can be about the hopelessly short nature of the current timeline. On average 30 percent of global electricity is now made renewably. How far along might we be if in 2030 (that is the nine years we have left to meet the IPCC deadline) 30 percent of all the fossil fuels we use for all the plastic sacks and nitrogen synthesis (which is to say, food), and polyester for clothing, and smelting of steel, and fuel for our car engines, and our airplane engines, and our lawnmower engines, and all the other engines, were simply gone. It wouldn't exactly be success, since the atmospheric warming we have already caused will still be here. But it would be a Gulliverian leap in the right direction. If we did it with one system via a hearty diversification, why not worry less and just set about doing it with all the others? This is a future for power that is in our human hands. We make it happen – with politics, changed investment strategies and young people in the streets who raise their voices in a pitched call for change.

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1. In answer to a question from the audience at: *A Line in the Sand. IPCC's 'Global Warming of 1.5°C' and the public discourse of tipping points*, 12 November 2018. Amsterdam.

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