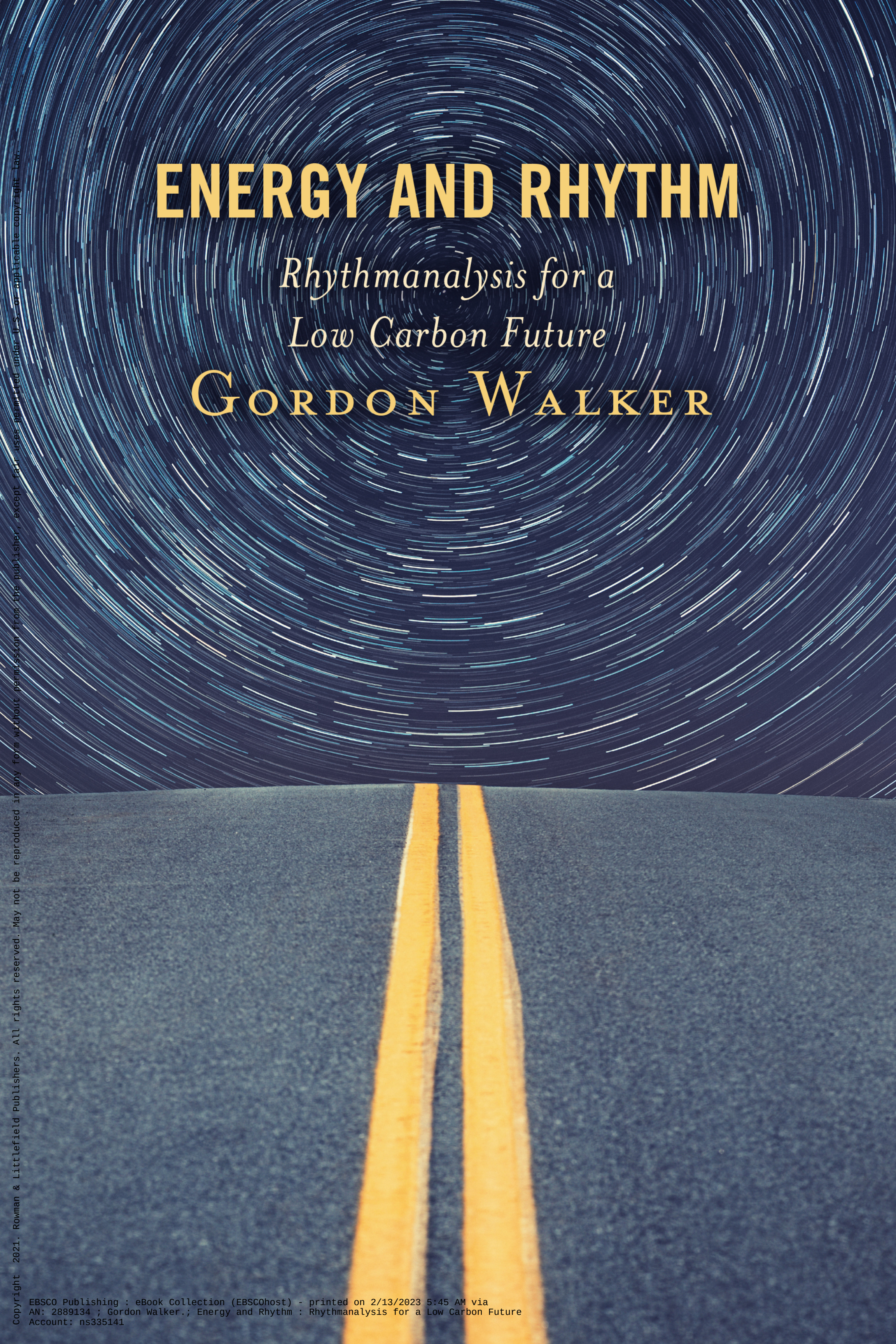
ENERGY AND RHYTHM
Rhythmanalysis for a
Low Carbon Future
GORDON WALKER

Energy and Rhythm

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Rhythmanalysis for a Low Carbon Future

Gordon Walker

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Acknowledgments

I finished this book in May 2020, whilst in lockdown due to the Covid-19 virus. I decided not to write this experience into completing the text. Readers may, though, find themselves reflecting on how the normal anticipations of repeating, interwoven rhythms of economy and society, places and everyday lives were starkly revealed by their prolonged interruption. Breaking with the normal order of things was vital, but much later than it should have been and undermined by arrogance and incompetence.

I started the book two years earlier, after experimenting with the ideas in various ambitiously rhythmic presentations at conferences, seminars and invited talks. I am indebted to many people along the way, including those collaborating in research projects that feature in the book. These include many colleagues in the Dynamics of Energy, Mobility and Demand (DEMAND) Centre, which ran from 2013–2019, namely Allison Hui, Mette Kragh-Furbo, Nicola Spurling, Rosie Day, Neil Simcock, Rose Chard, Stanley Blue, Sylvie Douzou, Catherine Grand-Clement, Elizabeth Shove, Frank Trentmann, Russell Hitchings, Mathieu Durand-Daubin, Gregoire Wallenborn, Giulio Mattioli, Greg Marsden, Janine Morley, Jacopo Torriti, Mitchell Curtis, Ben Anderson, Iain Goddard, Mike Allen and Torik Holmes. Visitors to the Centre and its event programme also shaped my thinking, including Conor Harrison, Yolande Strengers, Mikko Jalas, Tim Schwanen, Mikkel Bille, Anthony Levanda and Alan Wiig, as did opportunities to interact with Ralph Horne, Cecily Maller and others while at RMIT in Melbourne. Working specifically on rhythm with Elspeth Oppermann produced a paper in *Geoforum* on thermal rhythmanalysis in the context of climate change, which is referred to in various places in the book. Her insight and enthusiasm for rhythm-thinking were enormously motivating, as were comments made on chapter 3 of this book when I was unsure of where it was going.

In terms of the rhythms of the writing process, I am indebted to many friends and colleagues for sparks of ideas and for helping me in the end settle on a book title, including Nils Markusson, Giovanni Bettini, Duncan McLaren and Nigel Clark. Others gave me more entertaining rhythms and beats to lose myself in—The Peloton, Go Kojak, Off the Rails, The Metermen, Meadowalker, Schau Genau—back in the days when making sounds in rehearsal rooms and packed sweaty pubs was a normal thing to do. Ruth and Dan were instrumental in getting me to places in Iceland for photos and vignette making. Amy helped me with conversations about writing and sticking points, while Hannah and Sam let their homes feature in photos and vignettes and kept on being supportive, hoping the end was in sight. More than anyone, Fiona helped me get there, reading drafts, picking up my writing quirks and oddities, enduring holiday photos of meters, wires and PV panels, liking the vignettes and always being at my side. Thank you.

This book is dedicated to my mum, who knew a thing or two about keeping the rhythms of family life and caring for others in good order.

A website with resources supporting this book is available at
http://wp.lancs.ac.uk/energyandrhythm/.

Chapter One

Introduction

Energy and Rhythm Together

The turbine cycles. The train moves. The modem flashes. The lift rises. The tide surges. The wheel rotates. The light flares. The sun rises. The chest falls. The blood pulses. The leaf opens. The fire burns. The sky darkens. The room warms. The storm rages. The waters rise. The wind blows. The klaxon sounds. The day begins. The meal finishes. The lights dim. The boiler switches. The car roars. The cold freezes. The turbine cycles.

All energy. All rhythm.

There were two catalysts for writing this book. Whilst working in a social science–led multidisciplinary research centre focused on the dynamics of energy demand,[1] I was encouraged by colleagues to engage with rhythmanalysis as conceived by Henri Lefebvre, writing by himself and jointly with Catherine Régulier. As a human geographer, I was already sensitized to its distinctive spatiotemporal approach to understanding the polyrhythmic dynamics of cities and other social phenomena. However, I was not expecting to find energy in its definition of rhythm as space, time *and* energy in interaction, something that has been ignored by pretty much all of the body of rhythmanalytic work that has followed. Having become intrigued, the second catalyst was finding myself thinking about both the rhythms and the energy flows that were around me, which I was immersed in and that were animating the moments and worlds I was inhabiting. As in the list of things and verbs that opens this chapter, I found myself enumerating ways in which rhythms were energetic, and energies were rhythmic. And the more I engaged with the vastly open scope of the rhythmanalytic project, the more I found things to be said about the interrelations between energy, rhythm and carbon. In the second line of

1. The Dynamics of Energy Demand Research Centre; see www.demand.ac.uk.

Lefebvre's ([1992] 2004: 13) main rhythmanalysis essay, he proposes 'nothing less than to found a new science, a new field of knowledge: the analysis of rhythms; with practical consequences'. What more urgent 'practical consequences' to engage with than the current and future climate crisis?

In this book, I make the case for bringing energy and rhythm together. I argue that rhythmanalysis, if worked with in a flexible way, as heuristic rather than fixed method, drawing on a diversity of forms of knowledge from sciences and social sciences, has something distinctive and significant to add to the study of energy in the context of climate change and low carbon transition. A rhythmanalytic view makes clear that time and temporalities matter to stripping carbon out of energy systems. Not just in the sense of timescales of transition and speeds of change (Sovacool 2016), but also in the very substance of how energy systems work and how they are integral to the ongoing structure and order of societies. This means that it is rhythms *in* transition that matter to low carbon futures, not just the temporalities and rhythms *of* transition. Rhythms transitioning both within and beyond energy system boundaries, rhythms in energy resources, in working technologies, in everyday activity, in infrastructures, homes, bodies and cities, in energy supply and in energy demand. Rhythmanalysis provides a framework for an integrative analysis across wildly different rhythmic phenomena, and, in this book, for applying this to understanding how rhythms and their energies interact, combine, synchronize, beat together and evolve. This all adds up to a novel, constantly dynamic way of seeing and unpacking the challenges of decarbonisation and, what I will later call, de-energisation, in response to the urgent and potentially existential threat of climatic change.

Working with rhythmanalysis also makes very clear the need to go beyond the social and technological in understanding the fundamental energetic condition in which current climate concerns are embedded. For all the attention to we give to 'techno-energies' within wires, cables, pipes and tanks, there are also energies in atmospheres, in ecologies, in organisms and biologies that are foundational to the planet and the bodies we inhabit. For some disciplines, such an understanding is very basic and fundamental, but in the social sciences we can become so wrapped up in 'the social' that boundaries are drawn that are not at all helpful when energies and rhythms are busy pulsing, flowing and interacting across them. As a geographer, I have always been sensitised to the importance of engaging between 'the social' and 'the natural', between the human and the physical, and rhythmanalysis has a vastly untapped potential for so doing.

These are the arguments that will emerge from bringing energy and rhythm together, step-by-step, through the rest of the book. In this introductory chapter, I will outline in streamlined terms the building blocks and the structure of the chapters that follow, before considering matters of geographical scope and different ways of reading the book that might be adopted.

RHYTHM

Think of a rhythm. Any rhythm. Rhythms proliferate around us, in us. Maybe you thought of your heartbeat, or the rhythm of working and not working (a more complicated rhythm than it used to be), or the seasonal rhythms of spring, summer, autumn and winter (also, some would say, more complicated than they used to be). Or maybe the rhythm of music, of walking, of traffic lights, your washing machine, your tea drinking, Christmas celebrations, day and night, birdcall, the tides. Start thinking rhythmically and it is easy to keep going and difficult to know when to stop. We expect rhythmic repetitions, anticipate them, rely on them to keep going and provide some order to what comes next, tomorrow, next year; while knowing that even 'Groundhog Days' never repeat exactly, but with some degree of difference, unrealised expectation or surprise.

Repeating rhythms proliferate in their multiplicity as well as ubiquity, and all these rhythms, with their different beats and pulses, regularities and irregularities, forms, shapes and measures, do not exist in isolation. They coexist with others, they interweave and interact, they interconnect—they are 'inter' in various ways—forming *polyrhythmia* of diverse rhythms that run through your body, your everyday, the places you inhabit, the world that you live in, and live on. Contemplate the notion of biorhythms, or the 'circadian clock', and your corporeal rhythms become interconnected to the rhythms of the galaxy and its cyclical making of planetary day and night. Insert the sudden but timetabled rhythm of a flight to the other side of the world, and a certain rhythmic chaos enters into this interconnection in the form of jet lag to be managed, and rhythms of sleeping and eating to be re-established. Rhythms interconnected, interwoven, in bundles or polyrhythmia that are dynamic and open to change, and both human-made and beyond the intentionality of human action (see figure 1.1).

For Lefebvre ([1992] 2004: 28), 'the study of rhythms covers an immense area; from the most natural (physiological, biological) to the most sophisticated'. As discussed in chapter 2, he is not the only theorist who has engaged with seeing and analysing the world rhythmically, but he is alone in offering an account of rhythm that spans the vastness of the cosmos to the intimacy of the human body and a creative and open inspiration for analysing rhythms through diverse multidisciplinary ways of knowing. The work of other rhythm and time-engaged theorists will come and go in what follows, but, as

Figure 1.1. The rhythms of seasons, ecology, sunlight and air travel.
Photo by the author.

will become clear, Lefebvre's final book published posthumously, and based on ideas developed in earlier writing, including with Régulier (Lefebvre and Régulier [1985] 2004, [1986] 2004), will feature throughout as a touchstone and central orientation.

The task he, and they, set out is strikingly ambitious. Rhythmanalysis both puts forward a rhythmic ontology and the beginning of a methodology (Lyon 2018). Rhythm animates, there is 'nothing inert in the world' (Lefebvre [1992] 2004: 26), with the rhythmanalyst recognising representations (of many different disciplinary forms) by their 'curves, phases, periods and recurrences' (ibid.: 32). Seeing the world rhythmically is therefore an analytical process, something that I—in the sensing and thinking that I do, the data I draw on, and the words that I write—am actively engaged in undertaking and creating. In this book, I will not be following a set, step-by-step analytical method, and, as explained in chapter 2, I will not 'do' rhythmanalysis in an entirely conventional way. Rather, in taking inspiration from Lefebvre, and from others that have been similarly inspired, I will work with a rhythmic vocabulary, move across temporal and spatial scales, and deploy various tactics in order to attempt to capture the complexities of the rhythms and energies that the book is concerned with.

The product of one particular tactic will be found in the set of rhythm-energetic vignettes that are located in text boxes throughout the following chapters. These follow in their spirit, Lefebvre's evocative account of sitting in his apartment in Paris and observing the multiple interweaving rhythms of the city square below through the different phases and movements of the day. I will use this style of writing to evoke the multiple rhythms of different settings (at home, on the move, inside, outside) in which I have lingered and, in Lefebvre's terms, sought to (ibid.: 20) '*listen to the world . . . in which nothing is immobile*', also giving attention in various terms to the energies that are simultaneously in circulation.

ENERGY

So what about energy? Return again to the rhythms you thought about. They all involve energy, energy expenditures, energy flows or transformations, although some more obviously than others. The beating of your heart, the pulsing of your heart muscle, is an expenditure of the stores of energy in your body accumulated from the food that you eat; its generated movement, its rhythm is an expenditure of energy at a moment in time and in a particular space. The energy in the rhythm of a traffic light or washing machine is self-evident; the traffic light only pulses and the washing machine drum only circles if electricity provides the power and is used (and expended) to make those rhythmic movements, in those specific technologies. How about seasonal rhythms? That is a more abstract notion of a rhythm, but has at its foundation a cyclical annual variation in the solar energy received on part of the earth's surface, which then, in interaction with many other rhythms, shifts the weather conditions we experience and the ecologies that we see around us and live with. The seasons are about far more than energy, but they can be understood as energetic in their rhythmic returning manifestation and constitution.

We could work through the energy in many other examples of rhythms, and in chapter 3 there is much that will be explained in order to more precisely consider how energy and rhythm are related. For the moment, the general argument is that in thinking rhythmically we can also simultaneously think energetically, and therefore engage with how everyday life is run through with rhythmically structured and interconnecting flows of energy; both 'natural' and 'techno-energetic' to use a distinction that is deployed through the book. To grapple with energies (the plural being important) in such ubiquitous and varied forms (calories, electricity, solar radiation, heat, light), is to take on how physicists and others in various scientific fields understand energy through thermodynamics as a general concept; as the only 'universal currency', to use Smil's (2017: 1) phrase. It is also, I will argue in chapter 3, a way of making sense of energy being located in Lefebvre's definition of rhythm, in which space, time and energy interact, to quote 'everywhere where there is interaction between a place, a time and an expenditure of energy there is rhythm' (Lefebvre [1992] 2004: 15). My reasoning will require some justification as Lefebvre does not explain what meaning he is giving to energy, a word with multiple interpretations (Rupp 2013), but for me this opens up a productive space for exploring how to 'energise' rhythmanalysis through a thermodynamic interpretation.

To guard against misunderstanding even at this preliminary stage, my intention is not to reductively insist that rhythms can only be properly understood through their 'expenditure of energy'. As I will reiterate in chapter 3 and elsewhere in the book, rhythms are energetically constituted only in their *physical* manifestation. Rhythms have all sorts of quantities, qualities and meanings and can be understood and articulated through different knowledge systems, including those that see rhythm in a more figurative or symbolic sense (rhythms of thought or of artistic expression, for example). Rhythms can be imagined, anticipated and remembered and have consequences in taking such 'virtual' forms. Particular energies interacting in space and time can also be incidental to the rhythms that analysts are interested in understanding, therefore meriting little attention. However, for *my* purpose, recognising the energy in all (physical) rhythm is to establish a distinctive foothold in engaging with contemporary energy and climate concerns (climate change itself being a thermodynamic and rhythmic phenomenon), and for foregrounding the study of some particularly energetically significant rhythms over others, and some specifically energetic processes through which rhythms interact and interconnect.

ENERGY, RHYTHM AND CHANGE

Humans from their very origins have lived with and through the animations and dynamics of rhythms and energies, but as new forms of intentional energy conversion and making of energy services (from the warmth and illumination of wood fires, to the speed and excess of private jet planes) have been added into the mix, consequences have followed for how rhythms and energies are interrelated. Lefebvre captures something of these historical dynamics in this mechanical imagery of motion, power and hidden energy:

> society underwent something that recalls the great changes in communications. It saw cylinders, pistons and steam jets: it saw the machine start up, pull, work and move. Electric locomotives only present to the eye a big box that contains

> and conceals the machinery. One sees them start up, pull and move forward, but how? The electrical wire and the pole that runs alongside it say nothing about the energy that they transmit (Lefebvre [1992] 2004: 24).

Beyond such glimpses, there is no systematic analysis of how the interlacing of rhythmic and energetic change has come about and had consequence. Elsewhere there are histories of time-keeping, of time systems and, to some degree, of socio-rhythmic change (Adam 1990, Birth 2012, May and Thrift 2001, Zerubavel 1981, 1985), and there are detailed histories of energy and society relations (Nye 1990, 1999, Rosa et al. 1988, Smil 2017, Sørensen 2012), but no explicit attempt to integrate between them. In chapter 4, I begin to do this by unpacking how particular energy forms do valued 'work' in repeating, rhythmic patterns, and then tracing in a broad historical sweep how new patterns of techno-energetic expenditures have co-evolved with shifts in social, economic and technological rhythms. Light and heat provide the particular focus, as two pervasive energetic forms that have particularly significant histories, as well as distinctive rhythmic and thermodynamic characteristics.

Solar flows of light and heat that we experience as the cosmological rhythms of day, year and season are still the foundation for planetary life in all its diversity, but over long histories of innovation and then industrialisation, these have become locally supplemented and modified by the application of lighting and heating technologies deployed with particular purpose and intent. As illumination extended into the dark (in both space and time), the time-keeping role of solar rhythms diminished, and the rhythms of everyday activity took on different shapes. As thermal technologies emerged in varied basic and more complex forms, new rhythms of cooking and cooling foodstuffs became possible, new rhythms of indoor climates became increasingly decoupled from the outdoors, and lives became disciplined and transformed by powerful new rhythms of industrial production and radically accelerated mobility. It is increasingly hard for those in societies full of techno-energetic flows to imagine the beats and pulses of everyday life and economy without pools, beams and pulses of artificial light and without thermal energies enabling things to be done with anticipated speeds, intensities and patterns of routine repetition. They have become inbuilt, creating dependencies and social fragilities if the techno-energies and the polyrhythmia they run through are disrupted.

Such histories of rhythm-energetic change have generated both positive and harmful outcomes for the rhythms of everyday well-being and social cohesion, as well as for the metabolic rhythms of human bodies. How these have played out has much to do with processes of economic growth, development and accumulation, as politically driven and moulded, meaning that there are both deep material investments in the energetically powered rhythms of contemporary society, and beats locked together in sequences and synchronizations that resist change away from 'more of the same' (Edensor 2010b, Reid-Musson 2018). Furthermore, there is not just one story of rhythm-energetic change, rather a host of social and spatial differentiations, meaning that beneficial outcomes have been unevenly distributed, and the 'arrhythmic' harms done to human bodies, to social relations and globally to the rhythms of the climate have been readily marginalised and ignored. Accordingly, in concluding chapter 4, I argue that the interrelation between rhythms and energies in society is always dynamic and differentiated, but there is no 'silver bullet' that might rapidly snap future rhythm-energetic relations into a better shape and form.

POLYRHYTHMIC ENERGY SYSTEMS

Energy systems, as developed, invested in, profited from and argued over, have been absolutely integral to techno-energies becoming woven into the rhythms of 'modern' societies. Energy systems are multicomponent and dynamic things (Haarstad and Wanvik 2017, Bennett 2005), encompassing the use of energy to power technologies (such as kettles for boiling water) that are part of all sorts of practices (such as drinking tea); the distribution of energy to reach those end uses across infrastructures (such as the electricity network); the generation of particular energy flows (such as from power turbines); the accessing of energy resources (such as gas, or wind energy resources); and the waste products and damaging consequences that spin out of system functioning (such as carbon emissions). In chapter 5, the tools of rhythmanalysis are applied to conceptualising energy systems, and the rhythm-energetic flows they contain and enable, as complex polyrhythmic assemblages that in their carbon heavy forms are deeply implicated in the production of the climate crisis. Even coal, it is argued, an apparently inert fossilized mineral, has rhythm and rhythmic effects.

In a limited body of existing work, the rhythms of at least particular elements of energy and infrastructural systems have been recognised to have important qualities or implications (e.g., Jalas et al. 2016, Janzen 2017, Blue 2018, Walker 2014), but there is more to be drawn out, examined and systematically interrelated. A few examples, featuring in a more detailed way in chapter 5, which focuses specifically on big grid electricity systems, can begin to make this apparent.

Large-scale time-use data—generated by people filling out detailed diaries on what they are doing over a day—have been analysed, in a growing number of studies, to reveal temporal patterns in the demand for energy (e.g., Jalas 2005, Torriti 2014, 2017). Such studies follow the logic that energy use is embedded in activity, or to be more conceptually precise, in social practice (Shove and Walker 2014). So understanding the dynamics of energy use (over days, weeks, seasons) involves engaging with the rhythmic repetition, sequencing and synchronization of energy-using practices in everyday life; rhythms of cooking, showering, watching TV, using a computer and so on. Scaled up to a collective level, such studies can then tell us something about the dynamics of energy demand in the aggregate, as well as about the making of the rhythmic peaks of demand (a form of temporal synchronisation between rhythms), which for electricity grids are particularly crucial in terms of the maximum peak loads they have to carry day to day.

Keeping electricity supply and demand in balance is vital to sustaining a functioning grid infrastructure, and it is achieved through the careful management of relations between fluxes in demand and fluxes in supply. In chapter 5, I characterise this as a grand, ongoing orchestration of energetic beats and pulses, centred on achieving a harmonic 'isorhythmic' (meaning equality of rhythms) relation between demand and supply curves. Anticipation, as a product of rhythmic repetition, I argue, is key to this achievement. On the one hand, individual end-users of electricity proceed on the basis that their forthcoming future worlds will be similar to equivalent pasts. They therefore get on with the shared rhythms of every-day life anticipating that electricity will be available and technologies will start up as normal. At the same time, those governing electricity systems anticipate that the rhythms of everyday life at a societal level will play out as they have done before, rather than varying randomly, and also that the rhythms of natural processes will repeat in terms of how they directly and indirectly shape energy demand curves. Grid operators coordinate supply to meet demand based on these mutually supporting anticipations of rhythmic order. Rhythms of energy very much *in* society, a co-production of social rhythms and technologically made flows of electricity, fragmented only when grid failures and blackouts dramatically—or in some contexts more routinely—disrupt their interrelation (Nye 2010).

In these examples, we can see glimpses of relevant social, technological, organisational, environmental and cosmological rhythms (sometimes expressed with more specific labels), with their own patterns, shapes, dynamics and interactions. However, the rhythms that make up energy systems are not equal in their effects or status, and how they are managed expresses relations of power and political commitment. In chapter 5, I argue that the long-established big (carbon) power model of electricity grid development and operation views rhythms selectively, through a dominant lens that foregrounds circulations of carbon commodities to the ends of the rhythms that generate growth. Through this lens, energy demand rhythms are seen as an emergent outcome of economic and social progress, self-forming and a dominant force, not rhythms to be intervened in, other than to build them up. Demand will be what it will be and the rhythms of power generation will be tightly orchestrated to ensure that supply will always be in place, from the rhythms of resource extraction, transport and processing onwards. As a result, in electricity-dependent, electron-permeated societies, the rhythms of resource depletion, carbon emissions and waste-making have been long ignored and distanced, with implications that only now are beginning to fully unravel.

RHYTHMS IN LOW CARBON TRANSITION

It is clear, therefore, that the rhythms of energy systems are not just what they are but are actively made and managed. The need not to just sustain functionality, but to transition rhythms into new shapes, patterns and interrelations within electricity systems is the focus of chapter 6. Electricity systems as currently configured in much of the world have to change with considerable urgency and speed. A recent IPCC report (Intergovernmental Panel on Climate Change 2018) declares in stark terms, even in a carefully moderated summary for policy makers, how global warming will have a catalogue of damaging impacts when limited to a 1.5°C global mean surface temperature rise, and how much worse these will be if warming reaches 2°C. Exactly what this means and implies in terms of carbon targets, interventions and priorities is much debated but has intrinsically to involve reconfigurations of the polyrhythmia of incumbent electricity systems, with the carbon implication of electrons pulsing through infrastructural networks put resolutely in the foreground.

Some integral reconfigurations of rhythms are more obvious than others. The beats and pulses of renewable low carbon resources for generating electricity, such as wind and solar, are markedly different, and differently valued to those of coal and other fossil fuels. Instead of the closely coordinated rhythms of fuel extraction, transport and combustion, focused on the continuity of generation capacity at a few big power stations, the transition is to a future in which valued resource rhythms are widely distributed across a poly-energetic landscape. Rhythms of air movement, solar radiation and water movement coupled to fluctuating, discontinuous and intermittent cosmological-environmental rhythms that are variously predictable in their intensity and variation; and rhythms of electron flow that can be generated at macro and micro scales, powering both big grids and micro grids, or just a handful of locally connected technologies. The space and time of electricity generation is radically restructured, with low carbon rhythms valued over high carbon, and different possibilities opened up for who is in charge and who benefits.

Transitioning resource rhythms is only the start. Transferring the rhythms of hydrocarbon-powered mobility—fuelling, driving, refuelling—into the charging rhythms of electric vehicles where and when they are parked up introduces new peaks, troughs, intensities and unpredictabilities into the already complex task of orchestrating the rhythms of grid balance. Predictions of grid collapse and chaos are countered by visions of smart infrastructures and technologies tasked with making and sustaining a new isorhythmia of grid continuity, a version of what Coletta and Kitchin (2017) have termed algo*rhythmic* governance, extending into the active management of the timing of demand, searching out and incentivising flexibilities through forms of 'demand side response' (Torriti 2016). When the rhythms of battery storage at scale enter the mix, real-time sensitivities in relations between the rhythms of supply and demand begin to diminish, but the specific durations and speeds of battery charging and discharging come to newly matter. In these and other ways, the many rhythms that give the electricity system its polyrhythmic form start to beat together differently when removing carbon becomes a primary aim.

These are transitions already started and underway, but unevenly so, as there are many resistances from the anticipated and locked-together rhythms and norms of electricity grid systems and their management. Resistances, for example, that push back against attempts to intervene in the rhythms of demand to reorder how and when energy is used in line with smart rationalities. Resistances that also seek to hold onto old ways of making electricity, keeping existing rhythms of power (energetic, but also economic and political) in place, rather than opening up to a field of more diverse and distributed possibilities.

DE-ENERGISING RHYTHMS

Even if the new beats and pulses of de-carbonised electricity systems do strengthen and overturn old polyrhythmic orders, this will still be insufficient as a response to climate emergency. I argue in chapter 7 that there is a need to go further into our entanglement in rhythms and energies in order to address not only the carbon that is released, but also the techno-energetic expenditures and dependencies that continue to evolve and reproduce in high-energy contexts in the Global North. And to do so in ways that can build social and environmental justice within transition processes (Bickerstaff et al. 2013, Routledge et al. 2018), including in relation to who globally has been most responsible for making carbon emissions, and who inter- and intra-nationally still lacks the most basic techno-energisation of the rhythms of everyday life. Decarbonisation, in other words, needs to be accompanied by de-energisation where techno-energetic dependencies are most intense. Approached from a rhythmanalytic perspective, this poses a series of questions. How can we, in high-energy societies, live through social rhythms that are less entangled with and dependent on techno-energies? How can connections and dependencies be rebuilt with rhythm-energies *outside* of energy systems? How can better synchronizations be formed with times, temporalities and rhythms that have the capacity to counter patterns of fracture, dissonance and injustice in human and ecological life?

Seeking after de-energisation at scale is a daunting ambition, implying stripping techno-energy use out of very routine and sedimented rhythms of getting things done, extending interventions into areas of 'non-energy' policy (Royston et al. 2018) and instilling reorientations to how different types of rhythms and energies should be valued and prioritised. However, it is an ambition and an objective that commentators and activists, largely on the margins, have been arguing for and attempting to enact in 'disorderly' ways (Edensor 2010b: 2), if not explicitly through a rhythmic framing. There are therefore a number of principles that can be distilled from existing writing and action that have rhythm-energetic recalibrations, replacements and re-makings at their core.

In chapter 7, four such principles are identified and explored. *Deceleration* acting to slowing down the tempo of rhythmic repetitions and durations in mobility, but also in food systems, rhythms of consumption and product design; *reconnection* materialising forms of recoupling to bodily, ecological and environmental rhythms as a way of accessing energy services without techno-energies and managing energetic flows and interactions; *localisation* both in terms of spatially constraining the rhythms of movement and consumption, and attuning to the local poly-energetic landscape and its polyrhythmic patterning; and *sharing*, through forms of synchronization and sequencing that enable rhythms of reuse and recirculation, and economies of scale in energy terms from 'things being done together'. In following each of these de-energisation principles there is potential for realising co-benefits for bodily and ecological health and for socially progressive outcomes, but also tensions that can arise from applying them in blunt ways, without giving sufficient attention to difference and context.

A broad field of practical possibilities, extending far beyond the traditional domains of 'energy policy', flow out of these rhythm-oriented principles. To centre on some more concrete examples, in chapter 7 I engage with three sites of polyrhythmic formation—the body, the home and the city. These have some inherent 'nesting' in polyrhythmic terms, the rhythms of bodies being connected to those of homes and cities, and vice versa, and existing literature gives a starting point for conceptualising each of these sites in rhythmanalytic terms. Energetically they are also spaces in which multiple energies circulate, interact and have consequence, both 'internally' and in their interaction with other polyrhythmia. For example, bodies are both polyrhythmic and poly-energetic, as experienced through everyday bodily sustenance, activity and performance, the conversion of calories into muscular movement and ongoing immersion in rhythm-energies of light and heat. Activating the rhythm-energies of bodies to replace movement with engines with movement through the muscular beats of walking and cycling is an obvious example of deceleration (to some degree), reconnection and localisation, with co-benefits for health, conviviality and ecology. To take another example, the clock times of cities are consequential for their rhythms of circulation and activity—starting and finishing work or education, opening and closing of retail spaces and so on—providing degrees of coordination and common scheduling across the city populace. How the clock time of a city is set in its cartographic location within a nationally determined time regime is also consequential for its energy consumption, in terms of how well its aligned to the rhythms of the planets that make the daily and seasonal cycling of solar time and flows of light and heat. Better synchronization of solar and clock time reduces dependencies on techno-energies, an example of how polyrhythmic interaction across vastly different scales can be at the heart of de-energisation objectives.

These are only two of the examples to be engaged with in chapter 7, most being to some degree familiar or part of existing advocacy and practice. The objective in this sense is not to be strikingly innovative, but rather to show how diverse rhythmic changes can be integral to de-energisation, and how a rhythmanalytic integration across the varied sites in which techno-energies are deployed can make new connections and provide a foundation on which future work may build.

RHYTHM AND GEOGRAPHY

This outline of the building blocks of my interpretation and deployment of rhythmanalysis has foregrounded the importance of temporal structures and dynamics to how energy is in society and to how responses to the current climate emergency are being crafted and resisted. However, rhythms—and their expenditures of energy—are not only temporal, they are also spatialized phenomenon; they have and make geographies (Crang 2001, Edensor 2010a, May and Thrift 2001). Much of the rhythmanalytic literature has engaged with how rhythms are situated and give character and content to the dynamics of particular places and spaces. For Edensor (2010b: 3), a rhythmanalytic perspective 'avoids the conception of place as static', opening up instead how places are 'seething with emergent properties, but usually stabilised by regular patterns of flow that possess particular rhythmic qualities'. These counterpoints of stability and change will feature repeatedly through the book but resonate particularly in thinking about the rhythms of homes and cities in chapter 7. Similarly, it is clear from geographical, ethnographic and sociological work on energy and energy systems (e.g., Bradshaw 2010, Bridge et al. 2013, Calvert 2016, Castán Broto and Baker 2018, Huber 2015) that how energy flows through society—its amounts, intensities, forms and temporal patterning—is also a situated matter, subject to the particularities of history, culture, politics, infrastructure and environment, and thoroughly immersed in their making. There are universal laws of thermodynamics, and therefore of energetic exchanges and transformations, but how exactly energy is *in* society in all its diversity is far from the reach of any universal principle.

This means that geography matters to bringing energy and rhythm together, but in writing this book I have tried to be not too constrained to a particular geographical scope. Most of the research I have been engaged with has been empirically centred on the United Kingdom, so that geographical (rhythmic and energetic) context will feature more than others. But, I will be at pains to remember its particularity, and will attempt to point out significant dimensions of spatial, economic and cultural difference, without claiming to provide a properly global account or an analysis that is fully sensitive to place and situation. The rhythm-energetic vignettes that feature through the book are mine and can only reflect what and where I have experienced, but even so they are not only situated in my home setting.

READING THIS BOOK

I have written this book with various readers in mind; it has a multidisciplinary scope drawing from physics and ecology through to human geography, sociology and anthropology, and therefore I hope a multidisciplinary readership. While it is structured like most academic books with a linear logic—a structure that builds from chapter to chapter and introduces terms and ideas before their application—linear reading is relatively rare. With both different readers and patterns of reading in mind, I can suggest a few alternative paths. Readers interested primarily in rhythm might find particular value in chapter 2, which runs through core concepts in rhythmanalysis and adds a little in terms of categories of rhythm and rhythmic interrelation, proceeding then into chapter 3, which addresses rhythms in the conjunction of space, time *and* energy, before keeping track of the strategies of rhythmanalytical investigation used in chapters 4 through 7. Readers interested primarily in energy, might start with chapter 4 with its historical narrative, flipping back into chapter 3 to follow some of the lines of more conceptual argument, before then engaging with the analysis of rhythms in electricity systems, low carbon transition and the dynamics of de-energisation in chapters 5 through 7, depending on what is of most interest. If convinced of the value of thinking with rhythm, working through chapter 2 at some point would also be strongly recommended. Readers concerned primarily with climate change might have particular interest in the end of chapter 3 where I most directly engage with the rhythms of climate itself, before then tracking the implications of the historical narrative of rhythm-energetic change in chapter 4 for carbon emissions, and following the argument that transitioning rhythms is an integral part of carbon mitigation in chapter 6 and the need to do more than only decarbonisation in chapter 7. Other reading rhythms can of course be followed.

Chapter Two

Rhythm and Rhythmanalysis

Interpretation and Foundation

The decision to work with rhythmanalysis is because of what it has to offer to bringing energy and rhythm together, not because it is the only rhythm-based conceptual or methodological framework available (see discussion in Brighenti and Karrholm 2018, McCormack 2002). Across a rather scattered literature, some authors have worked with rhythm concepts within a particular domain, such as music or language (see examples in Desain and Windsor 2000), or have been concerned with rhythms as socially produced, time-structuring institutions (Zerubavel 1981, 1985, van den Broek et al. 2002), or as distinctly biological (Foster and Kreitzman 2004) or ecological (Cuvelier et al. 2014, Valtonen 2013) phenomena. Barbara Adam (1998, 1990) goes a considerable way towards conceptualising rhythm more completely, as part of a trans-disciplinary engagement with 'timescapes' and the multiple intersecting times of culture and the socio-physical environment. However, none of these examples of rhythm-thinking have the scope, breadth and creativity of the rhythmanalytical work of Lefebvre, writing alone and jointly with Régulier, exhibiting both extraordinary ambition and a rather frustrating open-endedness to their exploration of rhythmanalysis 'defined as a method and a theory' (Lefebvre [1992] 2004: 25).

The influence of rhythmanalysis on rhythm-thinking is evident from the proliferation of examples of its application and further development. As Lyon (2018: 35) comments, 'there is now a significant body of work which has taken it in different directions, in fields from health and education to cultural theory and sound art', also noting that geographers have recently figured prominently. However, for those new to rhythmanalysis, there is much to be introduced in terms of both ideas and vocabulary, and much to interpret, given the rather florid and sometimes disjointed style in which the original essay and associated papers are written. There are undoubtedly different understandings of rhythmanalysis, different ways of working with its methodological formulation, and different (in part disciplinary) orientations to the value and insights it can provide.

In this chapter, I therefore lay out how I read and draw inspiration from rhythmanalysis, aided by the insightful accounts of others (Chen 2017, Edensor 2010a, Elden 2004, Lyon 2018, Christiansen and Gebauer 2019b) and weaving in other lines of temporal and spatiotemporal thinking where it is helpful to do so. My reading and interpretation is a particular one. For example, in what follows I do not foreground the Marxist foundation of Lefebvre's work or delve very far into an alignment of rhythmanalysis with his major preceding texts on everyday life, although strands of both of these will figure later, particularly in chapters 3 and 4. I also do not lay out a conventional approach to doing rhythmanalysis as an embodied and sensory method, instead making clear my intent to be open to different forms of knowledge about rhythm, taking rhythmanalysis as a properly multidisciplinary endeavour. This will prove particularly important to bringing energy and rhythm together and working rhythmanalysis into energy system and low carbon concerns over the following chapters. Before heading in that direction, some foundations about rhythm need to be put in place.

RHYTHM AS REPETITION WITH DIFFERENCE

The word rhythm has its etymological roots in the Latin *rhythmus* (movement in time), which in turn comes from the Greek *rhythmos*, indicating 'measured flow or movement'. Thinking about rhythm and flow as movement is a good starting point for exploring the sense of animation that the term captures. That which is rhythmic, or part of a rhythm, cannot be resolutely static and unchanging. In some register, or in some respect, it has dynamism, however hidden that might be. As Lefebvre puts it, there is 'nothing inert in the world, no **things**' (Lefebvre [1992] 2004: 26, emphasis as in original). He repeatedly stresses the possibility of finding rhythm in even the most apparently inanimate objects, urging us to 'look harder and longer' (ibid.: 41). For example, in this extract Lefebvre and Régulier distinguish between the inert appearances of things and their inside or essential movement:

> We have to distinguish between appearances—which themselves are a reality—and what is actually inside these things. For example, they seem inert (this wooden table, this pencil etc.) and nonetheless they move, albeit only within the movements of the earth: they contain movements and energies; they change etc. (Lefebvre and Régulier [1985] 2004: 90).

And in another more ecologically inclusive paragraph:

> Now look around at this meadow, this garden, these trees and these houses. They give themselves, they offer themselves to your eyes as a simultaneity. Now up to a certain point, this simultaneity is mere appearance, surface or spectacle. Go deeper. Don't be afraid to disturb this surface, to set its limpidity in motion . . . You at once notice that every plant, every tree has a rhythm. And even several rhythms. Leaves, flowers, fruits and seeds. . . . Henceforth you will grasp every being, every entity and every body, both living and non-living 'symphonically' (ibid.: 89).

These two extracts exemplify the expansive inclusivity of theorisation about rhythm that rhythmanalysis offers. Maybe it is a little trite to observe that all things (tables, pencils) that are of the world are in motion, because they are on a rotating, spinning planet. But the point is made that what we immediately observe and sense (such as our apparent immobility while rhythmically circling at a speed of up to approximately 1,000 miles an hour) is not alone a reliable distinction between the inert and the dynamic. There is a 'surface', a 'simultaneity' an 'appearance' that is distracting, that occludes rhythm. It follows that rhythmanalysis is an active process of disturbing the surface, grasping and setting 'in motion', and, in so doing, making use of various ways of knowing diverse beings, bodies and entities. Rhythm, it is also made very clear, is thoroughly human and non-human, a characteristic of 'every entity'. Rhythmanalysis builds an account of rhythm as a general concept, of providing 'ideas and conclusions that are valid for all rhythms' (Lefebvre [1992] 2004: 15) regardless of where they might be revealed and the form they might take.[1]

It is not enough though to understand rhythm only as movement, flow or animation. Rhythm also demands repetition. As Lefebvre puts it 'no rhythm without repetition in time and in space, with reprises, without returns' (Lefebvre [1992] 2004: 16). Repetition is also a defining feature for other writers about rhythm. For example, Zerubavel (1981: 9) sees rhythmicity as recurrence, which can then be characterised in terms of rates of repetition and degrees of rigidity in temporal patterns. While recognising that some rhythms can have a more mechanical character than others, Lefebvre is insistent, however, that rhythm does not mean identical repetition, declaring that 'absolute repetition is only a fiction of logical and mathematical thought' (Lefebvre [1992] 2004: 17). Rather, 'there is no absolute repetition indefinitely', continuing to argue

1. It is relevant in this respect that the title of Lefebvre's individually authored essay was the expansive "Elements of Rhythmanalysis: An Introduction to the Understanding of Rhythms" (as translated from French). Its packaging into a book in English with the title *Rhythmanalysis: Space, Time and Everyday Life* gave it a narrower social scope and different framing.

that in examples such as ‘rites, ceremonies, fetes, rules, laws, there is always something new and unforeseen that introduces itself into the repetitive: difference’ (ibid.: 16). Others writing about rhythm concur. ‘Rhythm is not the same as metronomical correctness, it does not depend on regularity’ (Abel 2014: 105–6). Adam (1988: 210) finds ‘repetition with variation’ not only in social institutions but also in the rhythms of nature:[2]

> no two seasons are very alike, nor do the configurations of the planets repeat themselves, The earth’s rotation too is slightly irregular, relative to other timekeepers. All natural time sources are characterised by repetition with variation.

Such observations of difference, even if only minor variations from one repetition to the next, are important because of what this means for change, emergence and possibility. Repetition without difference implies stasis, whereas our individual, collective, ecological and planetary experience is one of change, and of futures (both immediate and longer term) that may appear to repeat what has passed, but not identically, and with always the possibility of sudden, radical departures from what has become normal and routine.[3] Chen (2017: 39) on this theme argues that ‘as “change” (renewal or rupture) grows out of repetition, the study of how change is brought about delineates rhythm as the fundamental experiential form’. And Young and Schuller (1988: 5), echoing earlier points about the stasis of outward appearance, argue that:

> Once time is recognised as a continuous flow—with the essential continuity being in the flow itself—what is being observed cannot be anything other than change, continuous change . . . whatever has pattern, structure, an appearance of the static, is made up of change wrapped within change.

However, the fact that the degree of variation or difference in repetition may be relatively small and incremental—and the pace of change relatively slow from moment to moment, day to day, year to year—means that rhythmic repetition can also provide for anticipation and order. A feeling of familiarity, that which has been experienced before, providing ‘a sense of orderliness’ and a ‘sort of temporal map’ (Zerubavel 1981: 12, 14). Richards (1925: 134, quoted in Young and Schuller 1988: 14) and writing about writing, captures how this gives rhythm a particular ‘texture’:

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2. Even the diurnal cycle over very long timescales is not constant. Hundreds of millions of years ago days used to be much shorter, in the Devonian period there were 410 days (rotations of the earth) per year. The duration of the rhythm of the day is still lengthening extremely gradually.

3. There are some obvious resonances with ways of talking about climate change here, in terms of shifting patterns of repeating weather extremes and ‘tipping points’. Discussion in chapter 3 will return to these. See also Oppermann, Walker and Brearley (2020) on applying rhythmanalysis to climatic change.

> Rhythm and its specialised form, meter, depend upon repetition and expectancy. Equally where what is expected recurs and where it fails, all rhythmical and metrical effects spring from anticipation. As a rule this anticipation is unconscious . . . the mind after reading a line or two of verse . . . prepares itself ahead for any one of a number of possible sequences at the same time negatively incapacitating itself for others . . . It is in terms of the variation in these twists that rhythm is to be described. . . . This texture of expectations, satisfactions, disappointments, surprisals, which the sequence of syllables brings about, is rhythm.

It follows that whilst rhythm with difference is indeed a way of conceptualising change, rhythmic repetition with only minimal or incrementally emerging difference is also a way of conceiving order and stability. As in the airport departure board in figure 2.1, there is a scheduled temporal order to when planes are departing that structures many other rhythms within and beyond the airport, but also discordances in enacting the daily timetable, which can shift over time as service reliability improves or deteriorates. The potential for severe disruption from storms, strikes and ash clouds is always also present. As Edensor (2010b: 3) puts it, despite their 'fluidity and dynamism . . . and the always immanent potential for disruption and destruction, many

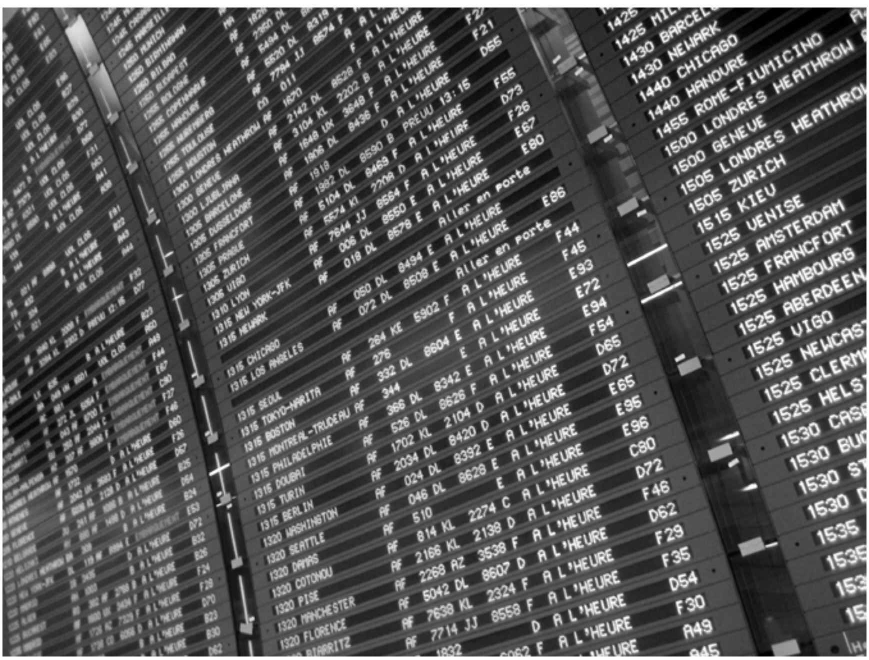

Figure 2.1. Flight departures as repetition with both order and difference.

Photo by Loj Pawel. www.flickr.com/photos/limaoscarjuliet/822938133. Reproduced under licence CC-BY-2.0

rhythms offer a consistency to place and landscape over time'. Parkes and Thrift (1980: 130) draw on Buttimer's notion of the dynamic 'lifeworld' to observe that there is an 'orderliness', which they see as 'rhythm in a loose sense', which means that 'the tacit assumption of a tomorrow . . . usually means a tomorrow of routine, planned or expected events'. Adam (2006: 121) also emphasises the practical use of being able to anticipate, predict and plan rhythmic repetitions:

> The ability to count, name, number and quantify change processes and repetitions facilitates predictability of the seemingly unpredictable. It allows for anticipation and planning. Thus, time reckoning, the getting to know temporal processes and rhythmic patterns, is also knowledge for practical use. It is know-how knowledge for the structuring, ordering, synchronizing and regulating of social life.

In chapter 5, we will consider the various practical ways in which rhythmic anticipation and expectation, held in tension with the possibility of disruption and shock, are central to the working and management of electricity infrastructures and our collective reliance on them. And in chapter 6, how low carbon transitions involve introducing rhythms that are more difficult to predict into energy systems at different scales. Accordingly, the relations between order and change will emerge as fundamental to low carbon futures.

PLURALITY, SCALE AND SIMILARITY

So far, we have worked through understanding rhythm in terms of movement, repetition and difference, and have done so through mobilising some quite diverse examples of rhythms, or rhythmic forms. The vignette in box 2.1, capturing my rhythmanalytic observation of an (energised) train journey, provides a further exemplification. Three further important positioning observations emerge from my reading of rhythmanalysis, serving in part to guard against an overly simplistic view of what constitutes rhythmic repetition.

First, as in the rhythmanalytic account of the train journey, rhythmic repetitions can be chaotic, disjointed and unstable, complex in their repetition rather than simple and uniform. Colloquially rhythm is readily equated with the beats of music and dance and the discipline of keeping to a strict, simple and regular pulse.[4] Rhythm is not so constrained, either in theory or in practice. Some of the most danceable music is in fact full of syncopation and subtle rhythmic differentiation: getting 'in the groove' means getting in with

4. Noted in conversations with friends when attempting an explanation of what I was writing.

BOX 2.1.
A Journey by Train

Crewe, Shrewsbury, Ludlow, Leominster, Hereford . . . A timetabled sequence of places and pauses, morning on morning. Irregular of course, a winter storm more viscous than before, trees that swayed and returned, some bent to breaking, a driver delayed, her usual arrival interrupted. Coffee, pastry, early ingestion, my body demanding a morning pattern, differently adjusted to circumstance and provision. The pulse quickens, caffeinated again. Two notes, a warning. The carriage moves faster. Low sun, long shadows, chaotic winter flashes of radiation over watery fields. A chatter of voices, journeys in synchrony for a distance, coordinated to arrive and depart, train and detrain through platforms, pavements, car parks. An infrastructure of shared movement, together for a while. A chatter of voices, planning, gossiping, lips moving, a learnt and practised rhythm of sound and meaning, sequences, overlaps, joke and chortle, request and explanation, beginning and ending. Two notes, a warning. Fingers tapping on buttons, in word patterns, data to networks, to networks and back again. Low sun, long shadows. Momentarily seen in a green field, a new life(cycle), in fresh woollen coat, an anxious body demanding feeding, relieving, repeating. One day grown and shorn, slaughtered, consumed, ended. The carriage moves faster, through landscapes, hills and escarpments, a slow, drawn-out symphony of geology, erosion, ecology, warming and freezing, season on season, earth around sun. Two notes. The city nears, the carriage slows. I depart and enter another mass, of urban pulses, beats and pathways.

the 'irregularities in rhythm, those elements which disrupt its strictness, repetitiveness and uniformity' (Abel 2014: 20).[5] Lefebvre notes how the rhythmanalyst observes 'curves, phases, periods and recurrences' (Lefebvre [1992] 2004: 32) of many different shapes and patterns, and 'how each rhythm has its own and specific measure: speed, frequency, consistency' (ibid.: 20). He continually emphasises plurality and diversity, even though at times also making rather simple dichotomous distinctions particularly between cyclical and linear patterns of repetition.

Second, it has already become clear that rhythmic repetitions can be revealed at very different temporal scales or resolutions. Lefebvre and Régulier ([1986] 2004: 96) 'insist on the relativity of rhythms' in that 'a rhythm is only slow or fast in relation to other rhythms with which it finds itself associated in a more or less vast unity'. For the Lefebvrian rhythmanalyst, the rhythms

5. There has been proposed 'a branch of study called "groovology" based on the notion of "participatory discrepancies"' (Abel 2014: 20).

of the body are often seen as an important reference point, providing a centre, or 'concrete site' (Chen 2017: 9), around which other rhythmic descriptions are oriented. In so doing though, it is important to not only reference the body's obvious and faster rhythmic character (breathing, walking), but also the dynamics of growth, maturing, ageing and decay, as a repeated rhythm across plural lives—human and non-human, including the newly born lambs observed from the train in box 2.1. In this passage, Lefebvre starts from the body but then stretches his view across other entities, scales and resolutions:

> The object is not inert; time is not set aside for the subject. It is only slow in relation to our time, to our body, the measure of rhythms. An apparently immobile object, the forest, moves in multiple ways: the combined movements of the soil, the earth, the sun. Or the movements of the molecules and atoms that compose it (the object, the forest) (Lefebvre [1992] 2004: 30).

In Young and Schuller's (1988: 14) terms, this means observing and revealing rhythm with a 'very wide-angle lens'; and also, we can add, sometimes with a microscope. Adam (1988: 215) contends that one of the strongest arguments for rhythm as a temporal concept is its capacity to capture cyclical biological and ecological processes across different temporal resolutions:

> Growing, healing and self-renewal cannot be grasped through structure or structural relations of time . . . They require a conceptual shift from structure to rhythm. They also necessitate and expansion of the time scale so that a multitude of feedback loops may be incorporated in the understanding.

Third, evidently the notion of repetition entails some finding of similarity between one repetition and another. The repeat needs to be in some way and degree similar to something that preceded it in order for it to be termed a repeat, rather than something else entirely. Sometimes that similarity may be found in a specific, located animated entity—the rhythm of the two note horns sounded by the train in box 2.1. Or it might be generalised across and between multiple similar and connected movements—such as the rhythms of tidal water movement, not only in my nearby Morecambe Bay in North West England (see box 3.1), but in and along other coastlines, bays and estuaries. Or it might take the form of a moving aggregated amalgam, a constellation of diverse entities and dynamics that can be conceived or measured as a whole—the rhythms of urban life in Manchester, the rhythms of European politics, or, as we will consider in chapter 5, the aggregate rhythms of the national electricity grid. There are many possibilities and no 'rules' here, only interpretations, emphasising again how working with rhythm is an active analytic process. As Chen (2017: 14) states, 'rhythms are not ready-made objects waiting to be examined'.

CATEGORIES OF RHYTHM

Much as it is important to be open to rhythmic diversity and multiplicity, it is also useful to have some simplifying categories or groupings to work with. I have already referred to rhythms in various descriptive and categorical terms, but without any systemization or discussion of the work that these categories are doing. It is useful to pause, therefore, to consider the categorisations of rhythm that are deployed in rhythmanalysis and worked with by other rhythm writers, and to settle on a scheme that I will follow in later chapters when focused on questions of rhythmic-energetic relations.

In the foundational rhythmanalysis writing, three broad categories of rhythm are mobilised: cosmological, corporeal and social.[6] These are described as 'levels' but can also be interpreted as sources or sites of rhythm-making (Chen 2017: 4).

> *Cosmological rhythms* are of the moving of the planets, the circling of the sun and rotation of the earth, experienced on the earth surface as the daily or diurnal cycle, the year or annual cycle and within that variously configured seasonal shifts. Also lunar rhythms from the cycling of the moon around the earth, as experienced in cyclical intensities of moonlight, the visual appearance of the moon and repeating tidal patterns.
>
> *Corporeal rhythms* are of the human body, as in the examples already mentioned of heart beat, pulse and breathing, but including also menstrual cycles and ovulation, the rhythms of the digestive system (and the repetitive inputs and outputs it needs), mechanisms of thermoregulation (shivering, sweating), blinking eyelids, the working of muscles to move limbs in walking, climbing and running, processes of growth, healing and ageing, and much more besides.
>
> *Social rhythms* are *all* those of the social world and extraordinarily diverse. They include rhythms variously made through mechanisms of clock time, timetabling and scheduling; all sorts of institutions, norms and conventions (cultural, religious, moral) that lay down the appropriate temporal patterning or time for undertaking particular activities or practices and the order in which they are sequenced; patterns of rhythmic synchronization between activities, people doing the same things in the same place and/or at the same time; and the explicit and implicit regulation and disciplining of rhythmical performances (at home, at work, on holiday, moving around). This incomplete characterisation evidently opens up a vast field of rhythmic forms and implicated devices, mechanisms and means of rhythm making.

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6. This scheme has parallels in Zerubavel's (1981) three forms of temporal order—physiotemporal (cosmological), biotemporal (corporeal but including other organisms) and sociotemporal (social).

This three-way scheme evidently does useful work in laying out the expansiveness with which rhythmanalysis finds rhythm in ‘every being, every entity’ (Lefebvre and Régulier [1985] 2004: 89). However, in combination the cosmological, corporeal and social are neither fully inclusive, nor sufficiently differentiated. For example, as already outlined, Lefebvre urges us to engage with the rhythms of stones, forest, insects, seeds and plants, which do not sit anywhere obviously in this scheme. The rhythms of waves in the sea that figure evocatively in Lefebvre and Régulier’s ([1986] 2004) discussion of the rhythms of Mediterranean cities, whilst connected to seasonal variations in solar radiation (and thus cosmological cycles), are subject to many other sources of rhythmic variation in the atmosphere and in interactions between air, water and landscape. The social category as already made clear is vastly differentiated, and it can be further broken down in many potential ways. It is also inhabited by technologies, devices and infrastructures that have some degree of rhythmic autonomy and agency—a dynamic vibrancy (Bennett 2010)—rather than being solely assignable to human intent.

In table 2.1, I therefore lay out a simple scheme that will be used in this book for grouping and talking about types of rhythms in terms of the broad domains in which they are located, giving examples of specific rhythms that will figure in later energy-focused discussion. These categories and subcategories do not simply align with ‘levels’ or ‘scales’, and it is certainly not a scheme that is all inclusive, or that neatly resolves overlaps, boundaries and definitional fuzziness. The social subcategories are especially imperfect, with particular instances of rhythms readily spanning across or falling in between. The terms I have chosen include descriptors already found in rhythmanalytical studies, or ones that work for me and my interest in energy and energy systems and all that they relate to.

Social and Natural Rhythms

Another broad categorical distinction that sometimes features in writing about rhythm is between social and natural rhythms, a bifurcation that cuts across the categorisation in table 2.1 and merits some examination due to its implications for engaging with the energetic constitution of rhythm in chapter 3. There is an extended philosophical and socio-theoretic debate on the society-nature, or nature-culture distinction (Castree 2005, Castree and Braun 2001, Whatmore 2002, Schatzki 2002). Within this swirl of discussion, Nigel Clark (2011), along with others, has powerfully critiqued positions seeing nature as always socialised. Tracing various lines of philosophical engagement with an ‘earth that does its own thing’, he asks:

Table 2.1. Rhythm Domains and Energy-related Examples

Rhythm Domain	*Description*	*Energy-related Examples*
Cosmological	Rhythms in and of the movements of planets and celestial bodies	Cycles of solar radiation; tidal movements
Corporeal	Rhythms in and of the human body	Muscular energy enabling bodily movement
Ecological	Rhythms in and of non-human organisms, and in combination in ecological systems	Growth and transformation of plants as energy conversion and storage
Environmental	Rhythms in the working of atmospheric, hydrological, marine, geomorphic and geological processes and their interactions	Movement of the air; flows of water in rivers
Social		
Cultural	Rhythms in cultural norms, conventions, institutions, rituals and festivals	Energy demand patterns at weekends, or at Christmas
Domestic	Rhythms that figure within and run through domestic settings	Use of appliances within the home
Organisational	Rhythms that figure within and run through organisational settings (private, public, community organisations etc.)	Opening hours, work-shifts that shape switching on of devices
Technological	Rhythms of specific technological devices, and of sets of interlinked devices	Thermostats, central heating controllers
Infrastructural	Rhythms within infrastructural systems (energy, water, communications, transport etc.)	Synchronization between supply and demand; energy storage
City	Rhythms that figure within and run through urban settings	Traffic flows

> can any approach that rebukes the exteriority or independence of nature, any theorem that restricts globality to an effect of human orchestration really get to grips with the full potential of the earth and cosmos? (ibid.: 25–26).

Following this line of argument, rhythm as a recurrent and ubiquitous spatiotemporal phenomenon cannot, for me, be considered purely social, as social practice (Moran 2015). Such a position is not tenable when faced with pre-human biological and ecological life, geological timescales, and the universe beyond our earthly existence. I am content that the earth was circling and rhythmic sequential repetitions of many forms were being made well before what we now call humans evolved from their forebears (Foster and Kreitzman 2004). And in line with more gloomy Anthropocene thinking, I can conceive that such rhythms will continue to exist long after humans have gone, if modified by our temporary destructive presence. It is certainly true that clock time, time systems of various forms, senses of time, time as 'kairos' (Szerszynski 2002) and so on are essentially human and social in their constitution. But there are cosmological, ecological and environmental rhythms that are not, that are beyond the human and indifferent to human existence (Castree 2014), and resolutely exterior to culture in their making and sustaining. As recent work on posthuman temporalities contends, there are non-human temporal structures in which human times then become entangled (Rossini and Toggweiler 2018).

Such a position resonates with the reasoning of Barbara Adam, who has done much expert navigation through different disciplinary perspectives on temporal questions, including problematizing the ways in which social and natural time are characterised and held as distinct. While she resolutely states 'from a temporal perspective there is no nature-culture duality' (Adam 1998: 13), her critique is less concerned with the idea that natural time, and natural rhythms, can have an independent non-human existence, than with rejecting any conception of the social world and social time as disconnected from and exterior to nature. This separation breaks down because humans are always part of and immersed in the times, temporalities and rhythms of nature, a nature that is already 'time-full' (Adam 1988: 219). As she argues:

> we, alongside most other living beings, are constituted by a multitude of circa-rhythms . . . this multitude of coordinated environmental and internal rhythms gives a dynamic structure to our lives that permeates every level and facet of our existence (Adam 1998: 13).

At the same, she powerfully argues that rhythmicity is not just a human construct, but rather something beyond that, more elemental, a physical reality and an inherent order in the world that plays into how humans make sense of it:

> Rhythmicity . . . is fundamental to nature and not an arbitrary retrospective grouping into episodes with beginnings and ends, which depended on the human capacity of reflection. For some periods and episodes such human structuring may well apply, but this very activity of the mind has a natural source in the rhythmicity of all phenomena that are regarded as living. Mind does not retrospectively impose the cycles of light and dark, the seasons, the tides, menstruation, the digestive system or attentiveness. These rhythmic cycles constitute living nature which includes humans and their capacity to experience rhythms and to order impressions, actions and thoughts in a rhythmical fashion (Adam 1990: 88–89).

To apprehend rhythm—to be a proto-rhythmanalyst—she argues is to be human in a rhythmically living nature. As we will see in the next chapter, she also has significant things to say about how energy exchanges and thermodynamics are intrinsic to this 'dynamic structure'.

POLYRHYTHMIA AND RHYTHMIC INTERRELATIONS

The argument that lives are permeated by multiple interacting rhythms brings us to perhaps the key concept of rhythmanalysis: polyrhythmia. This has been simmering in the discussion up to this point as rhythm in general, and different examples and categories of rhythms have been characterised, described and made sense of, but in largely singular and disconnected terms. However, rhythmic repetition does not occur, or have presence, in splendid pulsing isolation. Rhythms coexist and in their spatiotemporal patterning they interrelate: They flow, they vary and change in sets of complex relations with other diverse rhythms, in polyrhythmia. As Lefebvre and Régulier ([1985] 2004: 82) put it:

> Everyday life remains shot through and traversed by great cosmic and vital rhythms; day and night, the months and the seasons; and still more precisely biological rhythms. In the everyday this results in the perpetual interaction of these rhythms.

The 'remains' here echoes the critique of seeing rhythm in only social terms, while in another example there is a sense of how polyrhythmia emerge and evolve over time, in this case focusing on interactions between corporeal and social rhythms:

> The child, like the young animal, has its biological rhythms, which become basic but alter themselves (are altered): hunger, sleep, excretions. The latter in particular are altered by social life: the family, maternity. Educated rhythms are human, therefore social, rhythms (Lefebvre [1992] 2004: 52).

Other more descriptively rich terms for polyrhythmia are also used by Lefebvre and Régulier—including bundles, bouquets, garlands, ensembles and symphonies of rhythms—each to some degree interchangeable, but making particular aesthetic or normative associations. The notion of a symphony of rhythms[7] is also echoed in Adam's (1998: 13) account of the rhythmic interrelations that have structured human development:

7. There are also echoes in Buttimer (1976: 289) seeing 'lifeworld experience . . . as the orchestration of various time-space rhythms: those of physiological and cultural dimensions of life, those of different work styles and those of our physical functional environments'.

> A symphony of rhythms and temporalities thus underpins our development as humans and living organisms. It marks us as creatures of the earth, as beings that are constituted by a double temporality: rhythmically structured within and embedded in the rhythmic organisation of the cosmos.

Whilst polyrhythmia conceptualises the extended reach of rhythmic interactions from 'cosmos to corpuscle', it is also a way of looking inside, opening up the polyrhythmic interactions at work within apparently singular entities or organisms: 'the living—polyrhythmic—body is composed of diverse rhythms, each "part", each organ or function having its own, in perpetual interaction' (Lefebvre and Régulier [1985] 2004: 88). Although looking 'inside' does not mean losing hold of what is outside 'the surroundings of the body, the social just as much as the cosmic body, are equally bundles of rhythms' (ibid.: 88). It was emphasised above that revealing rhythmic animation is an active process, of moving across scales and resolutions, and the same applies to revealing polyrhythmia and polyrhythmic interrelations.

The term 'polyrhythmic assemblages' is developed by Chen (2017: 5), who interprets these as existing as a 'unity that encompasses a multiplicity', in a 'constellation of rhythmic entanglements' (see chapter 4 for further discussion). Certain sites and centres of rhythmic assemblages are readily identified she argues—such as a body—but 'there are also numerous sites of rhythmic activities which are unnamed' (ibid.), meaning that the sites of assemblage need to be actively constructed and distinguished by the rhythmanalyst. This reflects Lefebvre's description of rhythmanalysis as an act of polyrhythmic integration:

> the act of rhythmanalysis integrates these things – this wall, this table, these trees – in a dramatic becoming, in an ensemble full of meaning (Lefebvre [1992] 2004: 33).

While it is important to hold onto the idea of polyrhythmia as a 'spatio-temporal whole [globalite]' (Lefebvre and Régulier [1985] 2004: 89), although never isolated or forever stable, we can also ask what specific type of relations are made between rhythms that are constituent parts of an integrated ensemble, bundle or polyrhythmia. A substantial and diverse list of terms indicating some form of interrelation between rhythms can be found across the breadth of rhythmanalysis literature. Table 2.2 provides a non-exhaustive list of seventeen. This more than makes clear that we are in complex territory and that those working with rhythmanalysis are attempting to capture many different potential ways in which rhythms in general, or the specific rhythms and polyrhythmias they are concerned with, are interrelated.

Contrasting degrees of interaction between rhythms, and within polyrhythmia, are implicated in these different terms. Interweaving or braiding

Table 2.2. Terms Expressing Forms of Interrelation between Rhythms as Found in the Rhythmanalysis Literature

More Passive Interrelations	*More Active Interrelations*
Interwoven	Interacting
Braided	Intersecting
Entwined	Dominating
Synchronised	Entraining
Harmonised	Modifying
Contrapuntal	Disrupting
Interlocked	Clashing
Intermingled	Interfering
	Conflicting

imply a being together in a complex rhythmic form in which the strands stay intact and distinct; as in the chaotically interwoven bundles of electric cables in figure 2.2. Synchronicity similarly describes rhythms that fit together in terms of patterns of repetition, aligning side-by-side, but not necessarily acting on each other in so doing. Interacting, disrupting, modifying or clashing in contrast suggest that in coming together one or more rhythms are changed, in terms of characteristics such as their intensity, frequency or regularity, or broken into and more fundamentally disrupted. Entraining provides a way of describing how certain rhythms can act as 'zeitgeber' or 'pace makers' (Parkes and Thrift 1980: 19, Blue 2017), compelling others to fall into step,

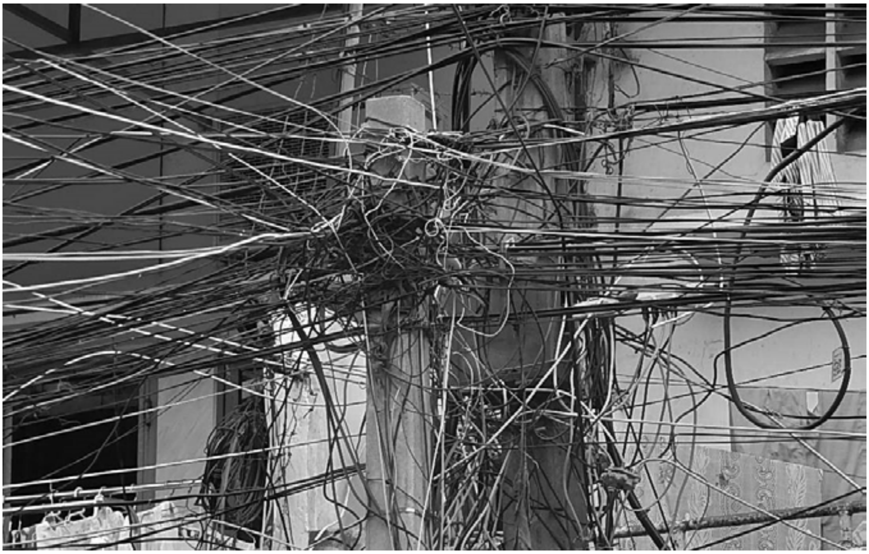

Figure 2.2. Interwoven electrical cabling.

Photo by Michael Coghlan. www.flickr.com/photos/mikecogh/12076503233. Reproduced under licence CC BY-SA 2.0

such that 'the stronger the entraining capacities of an element, the more its effects will ripple through a polyrhythmic ensemble as an accordion effect and the greater the rhythmic conformity that will ensue' (Schwanen et al. 2012: 2066). Evidently, it matters what form(s) of relation(s) are at work in polyrhythmia for the consequences, or outcomes that then follow, a theme picked up in the next section. In chapter 3, we will also consider how energy expenditures, flows and transformations have implications for the making and reproduction of rhythmic interrelations, and in many other places in the book we will focus on how particular rhythms interact and work together.

Questions of power are very relevant here, in that some rhythms can have a stronger agentive force within polyrhythmia, acting to structure the capacity for other rhythms to change independently, locking rhythms in place, obstructing them, or pushing them along particular trajectories. Lefebvre articulates in general terms how some rhythmic orders can come to dominate, and how devices such as timetables are inscribed with power, disciplining the rhythms of capitalist working practices. Capitalist rhythms are characterised as linear, regulated, mechanistic, encompassing 'the monotony of actions and of movements, imposed structures' (Lefebvre [1992] 2004: 18), clashing with and alienating people from the cyclical rhythms of bodies and nature. Others have further opened up the power-laden character of polyrhythmic interactions, extending beyond Lefebvre's rather patriarchal view of the everyday (Lyon 2018, Reid-Musson 2018). Edensor (2010b: 2), for example, emphasises how rhythmic power is instantiated in 'unreflexive, normative practices', but that these do not produce uniform outcomes so that 'some conform to dominant routines and timetables, while others reject such temporal structurings, or become sidelined because they are thought to be out of step'. Apparently overpowering and dominant rhythms are then not necessarily dominant for all, and the potential for resistance to generate newly differentiated flows of rhythm is always present. Such observations will be particularly important to discussion in chapter 7 on how low carbon trajectories in their more radical forms necessitate challenges to dominant rhythms, and the breaking apart of tightly coupled energetic-rhythmic relations.

EURHYTHMIA, ARRHYTHMIA, ISORHYTHMIA AND DYSRHYTHMIA

A final set of concepts to introduce from the rhythmanalytic lexicon are those that capture the accumulative character of interconnections and relations within polyrhythmia. Lefebvre characterises two key states of rhythmic interrelation, eurhythmia and arrhythmia. The former is when 'rhythms unite with one another in the state of health, in normal (which is to say normed!) everydayness' (Lefebvre [1992] 2004: 25). In the human body he likens this to a garland or a bouquet of rhythms, 'different, but in tune' (ibid.), in an equilibrium condition. A particular form of eurhythmia is also identified, that of an isorhythmia in which there is a perfect 'equality of rhythms' illustrated by the 'tight coordination of rhythms under the direction of the conductor's baton' (ibid.: 68). Other isorhythmic examples figuring in the literature include marathon organising (Edensor and Larsen 2018) and the rhythmic unity achieved between horse and rider (Evans and Franklin 2010). Later will we also encounter the balancing of the electricity grid as a carefully managed isorhythmic achievement.

Arrhythmia, in contrast, is a state of disunity or discordance in which there is a pathological condition, rhythms beating against or fighting with each other and failing to reach a harmony or equilibrium. In arrhythmia 'rhythms break apart, alter and bypass synchronization' (Lefebvre [1992] 2004: 78), with intervention then needed to 'strengthen or re-establish eurhythmia' (ibid.: 79) if stability is to be resumed. For Chen (2017), arrhythmia is a way of conceptualising how social relationships become rhythmically interrupted, with established rhythmic alliances refusing each other, breaking their synchronisation, leading potentially to crisis and social rupture. While most frequently referencing the ensemble of bodily rhythms, Lefebvre also refers to periods of movement towards arrhythmia and moments of severe rhythmic discordance or crisis in other rhythmic entities, including organisations, households, towns and economies. Others have explored arrhythmia, for example, in relation to various forms of mobility (Edensor 2013), the intervention of weather or traffic accidents into children's everyday travel (Kullman and Palludan 2011), natural disasters and action sports (Thorpe 2015) and instabilities in migrant workers' employment (Marcu 2017).

While eurhythmia and arrhythmia are often characterised as distinct polyrhythmic states, Blue (2017: 944) sees them as dynamically coexisting, 'every eurhythmia always already contains arrhythmia, pauses, breaks and off-beats', with some eurhythmia able to be resilient and absorb discordances, whilst others break down as arrhythmia reproduce and weaken connections, in time potentially building new eurhythmia. In Oppermann, Walker and Brearley (2020), we introduced the term dysrhythmic to capture how eurhythmia can readily contain disharmonies and discordant elements, with the prefix 'dys' indicating something 'bad', as used in medicine to indicate a rhythmic abnormality. There can accordingly be (by some metric) 'bad' rhythms that do not necessarily have overtly chaotic consequences, and in fact may play a eurhythmic role, enabling 'ideal' systems to continue operation where they otherwise might fall apart. Such conceptual vocabulary will figure later in discussing blackouts and power outages within electricity systems, as well as the rhythmic recalibrations and interruptions caused by carbon emissions to climatic systems.

MULTIDISCIPLINARY RHYTHMANALYSIS

Whilst there is much that is conceptual to engage with, rhythmanalysis is both 'a method and a theory' (Lefebvre [1992] 2004: 25), raising questions therefore about how it is to be enacted and knowledge about rhythm is to be produced and worked with. In this respect, it has become the norm for rhythmanalysis to be understood as 'an embodied research practice' (Lyon 2018: 45), one that involves some form of engagement with rhythms through and with the body and sensing capacities of the researcher. This stems from some of Lefebvre's own very lyrical writing about rhythms as experienced and encountered, and statements such as 'to grasp a rhythm, it is necessary to have been ***grasped*** by it; one must *let oneself* go, give oneself over, abandon oneself to its duration' (Lefebvre [1992] 2004: 37; emphasis as in original).

However, in looking across how researchers have developed embodied methodologies, Lyon (2018: 45) stresses the diversity of approaches, strategies and practices that have been deployed. These include active participation in which the body is used directly as 'auto ethnographic and metronomic device for registering rhythm a corporeal scale' (through sight, touch, hearing, sensation, emotion and smell), but also narrative and semi-structured interviews with those engaged in particular activities, diary-writing and audio and visual recordings. Others have drawn primarily on historical archival sources (Chen 2017) and on quantitative data (DeLyser and Sui 2013), for example mapping data on the movement of people through and between city spaces over time (Mulicek et al. 2016, Osman and Mulicek 2017). Lyon (2018: 103) concludes that rhythmanalysis is 'not a single off-the-shelf method that can be utilized in a technical manner', seeing it as an inventive approach that 'can bring together a versatile set of techniques'. Chen (2017: 51) similarly sees rhythmanalysis as foremost a heuristic method 'in which there are no set rules which affix how [it] may be exercised'.

Whilst, therefore, applications of rhythmanalysis have already extended methodologically beyond the sensory and ethnographic, there are very few examples that have taken up the epistemological pluralism its originators intended. Lefebvre and Régulier ([1985] 2004: 91) are clear that to match up to the scope of the rhythmanalytic ambition, the practice of rhythmanalysis needs to be open to 'both our senses and the instruments we have at our disposal', spelling out the 'transdisciplinarity' this implies:

> This analysis of rhythms in all their magnitude 'from particles to galaxies' has a transdisciplinary character. It gives itself the objective, amongst others, of separating as little as possible the scientific from the poetic (Lefebvre and Régulier [1986] 2004: 94).

Lefebvre later reiterated (assuming that rhythmanalysts would, like him, be male):

> Just as he borrows and receives from his whole body and all his senses, so he receives data from all the sciences: psychology, sociology, ethnography, biology and even physics and mathematics. He must recognise **representations** by their curves, phases, periods and recurrences. In relation to the instruments with which specialists supply him, he pursues an interdisciplinary approach (Lefebvre [1992] 2004: 32) [emphasis as in original].

Studies that have sought to take on this multidisciplinary potential, moving between the social, physical and natural sciences, include Jones' (2011) work on tidal rhythms, Oppermann et al.'s (2020) drawing together of ethnographic, interview-based and thermal physiological research, and my own account, working with atmospheric scientist colleagues, of the polyrhythms of urban air pollution (Walker et al. 2020). Along similar lines, through the rest of this book I will not be following a narrowly defined epistemology, or specific methodological design. Rather, I will be opening up the relationship between energy and rhythm and analysing the rhythmic dimensions of energy systems and low carbon transformations, through drawing on many different ways of knowing and understanding phenomena. These will include physicists' understanding of energy and energetic exchanges through thermodynamics, sociological understandings of social practice, statistical analysis of time-use diaries, ethnographic studies of everyday urban and rural life, natural scientific understandings of the making of the rhythms of waves, wind, water flow and temperature, interview-based accounts of the work of particular actors in energy management, and much more besides. This does not mean that all of these varied knowledge forms and the insights they generate can somehow be seamlessly integrated together, far from it. But in the pursuit of a synthetic account of energy and rhythm—which is both expansive in how energy and rhythm are to be understood, and specific in its grappling with the challenges of energy system transformation—there is much to be contributed from different knowledge-making traditions.

In boxed vignettes, such as in the account of the train journey in box 2.1 and others to be found throughout this book, I seek to connect with the embodied, being present and 'in the moment' tradition of rhythmanalytic investigation, taking the opportunity to be still, to sense, observe and 'give oneself over' to the rhythms of different settings and durations. In these moments, I am seeking to sense, think and then write about the rhythmic and the energetic together in order (hopefully) to capture something of what it is to be an energetic-rhythmic being, in a rhythmic-energetic world. But by itself such a mode of representation is insufficient to the task of engaging with what is a 'multiplex aspect of earthly existence' (Adam 1998: 9), or to connecting with more practical questions of energy-society relations and energy system transformation.

SOME REPETITIONS

This chapter has laid out some important groundwork for what is to come. I have explained how repetition, anticipation, stability, disruption and change are all part of seeing the world, and its vast constellations of 'movement in time', through rhythm. I have considered how rhythmanalysis seeks to connect across diverse sites, domains and scales, from the cosmological to the corporeal, and how key rhythmanalytic concepts capture forms of polyrhythmic interaction between rhythms, both more harmonic and more discordant and conflictual. I have introduced a categorical scheme to apply across this diversity of rhythmic forms and argued that we can meaningfully identify rhythms that are essentially non-human and natural in their making and repetition, as well as those that are socially made (across a very broad field), but always in some way entangled with natural and biological rhythms. Along the way I have stressed the expansive scope of Lefebvre and Régulier's rhythmanalytic view, their incessant urge to look harder and longer to find rhythms of a multitude of forms (using both the wide-angled lens and the microscope), and their openness to a strong epistemological pluralism. In providing this account of rhythm and rhythmanalysis, I have hopefully made clear my particular interpretations and the inspiration I take from the existing body of rhythmanalytic and related work. The next step is, though, one little taken to date by those working with an ontology of rhythm. That being to return to how the rhythm in rhythmanalysis is defined, in order to (re)discover and scrutinise its combined spatial, temporal *and* energetic foundation.

Chapter Three

Energetic Rhythms

Thermodynamics and Rhythmanalysis

Energy is not an entirely straightforward 'thing'. As a word and signifier, it is used in varied ways (Rupp 2013), and there are distinctions in meaning that are important to how I am going to bring energy and rhythm together and significant for the status of energy in rhythmanalysis. As made clear in chapter 1, a key initial orientation is to let go of the association of energy *only* with what is switched on, fired up, supplied and paid for; in other words, only with energy as a resource that is purposefully provided, managed and used through sociotechnical energy systems—what I refer to as 'techno-energies'. Energy is evidently central to the point of these systems existing, but it is not only located within their pipes, wires, tanks, stockpiles and end-use technologies. Energy was flowing, functional and fundamental long before any such technologically enabled flows and stores existed, in even their most basic forms, and is located far beyond their material form and scope. Even electricity, Anusas and Ingold (2015: 548) note, 'has been active throughout the eons of organic evolution . . . on such an evolutionary time-scale, the period of electricity's incarceration within the grid amounts to no more than the blink of an eye'. Remembering, again, that energy is more than resources, commodities, infrastructures and devices, I will argue, is very necessary in making progress in the face of the current climate crisis.

Just as rhythm, in its essential definition, is radically ubiquitous in space and time, so is energy. Energy expenditures can be found in very many forms—a burst of sound, the movement of a wave, the tick of a clock, the motion of a muscle, a blast of wind, the growth of a tree, the flash of a text message—and in such instances it is at the foundation of much of what we can think of as rhythmic repetition. This is a physical and directly tangible understanding of rhythm, which as discussed in chapter 2 is not the only way to approach or make use of it as a concept. But being material about rhythm is important to drawing out the practical implications of finding rhythms in energy systems, and relating the techno-energies that flow through energy systems to the infinitely more substantial flows of energy that are external to them. This interrelation is crucial to the discussion across chapters 5, 6 and 7, and in chapter 4 we will work through a set of rhythmic relationships that exist between energies that are internal to, converted and moved within energy systems, and energies that are external to them. Light, for example, evidently exists in both 'natural' and 'artificial' techno-energetic forms, and there are some strongly rhythmic relationships between them.

To begin our navigation through some quite complex terrain, including some brief forays into thermodynamics (which some may find unfamiliar, others very routine), we will start in the next section by returning to rhythmanalysis and the largely overlooked position of energy within its ontological foundation.

'ENERGY' IN RHYTHMANALYSIS

As outlined in chapter 1, Lefebvre (writing alone and with Régulier) questioned and deliberated the fundamental essence of rhythm at some length. Rhythm is repetition of some form, but is there something more to be captured and defined? In this extract Lefebvre considers a number of possibilities:

> Rhythm is easily grasped whenever the body makes a sign: but it is conceived with difficulty. Why? It is neither substance, nor a matter, nor a thing. . . . The concept implies something more. What? Perhaps energy, a highly general concept. An energy is employed, unfolds in a time and a space (a space-time). Isn't all expenditure of energy accomplished in accordance with a rhythm? (Lefebvre [1992] 2004: 74).

Here, therefore, energy comes into play, but not definitively so. Elsewhere it sits more robustly centre stage:

> everywhere where there is interaction between a place, a time and an expenditure of energy there is rhythm (ibid.: 15).

> that which connects space, time and the energies that unfold here and there, namely rhythms (ibid.: 18).

> Time-space-energy. These three terms are necessary for describing and analysing cosmological reality. No single one suffices, nor any single term-to-term opposition. Energy animates, reconnects, renders time and space conflictual (ibid.: 70).

While there is some conceptual flexing between these statements,[1] it is the repeated holding of energy, space and time in relation to each other that is significant. Rhythms, it is being asserted, are energetic as well as spatiotemporal. However, there is little within the set of rhythmanalytic writings that fills out what it means to 'expend', 'employ' or 'unfold' energy, or to explicate in what exact terms energy is constitutive of rhythm. Energy, Lefebvre notes, is 'a highly general concept' but little more. In his evocative description of the rhythms of Paris (see more in chapter 7), we encounter energised traffic and lights of various forms, and elsewhere he refers to the energy hidden within the machines of modernity, but this technologized understanding of energy does not match up to the scope of the space-time-energy conjunction that defines rhythm in all its diverse forms.

Other authors writing about or working with rhythmanalysis have offered little clarification. If the triadic definition of rhythm is mentioned at all, it is simply stated rather than reflected on, or rather weakly engaged with. For example, Christiansen and Gebauer (2019a: 6) follow a reference to the time-space-energy triad with the illustration of 'how time feels slower in an airport waiting for a connecting flight, because we have no energy to spend'. Brighenti and Karrholm (2018: 2) go a little further. As part of a discussion extending rhythmanalysis into an enlarged science of territories, they interpret energetic expenditures as 'investments in social life, as meaning and as concerted action', taking up a commonplace way in which people and collectives are seen to commit energy into activity. Some categories of rhythms can certainly be understood in those terms, but they remain limited to the broadly social (and to bodily entanglement in social processes), and to rhythms that have some degree of intent in their making. Given all that was spelt out in the last chapter about the scale and scope of rhythmanalytic conceptualisation and ambition—'from corpuscles to galaxies' (Lefebvre [1992] 2004: 51)—understanding the 'energy' in rhythm only within these limits is insufficient.

Energy as Physical

A more robustly applicable understanding of energy can be found in physics, and there is evidence that Lefebvre had been drawing physics thinking

1. A significant ontological difference could be implied by the use of the term 'connects' in the second of these statements, suggesting that rhythm has a causal status, when compared to the first which positions rhythm as emerging from space-time-energy interactions. The third statement is distinct again in positioning energy as having the agentive role of animating and (re)connecting, and it is not entirely clear why this necessarily generates time-space conflicts.

into his writing for some time.[2] In Lefebvre and Régulier's ([1985] 2004: 90) discussion of the rhythmanalytical project, there are several references to physicists' understandings of space-time relations and 'our place in the space-time of the universe'. In Lefebvre's ([1974] 1991: 12) *The Production of Space*, from nearly ten years earlier, he engages with energy, space and time as the 'concepts defined in terms of the broadest generality and the great scientific . . . abstraction'. Noting in particular, the steady state cosmology of the astronomer and physicist Fred Hoyle, he discusses how energy, space and time are necessarily held together in defining the 'substance' of the material world:

> When we evoke 'energy' we must immediately note that it has to be deployed within a space. When we evoke 'space' we must immediately indicate what occupies that space and how it does so: the deployment of energy in relation to 'points' and within a time frame. When we evoke 'time' we must immediately say what it is that moves or changes therein. Space considered in isolation is an empty abstraction: likewise energy [ibid.: 12].

Later in the same text he moves between physics and biology to outline a more localised physical interpretation of energetic relations between organisms and their surroundings:

> From a dynamic standpoint, the living organism may be defined as an apparatus which, by a variety of means, captures energies active in its vicinity. It absorbs heat, performs respiration, nourishes itself and so on (ibid.: 176).

This then builds into a discussion of how energy is accumulated such that a stock is retained ready to be expended by an organism when needed, with that release always giving rise 'to an effect, to damage, to a change in reality' (ibid.: 177). The differences between more substantial muscular expenditures of energy by human and non-human organisms and the 'minimal' energy enrolled into the flows of sensory data and information processing in the brain are also noted; both, it is argued, being productive and having consequence. He then notes:

> Productive energy implies the living organism's relationship with itself, and in this connection takes the form of reproductive energy; as such it is characterized by repetition—repetition in the division and multiplication of cells, in actions, in reflexes (ibid.: 179).

2. Harvey notes that Lefebvre and his contemporaries 'refused to see philosophy as an isolated or wholly specialized activity. They thought it important not only to grapple with the progress of science (the theory of relativity, for example) but also with the progress of everyday life' (Harvey 1991 [1974]: 426).

From these extracts, and others scattered throughout the *The Production of Space*, we can build a clear set of connections into rhythmanalysis. Energy-thinking is engaged with at scales from cosmological through to cellular, in planetary as well as muscular movements. Energy expenditures are productive, they make movement and change, and they exhibit repetition. Rhythmanalysis in this light aligns with on a foundation of energy-thinking built from physics, biology and ecology that Lefebvre had already mobilised in earlier work.

Some caution, however, is needed in interpreting Lefebvre's engagement with energy as a physical phenomenon. There is a long tradition of social theorists and philosophers looking to the sciences, and physics in particular, in order to draw analogies between physical and social worlds, or between scientific and social-scientific theorisation (Sorokin 1928). At times, it appears that Lefebvre is following a similar line, either in developing his own reasoning or engaging with the ideas of others. He may therefore be less concerned with energy and energetic relations as physical phenomena per se (and their status in rhythm) than with what they may, by analogy, reveal about society and social relations. Indeed, at one point in *The Production of Space* he makes a direct comparison and distinction between 'social' and 'material' energies and their respective tendencies 'like energy in a material form such as a molecule or an atom, social energy is both directed and dispersed, it becomes concentrated in a certain place, yet continues to act upon the sphere outside' (Lefebvre [1974] 1991: 192). However, he does not only find value and significance in social energies, and he guards against interpreting them in equivalent terms to the physical:

> There is no reason to assume an isomorphism between social energies and physical energies or between 'human' and physical fields of force. This is one form of reductionism among others which I shall have occasion explicitly to reject. All the same human organisms, like living organisms human or extra-human, cannot be conceived of independently of the universe (or of the world); nor may cosmology, which cannot annex knowledge of those societies, leave them out of its picture altogether (ibid.: 13–14).

This argument is given further exemplification by Lefebvre and Régulier in their discussion of light (a specific energy form considered further in chapter 4) as having interlaced subjective and objective aspects, neither of which are exhaustive:

> Consider light, for example. We perceive it, not as a waveform, carrying particles, but as something wondrous that transforms things, as the illumination of objects, a play on the surface of all that exists. This subjective aspect nevertheless includes an objectivity that has enabled us to arrive, after centuries of research and calculations, at the physical reality underlying the phenomena

> of light, yet without exhaustively defining that reality (Lefebvre and Régulier [1985] 2004: 91).

My interpretation therefore of the energy in rhythm is that its conjunction with space and time can be understood, initially at least, in physical and thermodynamic terms. For my purposes, I do not find value in engaging with the physical in order to draw analogies for the social because in what follows I am very much concerned with how energy systems capture, direct, manage and deploy energy flows in the various rhythmically structured forms they can take.

Energetic Theories and Lively Materials

Following a physical and thermodynamic understanding of energy and bringing this into engagement with other modes of thinking and theorising is not to step into uncharted territory. Various social scientific theorists have worked with energy in these terms, although none with rhythm simultaneously in focus. Energetic theories of society have been proposed, relating the progress of human civilization to the scale, efficiency, excesses and limits of energy flows understood in thermodynamic terms (Rosa and Machlis 1983, White 1943, Soddy 1912, Cottrell 1955, Stoekl 2007), generally with problematic deterministic conclusions. Ecological economists, political economist, geographers and anthropologists have provided critical analyses of the economic, social and environmental implications of the (capitalist) capture and direction of energetic flows, and of the first and second laws of thermodynamics (e.g., Adams 1975, Trawick and Hornborg 2015, Martinez-Alier 1987, Daggett 2019), including lines of Marxist historical materialist critique (Huber 2009, Bellamy and Diamant 2018).

In science and technology studies, Isabelle Stengers stands out as engaging at length with thermodynamic thinking and principles (Stengers 2010, Prigogine and Stengers 1985). Barry (2015), in discussing Stengers' work, argues that the 'material turn' in social theory has as yet underplayed how materials have an 'energetic liveliness', alluding to Bennett's (2010: 10) vibrant or lively materialism and her theorisation of 'a materiality that is much force as entity, as much energy as matter' (see also Cederlöf 2019). Barry argues that there is much more to be drawn out of natural scientific accounts of energy, including its essentially relational conception. Bryant (2014) is even clearer that there is more to be done in social theoretic engagement with thermodynamics, asking:

> How is it that philosophy and theory seem to so persistently forget work and energy as fundamental dimension of being? How is it that these two dimensions of being aren't basic concepts involved in every discussion of every issue?

My analytical concern for how energy and rhythm interrelate is very much in alignment with such questioning. However, it is important to be clear that a *solely* thermodynamic reading of rhythm and of interactions within polyrhythmia is not intended or sufficient. There is value in bringing thermodynamic knowledge into play, but selectively so and *only* alongside much else, including other diverse forms of knowledge. Just as it is limiting to see rhythm only as a physically sensible and measurable phenomenon, there is a gross reductionism that might be assumed from working with energy in physical terms[3] (Debeir et al. 1991). If all rhythms can be thought of as energetic expenditures, then a narrowing commensuration can follow that renders all rhythms as somehow equivalent and comparable. That is not my goal and it will be important to hold onto how different energetic flows and expenditures have extraordinarily diverse qualities, purposes, values and implications, including those that are ethical and political in content. As Soni (2017: 133) argues in relation to the principle of conservation of energy:

> the problem is not the principle which has extraordinary descriptive power. The problem would be to think that the principle is sufficient to discriminate between preferable and undesirable, better and worse forms of energy.

In what follows across the rest of this book, I therefore move in and out from thermodynamics, and continually engage with energy and rhythm in other terms; as phenomena that have other characteristics and other ways of mattering to how our relationships with energy systems have come to be and now demand transformation. With these important caveats in mind, the next step is to consider a little more thoroughly how energy is understood in the physical and biological sciences.

ENERGY IN THERMODYNAMICS

Thermodynamics is a branch of physical science that deals with the relations between heat and other forms of energy (such as electrical, mechanical or chemical energy), and, by extension, the relationships between all forms of energy. The energy that thermodynamics conceptualises is a product of reasoning and measurement, a way of making sense of phenomena and explaining physical processes and behaviours. Energy in these terms is an abstraction with a scope of explanation and application to entities, processes and interrelations that function far beyond the human, into the totality of

3. White (1943: 335) provides an example: 'Culture is a kind of behaviour. And behaviour whether of man, mule, plant, comment or molecule may be treated as a manifestation of energy'.

'nature' and the physical world. Lindsay (1971: 383) argues in suitably grand and declarative terms that:

> by common consent it is the physical construct which has proved to contain the greatest meaning for all aspects of human life . . . The interpretation of phenomena in terms of the transfer of energy from one place to another and the transformation of energy from one form to another is the most powerful single tool in human understanding of experience.

Illich (1983 [2009]) notes that before entering into the physicist's lexicon in the nineteenth century, energy had various meanings associated with a sense of liveliness or forcefulness, but step-by-step it became the generally accepted technical term for conceiving of an abstract 'force' at the foundation of the universe. Energy can take different forms (see the set of examples in table 3.1) and can convert from one form to another, but under the first law of thermodynamics it can never be destroyed. Lohmann and Hildyard (2014) argue that this momentous arrival at a universal currency for commensurating between extraordinarily diverse phenomena was not simply a matter of disinterested scientific advancement, but closely aligned to the drive towards energised mechanisation through fossil fuel use and the acceleration of capital accumulation. Illich (1983 [2009]) similarly comments that it was not a coincidence that energy became defined as the 'ability to do work' just at the time when work was being appropriated into capitalist structures as defining the value of a labour force. Daggett (2019: 5) goes further in characterising 'thermodynamics as an imperial science' in which:

> the Western epistemology of energy attached fuel systems to the gospel of labour and its veneration of productivity. The energy–work nexus was so friendly to the spread of fossil capital, so conducive to concealing its violence, and so minutely sutured as to leave little trace of its contingent pairing.

Such critiques will figure later on, but they centre on a history of ideas and their immersion in political economy that do not intrinsically undermine putting thermodynamic knowledge to other ends (see also Cederlöf 2019).

Table 3.1. Categories of Energy and Examples of Familiar Energy Forms

Categories of Energy	*Examples*
Mechanical energy (kinetic)	Working machines or muscles, wind, flowing water
Electrical energy	Lightning, neurological current, technologically generated electricity
Thermal Energy	Solar heat, fire, heated water
Electromagnetic radiation	Light, microwaves, x-rays
Chemical energy	Food, coal, biomass

Importantly, the notion of work in the context of thermodynamics extends conceptually far beyond labouring bodies or machines, to include any transformation in state or movement as a result of the application of force and the flow of energy. 'Work is at work everywhere in the universe or in being' (Bryant 2014). So a glacier slowly scouring and eroding the rocks beneath it is doing work in thermodynamic terms, as is the solar radiation that through photosynthesis leads to plant growth, and the heat energy in the atmosphere that is converted into kinetic air movement (see later discussion of climate change). Thermodynamics, in other words, is concerned with relationships between entities that are part of energetic exchanges and with explaining dynamic linkages of cause and consequence. When energy is expended, converted from one form to another, relations are activated and change of some type and degree occurs.

For example, in a lightning strike a sudden surge of naturally made electrical energy is converted into three other energetic forms: a linear streak of light energy, a thunderclap of sound energy and a hit of electrical and thermal energy into the tree, building, person or other material object through which the electricity is grounded. Or in another example, the living human body can be conceived metabolically as a continual energy converter; a thermodynamic system in which food intake adds quantities of energy into the body system that is then converted into various quantities and forms of work (as broadly understood). Figure 3.1 represents the body in this way for a notional day of activity, quantifying the energetic inputs from the metabolization of food and the energetic expenditures and work done in breathing, exercising, studying, sleeping and so on. The overtly rhythmic structure of this diagram, organised into a sequential temporal pattern across a diurnal cycle, should also be noted. Thermodynamics provides a framework for understanding complex sets of energetic relationships, with the laws of thermodynamics laying down rules and boundaries within which these can play out.

Whilst detailing the sets of energetic conversions involved in any defined system can become extraordinarily complex, these examples make clear that how thermodynamics functions is very much taken for granted as part of the material ordering of the world and practical understandings of how processes relate in sequence. Adam (1988: 213–14), as part of a deliberation on the separations made between social and natural time, expands on this point in relation to our basic conceptions of sequences in time, of what necessarily is expected to come before and after, and how this is structured by thermodynamics:

> in thermodynamics, unlike Newtonian dynamics, energy is conserved but cannot be reversed. This knowledge allows an observer to distinguish processes on a before and after basis. A hot cup of coffee will always cool, unless we

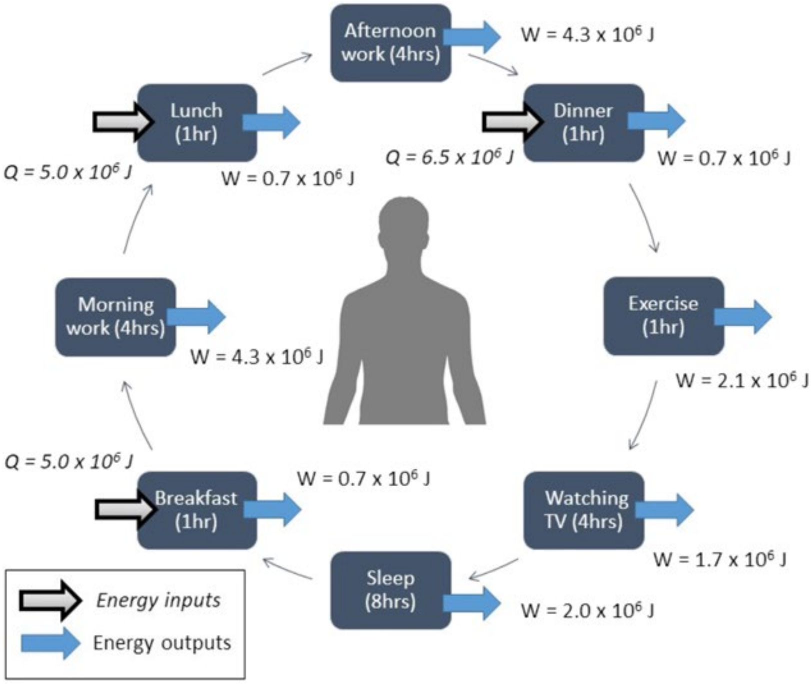

Figure 3.1. A body's cyclic thermodynamic process over a day. Heat energy (Q). measured in Joules (J) as the unit of energy, is added to the thermodynamic system of the body by metabolizing food; whilst work (W) is done in breathing, walking and other activities.

Adapted from Young and Freedman (2014).

> do something to prevent it; and shuffling an ordered deck of cars will mess up the order. Thus one knows that the hot state of the cup of coffee precedes the cool state, that the ordered state precedes the shuffled state of the deck of cards, and that the reverse process is so unlikely that we think it impossible. The energy exchange process is just one example of the 'arrow of time' but, as physicist tell us, there are many more natural phenomena that display such unidirectional and irreversible characteristics.

This physical and energetic explanation for understanding time as unidirectional is, as she states, familiar in everyday experience. In other examples she refers to how cars use up petrol, wood burns to ashes, and bodies need to be replenished with food; all physical sequences that we cannot expect to be otherwise. This has implications for how energy makes interconnections, and for how living organisms are interdependent:

> the directional processes encountered in the non-living world have thus to be extended for living beings to encompass growth, ageing, death and regeneration.

> . . . The energy dissipated by one organism forms the life-giving energy for another, in a never-ending, never-beginning interconnectedness, where everything affects everything else. . . . While single durational steps may be measured, living beings can only be grasped in their full rhythmicity and environmental interdependence (Adam 1988: 216).

The reference to rhythm at the end of this extract highlights one enormously significant 'life-giving' form of connectivity between thermodynamic energies and rhythmic forms. The next section focuses specifically on questions of connection, considering various ways in which the energetic content of rhythms has implications for how interrelations between rhythms are enacted.

TYPES OF RHYTHM-ENERGETIC INTERRELATION

In chapter 2 it was stressed that rhythms are always interrelated in polyrhythmia, and a distinction was drawn between rhythmic interrelations that are more active and those that are more passive, drawing from the range of terms used to talk about polyrhythmic relations in the rhythmanalysis literature. If rhythms are considered energetically, as dynamic repeating flows or expenditures of energy, what further implications does this have for how rhythms interrelate? And more precisely, does the materiality of the energetic form involved (across a diverse set, as in table 3.1) matter to the relationship between one rhythm and another? Considering three recurring types of rhythm-energetic relation, we can see that it does.

First are *aggregative relations*, in which distinct energetic rhythms, when occurring together in space and time, materially combine to produce a rhythm in the aggregate. As a simple example, a series of individual handclaps enacted separately in space and/or time do not accumulate; but when occurring together in a crowd they combine to generate an aggregate pulse of sound energy. Similarly, multiple rhythms of heat-making within a space—such as a meeting room full of heat-generating bodies—readily aggregate to make a combined rise in room temperature; and many light bulbs, simultaneously switched on and similarly directed, produce an aggregative pulse of brightness and illumination. In each of these cases, the aggregate outcome produces consequences that may count for more than just the outcomes of the individual rhythmic parts. Such aggregations are important in various ways to how both natural systems and techno-energy systems operate; for example, underpinning both the making of river flow and the making of electricity load curves, the latter featuring centrally in chapters 5 and 6.

Second are *causative relations*, in which one energetic rhythm agentively sets off another in a sequential relation. As noted earlier, moments of conversion from one energy type to another have this causative form, such as the energy in a leg muscle transferred into the movement of a pedal; or the energetic force of a bomb exploding in a building, blasting apart its materiality into separate fragments. Causative relations can this way have both productive and destructive outcomes. For energy systems causative relations are fundamental to the working of all kinds of technologies—the surge of thermal energy in a powered-up combustion engine making the rhythm of axle and wheel movement (see chapter 4); the rhythm of energy in the movement of the air turned into the spinning of a wind turbine (see chapter 6). They are also integral to how rhythms of pollution of various forms are generated—noise, particles, gases spinning off from pulses of combustion (Walker et al. 2020). As will be discussed further below, both causative and aggregative relations are at work in the chain of connections through which carbon emissions from the burning of fossil fuels accumulate in the atmosphere, leading to global heating and shifts in the rhythms of climate.

Third are *entraining relations*, in which more dispersed agentive effects are realised through the specifically energetic content of particular rhythmic forms. As discussed in chapter 2, entrainment is the way in which certain rhythms act as pace makers, compelling others to fall into step and to synchronise, at least to some degree. Various examples of how light and heat rhythms have entraining effects on other rhythms will be discussed in chapters 4 and 7, but the clearest example can be found in the way in which the diurnal rhythms of natural light have an extraordinary reach into corporeal and biological rhythms of many different forms, right down even to a cellular level (Geddes 2019).

The existence of aggregative, causative and entraining relations between energetic-rhythms, potentially, shows that the energetic constitution and specific content of rhythms can really matter for how polyrhythmia are formed and reproduced; in a body, within an ecosystem, a workplace, a city square, or even a global climate.

ENERGY AND RHYTHM TOGETHER: THREE KEY ARGUMENTS

To capture where this thinking about the energy in rhythm through thermodynamics takes us, in terms of what it means for human life and social formations, three key arguments or assertions can now be made.

First, as human beings and as human societies we are perpetually immersed and entangled in energetic flows, of multiple forms, just as we are perpetually making and caught up in interweaving rhythms of multiple forms. This logically follows from Lefebvre's argument that energy expenditures are constitutive of rhythm, but it has a deeper resonance once the implications of understanding energy through thermodynamics are laid out. If all (physical) rhythms by definition involve energetic expenditure, then all rhythms do 'work' of some form. They enact and have an energetic outcome in space and time, which may or may not be consequential in other respects. There are resonances here with Whitehead's observation that 'energy is merely the name for the quantitative aspect of a structure of happenings' (Whitehead 1985 [1926]: 128).

Where this conjunction of rhythm and energy is perhaps most consequential and profound is in, and for, the human body. That bodies are both polyrhythmic and 'poly-energetic' is readily experienced through everyday bodily sustenance, activity and performance (as conveyed in figure 3.1). Indeed, the rhythmic and energetic are so closely entwined that in combination they define what it means physiologically to be animate, to be alive. The dead body lacks the rhythm of breathing lungs or of a beating heart, and the minute electrical pulses in neurons. It lacks all obvious energetic expenditure and movement and is cold to the touch. To be alive is to expend energy in each rhythmic contraction of heart muscle, doing work to keep blood pulsing around the body, keeping circulations going. Rhythm and energy are at the centre (literally at the heart) of what it means to be a living human organism, forming the physiological substrate on which life in other terms is played out.

Shift scale to the cosmological rhythms of day, year and season, and these are rhythms that we experience in our earthly existence most directly as energy flows, as flows of light and warmth shifting in space and time diurnally and seasonally, which, as will be discussed in chapter 4, are enormously consequential in the forms of work that they then do. Similarly, the rhythms of the tides that shape coastal ecologies and provide structure to the temporalities of coastal communities (Jones 2011) are energised surges of water moved by the elliptical cycling of the moon around the earth and the strengthening and weakening of its gravitational attraction. The vignette in box 3.1 situates an observation and thinking through of the rhythms and energies of a tidal environment in North West England, along with other energies and rhythms at work in that setting. From corporeality to cosmology the human experience is immersed and entangled with co-joined rhythmic and energetic forms; and as we shall later discuss, there is much in the organisation and ordering of society, economy and culture that can be similarly described, particularly if we interpret the consequences that flow from energetic rhythms in more than solely thermodynamic terms.

Second, new patterns of energy expenditure introduce new rhythmic patternings and polyrhythmic interactions: There is a co-dependency and over time a co-evolution between rhythms and energies. Over the course of human

BOX 3.1.
Morecambe, Lancashire, UK

On the stone pier, in the sunshine, early spring. The tide flows outwards, boats are grounded. Channels twist and turn across the mud, not flat but undulating, carved by movement, a soon-to-come reversal and surge of water. That the moon so distant but cosmologically near can make this landscape? Ever moving, ever shifting, ebb and flood. A rhythm lasting geologic and hydrologic time, present now, in this moment. A rhythm that cuts across the clock, discordant, but only for timings in hours and seconds. The power in the surge that slowly comes is extraordinary, a vast salty mass pulled by lunar force, a roar of raw energy, moving liquid, solid, organism; and on the surface boats that move with both wind and tide. A surge worked on by wind and storm, sometimes to dramatic, damaging effect. Energies intermingled. Spinning turbines, now in hundreds, standing in distant Walney shallows, flickering in cycles on the horizon. I linger, immersed, played on by the breeze, warmed by the strengthening sun. Gazing with others in our rhythmic synchrony of movement and stillness, drawn to this exceptional place on a sunny spring day.

history, the making of new flows, conversions and intensities of energy have been interventions into both the energetic and rhythmic patterning of everyday life. The earliest management of fire by hunter-gatherer societies as a source of heat, light and material transformation both introduced new energies but also enabled new rhythms of daily and seasonal activity; including moving in and out of colder areas, hunting with fire-made weapons and different patterns of eating and social gathering (Sørensen 2012, Foley 1987, Clark and Yusoff 2014). Jumping forward more than 100,000 years and Castán-Broto et al. (2014) describe how across the differentiated 'energy landscape' of the relatively newly electrifying city of Maputo in Mozambique, socio-energetic relations are embedded in a host of everyday spatiotemporal patterns (see figure 3.2), including the rhythms of cooking and eating together, the marking of the start of the day in alarm clocks, the shared evening watching of TV soap operas and moving around at night along lit and unlit roads and pathways.

Many other examples will follow throughout this book, with chapter 4 focusing at some length on the trajectories of light and heat rhythms over time, but without suggesting a simple determinism. There is no consistent or straightforward way in which more energy *always* means more rhythm, faster rhythm, or more rhythmic complexity, even if we can expect some such relationships to exist (see discussion of social acceleration in chapter 7). There is also no necessary direction of cause and effect. Energetic expenditures can

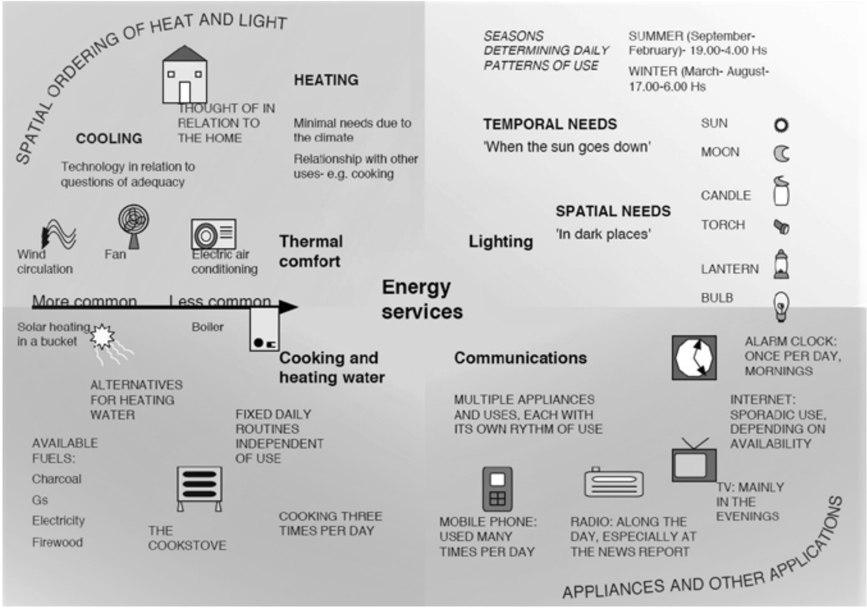

Figure 3.2. Diagram of different elements of the energy landscape in Chamanculo C, Maputo.

Reproduced with permission from Castan Broto et al. (2014) under licence CC-BY-4.0.

change because of socio-cultural shifts or innovations in rhythmic patterns, for example in the doing of laundry (Anderson 2016), or going on holiday (Fox et al. 2017), or listening to live music at festivals (Allen 2018). A key conceptual position underpinning the discussion of energy use and demand in chapters 4 and 5 is that energy is a necessary ingredient of the successful, routine and repeated performance of a multitude of different everyday practices (Shove and Walker 2014), which in their durations, sequences and synchronisations constitute and reproduce social time-orders. Energy-using technologies can therefore become more or less deployed in accordance with shifting rhythmic patterns in the social world; but they are also materially integral to how spatiotemporalities have been (and will continue to be) reworked or remade in processes of social change (Walker 2014). Notions of co-production and co-evolution are often rather imprecisely specified, but capture something of this ‘to and fro’ of relations between changing energetic and rhythmic phenomena and their open-ended dynamics.

Third, just as everyday life is shot through with rhythms that are both social and natural in their making; so is it run through with energetic flows and conversions that are both social and natural in their making. As discussed in chapter 2, Lefebvre, Adams, Edensor, Jones and others have made clear that the rhythms of social world have not entirely obliterated or supplanted those of cosmology, corporeality, or various forms of environmental process. Rather, they are interwoven in heterogeneously constituted polyrhythmia, rhythms beating together and dynamically interacting. Similarly, much as we have radically recalibrated the scale, intensity and diversity of energetic flows through technology, infrastructure, urbanisation and much else—with both productive *and* damaging consequences—we are still immersed in and subject to energetic flows that are essentially beyond the human. As Clark and Yusoff (2014: 206) put it, 'human energetic practices' are contextualized 'within a broader "economy" of terrestrial and cosmic energy flows'. This is not least because, as explored in chapter 4, daily and seasonal time structures are at their root also energetic ones, constituted in their origins by vast flows of solar radiation, without which the planet would be uninhabitable.

Take an everyday example. As I sit outside and type on my computer on an unnaturally warm February day (worryingly so), I am immersed in warmth and light from the sun in an air temperature that sets the basic conditions for, and permeates the inner workings of both my body and my computer; whilst my body and computer are generating their own internal thermal energies and the computer screen makes its own light. These 'inner workings' are responding to their thermal environment, and that work is calculable, but also rhythmically audible and visceral through the whirring of my laptop fan and the rate of my sweat-making. I can see the computer as the daylight illuminates it, I can read its screen as electricity produces its glow. There is a relationality between techno and 'natural' (extra-techno) flows of energy in this example that is particular, but, for heat in particular, constantly present (see further on this in chapter 4). There are instances of contemporary energy flows that are so technologically specific that there is no already present equivalent, or substantial relationship between the techno-energetic and the naturally occurring; but many others in which there are intrinsic relations at work, including aggregative and causative ones, as laid out earlier.

CLIMATIC CHANGE: DESTABILISING THE GLOBAL POLYRHYTHMIA

Such observations may seem rather mundane, but, along with the general arguments they emerge out of, they are connected intimately to the rapidly escalating global climate emergency. It is important therefore to consider what thinking about the energy in rhythm through thermodynamics implies (and enables) for engaging with processes of global warming, and resulting shifts in climatic patterns. The atmosphere is readily understood in atmospheric science as a 'non equilibrium' thermodynamic system, in which energy cycles, hot and cold reservoirs and other energetic phenomenon feature (Lucarini et al. 2010). The rhythms of received solar energy, heating the earth and its atmosphere as it spins and cycles in relation to the sun, have provided the basic thermal (and photosynthetic) conditions for the emergence of life on earth, adapting to variation over geological time in global and regional climatic conditions through colder and warmer periods. In the abstract, the living earth is a vast global polyrhythmia of cosmological, environmental and ecological rhythms, full of cycles, beats and repeating patterns, and, intrinsically, of energetic flows, conversions and exchanges: with corporeal, social, cultural, organisational and (eventually) technological rhythms added into the polyrhythmic mix as 'humans' have emerged and evolved over the last 200,000 years (see table 2.1 for these rhythm categorisations).

Over just the past two hundred years or so though, the dynamic balance in this global polyrhythmia has become newly and rapidly destabilised. As new patterns of energy expenditure emerged with industrialisation and the growth of techno-energy systems, the rhythms of social life and societal organisation co-evolved (as exemplified further in chapters 4 and 5), but other rhythmic entanglements were also implicated. Pollutants, as products of moments of combustion, were now added to the pre-industrial rhythms of the air and atmosphere, finding their way in turn into breathing lungs and bodily rhythms (Walker et al. 2020), and less immediately and directly into the rhythms of the climate. Each pulse of carbon dioxide emission—a material-energetic by-product of burning coal, gas and oil to make techno-energetic light, heat and movement—does not have an immediate causative or entraining effect, but its gradually accumulation with existing carbon dioxide in the atmosphere has served to subtly shift the balance of thermodynamic relations in the global atmospheric system. As a consequence, and as now being experienced in many places around the world, the locally and regionally anticipated patterns of repetition in rainfall, temperature, air movement and other aspects of the climate and day-to-day weather are increasingly unfamiliar and extreme. As Oppermann, myself and Brearley (2020: 284) have argued:

> Global climate change is in itself rhythmically structured: as a comparison between repeating patterns of variation in meteorological measures and abstractions that have shifted from how they 'used to be', and projected to continue to be rhythmically dynamic (in terms of changing cycles, durations and intensities) and—more terrifyingly—arrhythmic (in terms of 'runaway' climate change) in the future.

To cast climate change as arrhythmic in this way (see chapter 2 for discussion of arrhythmia and related concepts) is to see human societies as, at least to some degree, already adapted to the existing and anticipated rhythms of their climates and environments. This positions social rhythms in broadly a eurhythmic relation to those of weather as experienced, anticipated and lived with (Hulme 2017), with recurrent dysrhythmia affecting some populations and places already more vulnerable to extreme weather events and episodes than others. Climate change pushes these extant dysrhythmia further, with the potential to open up deeper and more pervasive fractures in relations between rhythms towards more fully arrhythmic outcomes; in more apocalyptic scenarios towards tipping points and the ending of the earth's capacity to support human life in any form.

Crucially, and in stark contrast, such arrhythmic outcomes have been and continue to be generated by the accumulated product of entirely normalized and routine rhythms of everyday energy use. Techno-energetic rhythms that, as further explored in chapters 4 and 5, have for much of the wealthier world become deeply embedded in the rhythms of being at home, at work, at leisure and being mobile; in the spatiotemporal patterns, sequences and synchronisations of being together in society; and, it follows, in the rhythms of energy infrastructures that enable the beats and pulses of everyday life to be sustained and reproduced in these ways. Climate change is thus fundamentally rhythm-energetic, in its causes, its manifestation and outcomes; and, it will be argued in chapters 6 and 7, also in its mitigation.

SOME REPETITIONS

Energy and rhythm, in happening together, are integral to cosmological, planetary, ecological and human functioning, and to the forms of sociality that have emerged through humans living collectively together and with the environments that materially support them. Without energy there can be no animation; without movement, no rhythm; and without rhythm, no life. Central to the development of this line of argument has been to see energy as decidedly plural, and as present both in natural and human-made materialities and environments. Opening up the energy in rhythm has involved taking the lead from thermodynamic knowledge and its capacity to move across multiple energetic forms and follow their conversions, exchanges and flows; an orientation that Anusas and Ingold (2015: 549) translate into metaphors of 'energetic conduction' and 'energetic weave':

> In tracing the material lineages of energetic conduction we weave in and out, both spatially and temporally, crossing the boundaries between living and non-living. We begin to perceive the material world as consisting not of discrete enti-

> ties with bounded interiors, but rather of knots or nodes in an energetic weave that criss-crosses different states of matter and life without beginning or end.

There are echoes here with how Lefebvre, Régulier and others have written about the interweaving of rhythms in polyrhythmia and the rhythmic animation of apparently inert things, but without paying specific attention to the integral energies that (physical) rhythms involve and that polyrhythmias interconnect. I have argued that there is potential to do far more with the space-time-energy triadic definition of rhythm in the foundational rhythmanalytic writing, taking inspiration from the attention Lefebvre gave to thermodynamic exchanges and conversions in parts of his earlier work. That potential is not to develop analogies for social processes, but rather to treat the energy in rhythm as material, agentive and significant stuff, which matters in vital ways to climatic threats to the contemporary planetary condition, and to their grounding in the practical functioning of energy systems and our everyday dependencies on them. A foundation is therefore now in place, on which further lines of enquiry and analysis can be developed.

Chapter Four

Solar and Social Rhythms

Light, Heat and Polyrhythmic Change

Energy and rhythm beat together, that has been made clear, but there is more to do in taking the vibrancy of distinct energetic forms (both natural and techno) seriously, and through this to put energy flows explicitly into our understanding of the changing rhythms of everyday life and social organisation. Social worlds, rhythmanalytic work has demonstrated, are rhythmically constituted in complex, multi-scaled and situated ways. Much has already been brought into explaining the polyrhythmic character of places, settings, activities and experiences, including timetables, infrastructures, work cultures and obligations, identities, economic capacities, bodily capacities, shared understandings, practical interlinkages between practices, routines and habits, and more besides (Chen 2017, Christiansen and Gebauer 2019b, Edensor 2010a, Lyon 2018, Reid-Musson 2018). How then to add energy into this polyrhythmic mix, and how to be clear about the purpose and value of so doing?

In principle, any enactment of rhythmanalysis could give attention to all three elements of the triadic definition of rhythm—the spatial, the temporal *and* the energetic—examining, therefore, how rhythms involve energetic expenditures and conversions in space and time, detailing their agentive outcomes in thermodynamic terms. A rhythmanalysis of trading on financial markets (Borch et al. 2015) could describe the kinds of bodily energies integral to being a trader and to the evolving array of technologies with which they are working. A rhythmanalysis of a London fish market (Lyon 2016) could include an account of the metabolic and techno-energies that are implicated when activity and movement happens, when noises are made and encountered. However, in these and many other examples of rhythmanalysis being put to very good use, it is unclear that any worthwhile insights would be generated by bringing energy more substantially into view, rather than treating is as a background enabling force or incidental resource.

What this indicates is that the starting point and focus of rhythmanalytic investigation needs to foreground how energy particularly matters and is more than incidental. One way to do that is to start with rhythms that are distinctly energetic—rhythms that involve a substantial flow of a particular energy form that repeats in patterns and has more than background consequences in being energetically constituted. Nothing better fits that description than the flows of energy that rhythmically permeate the earth from the sun. As already argued in chapter 3, the cosmological rhythms of day, year and season are rhythms that we experience most directly as energetic flows of light and heat, shifting in space and time diurnally and seasonally. These flows are still truly vital in and for all planetary life (human and non-human). However, the local spatiotemporalities of light and heat have been supplemented and modified in all sorts of ways by the application of lighting and heating technologies, and associated techno-energies, which now accompany much of human existence. This means that the rhythms of light and heat are no longer restricted to those of planetary cycling and environmental processes, rhythms to be lived with and adapted to. Rather light and heat are also now sociotechnically made and deployed with particular purpose and intent.

My objective in this chapter is to document, across a broad sweep of social change, how both the solar and the techno-energetic rhythms of light and heat have been (and have become) integral to the polyrhythmia of everyday life and social organisation. We will examine how these distinctly energetic rhythms have mattered and been deployed to particular ends; how their local patterning has shifted over time as techno-energies have been introduced in addition to natural terrestrial and cosmic energetic flows; and what this has meant for rhythms of social activity—work, industry, leisure, travel, home life—as well as for rhythms of the human body.

Starting in this way with a particular type of rhythm is akin to one of Chen's (2017: 51) two alternative strategies for initiating rhythmanalytic investigation. Her first strategy is to start from a specific rhythm and then to map out how it is associated with other sites of rhythmic production, building through this a polyrhythmic account. Her second is to begin with a polyrhythmic assemblage, to disentangle it and seek to recognise and reconstruct how separate rhythms interact, syncopate or jar with others within the polyrhythmic whole. Across this book different approaches will be followed, but here I follow her first strategy, starting with a type of distinctly energetic rhythm and then zooming in and out in terms of the generality with which this is considered in order to map out its association with other types of rhythm. In places, I take the time to consider a particular instance of light or heat rhythm in a moment, place, or material/infrastructural context, but mostly I deploy a wide-angle energy lens (rather than a thermodynamic microscope) drawing on a range of existing writing, for example, on the history of changes in energy use, the status and role of light and heat in society, and the history of timekeeping systems. Thus a deliberately focused and partial account of the energies in rhythms and their dynamic role within polyrhythmic relations will be developed, and a number of important implications drawn out.

LIGHT AS RHYTHM-ENERGETIC

Light is one of the categories of electromagnetic radiation emitted in enormous energetic quantities by the sun, reaching the earth and permeating its atmosphere. It is often associated with heat, and light is converted into thermal energy, but, as radiation, light and heat are thermodynamically distinct. Light 'travels' at an extraordinary speed, it cannot in any effective way be stored and held in place as light, only through its conversion into other forms (for the photons that make up light to exist, they have to be travelling at the speed of light). This gives it very particular time-space qualities, with potentially abrupt patterns of presence and absence.

Naturally made, visible spectrum radiation has locally bounded sources, for example in lightning, in volcanic activity and in forms of natural luminescence, but solar light is supremely pervasive. It is also deeply rhythmic in how planetary cycling around the sun and planetary rotation brings varying durations, intensities and transitions of light and dark to the earth's surface, repeating over diurnal and annual cycles. How solar light varies temporally is spatially dependent; from the constancy of diurnal duration and transition at the equator, to the strongly seasonal shifts at northern and southern latitudes. The reflected solar light from the moon brings another cross-cutting cyclical movement, potentially providing limited levels of illumination when direct solar rays are missing. In combination, these constitute a fundamental and predictable set of oscillations of natural light energy that bring rhythmic structure to the earth and much of what transpires on it. Solar light levels as experienced on the ground (and in the air) are always mediated by the more chaotic variations of weather and climate (cloud cover, fog, mist, rainfall, snowfall), but the underlying rhythmical structure is constant, at least over anthropogenic temporalities.

The outcomes of interactions between solar light rhythms (diurnal and seasonal) and corporeal, ecological, social and technological rhythms are summarised in table 4.1, focusing on those that matter most directly and indirectly to human life, experience and social organisation. Evidently solar light rhythms have extraordinarily important entraining and causative relations (see chapter 3) with other rhythms, reaching into the biorhythms of humans (and other organisms) down to a cellular level, into the foundations and functioning of ecological processes and all that depends on them, and into the temporal organisation of patterns of human activity. As Adam succinctly puts it: 'For living beings the sun has a multitude of functions. It is a source

Table 4.1. How Corporeal, Environmental, Social and Technological Rhythms Interact with Solar Light Rhythms and the Human-Social Outcomes That Follow

Category of Rhythm	*Interactions with Solar Light Rhythms*	*Human-Social Rhythmic Outcomes*
Corporeal rhythms	Entrainment of circadian rhythms within the body Light-level consequences for vitamin D levels and mood	Diurnal rhythms of sleep, tiredness, hunger and much else down to a cellular level Seasonal and longer-term patterns of physical and mental health
Ecological rhythms	Rhythms of plant growth through photosynthesis Light conditions as cues for migration, movement and hibernation	Seasonal rhythms of food availability or production (gathering, hunting and growing) Diurnal rhythms of predator presence, feeding and safety Seasonal rhythms of landscape change and experience
Social rhythms	Rhythms of illumination and the possibility of visibility Temporal markers (sunrise, sunset, longest and shortest day, lunar cycle)	Diurnal and seasonal patterns of activity and performance of social practices Structure of time systems and timekeeping Affective responses to rhythmically moving patterns of light Seasonal rhythms of festivals and religious observance
Technological rhythms	Rhythms of conversion into electricity in PV cells	Rhythms of solar electricity production (see chapter 6)

of energy, a carrier of physiologically relevant information, and the root of rhythmic organisation' (Adam 1990: 73).

In terms of human-social rhythmic outcomes there is no simple determinism, in that variation in light is typically mediated by multiple other phenomena, including ones that are themselves rhythmically structured. For example, plant growth is not simply a matter of solar light being available for photosynthesis as this growth is strongly mediated by water and nutrient availability and by temperature. And evidently there are many, variously rhythmic, processes that intervene in how plant growth translates into available food, and for whom that food is available. So how strongly, intensely or consistently solar light rhythms do different forms of work, and have identifiable rhythmic outcomes within polyrhythmia, will vary in multiple dimensions.

Artificial light has been added to this elemental rhythmic patterning of light energy and relations with other rhythms, through the conversion of other energies (wood, wax, gas, electricity) into light, in a historically evolving and diverse set of light-making technologies and associated connected infrastructures (Cubitt 2013, Nye 2018). The pools and beams of artificial light that are produced are radically more bounded and limited in spatial scale and scope than natural light; and in being subject to purpose and intentionality in their deployment have no *pre-determined* rhythmicity—cyclical or otherwise—even if in practice they may often be deployed in an alternating counter-rhythm to the availability of natural light. In its deployment, artificial light has the capacity to modify interactions with corporeal, ecological and social rhythms and associated human-social outcomes, across all of the categories identified in table 4.1. So, for example, the human health benefits of repeated sunlight exposure can be supplemented by the use of 'daylight bulbs'; and the rhythms and spatiotemporalities of the making of organic matter through photosynthesis can be recalibrated by the use of full-spectrum artificial lighting (see figure 4.1) in spaces and times devoid of sufficient sunlight, sometimes on an industrial and heavily energy-consuming scale.

Figure 4.1. Making rhythms of photosynthesis through artificial lighting.
Photo by the author.

Not all of these categories and relationships can be considered in detail, but for later discussion of the rhythms of energy demand (in chapters 5 and 6), it is consequences for the rhythms of human-social activity in time and space, and how these relate to sociotemporal institutions and systems of timekeeping, that are most significant. It is therefore on these rhythmic-energetic relationships that we will initially concentrate.

Illumination and Rhythms of Activity

For human beings, light most directly performs the work of illumination and visibility. This rests on a chain of conversions of light energy, starting in the light sensitive cells of the human eye and on through a sequence of all but instantaneous causative energetic relations; from electromagnetic radiation into chemical energy and then into electrical signals through the optic nerve and into the processing and sense-making of the brain. All the ways in which light, encountered directly from luminous entities and by reflection from, and/or transmission through illuminated materials, is then interpreted and responded to, evidently far exceeds any simply energetic explanation. Light has deeply affective and cultural dimensions, both in its absence as well as presence (Bille and Sørensen 2007, Ingold 2000, Entwistle and Slater 2019), and their overlaying rhythmicities are important to how illumination interrelates and interacts with social and corporeal rhythms.

Most immediately consequential for human activity is how light enables entities to be visible, to be sensed as present, positioned, and as taking particular sizes, shapes, textures and colours. Light and visibility enable bodily activities, and in particular interactions with other things and people, to be effectively carried out, coordinated and sequenced. Light of sufficient or particular intensity and/or quality (for which there are typically complex descriptive vocabularies) is then, for many activities, a taken-for-granted background resource. Or in the language of social practice, a necessary and taken-for-granted ingredient or material element of their possible and/or successful performance (Hui et al. 2018). Being or becoming blind and lacking the capacity to enrol light and visibility into everyday practice is not an intrinsic limitation, but requires alternative ways of performing activities in which visibility is generally integral (reading through touch rather than sight, for example). It follows that rhythms in the temporal and spatial availability of light and illumination will shape or more strongly entrain patterns of individual and social activity; potentially very directly where there is a strong dependence, as well as in more subtle ways.

For most of human history, the rhythms of solar-made light[1] have been deeply consequential in structuring the basic rhythms of everyday life. Key

1. Both directly received and reflected by the moon as moonlight. Patterns of nighttime activity can sometimes shift with the availability of stronger moonlight.

tasks such as food provisioning (hunting, gathering and cultivation) and moving from one place to another are generally more practically difficult and/or dangerous when it is dark, such that when solar light defines or dominates the possibilities of illumination, the carrying out of many practices are broadly structured into 'things done' in daytime and at nighttime. They are entrained in their periodicity by solar rhythms.

In northern latitudes where seasonal transitions in the temporality of daylight and darkness are most extreme, this has traditionally meant quite radical shifts in patterns of activity over the year. Icelandic cultural traditions, for example, are suffused with seasonality, for example in terms of how food and diet has been oriented to sustaining nutrition through the dark (and often frozen) winter months (Rögnvaldardóttir 2002) and in the very different possibilities for doing work and being mobile in the long sunlit days of the summer. In the vignette in box 4.1, I reflect on rhythms of light, environment, ecology, infrastructure and everyday life when in Iceland close to the longest day of the year and near-perpetual daylight. The role of illumination in such spatiotemporal patterning cannot be neatly disentangled from rhythms in climatic and ecological conditions (e.g., plant growth, animal migrations, snow and ice cover), although these themselves are substantially solar driven. Adaptations to more extreme conditions, such as very hot temperatures, can also mean that the 'most sunlight' parts of the day are not necessarily the most socially active, but rather cooler periods nearer to dawn and dusk, so the intensity of illumination and patterns of activity are by no means simply related.

BOX 4.1.
While Staying at Heiðarsel, Iceland

Shadows have lengthened, but the dark is at bay. Valley slides away to the sea. River runs, crashes with force. Ice replaced by water, life in full process not frozen. The solar heat sustains the day and the grass grows. Lengthening, each blade wavering in the breeze. Calories for sheep, munching, breathing, hearts beating. Wandering to and fro. Defecating, again. Hanging together in a metal barn, rusting. Near rocks, eroding, a glacial pulse from a violent eruptive beginning. Still, but not quite. A car passes, rarely, not a strong rhythm. Families once lived here, for generations, a cycle of passing from one to another, land and building. Living with seasons, with dark, with ice, with life frozen, then warmed. Repeated, endured. The remains of electricity made from channelled water, pulled by gravity, are scattered behind the cottage—wire, pole, generator. 3kW for light, power, for making different beats. Maybe that helped to endure the dark, the cold? Now connected to the island-encircling network. Now a cottage for temporary booking, for strangers arriving and leaving. New rhythms on old. Watch ticks, midnight comes, sky glows red and gold; but somehow the day stays in place. A near solstice rhythm, woven always with many others.

There are therefore no formulaic rhythmic relations, but certainly the diurnal cycling and annual variation in solar light has directly figured for a long time as a source of sociotemporal order. Johnson (2001: 91) notes that the rotation of the earth within the solar system 'may be the largest timepiece we possess (space calibrating time)'. Sunrise and sunset in pre-modern rural societies were (and still are) markers of the period within which field-based agricultural work practices would be undertaken. The 'working day' therefore shortens and lengthens (depending on latitudinal location) in alignment with the movement of sunrise and sunset, with significant festivals also sometimes aligned to key moments in the cycling of the length of day. Birth (2012) describes how procedures of canonical bell ringing in churches and monasteries in the middle ages varied their 'hourly' periodicity depending on the amount of sunlight at the time of year, rather than having a standard duration, with midnight also marking the middle of the period between sunrise and sunset, not a fixed point in clock time. In various ways then, and as many historical accounts have documented, the cyclical movement of the planets, and the rhythms of solar energy as light, have long permeated, in culturally specific ways, sociotemporal structures and modes of timekeeping.

Artificial Light and Rhythms Reworked

What then does artificial light add into, disrupt or reconfigure in relationships between the rhythms of natural solar light and activity? In physical energetic terms it to some degree disrupts the cyclical patterning inherent to the availability of solar light, introducing, as noted earlier, *counter rhythms* or locally smoothing the strength of natural oscillations. Artificial light can be both *additive* to lower levels of solar light, increasing available light energy and enhancing visibility, or more substantially *substitute* for its absence, lighting otherwise dark spaces, including bringing light energy into spaces that sunlight never reaches. In both respects, artificial light can therefore enable the extension of the performance of existing, light-dependent human activities into periods of time and into spaces that otherwise such activity could not inhabit; or inhabit as well. Artificial light may also be integral to existing practices being performed in substantially different ways; or be significant to the emergence of new practices with their own rhythmic patterning. Artificial light therefore has the potential to both rework rhythms of illumination *and* their relation to rhythms of social activity.

There is a long history of use of basic lighting technologies (fires, torches, candles burning wax or tallow, oil lamps) to provide variously limited pools and intensities of light so that practices (both static and mobile) could be carried out when natural light does not provide sufficient visibility. Nye (2018: 15), in considering the role of light in cities before the introduction of networked lighting infrastructures, describes an evolving and contingent scheduling of patterns of activity moderated by the possibility of some degree of illumination of the dark:

> Ordinary people divided their tasks into those that had to be done by day, and tasks that demanded less light and could be performed at night. Some trades such as baking or garbage collection were primarily night activities. Circumstances dictated many tasks. A child or foal might be borne at 2.00 a.m. A patient might need medical attention in the wee hours. Many amusements took place mostly at night, such as workers drinking in a tavern, farmers holding a dance or high society attending a ball . . . Farmers rose before dawn and carted their produce to city markets where customers began to arrive as day was breaking.

While, he argues, it would be wrong to assume that before street lighting 'the city went to sleep after nightfall' (ibid.: 15), for many authors it was the arrival of lighting with gas and electricity and the more practical extension of lighting infrastructures both inside and outside of built structures that heralded the most substantial recalibration of relations between rhythms of illumination, activity and temporal organisation. For example:

> Starting with the widespread diffusion of gas lighting from the beginning of the eighteenth century and development in pace through the beginning of the nineteenth century, there occurred what Melbin (1987) has referred to as a progressive 'colonisation of the night'. Though occurring only slowly, such processes had the effect of blurring the distinctions between night and day, such that by the end of this period they were beginning to displace a sense of time rooted in the more natural rhythms of the diurnal cycle (May and Thrift 2001: 11).

> for most of our ancestors before the invention of the mechanical clock, and especially before 1820 when Pall Mall became the first street in the world to be lit by gas, the intervals that mattered were the intervals established by the earth and the moon. The beats were comparatively slow. It has only been as the tick-tocks have been made to sound in every cranny of every institution that the critical intervals have become so short (Young and Schuller 1988: 1–2).

As made clear in these extracts, these newly energised lighting systems were not just about extending patterns of activity in time, but also had a role in the gradual recalibration of senses of time and 'the beats' that structured the rhythms of social order, with outcomes that have been evaluated in both critical and more positive terms.

Those concerned with the technological and energetic shifts that underpinned the emergence of industrial capitalism and its exploitative labour relations see the extension and regularisation of the (urban) working day as enabled by technologies that illuminated working environments into the evening and night. In *Das Kapital*, Marx provided a trenchant critique of how 'vampire-like' capitalism took apart the distinction between day and night in delimiting the working day:

> All bounds of morals and nature, age and sex, day and night, were broken down. Even the ideas of day and night, of rustic simplicity in the old statutes, became so confused that an English judge, as late as 1860, needed a quite Talmudic sagacity to explain 'judicially' what was day and what was night. Capital celebrated its orgies (Marx [1867] 1887: 184).

Drawing on a study of temporal shifts in nineteenth-century Canada, Stein (2001: 118) notes how the introduction of gas and electric lighting systems 'allowed factory managers to further exploit their workers by extending the working day', with light therefore instrumental in the instilling of new time and work disciplines on top of pre-industrial work and religious routines. Debeir et al. (1991: 112) quote a report to the Chamber of Commerce of Paris in 1847 that saw both factory mechanisation and light systems as enabling workers to 'extend their work towards day and night work, advancing ever nearer to perpetual motion'. Lefebvre echoes such critique in various parts of his writing, contrasting the ways in which the cyclical timescales of nature that 'held sway' ([1947] 2014: 341) over everyday life had become replaced by the linear, mechanical and brutal time of capitalism, imposing and instilling temporal disciplines that 'shattered cyclic time' (ibid.: 342).

Recent developments in chronobiology have added further layers to such critique, revealing the damaging consequences for the health of workers on night shifts from being 'out of step' with the natural cycling of daylight, characterised as a form of 'social jet lag' (Foster and Kreitzman 2017). Working at night in artificial light and then (attempting) to sleep during the day has been shown in epidemiological studies to have a raft of serious consequences for health, including higher risk of heart disease, stomach ulcers, depression, type 2 diabetes and breast cancer (Geddes 2019). Nearly half of the body's genes have been found to be under circadian control, including those associated with many serious illnesses, rooting cosmological rhythms deeply into corporeal ones. Circadian desynchrony is dysrhythmic, if not fatally arrhythmic for those with work-life patterns out of step with the cycling of solar light.

Beyond the domain of work, the gradual arrival and dispersion of new lighting technologies and systems through the nineteenth and twentieth centuries are ascribed a wide range of social consequences and outcomes. For example, they were integral to extending the 'public sphere' as people met and congregated at night in public spaces (Nye 2018); they were drawn into the already established use of illumination (fireworks, torches and bonfires) as part of public displays and spectacles; into new varieties and forms of entertainment (theatre and cinema), and innovative advertising and design practices (Cubitt 2013, Bille and Sørensen 2007). Illuminating routes for, and being attached to, mobile vehicles, they enabled safer and faster speeds of travel. In entering into polyrhythmia of everyday life, lighting technologies became entangled in a whole host of such spatiotemporal shifts, and as lighting systems became more sophisticated, they had increasingly subtle roles in shaping the spaces (and rhythms) they illuminate. As Entwistle and Slater (2019: 2024) argue, 'when lighting professionals cast light on a social scene, they perform complex socio-technical assemblages that produce social spaces, with implications for how spaces are populated, used, and experienced'.

Most historic and contemporary accounts largely privilege the particular (largely urban) experience of the Global North, but there are parallels in contemporary accounts of the impact of new lighting systems in rural communities in the Global South. For example, drawing on work in Zanzibar, Winther and Wilhite (2015: 572–73) observe how 'electricity was quickly integrated into funeral and wedding ceremonies . . . by providing light for cooking and other activities at night' and that with electric lighting 'outdoor space was regarded as safer to humans because spirits were thought to prefer darkness and tended to withdraw from (en)lightened villages'. More generally, and echoing historical analysis in other settings, they note that:

> electric light brings with it a fundamental impact on the distinction between day and night. Instead of depending on the natural cycles of sun and moon, daily activities can be shifted in time and space. In this sense electricity enables people to overcome 'natural' limitations and to experiment with new practices (ibid.: 575).

Gupta (2015) adopts a more critical perspective in seeing the arrival of electric lighting as part of a 'biopolitical' project in which the imprint of modernity and certain visions of family life, consumption, surveillance and public interactions are inscribed. She argues that rather than being still and empty, the pre-electric dark was a time in which there was a lively social and political sphere, with this being diminished, rather than enhanced, through illumination:

> After dark, once all of the day's chores were done and before going to sleep, there was time for amiable sociability. Small groups of men would gather on the porches of homes, while women would gather at each other's homes, exchanging information, gossip, and news. Children would play in the streets. The whole village was abuzz with sounds. With no other entertainment and with no light to elongate the working day, this time was spent in creating and maintaining a public sphere. The darkness, paradoxically, enabled a sense of community to be built in the village (ibid.: 558–59).

Changing Light Rhythms and Polyrhythmic Outcomes

To summarise, light as a very familiar and pervasive energetic form plays into and has consequence for the polyrhythmic patterning of everyday social activity. In its presence and absence, it is integral to the spatiotemporal ordering of social practices, in ways that have changed over time as artificial light sources have become prevalent and a very ordinary part of getting on with life, alongside and in relation to the anticipated cycling of natural, solar light. Being able to turn lights on, to illuminate particular objects and activities, to do things in periods of the day or year when solar light is absent or insufficient, have become progressively integral to dependencies on energy infrastructures, the light making technologies they power and 'energy services' they provide. And at an aggregate level, these dependencies and the rhythms of activity they support are imprinted into the rhythms of demand on energy infrastructures (as will be discussed in chapters 5 and 6) and the knock-on consequences they in turn generate, both when functioning normally and when breaking down.

Working through the example of light has also demonstrated that changes in the rhythmic patterning of fundamental energy flows have outcomes, through their interaction with other rhythms, which may be evaluated both positively and more critically. Changes in the rhythms of particular energetic forms are intrinsically neither good nor bad, intrinsically neither eurhythmic, nor dysrhythmic or arrhythmic in their effects (see chapter 2 for explanation of these terms). Much rests in any such normative judgment on what outcome or consequence is being considered, and at what scale the polyrhythmic whole is being conceived. The supplementing of solar rhythms with artificial light rhythms might well be seen as having produced broadly eurhythmic outcomes across a society or an economy as a whole; but when located in the patterns of shift work of particular labouring bodies they emerge as distinctly damaging and dysrhythmic in their interaction with the embedded circadian rhythms of healthy bodily functioning. The notion of light pollution also captures the ways in which the provision of artificial lighting can be disruptive to the biological rhythms of other organisms, as well as detracting from the human enjoyment of the rhythms of dusk, sunrise and the natural dark (Meier et al. 2014).

In such ways, the rhythms of techno-energised artificial light can be evaluated in relation to their purpose and intended and unintended consequences, as well as to how well matched these rhythms are to their actual functional use, and how desynchronised they are from the rhythms of available natural solar light. The setting of local time zones and related clock-shifting protocols, in relation to the spatial patterning of solar illumination, is one scale at which questions of misalignment can be considered; with the institutionalisation of 'summer time', moving the clocks backwards and forwards, argued for on the grounds of limiting the use of artificial light and related energy consumption (discussed further in chapter 7). At more local scales there is also plenty of evidence of artificial light that is switched on when there is readily available solar light, rather than in response to its absence (see example in figure 4.2); and of lighting practices and infrastructures that serve very ephemeral and insubstantial purposes, or that could have been made differently if the

Figure 4.2. Artificial light in daylight.
Photo by the author.

possibilities of relying on natural rather than artificial light rhythms had been prioritised (Phillips 2004). In this sense, not all artificial light rhythms are equal, but can rather be sorted through in terms of their necessity, value and consequence. Such questions may seem trivial, too readily falling simplistic calls for 'saving energy' by switching the lights off; but at scale and in their formulation, they are more than relevant to ways of thinking about and practically moving towards a de-energised low carbon future.

HEAT AS RHYTHM-ENERGETIC

Heat shares some important commonalities with light as an energetic form. The most substantial source of heat, by an enormous margin, is solar radiation, in both the infrared radiation directly received and the visible light that is absorbed by materials (rather than reflected or transmitted onwards) and re-radiated as thermal energy. Just as with solar light, the thermal potential of solar radiation (as it enters into the earth's atmosphere) also, therefore, has a known rhythmicity that follows diurnal and seasonal patterns. However, in thermodynamic terms heat is far more complex in how it flows, accumulates and disperses. To put it very simply, light has an 'on-off', an abrupt rhythm of being and not being present, that heat does not share.

Solar-made heat lingers into the night after solar radiation has disappeared. It is held in the atmosphere, through the greenhouse effect, and is integral through this in making the planet habitable (and with global warming potentially uninhabitable). It is absorbed into warmed rocks, into heated seawater and all kinds of other material things, and re-radiated from them or exchanged with other materialities through convection or conduction. Heat does 'phase change' work in transforming solids into liquids, and liquids into gases. As measured in temperature it can be added to through warming and subtracted from through cooling. Heat also has a vast multitude of sources, or moments and points of production. It is generated in the human body (Ong 2012) and in other organisms, in the pressing down of rocks on rocks, in friction, in fires, in chemical reactions and much else. Indeed, all matter with a temperature greater than absolute zero emits thermal radiation of some amount, making it an ever-present energetic phenomenon. As Elspeth Oppermann and myself (2018: 129) have summarised:

> When understood through thermodynamics . . . heat is the key register of being and emergence: embroiled in all that is human and non-human, it plays a foundational role in the basic transactions, flows and formations of the universe, from the 'big bang', to exchanges within ecosystems, to the tiniest metabolisms of energy in the body.

For these reasons, and more besides, a simple distinction between 'natural' and 'artificial' heat is far more difficult than for light. There are 'heating and cooling' technologies evidently, but heat is also emitted as a by-product of a host of other technologies: light bulbs, computers, engines, fridges, to name a few. And there are technologies that act to retain, intensify or dissipate heat made from natural solar radiation, rather than generate it anew, making the consequent heat store or flow a sort of socio-natural hybrid. While following apparently simple physical 'rules', heat as it becomes manifest in the world is an extraordinarily complex phenomenon.

It follows that the rhythmicity of heat is not straightforward to characterise. There is a macro scale of broad seasonal cycles in the temperature of outdoor environments, meaning that we roughly expect certain ranges of temperatures at different times of year, depending on where we are located geographically. These thermal cycles are crucial to a whole host of environmental and ecological processes (including the working of the water cycle) that respond to the broad dynamics of solar radiation through the year. They also remain an important part of the human thermal experience (Shove et al. 2014a) and strongly shape the rhythms of various more thermally dependent practices, such as agricultural work, outdoor skiing and sunbathing. However, we also (increasingly) expect exceptions and anomalies to these broad seasonal patterns and live with much chaotic patterning cutting into cyclical repetitions from year to year.

At more micro scales, there is *not* a patterning to heat flow that fits any simple cyclical or other rhythmic description, but heat still has repeating, temporal qualities. Heat is a form of 'energy in motion', and there are spontaneous, predictable and repeating patterns in how thermal energy moves through space and time. In conduction and convection, heat moves at a rate dependent on the characteristics of the material involved. Any material entity heats up or cools down according to the temperature gradient between itself and what else it is in 'contact' with or immersed in. And how heat moves within and through the material entity is dependent on its own conductive or convective properties. A pan on a stove gradually heats up from being in touch with the hotplate, the water in the pan in turn gradually heats up through its contact with the pan. Both 'take time', in a knowable and predictable way. There is therefore a temporal structure to heating and cooling, to the movement of thermal energy, which under the same conditions will repeat in thermodynamic terms.

Although outside of laboratory conditions all things are never *exactly* equal, thermal conduction, convection and radiation follow physical rules that bring some degree of rhythmic order, expectation and anticipation to the thermal qualities of environments, and of our activities and experiences within them.

BOX 4.2.
Whilst Visiting Jamaica Plain, Boston, USA

Getting up, warmth suffocates the air, no further layers needed on my skin. Not the home routine. The long-suffering radiator fizzes, pipes groaning, weaving through apartments, from a shared basement boiler making water alive, red hot. The open window inconsequential. The first cup of tea, no pre-warming needed, for waking up, not warming up, like the shower. Not the home routine. Milk from the fridge cools the tea, but not much, I drink in between doing other things, in gulping pulses, before it cools much more. Work begins. Hours pass. I re-dress to run. Outside sunshine lifts the air above freezing, I hope. A light cold breeze. Dressing for keeping warm, but not too warm. Gloves, hat, for thirty minutes of elemental exposure, around the pond, icy and bright. With others circling, foot after foot, trails of steaming breath, energised, breakfast powered, exhaling heat into atmosphere, lost in the vibrating moment. Sweat, lingers, cools. Inside turned outside. Returning, the running pulse slows to walking pace. Settling, calming . . . readied to re-enter furnace air, re-dress, re-hydrate, re-fuel and re-join the indoor climate.

As discussed in chapter 2, anticipation and order are key qualities that emerge from rhythmic repetition, and in part are enabled by how physical processes, such as those understood through thermodynamics, repeat in expected ways. In the vignette in box 4.2, I reflect on a set of my own experiences and anticipations of thermal conditions (of various environments and things), relating these to a sequence of ordinary activities, rhythmically ordered in relation to each other, including the heat, or what Jerstad (2016) terms the ‘mundane energy’, my own body generates as it moves and does work. All very much taken for granted and learnt through experience, if, in this case, uncertainly adapted to a temporary and unfamiliar setting away from home. A sort of rhythmically structured, adaptive, everyday lay thermodynamics.

Combining the inherent dynamism of heat flow with the multiplicity of points and moments of thermal production and exchange, we can see both that there will be (i) multiple and diverse rhythms potentially at work in contributing to the ongoing making of specific situated thermal conditions, environments and intensities; and (ii) specific forms of physical interaction—both aggregative and causative, to deploy terms from chapter 3—taking place between rhythms in a polyrhythmia, when those rhythms have, or implicate, a heat energy form.

While constructing detailed thermally attuned analysis of interrelated rhythms could be one way to proceed—as we assembled in Oppermann et al. (2020) centred on thermal load in working bodies—there are broader trajectories to consider in how heat-related rhythmic-energetic work has been significant to, and evolved through social history. Three examples of increasing scale and energetic significance—cooking and freezing foodstuffs, the making of indoor climates and the powering of work and mobility—are discussed in these terms below. These each demonstrate how heat has been made amenable to human intentionality, with the possibility for thermal flows to be localised, intensified, speeded up or slowed down becoming consequential across diverse dimensions of socio-rhythmic change.

Cooking and Freezing as Time Orchestration

The capacity of heat to do work to transform materials from one state to another is familiar in nature (including most dramatically in volcanic processes) but has been corralled through multiple technological innovations to social, cultural and economic ends (Clark and Yusoff 2014). One everyday example is the transformation of foodstuffs. Applying heat in an intensive and focused way in order to transform organic matter into cooked food has been achieved through various energised technical means (open fires, stoves, slow and fast cookers, bread makers etc.) and with sets of immediate material outcomes, including enabling a broader range of matter to be digestible and safe for consumption, diversifying the range of tastes and textures to be consumed and in some cases extending food lifetimes (e.g., through transforming fruit into jam or marmalade). Cooling and freezing food through refrigeration similarly extends lifetimes and enables storage, but with less significant (and irreversible) material transformation.

The temporal characteristics of foodstuffs themselves are clearly changed through such techno-energy-enabled transformation, but changes are also implicated in how the rhythms of cooking, cooling or freezing become embedded in bundles and sequences of other food-related practices (Southerton et al. 2012). Eating evidently can take place without any heat-related transformation, but when it does other activities then become ordered in relation to the type of transformation involved. For example, the mundane sequence of preparing food for cooking, the cooking itself and the clearing up of pots and pans afterwards is necessarily structured in that order, with a rhythm that relates in part to the means of cooking and related aspects of food culture. Stir-frying has a different rhythmic pattern to a slow-cooked stew, and both draw on different intensities and durations of energised heat-work. The switched-on kettle and the toaster have a periodicity to them that is relevant to both what else is done while the water is boiling/toast is burning, and what then follows the completion of their energetic work. Such appliances are often cast as 'time-saving', opening up durations for other things to be done, but they also make temporal structures in so doing; as Lefebvre and Régulier ([1985] 2004: 83) more generally put it, 'objects are consumers of time, they inscribe themselves in its use with their demands'. The provision of cooked food in restaurants is similarly orchestrated into a whole set of rhythmic sequences tuned to providing a particular style of service and eating experience, assisted by various 'at scale' energy-using devices. The rhythms of thermal technologies applied to food are therefore consequential both for the rhythms of energy use, and indirectly for the structuring of other rhythms that orientate in relation to these moments and patterns of purposeful thermal intensity.

Refrigeration in the form of cooling and freezing does particularly significant temporal work in how it stretches the period over which perishable foodstuffs can be maintained in a good condition; to the point of breaking down seasonal cycles of availability. Frozen peas have a quite different life-rhythm to fresh ones, with the techno-energetic work of freezing acting against the 'natural' energetic-work of pea deterioration (a point emphasised in 'frozen fresh from the pod' marketing). As Osti (2016: 3) notes, the arrival of cooling technologies had other spatiotemporal effects: 'the extreme capacity to store through cold did away with the need to cook every day and keep an entire room as a cellar'. Refrigeration at scale does rhythmically more than this though, enabling the movement of foodstuff through sets of refrigerated spaces and stretching the possibility of their travel in space and time. Spatially extended, energy-intensive infrastructures of cold storage are now essential to the rhythms of industrial-scale food supply and provisioning; and to various aspects of the critique that surrounds these highly technologized and de-natured systems.

At the end of such cold infrastructures are domestic fridges and freezers. When introduced into the domestic space of households in wealthier countries such as the United States and United Kingdom, food freezers acted, in Shove and Southerton's (2000) analysis, as a form of 'time machine' reconfiguring the coordinated relations between shopping, storing, preparing and eating food, redistributing time and labour in the context of spiralling time pressures in everyday life. In Hand and Shove (2007) the freezer is referred to as an 'orchestrating node' around which the temporalities of multiple aspects of consumption and provision converge, but in significantly varied ways rather than enacting one version of what is 'normal'. In a similar vein, Rinkinen et al. (2017) have traced how the more recent rapid diffusion of fridge-freezers into households in Bangkok and Hanoi has varied trajectories and explanations, enabling, amongst other shifts, 'the spatial and temporal reconfiguration of shopping, cooking and eating', along with significant resulting increases in domestic energy demand.

These examples show that there is no one, common rhythmic trajectory to distil. The emergence and global spread of fast food, and all of the rhythmic structures that go with that mode of provisioning and consumption, may be enabled by such technologies, but cannot be attributed to them alone. And fast food involves technologies that in some respect speed up rhythms (the microwave, or fast fryer), but also slow them down (the freezer). Furthermore, despite some degree of global homogenisation towards 'western diets', the enactment of food-related and eating practices (Warde 2016), and the use of energised thermal technologies as part of these, remains culturally differentiated and situated; and within different settings energised thermal technologies will also not be equally deployed, or depended on.

Such considerations are equally relevant to normative judgments about both the direct and indirect polyrhythmic consequences coming from the thermally enabled re-rhythmising of food provisioning. Claims can certainly be made about the many valuable outcomes derived from being able to thermally modify organic matter for human consumption—improving the rhythms of food availability, deterioration, storage and movement. Bodily rhythms, better supplied with energy and nutrition, have thereby been enhanced, and at significant scale. At the same time, though, thermal technologies are deeply implicated in patterns of food-related obesity, poor nutrition and ill health and the food systems that sustain these, with dysrhythmic and potentially arrhythmic consequences for bodily health. And some thermal technologies, such as the biomass-burning open fire or cook stove, are the cause of repeated, intense pulses of indoor air pollution that for poorer households in the Global South have devastating consequences on breathing and bodily health (Fullerton et al. 2008). Where thermal technologies are not generating immediate pollution rhythms, more distant rhythmic consequences as part of processes of carbon accumulation and climatic change certainly are, not only at particular moments of heating or cooling foodstuffs, but across all of the rhythmic structures of modern food provisioning. Food-related thermal technologies and the food provisioning and eating practices they are part of are therefore, on a number of grounds, an object of critique and site for potential transformation.

Making Enclosed Climates: Rhythms of Life Inside

Technologies for both heating and cooling are also implicated in the second example of shifting heat-energy rhythms. Shelter from its very earliest forms has always been about trying to achieve some degree of control and management over 'indoor' (or at least less exposed) conditions. In being 'protected from the elements', sheltering is about keeping 'unruly nature' external to the boundary of an enclosed space (Kaika 2005). In thermal terms, this means being able to (i) limit flows of thermal energy into and/or out of the indoors; and (ii) add to, or subtract from, the thermal energy circulating in indoor space in order to stabilise internal temperatures to the benefit of its human (and non-human, organic and inorganic) inhabitants (Shove et al. 2014a).

Technologies for enacting such indoor climate control have embedded rhythms in their operation, but in being thermally active they are always interwoven with other thermally significant rhythms (see, for example, the polyrhythmia of household heating in box 6.1). Most importantly, the work of fires, heaters, air conditioning units and ventilation systems is always to some degree in relation to the seasonal and diurnal rhythms of outdoor temperature in the external environment, thermal conditions that are differentiated across topographical space. As with light, heat-work will be done in an energetic *counter-rhythm* of some shape and intensity. Indoor heaters do more work to reach a given room temperature when there is less thermal energy in the environment 'outdoors' and vice versa, although much depends in that relation on the materiality of walls and glazing, practices of window and door opening and shared 'room temperature' cultures. As will be discussed in chapter 6, synchronous and asynchronous relations between external and internal temperature, mediated by thermostats working as automated 'rhythm linkers' (in their millions), are fundamental to the rhythms of techno-energy demand, and a major challenge for cutting heat-related carbon emissions.

Such technologies also have implications for the rhythms of indoor life, both more static (in buildings) and more mobile (in moving railcars, automobiles, airplane cabins). There are many patterns of social rhythms that are directly and indirectly interlinked with the development and diffusion of heating/cooling technologies (Spurling 2018). In domestic settings the traditional cultural significance of 'the hearth' as the focal point of communal activity is often stressed in historical accounts of living in colder climates; the one place in the home that is continually kept warm, gathering occupants into its vicinity and creating a hub of rhythmic activity. As Carlsson-Hyslop (2016: 78–79) describes, even in the mid-twentieth century in the United Kingdom, heat-making was still very spatially focused:

> Most households . . . heated only their living room, usually through a coal fire in a grate—three-quarters (74 per cent) of working class households heated only one room in February and March 1942.[2] Those who could afford to combined

2. Referencing the source of data as Chapman, Dennis assisted by Geoffrey Thomas. 1945. 'Heating of Dwellings Inquiry: An Inquiry by the Wartime Social Survey, Appendix 1' in Department of Scientific and Industrial Research, Heating and Ventilation (Reconstruction) Committee, Heating and Ventilation of Dwellings. London: HMSO.

> such 'background heating' with other heat sources for 'topping-up' in other rooms or e.g. during cold evenings in spring or autumn.

The 'living room' was therefore aptly named as the space where the rhythms of family life would be concentrated during cold and dark winter periods, with bedrooms, kitchens (if distinct from the living room) and other spaces more functionally and temporally specific in their use. The subsequent introduction and normalisation of other heating technologies, and in particular the arrival of whole-house central heating, thus played into and enabled a greater dispersal of activity within the home, the rhythms of domestic activity becoming less focused on a particular (heated) space. As Kuijer and Watson (2017: 81) describe, drawing on research on the co-evolution of heating and everyday life in council housing in the United Kingdom, new infrastructures enabled sets of activities to be eliminated and others to be re-patterned:

> Changes to infrastructures of provision, and associated developments in end-use technologies facilitated a spread of space heating and heating-dependent activities throughout the home: cooking to the scullery, bathing to the bathroom and direct heating to the bedrooms. With pipes, rather than people carrying water, warmth and fuel, activities requiring heat and (warm) water no longer needed to be performed near the home's main coal fire.

In different climatic settings, the diffusion of cooling through air conditioning has been similarly ascribed significance in the detailed socio-spatial patterning of domestic life (Hitchings 2011). For example, in histories of air conditioning in America (Ackermann 2002, Cooper 1998), a series of shifts in the conventions and practices of everyday life are implicated, such as the tradition in the American South of sitting on the veranda or porch in the evenings being replaced by an indoor enveloping in artificially cooled air; in turn meaning the loss of rhythms of sociable, neighbourhood interaction and exchange (Arsenault 1984). More recently in Singapore, Hitchings and Lee (2008) similarly trace a 'retreat indoors' as the provision of air conditioned space has become ubiquitous, and social routines and rhythms have accordingly adjusted around having a cooler and dryer environment to organise life within—a form of 'routine human encasement' as they characterise it. Air conditioning has become part of the rhythms of culture, expressed not only in the use of space, but also, for example, in patterns of dressing for anticipated indoor climatic conditions.

Beyond domestic settings, there are many other 'indoors' that in becoming climatically de-coupled from the rhythms of outdoor temperature have enabled or actively generated new rhythms of social practice to emerge. In hospitals in the United Kingdom, the rapid growth of mechanical cooling has

Figure 4.3. Indoor ski centre in Dubai.
Photo by Timo Tervo. www.flickr.com/photos/totervo/8144691225 Reproduced under licence CC BY-SA 2.0

been implicated in both the introduction of new technologies into patient care and the intensification of demands on the use of space, cooling therefore becoming an integral part of the evolving rhythms of hospital organisation and operation (Walker et al. 2014). In leisure and retail settings, there are many examples of controlled indoor climates that act to eliminate seasonal cycles of activity; such as indoor ski centres that enable (see figure 4.3) a 'winter sport' to be de-coupled from its seasonal rhythm, forming rhythmically 'de-natured' spaces for skiing and snowboarding, even in hot, desert environments. These are just one case of what Marvin and Rutherford (2018) describe as a wave of new and renewed types of 'urban enclosure' various designed for human occupation and activity, ecological conservation or food production, in which control over the rhythms of indoor micro-climates, and disconnection from outdoor ones, is integral.

While social rhythms are therefore variously related to the changing thermal conditions of indoor environments, corporeal rhythms are also implicated. Heart rate and rhythms of sweat, shivering and other physiological responses are all elements of the thermoregulatory responses of the body that keep the core bodily temperature within a healthy range (Oppermann et al. 2020). Immersion in temperature extremes present a dysrhythmic or potentially arrhythmic threat to bodily well-being through putting stress on these mechanisms. At an aggregate level, statistics on spikes in hospital admissions and 'excess' (winter or summer) deaths demonstrate that the dynamics of bodily health can be (at least partly) synchronized to the rhythms of extremes of environmental heat and cold (Healy 2003). Indoor heating or cooling mediates this relationship through immersing bodily rhythms in air that is more thermally constant; such that being unable to sustain adequate room temperature conditions at home has become a key indicator of being in fuel or energy poverty, and vulnerable to its consequences (Walker and Day 2012). Heat as a rhythm-energetic phenomenon, flowing through sets of situated polyrhythmic interactions, is therefore not only a material element of shifting patterns of everyday practices (Oppermann and Walker 2018), but also potentially a life and death matter in which vulnerabilities unequally play out.

We can therefore sort through the achieved thermal rhythms of indoor environments and position them very differently in terms of the normative significance and orientation of their polyrhythmic outcomes. Techno-energetic heating and cooling rhythms can be both excessive and insufficient in relation to their interaction with bodily rhythms, and both vital and trivial in what they enable and achieve in social terms. They can also be cast as having an 'inefficient' relation to the natural rhythms of outdoors, with building and technology design both making poor use of naturally available heat, or failing to contain the energetic input made with the intention of heating or cooling down indoor space (see further discussion in chapters 6 and 7). The rhythms of actually achieved indoor thermal conditions may for such reasons never achieve a 'good' shape—a leaky building, for example, failing to reach minimum room temperatures, or its internal temperature profile dropping away rapidly when thermal inputs are removed; or may only do so through the input of a substantial and costly repeating pulse of energetic expenditure, a major issue for the impacts of living in fuel poverty (Chard and Walker 2016, Wilkinson et al. 2004).

Concentrating Heat: Work and Mobility Rhythms

The third example of shifting heat-energy rhythms and their interweaving into processes of social change is by far the most significant in terms of its social and environmental implications. Concentrating techno-energetic heat-making into intense moments and spaces of very high temperature combustion has, as many critical commentaries and histories have analysed, been fundamental to the rise and force of industrial capitalism and all that has come with it—including the escalating surge of carbon emissions from fossil fuel combustion. Whilst nature external to human agency includes very high temperature energetic processes—including those in the sun that generate solar radiation—the sets of technologies that have applied intense heat production to the ends of industry, mobility and warfare have enabled all kinds of new patterns of rhythm making, transformation, disruption and destruction to emerge.

There is too much here to work through systematically, but some examples of key shifts in rhythm-energetic processes can be sketched out. Various authors see all of the experimental and engineering work that led to the successful development of early steam-driven machines as fundamental both to the emergence of the scientific understanding of energy, as well as to the basic structures of capitalist accumulation and organisation (Daggett 2019, Debeir et al. 1991, Illich 1983 [2009]). Turning water into steam was not an end in itself, but about converting that energy into controlled and concentrated mechanical power, generating new stronger and often faster rhythms of extraction, processing, making and movement. Rhythms that enabled the rapid concentration of wealth and political power, and that directly and indirectly cut into the lives of workers, communities and environments. Marx ([1867] 1887: 194) intimately connects the re-rhythmising of work and home life in early industrialisation to the rise of steam power and the brutalising extension of the working day; and in similar terms, the monotonous, repetitive machine or beating hammer is a key metaphor for Lefebvre's critique of everyday life under capitalism, and in rhythmanalysis the clash between the linear rhythms of industry and the cyclical rhythms of nature.

Steam power became rhythmically significant in other ways. Accounts of the development of systems of timekeeping often make reference to the standardising outcomes of early rail systems (May and Thrift 2001, Zerubavel 1981). Rail company schedules and timetables, requiring the rhythms of local mobility to be coordinated with arrival and departure of trains along newly laid out rail infrastructures, were much more effective when time systems at each station synchronised; rather than the settings of clocks being place-specific and eclectically determined. Conformity to the rhythmic, coordinating structure of 'standard time' was not only an outcome of the energised mobility of steam railways, but was certainly facilitated by it (Bartky 1989).

Steam trains also meant that the rhythms of travelling for (some) people and (some) things could now be faster and less broken up, for long journeys across days of slower travel. The rhythms of mobility jolted into new spatiotemporal patterns, with consequences also for what went before and after the journey itself. Journeys became newly rhythmically synchronised together, their separate space-time pathways converging at points and timetabled times of embarkation at stations; then held together during the journey and separating after arrival at their distant destination (see box 2.1 in chapter 2). Stations became important spatiotemporal nodes around which other activities were located and rhythmically coordinated, and railway lines became relied on as crucial connective networks, remapping geographies and the flows that made them (Stein 2001).

With steam-powered mobility, what Harvey (1990) and others have referred to as time-space compression (or convergence)—an inherently energised process of rhythmic recalibration—therefore began in earnest, subsequently taken further by the development of other technologies for turning the heat of combusted fossil fuels into mechanical power; the internal combustion engine, the propeller and then jet engine. With powerful engines added to road vehicles, there could be more spatial and temporal independence in when engines were doing work and to what end, mobility rhythms for car owners became less directly synchronised at particular stops and stations, and more dispersed across sprawling, suburbanised city space; a pattern of laying out development enabled by a newly energised rhythm of car travel and access to workplaces and services. With air travel airports became newly significant sites of timetabled departures and arrivals, with the accelerated, long-distance travel of international long-haul flights, ripping bodies out of one situated chronobiological synchronisation with diurnal light cycles, and into another, with 'jet-lag' emerging as an expression of polyrhythmic discordance and readjustment (Birth 2012). Jet fuel–powered travel became one of the key vectors along which globalisation could accelerate, enabling new rhythms of international economic activity, trade, leisure and migration, locking new, extended spatiotemporal relations into place.

Within the seemingly heady pace of such accounts of combustion-powered acceleration in the rhythms of human and social life, it is important to guard (again) against a deterministic reading. For example, Nye (1999: 179) is clear that the car did not pre-determine the American suburb, whose distinct spatial and polyrhythmic form had already emerged around railway stations and streetcar stops, but rather helped to realise existing ambitions and cultural values. As he argues, 'the use of the car in America expressed cultural values, not a technological imperative. The automobile ministered to a pre-existing penchant for mobility. It did not cause suburbanization'. Determinism can also play into eliding the very unequal consequences that combustion-powered shifts in mobility rhythms have had for different places and social groups. Not everyone within a relevant time period started travelling by train, by car or by aeroplane; not everywhere became newly connected and internationally networked, and immersed therefore in new polyrhythmic relations. Huber (2015: 33) concisely argues that:

> The ways in which energy is consumed—whether in an industrial steel agglomeration, a form of automobility, or the heating of residential space—is constitutive of the social production of space. The uneven access to energy systems also reveals that energy consumption patterns reflect social and political patterns of inequality.

There is not, therefore, one homogenously experienced historical narrative of energetic-rhythmic change. Rather a host of differentiations, in which new rhythmic possibilities are captured by elites and middle classes, whilst remaining inaccessible to others—from the comfort of thermally controlled indoor living, to the accelerated high life of international flying; whilst the harms done by the recalibration of the rhythms of everyday life and the vast energetic flows that have powered them are also far from evenly distributed, with strongly regressive differentiations. Illich (1978: 15–16) goes as far as to argue in law-like terms that 'high quanta of energy degrade social relations just as inevitably as they destroy the physical milieu', such that 'that over a certain threshold energy grows at the expense of equity'. High-energy societies are therefore unequal ones, full of 'fractures', 'impotence' and 'enslavements', with techno-energies of powered travel contrasted with the metabolic energies of walking and cycling. Such critique, whilst questionable in some of its detail, makes clear the importance of a rhythmanalytic attention to power and dominance, and to how rhythm-energetic consequences play out over a differentiated social field.

SOME REPETITIONS AND REFLECTIONS

So what general conclusions can be reached from this engagement with the solar and the social, following the history of light and heat as particular examples of rhythms that are distinctly and substantially energetic? First, it is clear that thermodynamic characteristics matter to the patterns of distinctly energetic rhythms in the world and to the polyrhythmic relations that these form with other social, corporeal and technological rhythms. The thermodynamics of light and heat are related, but distinct in how they have rhythmicity in their patterns of intensity, duration, presence and absence. The dark as an absence of light has no ready equivalent in heat. Heat is always present to some degree, flowing through conduction and convection and being generated through a myriad of local thermodynamic conversions. The particularities of these energetic forms therefore matter to their rhythmicity and vibrancy, and we should expect other energies, beyond light and heat, to be differently (poly)rhythmic in their own distinct ways. As Lefebvre ([1974] 1991: 260) notes, 'rhythms differ from one another in their amplitude, in the energies they ferry and deploy' and, following this logic, in chapter 5 the differentiated rhythms of electricity, as a very particular energetic form, will be very much in view.

Second, to reiterate arguments already made, distinctly energetic rhythms are both sociotechnical and natural in their making and presence. For the solar energies of light and heat that suffuse the world in particular, techno-energetically generated rhythms are extraordinarily insignificant in the grand thermodynamic scheme. However, this does not render them insignificant in their social consequences and implications. As we have seen, purposefully made rhythms of light and heat have been integral to all sorts of changes in the rhythms of social activity, in the making of temporal orders and time structures, in changes in labour rhythms, in the rhythms of food and eating, living in buildings, movement and mobility. At the same time though, it has been clear that we must not lose hold of the relations at work between techno and natural energies, and in particular of how increasing disconnection from the rhythms of natural energetic flows has had consequences for societies, bodies and our impacts on ecological and environmental systems. There is, for this reason and others, a politics to our evolving connections to and disconnections from natural energetic rhythms (see chapter 7).

Third, the co-evolutionary relationship between changing techno-energetic expenditures and dimensions of social change is not uni-directional and not only historic, but of the past, present *and* future. Shifting light and heat rhythms, and shifting relations between their natural and techno-energetic forms, have not been deterministic in their effects, but always wrapped up with other dimensions of socio-rhythmic change, situated and context-dependent. As David Nye has been at pains to stress across his work on the social histories of energy, electricity, light and related infrastructures, there is not one narrative of cause-effect, or of the character of change to be revealed. The same is true for the engagement in this chapter with the histories of energy and rhythm. While some degree of cross-cultural generalisation might be appropriate, particularly given how 'standardisation' processes can operate internationally (Shove et al. 2014b), recognising difference is always important. While then the contemporary narrative of relations between light and work might in some settings point to the recent emergence of so-called 'dark factories' (Morley 2017) entirely automated with robotic machinery that does not require illumination to function, in other settings the rhythms of labour, such as for subsistence agriculture, are still fundamentally tied to the cycling of natural light. Future trajectories of light (and heat) as rhythm-energetic will be similarly fractured and differentiated.

Finally, and to return to the rhythms of climate, we now know that the pasts, presents and futures of rhythm-energetic change are implicated in producing (and we hope responding to) the crises of a climatically changing world. Through human history, most of the means by which light and heat have been techno-energetically re-rhythmed have implicated the generation of carbon through combustion, either directly or indirectly. Disconnecting from the 'constraints' of natural cycles has been enacted at a great carbon cost, which is now ‘acting back’ to destabilise the ways in which these very cycles (of heat in particular) are refracted through atmospheric and environmental processes. And having got to where we are in carbon-heavy, techno-energy-dependent societies, it is proving very hard to break away from the multilayered and sedimented rhythm-energetic patterns, anticipations and expectations of light and heat (and other energetic rhythms) that are now in place. This is not only because of their inherent entanglements and complexities, but also because rhythm-energetic change has enrolled the beats of money and accumulation, the circulations of commodities and products and the intense metabolisms of modern cities (Huber 2015). Reading, through an energy-carbon lens, Lefebvre’s ([1992] 2004: 6–7) observation of how commodification creates pervasive rhythmic orders is instructive:

> The commodity prevails over everything. (Social) space and (social) time, dominated by exchanges, become the time and space of markets; although not being things, but including rhythms, they enter products. The everyday establishes itself, creating hourly demands, systems of transport, in short, it’s repetitive organization.

This ‘repetitive organisation’, through the commodification of both rhythm and energy together, has also shifted notions of who we are and what we aspire to. As Nye (1990: 390) argues in relation to the history of electrification in America, ‘People do not merely use electricity: the self and electrified world have intertwined’. It is deeply problematic that the rhythms of a changing climate are now also so entwined in individual and collective identities. Some of the potential routes out of this human-made global predicament will be traced in later chapters, but it is to the systems and infrastructures through which these rhythm-energetic relations have been enabled and sustained that we next turn.

Chapter Five

Rhythms in Energy Systems

Grid Electricity and Big (Carbon) Power

In the last chapter, I argued that there has been, and continues to be, a co-evolutionary relationship between changing social rhythms (of many different forms) and changing patterns of energetic expenditure. We saw that new technologies that convert one energy form into another have been integral to major changes in the rhythms of work, moving around and home life; to new ways of regulating the temporal organisation of everyday life and to new patterns of activity, increasingly disconnected from the natural diurnal and seasonal cycling of solar energy flows. There was, however, something important lurking in the background of these evolving uses and rhythms of techno-energy; namely the infrastructures, energy resources and energy-supplying technologies that made them possible. That brought the electricity to the light switch, the petrol to the engine, the gas to the cooker, adding new thermodynamic intensities to polyrhythmic relationships already at work in the world; and enabling new pulses, bursts and intensities of techno-energetic expenditure to proliferate, colonising and re-rhythmising the places, practices and people they extended to.

In this chapter, we shift attention to energy systems, and the rhythm-energetic flows they contain and enable, in order to consider what the discussion and argument pursued through chapters 2, 3 and 4 means for what these systems do, how they function, their politics, and the integral role they have played in releasing carbon into the atmosphere. Energy systems have been approached analytically through many different lenses, but rarely with attention to rhythm. Thought of in material terms, the physically obvious elements of energy systems can appear pretty much inert. An overhead power cable, a gas pipe or oil storage tank, a lump of coal does not display much in the way of a rhythmic pulse, beat or measure. But in their energetic essence and in being part of a functioning system, they are thoroughly polyrhythmic, full of temporal structure and repetition, as well as having rhythmic consequences in their after-effects and wider interactions. These rhythmic qualities demand specific attention, it will be argued, given that how they are configured and how they are sustained are consequential for the production of the current climate crisis, and for the transitions in rhythms that are an integral part of moving to a low carbon future.

In order to make the general case that energy systems are polyrhythmic, permeated with multiple, heterogeneous, interconnected and interacting rhythms, this chapter will focus on electricity, and the 'big power', carbon-heavy, grid-based systems that became standard infrastructural forms through the twentieth century; that is, in industrial and more wealthy economies, and in urban settings more generally (Luque-Ayala and Silver 2016). This focus on electricity systems is in part because they are particularly involved and significant in rhythmic terms. They interconnect and aggregate the energetic work of an extraordinary diversity of social and technological rhythms, they are managed as rhythmic entities, demanding closely synchronised coordination, and they are entwined in specific ways with the cycling of solar, hydrological and other environmental rhythms. They are also the focus because they are, on the one hand, (generally) enormously carbon-polluting, but, on the other, central to low carbon transition pathways. Most mainstream low carbon transition strategies are built around extending the reach of electricity into the powering of ever-more technologies, as part of many more lives across the world, and doing this using low carbon energy resources. Analysing, in this chapter, the polyrhythmic qualities of 'big power', carbon-heavy, grid-based electricity systems provides a foundation for then, in chapter 6, examining the (partial) taking apart and reconfiguration of the rhythmic structures of current electricity systems into lower carbon forms.

In the next section, I will outline a polyrhythmic conceptualisation of energy systems and consider how they can be studied through a rhythm-analytic approach. I will then focus specifically on established electricity grid systems, the demand and supply rhythms they are made of and how the pursuit of 'isorhythmic' grid balancing in order to sustain continuity of operation traditionally has been enacted. I will argue that within the established infrastructures and norms of electricity generation, rhythms have been seen selectively, through a dominant lens that has foregrounded the apparently eurhythmic circulations of growth, energy commodities and capital, over the increasingly dysrhythmic circulations of environment and climate. In becoming electricity-dependent, electron-permeated societies, the resulting rhythms of resource depletion and waste-making have been readily ignored and distanced, with implications that we are only now beginning to unravel.

ENERGY SYSTEMS AS POLYRHYTHMIC

What is within scope of the term 'energy system' can be variously interpreted, but is taken here to include energy resources, generation and conversion technologies and infrastructures of distribution that get energy to where and when it is 'consumed' in end-use technologies. In being conceptualised by Hughes (1993 [1983]) and others as key examples of 'large technical systems', they are seen as being composed of 'interactions and inter-relationships, both between different technical artefacts . . . and between technical and non-technical components such as laws, regulations, and economic frameworks' (Bolton et al. 2018: 3). While this multipart heterogeneity is important, large technical systems have tended to be characterised in rather stable and permanent terms, component parts locked together in unyielding ways. Haarstad and Wanvik (2017: 433), amongst others, see this as problematic and argue that energy systems are better characterised as assemblages, capturing both the holding together of very diverse elements, but also the inherent contingency of the 'more of less impermanent relationships' that are so-formed. They work through the example of the global oil industry, ranging across multiple dimensions and multiple spatial scales, from extractive 'hot zones' of oil production, to sites of urban consumption and practice, to reveal both stabilities and instabilities in how the oil system holds together but is also subject to change. Bennett (2005: 446) uses assemblage theory specifically to conceptualise the electricity grid, characterising it as a 'brittle assemblage', consisting of 'a volatile mix of coal, sweat, electromagnetic fields, computer programs, electron streams, profit motives, heat, lifestyles, nuclear fuel, plastic, fantasies of mastery, static, legislation, water, economic theory, and wire and wood—to name just some of the actants' (Bennett 2010: 24). She emphasises the inherent vibrancy of such a heterogeneous assemblage as a 'living, throbbing confederation' (ibid.: 23), with both the separate parts of the assemblage and the assemblage as a whole having a 'certain vital force' and emergent, agentive outcomes.

It is a step further to conceptualise an electricity system not just as an assemblage but as a polyrhythmic one, characterised not only by its heterogeneity, dynamism and vibrancy, but by the constant interweaving of multiple rhythmic forms. Chen (2017: 5) deploys the notion of polyrhythmic assemblage to capture how entities are constituted by processes that 'exist in a constellation of rhythmic entanglements' playing out in space and time (as discussed in chapter 2). Electricity and other energy systems, in their totality and in their distinguishable parts, are good examples. Energy systems cannot help but be a mass of rhythmic entanglements, not only because of the energetic forces that are inherent to them, but also because of how they are immersed in the ongoing flow of social worlds and in rhythmically constituted and thermodynamically significant natural processes (as discussed in chapters 3 and 4). Accordingly, just about all of the five main categories and multiple subcategories of rhythms listed in table 2.1 are in some way implicated in the polyrhythmia of electricity systems, in how they hold together over time and sometimes break apart, and in the outcomes and agentive effects they materialise.

Another way that energy systems are commonly approached is as material infrastructures, and they certainly have key infrastructural qualities. Energy infrastructures interconnect, provide for and carry flow across physical space. They also crucially form relations over (and in) time, connecting the temporalities of energy provisioning with those of energy using, and enabling continuity in the *possibility* of using powered technological devices—or disrupting that continuity if the flow of energy resource becomes fragmented. Energy infrastructures are therefore 'circulatory' (Edwards 2003), full of flow and movement, sometimes slow, sometimes fast, with repeating patterns, durations and intensities of activity. In related terms, Jalas et al. (2016: 17) outline a preliminary case for seeing energy infrastructures rhythmically, arguing that 'they can be understood and analysed through the rhythmicity that they produce and are embedded in' and 'that energy infrastructures organize time and produce collective rhythms'. From a rhythmanalytic perspective, it is indeed the case that whilst outwardly often appearing rather inanimate, they are rhythmic things, doing mundane and frequently invisible work in space and time; producing, carrying, interconnecting and mediating between rhythms of many different forms, including those that figured in the evolving light and heat rhythms of chapter 4.

How then to approach revealing these rhythm specificities? In the last chapter, the first of Chen's (2017: 51) two alternative starting points for rhythmanalytic investigation was adopted. Here the second fits better with an intent to develop an account of an infrastructural system as a whole. This means beginning with a polyrhythmic assemblage, disentangling it and seeking to recognise and reconstruct how separate rhythms interact, synchronise or jar with others within the polyrhythmic whole. Disentangling the polyrhythmia of an energy system could proceed in many different ways, with varying degrees of empirical specificity and resolution. An obvious approach is to consider separately rhythms in the making of energy supply and rhythms in the making of energy demand, given that all energy systems involve a supply-demand relationship. How then within the very aggregated notions of 'supply' and 'demand' particular types, instances or effects of rhythms are identified and focused on is a matter of analytical purpose and intent, guided by which rhythms or rhythmic interactions are seen most to matter, including for the sustaining of 'high carbon' throughputs.

In the discussion below (as well as in chapter 6), a broad separation between demand and supply is therefore followed, but much attention is also given to the interaction between demand and supply, given that within electricity systems this presents particularly acute challenges to those concerned technically, economically and politically with keeping electricity flowing. There is an objective therefore not just to reveal and characterise rhythms and their interactions, but to consider how rhythms themselves are the object of governance and management. Things to be worked on and with, and moulded into particular sought-after forms that fit with the ideas, intentions and ideologies of key actors. Which rhythms powerful actors see as being important, and which are obscured, resisted or denied, will become an important line of discussion as the analysis progresses.

CONVENTIONAL GRID ELECTRICITY

Grid-based electricity systems first emerged in the United States, Western Europe and other industrial economies in the late nineteenth and early twentieth century, starting often as locally bounded urban grids connected just to a local power station, and then expanding in spatial extent through grid interconnection and integration, and through strategies of grid extension into rural areas.[1] In 1930 in the southwest region of the United Kingdom, there were as many as 165 separate utility companies supplying electricity to their customer areas (Hughes 1983: 360), which were then gradually integrated into what was termed the 'National GridIron'. Globally, processes of grid formation and extension, and the development of large-scale generation capacity to supply into them, have continued through to the present day as both state and commercial actors have sought to extend their reach, bringing electrical connection and consumption into more lives, businesses, organisations and economies; although 11 per cent of the world's population still lacks the possibility of access to electricity infrastructure.[2] As various excellent analyses of the development of grid infrastructures around the world have shown (Harrison 2013b, Hughes 1993 [1983], Nye 1990, 1999, Cupples 2011, Luque-Ayala and Silver 2016, Bakke 2016, Kale 2014), these processes have been accompanied by sets of normative meanings and objectives that have explicitly promoted the advantages of electrification to end-users, to economic

1. We will see later that grid expansion can have interesting consequences in terms of the rhythms of electricity demand that are integrated together.
2. Data from https://data.worldbank.org.

development and to the flourishing of society more generally. In so doing they have served powerful economic interests and provided massive returns on investment, as well as carrying more implicit intentions, such as exercising state power and authority over territories (Power and Kirshner 2018).

Within this ideational and ideological work can be found many examples of how new technologies powered by the silent and continuous flow of electric current have been presented as bringing positive rhythmic consequences, recalibrating or modifying rhythms of everyday life, or replacing dependencies on the rhythms of natural systems. As discussed in chapter 4, for industrialists, the possibility of installing new electric lighting systems was seen as a way of extending the working day beyond the shifting cycles of natural light, with electricity also integral to the redesign of factory floors to produce the rhythmic efficiencies of Taylorist production lines (Verdeil 2016), with all their consequences for workers and for systems feeding modern consumerism. For households, and women in particular, domestic electric appliances were widely promoted as eliminating the physical drudgery of domestic cleaning, washing and ironing, liberating time and the rhythms of bodily energy for other purposes (Moellers and Zachmann 2012, Nye 1990). For example, in figure 5.1 an advertising poster from the United Kingdom in the 1950s evocatively (and ambitiously) describes electric heaters as realising 'sunrise in your bedroom' such that 'early rising and chilly mornings have no terror for the users of electric fires', enabling the type of disconnection and protection from the thermal rhythms of the winter discussed in chapter 4. In contemporary examples, rural electrification is amongst other things promoted as bringing modern communication technologies into the lives of remote communities, with all of the temporal effects of connection and coordination that implies. Such anticipated outcomes of electrification cannot just be taken at face value, with much historical contingency and differentiation in how technologies have temporal consequences; but the general point that electrification has been integral to a host of (ongoing) shifts in the rhythms of social and economic activity is clear.

Once in place, the electrified rhythms of working technologies and the practices they are part of then in effect become 'hard-wired' into the electricity systems on which they rely. Star and Ruhleder (1996: 113) stress the co-dependencies that form between infrastructures and practice, including in rhythmic terms; 'As we learn to rely on electricity for work, our practices and language change, we are "plugged in" and our daily rhythms shift'. Coutard and Shove (2019: 10) argue that infrastructures are part of the process of creating what becomes to be seen as normal and necessary; 'rather than simply meeting existing needs, infrastructures shape relations between practice, material artefacts and related concepts of service'.

Figure 5.1. Advertising the virtues of electric heating in the 1950s.

Reproduced with the permission of the Science and Society Picture Library.

For those concerned with running electricity systems and/or with ensuring their performance, this reciprocal interrelation between the embedded rhythms of electrically powered technologies (demand) and the rhythms of their powering through electricity (supply) is crucial; something that has to be continually managed in an attempt to achieve continuity of delivery, across all of the network of transmission cables and substations, through to the wires, switches, plugs and sockets of consumers. The 'modern infrastructural ideal' (Luque-Ayala and Silver 2016) established early on in the history of grid formation, integral to ideas of equal citizenship and universal provision of essential services, is that there should be no discernible rhythm to the availability of electricity. It is always 'on call', its continuity enabling all sorts of rhythms of technologies and practices to pulse, beat and repeat, and do rhythmic-energetic work in the conversion of electrical energy to light, heat, movement and so on, but enabled by an electricity provision that is flat, stable and ever-ready. This stability is now something included as a regulatory requirement for those running electricity grids (Jalas et al. 2016), and it is policed politically and in media reporting with much force. Continuity in this way has been about more than just functionality. It has been part of a longstanding political determination that electricity provision at scale is essential to the rhythms of a growing economy, that growth is good, and if that means more intense electricity-use rhythms, then those are rhythms that will need to be provisioned and provided for.

My own experience as a user of the electricity grid in the United Kingdom is of near-universal achievement of the 'ideal'; of continuity of electricity provision, at home, where I work and in other settings. My actual use of electricity (if I think about it) has a daily rhythm, a weekly rhythm, various seasonal rhythms, along with various more chaotic patterns. But except for very rare circumstances, there is little in my experience that has prevented these patterns of repetition from being realised and reproduced. In box 5.1 I reflect on my experience of one of those 'very rare circumstances', in which a significant local grid failure in Lancaster[3] meant that without powered technologies, all kinds of normal, taken-for-granted things became problematic, and routines became fragmented (DEMAND Centre 2016). As various commentators have observed, failed infrastructures reveal the dependencies that have formed around them and their role in structuring the rhythms of everyday life (Trentmann 2009, Graham 2009). For Jalas et al. (2016: 20), blackouts are 'rhythm events' revealing 'a rhythmicity that in normal states is hidden by a properly functioning infrastructure'; whilst for Nye (2010; 33) they are 'carved out of the normal flow of time' rhythms recalibrated as energetic flows and the technologies they power stall and fracture.

The experience of other people within settings where grids are robust but who struggle to pay their bills and regularly 'self-disconnect' (O'Sullivan et al. 2011), or who have to live with infrastructures that are more continually fragile or overloaded, can be of a far more normal discontinuity in electricity provision (Silver 2015). But at least for those with privileged infrastructures and incomes, the 'ideal' of continuity is generally realised, and, as a consequence, any blackouts that do occur are significantly arrhythmic in their effects.

However, the irony is that achieving continuity from the consumers' perspective entails grid operators and other actors at a system level handling a

3. A six-day period in December 2015 when the Lancaster electricity grid network failed, was repowered in a fragile state, and then fully restored. The failure was due to the flooding of a main substation after very heavy rainfall and unprecedented levels of flow in the River Lune.

BOX 5.1.
Lancaster without Electricity

The rhythms of energy have been not in their usual pattern. Whilst gas flowed through pipes, and piles of wood continued to find their way into wood burners, electricity in cables and wires disappeared, reappeared, came and went in some places and not others. This chaotic absence and presence of mains electricity disrupted other energy flows—petrol stations shut down, some kept running on generators; natural gas travelled as far as central heating boilers but not into them as electric controls went still; propane in gas canisters emerged from cellars and sheds to become useful in unanticipated times and places. The electricity stored in many thousands of batteries (torches, bike lights, radios, computers, cars) across the city similarly became unexpectedly important, every mini and mobile electricity flow proving significant in the absence of its grid-bound version. Trains to Lancaster were suspended, then restarted, then halted again. On the city streets traffic flowed, if anything more vigorously, despite the absence of working traffic lights, street lights or illuminated road signs. Abnormal journeys started, in pursuit of food, matches, a warm pub, a mobile phone–charging opportunity; or to travel to the refuge of the home of a relative or friend in still electrified locations. Other routine rhythms and pathways became disrupted, schools and workplaces shut down, cold, unsafe, still. Phone boxes again became important, queues of unfamiliar users waiting in the cold to communicate, the mobiles in their pockets dysfunctional. I heard that restaurants had to let their customers go without paying when the power went down, no card payments possible, no cash machines to send them to. Systems broken, time re-jigged, rhythms in space and time remade.

rhythm of aggregate demand that is anything but stable and continuous; rather a demand that moves constantly in complex patterns and that under conventional grid-management logics is assumed and allowed to do so without restraint. Furthermore, achieving this continuity—or what is termed 'energy security' in policy discourses and debates—turns out to be achievable only through a very intense engagement with and management of rhythms that are continually at work within the electricity system as a whole; and for a long time simultaneously ignoring the damaging rhythms that spun off from it.

Grid Balance, Storage and Instantaneity

The need to sustain what, in rhythmanalytic terms, can be seen as an ongoing isorhythmic synchronisation (meaning an 'equality of rhythms' Lefebvre [1992] 2004) between the rhythms of demand and supply at an aggregate level, stems from electricity's distinctive materiality and thermodynamic characteristics. As discussed in chapter 4, different energetic forms have different rhythmic qualities—light is rhythmically different from heat in various important respects—and such is the case for electricity. Electricity in its natural manifestations (as lightning, for example) does not occur in quantities or forms that make it accessible for feeding into electricity infrastructures; and until very recently, technologies for storing electricity were very limited in performance and capacity. Hence, for grids to function electricity has to be generated by technologies (added into to the system) as soon as it is consumed (drawn off the system), a real-time instantaneity. To sustain system stability and prevent brownouts (a drop in voltage that can harm connected equipment) and/or blackouts (the loss of power to parts or all of a power network), the electricity grid has to be kept in 'balance'. Keeping in balance means paying attention to another specific rhythm—technological and fast oscillating—the AC frequency of the electricity supply, which must be within a tightly constrained range, typically close to 50 or 60Hz (cycles per second) depending on the system standard. In a very specific example of technologized rhythmic interaction, AC frequency will drop when demand and supply rhythms begin to become desynchronized, supply struggling to keep up with demand, and if it drops too far, systems to protect technical integrity will begin to kick in and grid outages will follow. *This makes rhythm and timing absolutely integral to electricity infrastructures*. Over a conventional electricity grid powered by large power stations there is a spatial dislocation between generation and consumption, happening in places often very distant from each other (Anusas and Ingold 2015). But there *cannot* be a dislocation in time, because of the particular materiality and rhythmicity of grid balance. The logic of big power grid systems is that the system will provide, and it will provide wherever and whenever, in the instant, electricity is demanded.

This makes electricity distinct from *all* other forms of managed and supplied energy, which can in some way be stored and held in waiting, providing for a pause in the flow of energy and a smoothing of peaks and troughs of demand. For purchased petrol, wood or liquified petroleum gas (LPG), for example, repeating bursts of consumption simply use up a local store of fuel, and with greater frequency of repetition and/or intensity of consumption the store gets used up more quickly. The rhythm of then replenishing and filling up the store (tank, wood pile or canister) will contribute to the overall level of demand flowing through the supply system, however, there is not a tight coupling between the detailed rhythms of energy conversion—each moment of driving, burning wood or cooking with LPG—and any consequence for the wider system. Local storage therefore acts as a form of *temporal buffer* between moments of use and aggregated demand, as manifest and measured within the supply system. Fuel storage in effect prepares for and secures future consumption, stockpiling to meet future rhythms of use (Osti 2016), and ensuring the continuity of rhythm-energetic work through so doing.

For networked systems of energy provision—electricity, natural gas and sometimes heat—the temporal relations between use, demand and supply are different, and potentially much more acutely configured. Such networks extend their reach *furthe*r into where the energy they carry is to do work, meaning that there is a more temporally immediate connection between moments of use and draw on the system of supply. Electricity flows from the cables of the supply system to the light bulb when it is switched on; gas flows from the pipes of the gas system to the cooker when it is fired up. And given that such flow rhythms aggregate together across the network—a particular example of aggregative rhythm-energetic interrelations discussed in chapter 3—the moment-by-moment combined rhythms of end use of energy directly constitute the moment-by-moment rhythm of total demand on the supply system.

But again, electricity is distinct. For gas there is some flexibility inherent to its materiality as the pipeline network provides in effect a long and stretched-out storage system, referred to technically as 'linepack' (Wilson and Rowley 2019), which can accommodate some degree of imbalance between gas out and gas in, and associated variation in gas pressure. Heat networks, with heated water flowing along pipelines over sometimes significant distances—for example over hundreds of kilometres in Iceland (Lund et al. 2008)—similarly have inertia in how their supply and use are temporally related, and this allows some accommodation in terms of pressure and temperature at point of delivery.

Established electricity systems do include large-scale stores of energy ready to *convert* into electricity—coal bunkers at power stations, gas in tank farms and underground caverns and water in hydroelectric reservoirs—but for nearly all of the history of electricity-making, the moment electricity is used it must be generated; and the moment it is generated it cannot pause or hold still, but must find its final destination. This means that grid operators need to be acutely aware of the rhythms that make demand and supply in order to know, manage and/or coordinate them. In principle, this could be done in various ways, but for a long period the dominant logic has been to anticipate the shape of the demand or load curve and to manage supply to synchronize closely with whatever demand will be. We will consider both of these tasks in later sections, as well as how the intrinsic relation between anticipation and rhythm has been central to grid management. First, though, we need to examine further where the rhythms of demand come from and how demand can be understood in dynamic, polyrhythmic terms.

DEMANDING ELECTRICITY

The temporal patterning of the work of powered technologies that bring techno-energetic electrons into everyday life is rarely constant. Rather they switch on and off, technologies that operate and then are still, making bursts and durations of electricity consumption rather than ever-sustained ones. Across the enormously varied landscape of electricity uses at the 'fingertips' of grid systems (van Vliet et al. 2005), there can be found a whole host of such electricity rhythms; some repeating chaotically, but most with some degree of discernible regularity or patterning over diurnal, weekly or seasonal timescales, or other periodicity. A home occupied and technologically active during the day on weekends, but not on weekdays; floodlights at a football ground switched on for matches happening in winter evenings, but not for others; shops with opening and closing hours; electric trains or trams following a timetable that varies in intensity to fit with rush hours, slow periods, weekends, public holidays and so on. A host of different rhythmic profiles, that, as discussed in chapter 4, have become produced and reproduced, co-evolving with the development of new energy-using technologies, and thoroughly embedding electricity in the steady rise of energy-dependent modernity.

Practice Rhythms and Social Synchronizations

While rhythms of electricity use can be seen in particular technologies and activities, for large-scale electricity systems the millions of instances of switching on and off that occur in specific devices coalesce (in a quite extraordinary way) into the aggregate rhythm of the moment-by-moment load on the system. In figure 5.2, a 'load curve' traces the aggregate electricity demand on the national grid in Great Britain over one week in 2018. Immediately apparent is a shape, a rhythmic profile, repeating each day. Demand falls away markedly overnight, picks up in the morning to a peak, then declines slightly again and moderates during the rest of the day, before building to another larger peak in the late afternoon and early evening, before falling away into the later evening and entering the next repetition. The exact shape of each daily load curve varies across the seven days of the week, but there is a clear drop in the intensity of demand on Saturday and Sunday. Looking ahead to figure 5.4, showing the daily average weekday pattern across the months of the year, and a seasonal shift in the intensity (and to some degree the shape) of the daily load curve can also be seen.

What these load curves are in effect displaying is how electricity-using technologies are caught up in the flowing polyrhythmicity of a techno-energy-

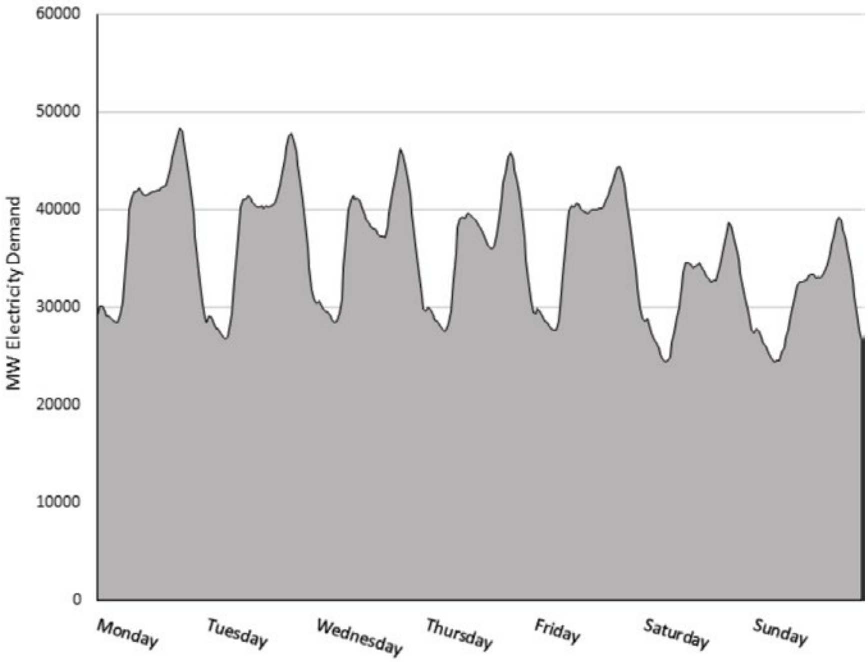

Figure 5.2. The total demand for electricity in Great Britain for the week beginning 5th March 2018.
Prepared using data from National Grid.

dependent society and in patterns of social synchronization. Load curves represent back to us how our days have a broadly shared temporal structure to them, how weekends are defined as a shared social institution and how there are seasonal shifts in patterns of activity and in the work that electrical devices are doing. Connecting to the arguments of previous chapters and taking a further conceptual step, load curves provide a trace of how cosmological, environmental, social and technological rhythms continually, but repetitively, intertwine in the everyday; and of how energetic flows of both natural and artificial forms are intrinsic to making those rhythms what they are.

This rather dense set of assertions merits some unpacking. To go back to the arguments of chapter 3, seeing the social world as made up of practices provides a powerful way of conceptualising everyday life and how techno-energy use is part of this (Shove and Walker 2014, Hui et al. 2018). Most social practices, across broad domains of home, work, leisure and moving around in a technologized society, entail some form of energy demand. They call for some conversion of energy resources to provide services (such as heat, light, movement, power) that are integral to the ongoing performance and reproduction of those practices. Understanding the temporal patterning of energy demand therefore involves stepping back from energy itself to examine how energy-using practices are positioned in time, how they are bundled and sequenced together, and to what extent people are doing similar things in synchrony, in shared routines rather than in individual or chaotically varying patterns. To reiterate points made in chapter 2, living in collectives implies living within a common temporal structure. 'All social life is timed. It has a time-based order. Synchronisation and "time structuring" are fundamental to any collective order' (Adam 1990: 108), such that 'the rhythmic structure of the day is not merely individual but collective and relies upon the synchronisation of practices that become part of how "we" get things done' (Edensor 2010b: 8).

Such collective social synchronisation can be observed in different forms at different scales. For example, the traditional convention of people eating together in the same space is a synchronisation, which, combined with shared expectations of when breakfast, lunch or dinner happen during the day, means that eating is to some degree synchronised across society (Warde et al. 2007), with implications for the timing of the energy demand that makes that eating possible (as discussed in chapter 4 in relation to cooking and freezing). Detailed time-use studies focusing on periods of peak electricity demand (Torriti 2017, Torriti et al. 2015, Anderson and Torriti 2018) show that peaks are made both because many people can, in this way, be performing the same practice at roughly the same time of day; but also because multiple interconnected practices are clustered together in time—for example, cooking, using laptops, having lights on, running dishwashers, watching TV all happening together in the busy early evening. Here each separate practice is unlikely to be tightly rhythmically synchronised (everyone running the dishwasher at exactly the same time), but there is a shared pattern of sets of electricity-using practices of various forms happening during roughly the same period of the day.

While some synchronisations are about day-to-day habit and routine, others are more sporadic but no less structured. For example, Christmas involves a shared pattern of most people in the United Kingdom not being at work (including those who do not culturally recognise Christmas as a significant event) and instead doing other things, often at home, and with some common sequencing in terms of cooking, eating, watching TV and so on. A social synchronization is at work, which, as shown in figure 5.3, can be observed in the trace of the national transmission system load curve, which is significantly reshaped during the Christmas and New Year period compared to the preceding two weeks.

Other collective moments of apparent national togetherness are also regularly commented on in the UK media—traditionally the turning on of millions

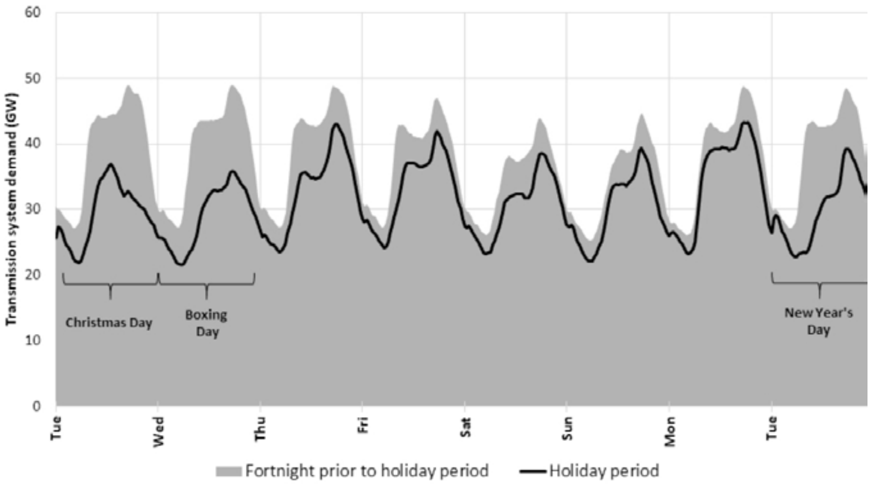

Figure 5.3. UK transmission system demand over the Christmas period 2017 compared with the previous 2 weeks.

Prepared using data from National Grid Winter Grid Outlook 2018 Workbook. https://www.nationalgrideso.com/publications/winter-outlook

of kettles to make a cup of tea at half time of important football games; and recently the announcement of the birth of a royal baby, which rather strangely had the effect of momentarily reducing aggregate electricity demand.[4] It is telling that electricity has become so embedded in technologized societies that variations in demand can act as an indicator, of sorts, of the moment-by-moment activity and shared commitments of their populations. We have become, in some ways, what we power.

Such sociotemporal structures are culturally embedded, reflecting the shared conventions and norms of a particular place, society or culture, as well as the degree and profile of their energy dependence. As Nye (1990: ix) emphasises, there are many different versions of an electrified society: 'Electrification is not an implacable force moving through history, but a social process that varies from one time period to another and from one culture to another'. International comparative analysis of time-use data shows sometimes significant variation in patterns of social synchronisation, these being stronger and weaker and/or taking on a different character for particular practices from society to society (Southerton et al. 2012, Torriti and Santiago 2019). Durand-Daubin (2016) compares the shape of electricity load curves in the United Kingdom and France (see figure 5.4), with the French curve having a much higher relative demand during the night and a less pronounced

4. See https://www.utilitydive.com/news/how-britains-new-royal-baby-caused-an-800mw-demand-drop/155053/.

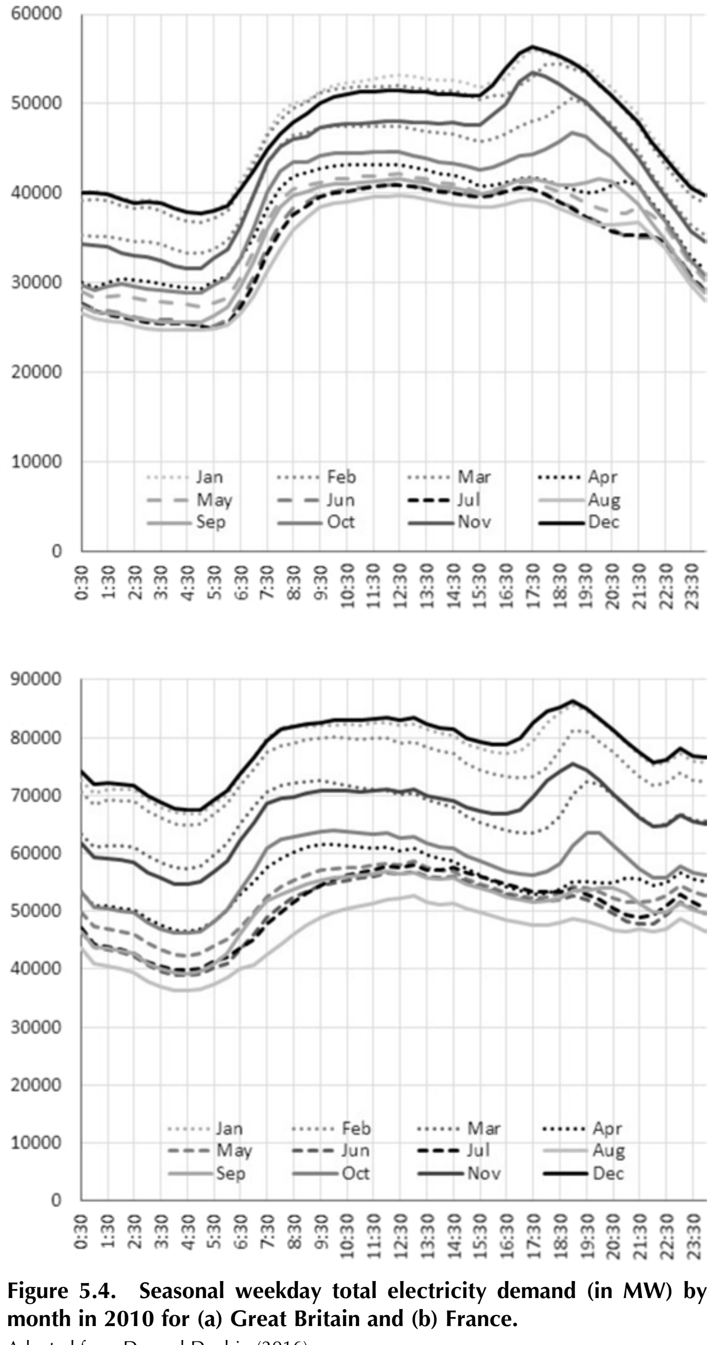

Figure 5.4. Seasonal weekday total electricity demand (in MW) by month in 2010 for (a) Great Britain and (b) France.

Adapted from Durand-Daubin (2016).

evening peak relative to earlier in the day (at least over most of the year). He explains their different profiles by noting important technological differences, such as much more electric heating in general and the widespread use of overnight water heaters in France (an example of automation commented on further below), but also a more culturally structured pattern to time use in France compared to the United Kingdom, with shared cooking and eating times particularly significant.

Rhythms of time use and social synchronizations also shift and evolve over time, including in relation to changes in technology as discussed in chapter 4, and we might therefore expect to see associated changes in the shape of load curves. Anderson and Torritti (2018) traced the evolution of UK electricity demand from 1974 to 2014 in relation to time-use patterns, concluding that whilst the temporal structure of everyday life has remained broadly in place, changes in activities such as overnight shift-working, food preparation and eating, personal care and use of media, along with demographic changes such as the relative ageing of the population, have contributed to shifts in time structures, and in turn to the shape of the aggregate electricity load curve. Focusing in on a specific practice, Anderson (2016) analysed the timing of 'doing the laundry' in the United Kingdom over a twenty-year period, concluding that it had been, to some degree, moving out of peak demand periods. He connects this to changes in the participation of women in the workforce (laundering being a strongly gendered practice) amongst other social trends, as well as the greater use of tumble driers meaning that drying wet clothes have a different duration and temporal structure to 'hanging the washing out' (see chapter 7). Social and technological change therefore very much intertwined, generating shifting patterns in the timings of energy demand at an aggregate level.

Automations, Charging Rhythms and Digital Dynamics

'Time people spend doing things' and how this is socially ordered is, in such ways, important for explaining the shape of load curves, but it does not provide a full picture of the making of demand rhythms. There are technological rhythms—which nearly always entail techno-energy use—that generate rhythms in automated ways disconnected from immediate patterns of human activity. Examples include central heating systems or overnight water heaters with electromechanical timers automating their switching on and off (Rinkinen et al. 2015: 12), timers on ovens, washing machines and lighting systems, and also all sorts of controls that automatically regulate what technologies are doing. There are also 'charging rhythms' for a growing diversity of technologies that carry a small store of electricity with them in batteries—vacuum cleaners, laptops, electric bikes, mobile phones—which means for load curves the timing of being connected to the electricity supply infrastructure matters, rather than patterns in their active use. Although rhythms in active use have a consequence for how often, and for how long charging becomes enacted. Patterns of charging are a key issue for the shift to electric vehicles, as discussed in chapter 6, and are a good example of the ongoing dynamics in relationships between social rhythms—which continue to incorporate and adapt to newly produced and marketed consumer products—and the rhythms of energy use and dependence they generate. In box 5.2, I reflect further on charging rhythms in everyday life, how I orientate to these and how they have become part of what I do.

Energy-using technologies can also be detached from immediate human activity in the way that they are deployed to provide services to support the *possibility* of practices happening, rather than when they are actually performed. For example, the early evening period of peak electricity demand has been recognised as a time when homes, offices, industrial units, shops, railway stations, restaurants and so on overlap in being lit, heat and otherwise energised (Durand-Daubin 2016), with this multiplying the background level of electricity use that is being demanded. As Hui and Walker (2018: 26) comment:

BOX 5.2.
Charging Rhythms

I pause to consider the electrons draining away in small amounts in the batteries around me. Scattered in cupboards, draws, pockets, bags. Ten, maybe twenty? Making light, heat, connectivity, movement; in devices with batteries on the inside, as tubes, blocks and panels of small electricity, mobile, on the go. Their electrified rhythm is in charging, in minutes, hours of being connected to an infrastructure, through a plug in a socket, to a cable, to a substation, to a generator somewhere else. Their electrified rhythm is in use, in making things happen, and, as a consequence in their charge diminishing; and then, maybe, in being powered again, ready to blink red, green, to vibrate and activate. An oscillation of (de) and (re)energisation. I pause to consider how my intuitions about electrons give structure to my everyday. My electrified rhythm is in my orientation to where and when I will, or may be able to, recharge; to the possibilities of plugging in on the train, in the café, the car, at work; to the battery pack, or the peloton of whirring alternators at a music festival. My electrified rhythm is in the eking out of electrons, the hopeful duration of typing, watching, listening and talking, over which maybe the charge will be sufficiently sustained. I pause to consider how our electrified rhythms being now so intermingled, human and non-human, used to be less so, less important, less of a matter. My heart beats with electrical impulses; my schedule beats with batteries.

> A great deal of energy is being demanded in order to present possibilities for where any one person might perform activities—even if these opportunities are not taken up. At the same time that energy demand is about the practices that are done, it is also evidently about where and when practices could but may not be done.

In this way, demand is closely linked to how competition for consumers' time and money is structured into market economies. Diversity of choice as a key liberal principle implies a diversity of energised places and experiences through which that choice can be enacted.

Digital technologies add further distributed complications. Creeping into all sorts of aspects of everyday life, they have in some respects fragmented previously held together temporal patterns (Hubers et al. 2008), but have also multiplied the simultaneous use of multiple devices as part of diverse activities (Widdicks et al. 2017). For Ropke et al. (2010), focused on domestic uses of information and communication technologies, this represents a 'new round of household electrification' with significant, but not straightforward, implications for energy demand and its temporal patterning. Digital devices generate electricity demand through being connected to the local and vastly extended infrastructures of the internet, such that the rhythms of the use of a device, and many millions of devices when aggregated together, can have widely distributed synchronous and asynchronous effects on electricity demand, in distant places and distant energy systems, *not* just the most geographically proximate. As Wiig (2018: 46–47) puts it, in relation to the use of mobile phones:

> Demand for standby, 'always on' wirelessness . . . entails a constant provision of wireless signals pulsing between smartphones and base stations, transnational communication systems, and data centers around the world. These inanimate, obdurate systems of connectivity have a particular, material arrangement stretching beyond each user that is produced through and grounded in electricity.

Such trends have scope to significantly restructure the rhythms of demand, as well as providing tools for its smarter management, a bifurcation that will be further examined in chapters 6 and 7.

Demand Rhythms as Socio-Natural Hybrids

We have established how the rhythms of electricity demand in the aggregate are an outcome of interweaving social, cultural, organisational and technological rhythmic forms. But with rhythms and energetic relations not all is human-made. As made clear in chapters 2, 3 and 4, both rhythms and energetic flows are social *and* natural in their making, and this logic extends into the shaping of electricity demand and the shifting profile of demand curves.

Most fundamentally, it is apparent, and integral to a rhythmanalytic perspective, that many of the rhythms we have considered are not divorced from cycles and temporal patterns that originate in domains beyond the social. The trough in energy demand that remains a general feature of electricity load curves during the nighttime is a dynamic made by a social-natural rhythmic hybrid, given that sleeping every day and with some synchronised regularity is not a purely social invention, but deeply linked to our internal bodily chronobiology and its entrainment to the daily energetic cycles of the planet (as discussed in chapter 4). The rhythm of energy demand that comes from repeated instances of eating (and all that goes with that before and after) is also, in a different way, a social-natural rhythmic hybrid. And we can relate these two examples, in that the rhythm of sleeping is not entirely disconnected from the rhythm of needing to feed, and the relation between nighttime and sleeping is one that connects to both the rhythms of the cosmos and the embedded chronobiology of the body. That environmental and biological rhythms interpenetrate the making of energy-use rhythms in such ways is a logical outcome of Adam's (1998: 13) more general assertion that a 'multitude of coordinated environmental and internal rhythms gives a dynamic structure to our lives that permeates every level and facet of our existence'.

More specifically though, it was considered in general terms in chapter 3, and specifically in relation to light and heat in chapter 4, how there are all kinds of thermodynamic relations between the energy flows inside of and outside of energy systems, between energies in their natural and techno-energetic 'artificial' forms. These thermodynamic relations, and their rhythmic manifestations, have significant consequence for the patterning of the demand within electricity systems. At the level of individual devices, there are stronger and weaker effects. Fridges as thermal devices, for example, appear to have a pretty steady constancy in their draw of electricity, disconnected from diurnal cycles of night and day. Seasonally though, a fridge will need to 'work harder' in the summer than in the winter to achieve the same level of internal cool, and patterns of eating (fuelling the body) and hence fridge stocking and door opening will also shape the switching on and off of its compressor. The energy demand from a fridge is therefore not entirely disconnected from cosmological and corporeal rhythms, but neither are at all strong or dominant.

For lighting the socio-natural rhythmic hybridity works differently. The demand for electricity for lighting has a strong diurnal as well as seasonal rhythm. Lights are switched on generally when it becomes darker in the late afternoon or evening (although not entirely, some lighting is on 24/7 or relates to other, for example, commercial rhythms), and the period of lighting is generally longer in the winter than in the summer (something that varies over space and time across the globe). Many automated control systems are in effect mediating between different thermodynamic rhythms: an automatic light sensor is switching on or off in relation to the rhythms of illumination from natural solar light, a temperature control on a heating or cooling system is matching its operating rhythm to the measured dynamics of heating and cooling of an internal space and how that relates to the dynamics of external temperature (see the characterisation of thermostats as 'rhythm linkers' in chapter 6).

At an aggregate level, such thermodynamic processes are reflected in the shapes of electricity load curves. For example, looking back to figure 5.4 we can see a strong seasonal shift in electricity load curves in both the United Kingdom and France, as durations of natural light, outside air temperature and other aspects of climate both directly and indirectly shape how much electricity in total is being used, and when in the day peaks of shifting intensity are happening. These variations during the yearly cycle are clearly mediated by how UK and French societies socially and technologically live with the seasons, but the rhythmic imprint of cosmological rhythms and their energetic manifestation is still very much present. In another example, a recent study of energy demand for cooling in Italy (Alberini et al. 2019) found that electricity demand stayed within a narrow range up to air temperatures of 24.4°C, but then increased sharply with rising temperatures. On exceptionally hot summer days, temperature alone accounted for 12 per cent of hourly electricity use, a finding that is more than a little relevant to the energy demand implications of climate change.

It is important to recognise, therefore, that the dynamics of electricity demand (and of the demand for other energy forms) have a combined imprint of social and natural rhythmic interweaving. The natural rhythms of planetary cycling and climatic regimes never act alone in making demand, but do act in various ways, and to varying degrees in their entanglement with social rhythms. What this means for aggregate energy demand, for the scale of peaks in demand and for related carbon emissions depends on the degree to which the natural fluxes of energetic rhythms are fought *against* by the deployment of techno-energies, rather than worked with; and exactly what techno-energies of what form and scale are used to that end. Such questions of polyrhythmic and poly-energetic hybridity will be revisited and taken much further in chapter 7.

ELECTRICITY ISORHYTHMIA: SUPPLY RHYTHMS AND GRID BALANCE

In conceiving electricity systems as complex polyrhythmic assemblages, we have so far worked through how electricity demand in the aggregate is rhythmically profiled. The significance of the overriding institutionalised concern for continuity of provision in the face of a demand that is far from constant over time has also been made clear. The next step in this polyrhythmic analysis is to disentangle rhythms on the 'supply side'; the resource and provisioning systems through which electricity is generated and brought into electricity grid infrastructures in order to sustain the isorhythmic condition of ongoing grid balance. In moving to the supply side, attention will continue to be given both to individual rhythms and polyrhythmic interactions, zooming in and out across different scales; and to how the rhythmic makeup of established grid systems is implicated in the long-embedded production of carbon emissions, and in the challenge of decarbonising existing energy infrastructures.

Resource Rhythms of Big (Carbon) Power

All energy resources, however seemingly inert, have rhythmic qualities and characteristics. For the traditionally conceived and materialised electricity grid—big in scale, centralised and managed as a unit performing to the continuity ideal—some energy resource rhythms have been seen as better for electricity-making than others; better thermodynamically and better able to be managed, controlled and made amenable to the demands of both continuity and growth.

Around the world various energy resources have been drawn into big power grid systems, but the combustion of coal and its thermodynamic conversion into electricity has been dominant globally through all of the twentieth century and in the twenty-first; with hydroelectric, nuclear, gas and oil playing generally minor roles, but more significant in particular countries. So what rhythmic qualities does coal exhibit as an energy resource? Chen (2017: 69) argues that 'contrary to the intuition that rhythms only belong to the animate and the living, inanimate things also generate rhythmic relationships in their temporal-spatial arrangement'. For coal, this means looking beyond its immediate, inanimate mineral form and into the rhythms of its making, exploitation and eventual dissolution; working through the time-spaces of its 'pre-life', its transformation into a resource and commodity, and its 'after life' of what it leaves behind, after electricity-making is complete. Adopting a 'wide-angle' lens in this way makes sense in both rhythmanalytic and thermodynamic terms, given the fundamental principle that energy is never created and never destroyed, only converted from one form to another.

In box 5.3 the rhythms of coal are characterised across its energetic and resource 'life-cycle', and in figure 5.5 specific sites of rhythm making and management in a coal-fired power station are illustrated. These make clear that as a resource, and a means of making of electricity, coal has a specific set of rhythmic qualities, which, in three key ways, have been fundamental to the big power electricity generation model.

BOX 5.3.
The Rhythms of Coal as Mineral, Commodity, Resource and Waste

Coal, a concentrated chemical-mineral manifestation of solar energy, made from dead organic matter, transformed, compressed, fossilised. The duration of this 'coalification' is far beyond human time, in the Carboniferous (aptly named), 345–280 million years ago. Through coalification, cycle after cycle after cycle of energetic photosynthesis making new organic life is rendered still and subterranean within coal seams, save uplifts, twists and fractures. A very slow rhythm, an enduring fossilized pause . . . broken violently by extraction, a dramatic ripping out, fragmented through explosives, machinery and labour. Coal now surfaced, a commodity racing into the fast, urgent rhythms of transport, storage, coordination, sale and purchase. In the power station an even more violent transformation, fed as mineral-chemical from the hopper, to becoming heat in the furnace, then into steam, spinning turbines making electricity. Turned up and down to satisfy the rhythms of energised society, rapid, metronomic, alternating oscillations of current flow out and onwards. But slower rhythms of wasted heat, solid, and gas also quietly emerge, spinning away to be lost in the arrhythmia of bodies, ecologies and climates. The Carboniferous reappearing in the present, bringing discordance into the rhythms of the future.

Figure 5.5. Some sites of rhythm making and management in a coal-fired power station. From top left clockwise: coal hopper, combustion surface, turbine, control panel. Museu da Electricidade, Lisbon.

Photos by the author.

First, coal is energy that can be managed in and over time and space. Once extracted, it can enter into the coordination of rhythms of transport to where and when it is to be combusted, held in store, fed in spatiotemporal synchrony into its combustion with a controlled repetition and regularity that can, in principle, sustain electricity generation at a level of 'system need'. The natural rhythmicity of the making of coal is lost, out of view and in the distant past; a rhythm also of replenishment that is readily ignored and rendered irrelevant by those more interested in its energetic stasis and intensity in the here and now.

Second, in becoming a commodity, coal is embroiled in sets of polyrhythmic relations that need to work together to produce its value as a resource; chains of connected social rhythms of investment, extraction, labour, transport and distribution and sale, just as any traded mineral product, with shares of its substantial commodity value distributed across this chain. Its managed continuity as an energy resource therefore demands active spatiotemporal coordinations of many kinds to hold different elements together. As Haarstad and Wanvik (2017: 445) argue, this is a generic quality of fossil fuels; 'carbonscapes are systems with closely intertwined and co-dependent parts', with political priorities bent towards resisting threats to their disruption—such as from labour disputes, technical breakdowns, the movements of market prices or (geo)political conflicts. As Valdivia (2018) argues in relation to the viscosity of oil, but just as relevant to coal and other hydrocarbons, 'flow is not naturally inherent to oil—and neither is profit', meaning that 'protecting this ethos of flow—and the wealth it generates—is imperative for industrial capital'.

Third, for much of the period of its exploitation, the after-life of coal, the wastes and products of combustion, could be just as ignored as its pre-life, including in economic analysis. The surges and pulses of generated waste and pollution could be readily dissipated into the rhythms of ecological and environmental systems, treated as external to the polyrhythmia that mattered to strategies of growth, competition, political power and industrial strength. Rhythms seen selectively, through a dominant lens that foregrounded eurhythmic circulations of commodities and capital over the increasingly dysrhythmic circulations of environment and climate. The centralisation of the rhythms of combustion in only relatively few sites of electricity generation also enabled this selectivity, separating and isolating of the rhythms of pollution-making from the very dispersed rhythms of electricity consumption and revenue retrieval by supply-side actors.

These three rhythmic qualities, along with much else, including the material geography of coal seams, have been integral to the global primacy of coal as an electricity-generation resource (although this has now diminished significantly in some countries). As summarised in table 5.1, other forms of fossil fuel resource (oil and gas in various guises) with some variation are

Table 5.1. The Rhythmic Qualities of Fossil Fuels, Nuclear and Hydroelectric Resources for Electricity Generation from 'Pre-life' to 'After-life'

Energy Resource	*Pre-life Rhythms*	*Rhythms within Energy System before End-use*	*Rhythms in Energy Delivery*	*After-life Rhythms*
Coal, oil, gas	Very long geologic duration; ancient solar	Multistage, discovery, extraction, movement, processing and storage; momentary point of combustion/conversion	Managed constancy, but with potential for disruption	Multidimensional short to long duration; multi-generational; health, social and environmental impacts
Nuclear	Very long geologic duration; ancient uranium	Multistage, discovery, extraction, movement, processing and storage; short duration fission/ conversion	Managed constancy; but regular and unforeseen time 'off-line'	Short to very long duration; multi-generational; health, social and environmental impacts
Hydroelectric	Within working of hydrological cycle; various temporalities short to long	Flow management and storage; momentary point of conversion	Managed constancy, but variously predictable seasonal flows	Long-term river/landscape change and social impacts

rhythmically similar, as is nuclear power. Nuclear has a geologically long energetic pre-life in long-ago formed uranium deposits, and a vastly extended and risk-filled after-life, with potential for harm and need for ongoing management that is of a unique temporal duration (Adam 1998). These risks have been just as pushed aside, particularly in the ongoing development of new nuclear facilities without any material solution to dealing with the very long-term after-lives of radioactive waste.

Large hydropower is different rhythmically, its 'energetic pre-life' coming from the kinetic potential in water lifted through the thermodynamics of evaporation into cloud systems, then deposited through rain and snowfall onto higher ground, accumulating through runoff and trickling through soil and rock systems into streams and rivers and then into the water body of a reservoir. An accumulated and stored kinetic potential that, when required, is then releasable to drive turbines and generate electricity. The timescales involved in the formation of this energy resource are radically shorter than for fossil fuels and nuclear—the hydrological cycle operating over days to decades—meaning that a rhythm of replacement is feasible, but subject to the rhythms (both more regular and more chaotic) of weather and climatic conditions. Hydropower systems do routinely run short of water, sometimes, as in Brazil, for extended periods of time (Hunt et al. 2018). In many respects, therefore, large hydropower rhythms have more affinity with the sustainable, low carbon resources rhythms that will figure in chapter 6, than to those of fossil fuels. Degani (2013: 184), commenting on the politics of energy in Tanzania, notes how the rhythmic dependencies and midterm temporalities of hydropower—in particular the need to accommodate the 'wet and dry season ecology so central to much of East African life'—has meant that hydro infrastructure has become increasingly displaced with the running 'fast and hot' lure of imported oil and gas as an alternative means of electricity generation.

Whilst, therefore, sets of rhythmic qualities can be important to how different energy resources become valued and preferred to others, the apparent reliability, manageability and continuity of some systems compared to others is not an absolute matter, but politically judged, claimed and represented. Fossil fuel systems with their chains of co-dependent and extended parts may, when smoothly functioning and generating profitable returns, be represented as dependable, 'well-oiled', eurhythmic machines; but the need to constantly reproduce coherence and coordination is also a vulnerability that can be broken apart. Nuclear power systems are similarly fragile, with vulnerabilities in the inherent and intense risks they contain; risks that have 'acted back' to undermine claims of eurhythmic constancy and reliability, the truly arrhythmic disasters at Chernobyl and Fukushima being emblematic cases. More mundanely, nuclear power stations also have a track record of significant periods of time ‘off-line’ for both regular maintenance, unplanned problems and faults, and lack of cooling water during periods of hot weather, as has occurred during recent heatwaves in Europe.[5] They are not, therefore, the un-rhythmic, reliably generating powerhouses they are often said to be. Questions of how the rhythmic qualities of different modes of electricity generation are represented and contested are significant, therefore, and will resurface in chapter 6 when the ‘intermittencies’ of very different sets of energy resources are considered.

Ordering Supply and Rhythmic Anticipations

With particular types of energy resources and resource rhythms being corralled into the generation of electricity, how have these been organised into achieving the synchronous rhythmicity of supply and demand that is core to big-grid functioning? From the very beginning of grid formation, the need for rhythmic coordination has posed major practical challenges for grid system operators (Ozden-Schilling 2015, Hughes 1993 [1983]). As a central task, it has been approached asymmetrically and with a particular orientation and discipline that centres almost exclusively on coordinating and managing the rhythms of electricity generation. Supply is seen as something controllable and governable. Demand, in all its distributed complexity and status as an indicator of modernity and economic strength, is seen as an inevitable and emergent outcome of a well-functioning society and economy. Something to be met and matched, rather than managed to the ends of grid integrity.

In practical terms, managing the rhythms of supply has involved coordinating through various ‘load dispatching’ mechanisms, the available sets of large-scale power-generating facilities to turn them up and down as needed in real time; also based on the assumption that the resources that power them (the coal, the power rods, the flow of water) will be available when needed, rather than more sporadically or chaotically rhythmed. For example, in the United Kingdom with the formation of the Central Electricity Board (CEB) and the putting together of a ‘national grid’ from previously separate networks in the early decades of the twentieth century, ‘generating programmes’ were set up for, what was at the time, the almost entirely fossil-fuel profile of power stations, with some hydroelectric and later on nuclear added into the mix. A first set of power stations were categorised as ‘baseload’ stations, operating non-stop for most of the year. A second set were run only in the daytime to meet peaks in electricity demand and to be ready to respond in the event of interruption of supply from the ‘baseload’ stations; and a third set

5. See https://www.reuters.com/article/us-france-electricity-heatwave/heatwave-to-affect-french-nuclear-power-generation-beyond-july-26-edf-idUSKCN1UK0HR.

were operated only for a few hours a day in the winter to meet the strongest peaks in demand, hence termed ‘peak load’ stations (Hannah 1979: 125–26).

In effect, different power stations were assigned to generating profiles in accordance with the rhythm of their planned contribution to electricity supply—to use musical analogies, a relatively unyielding drone, a regular daily beat with capacity to throw in the odd unexpected syncopation, and an additional extra-heavy beat on a sporadic (seasonal) basis. The fitting of specific generating facilities into these categories related to factors such as their age and comparative cost-efficiency (Hughes 1993 [1983]), and with HEP sometimes their seasonal availability, but also to the temporal shape of their starting up (and shutting down). The intrinsic material rhythm of their operation means that some instances of electricity generation are better suited (economically and technically) to droning on (baseload), and others to being started up quickly to hit maximum volume (peak load). Working this all out is integral to the practices of technical calculation that Mitchell (2008) argues were central to developing and operationalising electricity infrastructures from their earliest stages. Significantly, and reflecting arguments made in the last section, only relatively recently has this orchestration begun to incorporate the implications for rhythms of carbon generation into its calculations (see chapter 6 for further discussion).

That this carefully ordered generating programme could be deployed at all relied on a key quality of rhythmic repetition: *anticipation*. As discussed in chapter 2, all rhythms have at least some degree and measure of repetition, meaning that they can be expected to re-occur in the future (in space and time), and therefore be anticipated. Rhythm-based anticipations play into achieving grid balance in two ways (see figure 5.6). On the one hand, individual end-users of electricity, performing routinized and variously synchronised

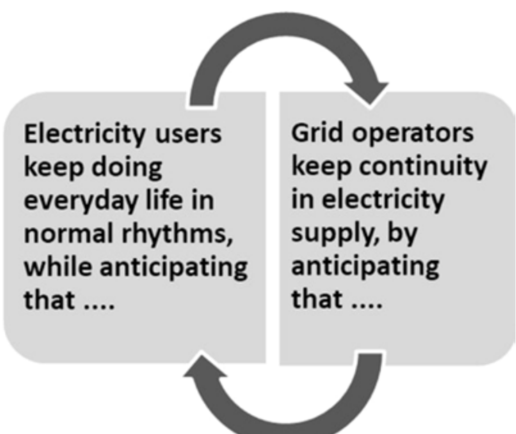

Figure 5.6. Rhythm-based anticipations between grid operators and electricity consumers.

practices, proceed on the basis that their forthcoming future worlds will be in many ways similar to equivalent pasts, including in terms of electricity being available to power devices, as it has been before. They therefore get on with the shared rhythms of everyday life, of society and economy, anticipating that technologies will start up and enable things to be done in expected ways, with predictable speeds and durations, fitting together in familiar sequences.

At the same time, those governing electricity systems and seeking to keep electricity flowing to meet demand anticipate (i) that forthcoming social futures in the aggregate will be similar to equivalent pasts, meaning that the rhythms of everyday life at a societal level will play out as they have done before, rather than varying randomly or chaotically; and that (ii) the rhythms and thermodynamics of natural processes will play out as they have before, in terms of how they directly and indirectly shape the dynamics of energy demand. As noted in chapter 2, natural physical processes, including thermodynamic ones, have an important role in reproducing regularities in everyday experience, even if complex chaotic interactions can sometimes prevail, for example in weather systems.

In combination, these two mutually supporting anticipations by electricity users and electricity providers serve to reproduce the rhythm-energetic dependencies of societies that have co-evolved with electricity grids. Societies that have become rhythmised with electricity function to an energised beat, which in its predictable repetition allows grids to continue to operate. Rhythm and repetition are therefore integral to the big grid model; to the continued, emergent possibility of real-time isohythmic balance in the electricity system, such that demand can be reasonably predicted, and supply planned to follow its dynamics.

In practical terms, this means that grid operators need to undertake analytical work to forecast the anticipated patterning of social and natural rhythms and interactions that make up the dynamics of demand—as laid out earlier in this chapter. Such analysis distinguishes, for example, between the expected demand profiles of different days of the week, between normal working days and public holidays, and attempts to take account of the impact on demand of specific, socially shared events that might generate 'non-routine' spikes or troughs in loads (as discussed earlier). It can also factor in the readily knowable cycling of light and dark over time (the creeping forward and retreating of dawn and dusk) and forecasting of the impacts on demand of future weather conditions, although always with uncertainty (Thornes and Randalls 2007). There is now a whole set of specialist consultants and agencies providing 'weather and climate services' for the energy industry over timescales from days to decades (Troccoli 2018), forecasting the rhythms of future thermodynamic processes in the environment.

In all of this anticipatory analytical work, there is ongoing learning from past rhythms to anticipate future ones, and with the recent explosion of data sources and data analytics, more and more sophistication has become possible, entering with full force into work of actors involved in contemporary electricity markets, which as Silvast and Virtanen (2014) note have specific temporal dimensions. Grid balancing, which was traditionally enacted by integrated public (or sometimes) private utilities managing the grid and generating power stations together, has in 'liberalised' systems become something enacted through bidding and trading across sets of markets to provide capacity and responsiveness over different timescales, putting incentives into the ability of different actors to develop future-oriented market intelligence. Ozden-Schilling (2015: 584) describes how market analysts working in US energy markets, and seeking to achieve a competitive advantage, are 'encouraged to excavate and incorporate every possible grain of information about real-time electricity conditions at ever-shorter timescales into the mass of data analysed by their models'. Silvast and Virtanen's (2014: 102) research carried out with workers on energy trading floors in Finland reveals that despite all of the data analytics being drawn on there was still room for 'gut feeling', hunches and intuition. They described it as like managing a 'living infrastructure'—in other words one full of rhythms—that were not fully predictable in their repetitions or interactions. As one of their interviewees described:

> The process is alive all the time . . . when we make some guess about the temperature and what could be the consumption, it's a living process even though there have been similar temperatures in the past. Its alive and production is alive too (ibid.: 102).

Keeping sufficient generation capacity available to meet demand also entails engaging with the longer-term rhythms in the materiality of generation technologies. Power stations of all forms age over time, reaching the point at which they are no longer functional, uneconomic or too expensive to upgrade. Their life-course rhythm has to be predicted, with then strategies put in place to incentivise their replacement, or in some other way fill the gap they leave when at the end of their life (which might also have local or regional implications in relation to grid capacity). As Breslau (2013) details in a case study of the creation of a 'capacity market' in Pennsylvania, New Jersey and Maryland in the United States, there can be much contestation and political work around how such strategies are implemented. Longer-term predictions of the rhythms of balance between future supply and demand can appear technical in character, but are also political devices, designed in particular ways and with implicit assumptions that determine how they see the future.

Experience shows that predicted demand trajectories, that readily elide any distinction between the 'need' for electricity and the scale of expected consumption, have routinely far exceeded what then actually transpired, serving the interests of those already invested in the rhythms of supply and benefiting from these growing in scale. As Warren (2019: 10) comments in a UK context:

> Without fail all government forecasters seem to overestimate future demand. Past projects have long prompted far too many political interventions designed to solve a perceived problem that actually seldom exists. Tax breaks galore have been offered up to energy suppliers . . . each designed to encourage more and more energy supplies.

'Keeping the lights on' is a recurrent and commonplace idiom and metaphor, and discursive tactic, that has been used to sustain and reproduce the apparent necessity of the big power grid model (Walker 2019). The embedded logic of 'keeping the lights on' discourse is that in order to avoid the frightening arrhythmia of the dark, the rhythms of supply-side investment have to be sustained; replacing power stations when they come to the end of their life, investing in new capacity because energy demand is (always) going to be greater in the future than it is now, and always securing ways of generating electricity that are properly secure, reliable and predictable because that is what meeting the essential rhythms of demand requires. The extract below from an article titled 'Shale and Nuclear Are the Way to Keep the Lights On' in the business pages of *The Telegraph* newspaper (Ratcliffe 2016) aptly displays this supply-dominated logic:

> If we assume that coal will be phased out in the next few years then the burden on gas and nuclear only increases. We are totally dependent today as a country on gas and nuclear. There are no viable alternatives on any sensible time horizon. But, and it's a big but, we are fast running out of gas in the North Sea and our nuclear fleet is ageing. North Sea gas production peaked in the year 2000, and is now running at less than 50% of its peak; in 10 years' time it will be at less than 20%. So we must choose between Russian imports and expensive LNG imports, or developing a shale industry of our own.

As in this article, the urgent focus on bolstering supply is often built around responding to a sense of impending crisis—a narrative that assumes that keeping the lights on will not be possible by other means, that the route being advocated is vital and that to do otherwise is to risk failure and political ignominy. Using a crisis discourse has been long recognised as a temporally structured, political tactic in attempting to force or justify government action of a particular character and form (Jhagroe and Frantzeskaki 2016), including in relation to 'peak oil' discourses (Bettini and Karaliotas 2013, Huber

2011). Raising the spectre of rhythmic desynchronization and the coming of the dark can be equally read as intentional crisis-making intended to support incumbent interests in the big grid energy system.

Making and Managing Load Rhythms

While by far the dominant discipline of grid balance has been to coordinate (and invest in) the rhythms of supply, with demand viewed as 'aggregated needs that have to be met by extending network capacity' (van Vliet et al. 2005: 32), there have been within the historical practice of the big grid model, some limited ways in which the shape of the repeating rhythms of demand have been intervened in.

In the United States and other countries in the early period of expansion of electricity grid, there was intense work undertaken by utilities to boost consumption. This was about *creating* the demand for electricity through investing in the development and promotion of new end uses, but also doing so in a way that smoothed out, to some degree, the rhythms of the daily load curve. In economic and technical terms, a flat load curve is much preferable to having generation capacity sit idle ready for meeting peaks in demand. Hughes (1993 [1983]: 364) captures this intent by noting that 'turbines were in effect supply in search of demand', rather than the reverse. One tactic described by Hughes (1993 [1983]: 369–70) was to go bigger and extend networks to incorporate different non-synchronous demand rhythms. In early periods of grid development when networks were beginning to interconnect geographically dispersed and distinct communities, system managers realised they could work out, and exploit, variations in the processes that drove the social, cultural and environmental rhythms of load on the system:

> Differences in living and working habits arising from variations in the time of sunrise and sunset, contrasts in temperatures and rainfall in highland and lowland regions—even differences in social customs stemming from varied ethic composition and history—were used to shape the load curve. In the United States a few utilities could take advantage of the difference in time zone within one area of supply, for the east side experience the late afternoon peak load an hour earlier than the west. In Germany, a utility extending from one historic province to another combined advantageously the diverse demand that arose from different religious holidays and other patterns of culture involving the use of appreciable amounts of energy.

Harrison (2013a: 176) also describes how it was realised early on that the best way for electric utilities in the United States to maximise profitability was 'to find a diversity of heavy power users that used power at different times of day. For example, electric street railways would use considerable power during the morning and evening commutes, while a factory may use most of its power in the middle part of the day'. Hence, such users were aggressively recruited at very low electricity rates to fill in gaps in the existing rhythms of the load profile. Demand has not always therefore been entirely a given, rather its rhythms have been sometimes actively moulded into a 'better' shape, from the point of view of those invested in the big grid model. Such strategies as traditionally practiced have not sought, however, to limit or constrain either the demand for electricity in the aggregate or the scale of its provision. Indeed, in most cases they have done exactly the opposite through encouraging the growth of electricity consumption and its active weaving into the rhythms of societal organisation.

That any more draconian strategies of restriction and restraint on demand have been seen as aberrant episodes (Pasquier 2011) serves to further reinforce how big (carbon) power electricity grids have been designed and required to work to a particular polyrhythmic discipline. It was made clear earlier that sustaining coal as a flowing electricity-generation resource depends on a whole set of polyrhythmic interconnections, which in their need for ongoing coordination can also be broken apart. When coal miners in the United Kingdom in the early 1970s went on strike, refusing to play their part in the routine performance of the rhythms of underground labour and energy resource extraction, this directly disrupted the coherence of rhythms of supply in the electricity system. The threat to sustaining system-level isorhythmia was responded to by emergency regulations re-rhythmising demand; including limiting the length of the working week, restricting the supply of electricity to homes on a rota basis and rescheduling the switching on and off of street lights and the durations of TV broadcasting (Cochrane 1990, Ledger and Sallis 2017). These interventions into the energetic-rhythmic patterning of everyday life kept the grid functional to some degree but were seen as a major failure of system management and a disruptive success for the striking miners. By the time of further industrial action in the early 1980s, much had been put in place to resist the close coupling between withdrawn labour rhythms and the ability of the system to sustain the normal discipline of grid balance. This included the planning of coal stocks (storage smoothing over interruptions in regular flow), finding alternative rhythms of generation in oil-fired power stations and using computer simulations to test 'the integrity of the system [. . .] both well ahead and day-to-day' (Ledger and Sallis 2017: 211). Such steps in combination were described by those involved as providing the necessary 'flexibility' that enabled the system operator 'to use the full potential of the Board's generation capacity' (ibid.: 220). Most importantly, it satisfied the political demand of the government not to let strike action again disrupt the rhythms and routines of 'normal and necessary' consumption in the way it had ten years earlier.

In contrast, in countries or regional contexts largely in the Global South, where electricity infrastructures are starved of investment, outpaced by urban expansion, or particularly vulnerable to disruptive shocks (including from disaster events), demand-rationing measures can be the norm rather than the exception. Not all blackouts are unexpected 'shocks to the system', and sometimes power outage rhythms can be quite regular and routine, following an organised and advertised programme of electricity rationing, rolling from neighbourhood to neighbourhood across a city or district. While such discontinuities in electricity supply are the subject of intense criticism and practical frustration, research has shown that adaptations are often made in both the rhythms of alternative electricity supplies (such as local diesel generators and small-scale battery systems that kick in when the grid goes down), and in the rhythms of electricity-using activity, with users scheduling electricity consumption into periods when it is expected to be available (Silver 2015, Verdeil 2016). Whilst problematic in many ways, including in their unequal distribution and reinforcement of societal fragmentations (Luque-Ayala and Silver 2016), such adaptations and different experiences of rhythmic interrelations between demand and supply indicate, at least, that alternative patterns and flexibilities are possible. Making clear that the all-dominating big grid, powered by large-scale, high carbon generation, and managed always to follow the aggregate rhythm of demand (or to collapse in attempting to do so), is only one model of electricity infrastructure and only one potential discipline of energy-rhythm management.

SOME REPETITIONS AND REFLECTIONS

Approaching big power electricity grid systems as polyrhythmic assemblages has enabled the systematic opening up of their inherent, multidimensional and multiscaled rhythmicity. Nothing essentially is inert, and without rhythm, from the lumps of coal ripped out of the earth and fed into power station furnaces, to the mobile phones plugged in and charged up whilst their users are sleeping. Electricity grids are assembled infrastructures, into which energy resources enter, become converted to electrons, move instantaneously through networks, ending up in the distant places and moments of switched-on technologies, thereby implicating and interconnecting a vastly complex and distributed set of rhythmic forms—variously social, technological, environmental and cosmological in their making. Managing this dynamic mass, it has been argued, rests intrinsically on the repetitions inherent to rhythm; on how regular cycles through to more chaotic patterns of consumption in space and time can be anticipated and predicted, and made integral to the objective of isorhythmic grid balance.

While there is much to be applauded in this weaving of electricity into the polyrhythmic structures of everyday life and of society more generally, as well as in the sheer technological achievement of coordinating such rhythmic complexity, there are also far less welcome outcomes and implications. Along with large-scale electricity systems has come a growing and intensifying energy dependence, intrinsic to their scale and reach; for Boyer (2015: 533) the grid 'is an apparatus subtly inclined to encourage demand, to expand itself, to solicit further dependency on its power, which then grows in response'. What follows is a potentially arrhythmic fragility to the social order in the event of grid failure (the more that dependence has developed); a continued building up of supply rhythms to meet escalating (anticipated) demand rhythms; and, most important for the contemporary context, the spinning off of damaging pulses of ever-accumulating carbon pollution into the cycles, patterns and repetitions of atmosphere and climate.

These outcomes are not inherent to the generation and provision of electricity per se. They are rather the product of a particular model of generation, coordination, distribution and growth. A model built on sets of interrelations between the rhythms of preferred energy resources, a particular disciplining of rhythm management and a prioritising of certain rhythms that are seen to matter, over those that are not. Crucially, the rhythms of coal as the globally dominant electricity-making resource have long been selectively valued. In the foreground, for those invested in the big power grid model, are coal's stable thermodynamic intensity, its capacity to be managed and to accrete value as it moves through the rhythms of extraction, movement and accumulation, and then to be aggregated and controlled in its combustion into electricity. Submerged and ignored have been the slow cyclical rhythms of coal's making in distant geologic time, hidden in its inertness in the here and now; and the rhythm of its pollution and risk-making. Rhythms equally submerged in uranium's production of power in nuclear generation systems.

While such sets of rhythmic interrelations and selective ways of valuing rhythms have long been resonating together in incumbent infrastructures, institutions and professional norms, it is inherent to the notion of a polyrhythmic assemblage that it is always 'in the making'. This contingency means that its coherence may become eroded, through shocks or discordant and disruptive rhythms that are introduced from within, or through interactions with rhythms coming from the outside. As Graham (2009: 11) states, 'any coherence that the electrical assemblage achieves as an infrastructure must never be assumed or taken as permanent and inviolable'. Blackouts reveal the essential fragility of electricity infrastructures—in blacking out a lot is often 'lit up' (Bennett 2010: 36)—but the pressures on the rhythmic coherence of big (carbon) power electricity grid systems do not only express themselves in sudden failures. Rather they are now found in carbon calculations, the surfacing of the submerged rhythms of pollution and risk, the valuing of other quite different resource rhythms and the realisation (and demand) that electricity-making should be differently conceived, scaled and rhythmically managed. In the next chapter we will examine how new rhythms and polyrhythmic interrelations are integral to the transition of electricity infrastructures into low carbon forms, but also consider the resistances that embedded entanglements of old rhythmic patterns present to making change happen.

Chapter Six

Low Carbon Rhythms and Electricity Systems in Polyrhythmic Transition

It has now become very clear that the particular and destructive rhythms of carbon-based energy systems, and all that surrounds, protects and profits from them, will have to be made a relic of a previous, blindly polluting age. Catalysed with new force by climate emergency activism, and by evidence week by week that climatic change is now upon us, we now *really* have to face up to the potentially existential global consequences of ripping past energetic accumulations out of the earth and liberating the products of their burning into the atmosphere, as characterised in arrhythmic terms in chapters 3 and 4. It is a grim truth that we cannot now stop the re-rhythmising of the climate, or the many cascading impacts that will play out unevenly across a very unequal world. But acting to transform energy systems into new rhythmic shapes and new sets of polyrhythmic and energetic interactions can be at the centre of holding back the further acceleration of climate chaos into the future. Low carbon futures, it will be argued through this chapter and into chapter 7, are necessarily about the making of new and interrelated polyrhythmic and thermodynamic futures, valuing rhythms differently and taking hold of the possibility of transitioning rhythms within and outside of energy systems and steering them into better shapes and interrelations.

Chapter 7 will grapple with de-energisation as a necessary complement to decarbonisation, exploring ways of taking the consumption of techno-energies out of the rhythms of social reproduction. In this chapter, we stay in the more bounded territory of electricity systems, and their transitions as polyrhythmic assemblages into low carbon forms. Taking apart the rhythms that run through and out of 'big power' carbon-dominated electricity systems evidently has to involve changing the resources and technologies of electricity generation. However, unplugging an old carbon-heavy coal-fired power station and plugging in a new low carbon generation technology is certainly *not* the end of the decarbonisation story. The polyrhythmic assemblage has to be recast in more substantial terms, its diverse elements and interactions remade in a conjunctural interruption of 'habitual patterns of relating things' (Chen 2017: 50), in order to remove the spinning out of the material energies of pollution into the rhythms of vulnerable organisms, ecologies and social systems.

This means a striking shift in the scale and distribution of techno-energy making, transitioning from only 'big power' to multiple sizes of low carbon power, each contributing in different rhythmic, spatiotemporal terms to realising the continued flow of electrons within and outside of grid systems. This in turn demands a major reworking of how electricity grids are governed, in particular how the rhythms of supply and demand are held in isorhythmic synchrony, along with the introduction of significant new dynamics and intensities into the repeating and anticipated rhythms of electricity-demand load curves. No longer can dominant ways of valuing and managing rhythms locked together in sunk capital investments and institutional norms be sustained. Instead, sets of rhythmic interactions have to be prised apart, disrupting their momentum in order to challenge some of the core assumptions of the carbon-heavy era. Whilst 'the effort required to maintain rhythmic and temporal order should not be underestimated' (Edensor 2010b: 15), neither should the effort needed to disrupt and align incumbent rhythmic structures into new working configurations.

While this chapter focuses on electricity, this does not mean that other existing flows of techno-energy are absent. Given that decarbonising includes moving away from existing ways of powering technologies—away in particular from the direct burning of gas and oil-based fuels—such existing hydrocarbon-based energy systems, and the rhythms they make and implicate, will also be in view. So, as we will see, the transition from petrol- and diesel-powered vehicles to electric ones means grappling with deeply embedded rhythms of vehicle use, travelling and refuelling, which through their familiar repetition and entanglement in social and economic life can readily resist the replacement of one energetic form with another. However, not all dimensions of low carbon electricity system transition can be addressed, given that there are many different imagined trajectories of change, and many different innovations proposed and debated. The discussion is therefore directed towards some of the key shifts already underway, and towards aspects of transition with which I have already engaged in recent research *and* that demonstrate the relevance and power of thinking rhythmically. Along the way we will encounter, for example, thermostats as 'rhythm-linkers', smart meters as 'rhythm-revealers' and batteries as 'rhythm-smoothers', each attuned to their role in enabling and sometimes obstructing attempts to make the rhythms of electricity systems work in different ways. To begin, though, we will start with resource rhythms, and how valuing the temporalities of renewability and sustainability are both central to electricity system transformation and fundamental to the new sets of rhythms that are entering into the low carbon polyrhythmic assemblage.

RHYTHMS OF RENEWABLES

The terms 'sustainable' and 'renewable' have been attached for some time to particular ways of generating electricity, and not others. Both terms have inherent temporal qualities. Sustainability, while slippery and ambivalent in meaning (Walker and Shove 2007), is at least in some way about achieving longevity of basic resource access, social needs and environmental well-being, over generational timescales. Renewability, similarly, is about long-term continuity, specifically in the availability of an energy resource, characterising an ongoing energetic flow, rather than a stock that is used up and cannot be remade. These qualities, if thought about rhythmically, mean that the beats and pulses of sustainable and renewable resources for generating electricity are markedly different, and differently valued to those of coal and other big power fuels, as characterised in chapter 5. Fossil fuels may have the same fundamental energetic beginning as most renewable energy resources, being derived from the energies contained within received solar radiation; but the rhythmicity of how, as resources, renewable energies originate from solar flow and are then drawn into the generation of electricity is very different.

There is not a singular rhythm of renewables that can be contrasted with the rhythm of big power electricity generation. Rather renewables are rhythmically diverse, due largely to their tight energetic coupling to rhythms rooted in various environmental and cosmological processes. Considering, in turn, a number of renewable energy forms (wind, solar photovoltaic (PV), tidal and biomass), and the rhythms of their energetic 'pre-life' through to energetic 'post-life' makes that clear, demonstrating differences in rhythms of their energetic intensity across diurnal and seasonal timescales, and in the rigidity and predictability of the particular beats and patterns of their potential for conversion into electricity.

Wind energy is derived from the ever-shifting patchwork of differential heating of air, land and water by the sun, and sets of complex thermodynamic relations that lead to air movement. Solar thermal energy is converted to moving kinetic energy with a direction, intensity and duration of flow that is chaotic over time, if to varying degrees locally predictable, following broad seasonal and/or diurnal rhythms. When a flow of air movement encounters the blades of a wind turbine, some of the kinetic energy of air movement is instantaneously transferred into the cyclical movement of the blades and the spinning of the hub and turbine they are connected to. There is no energetic pause or intermediate stage, no storage, or opportunity to manage the timing of conversion from air movement to electricity. The natural rhythms of air movement and technological rhythms of energy conversion, generating the rapid pulsing of AC electricity, are therefore tightly coupled, subject to the rhythmicity of ongoing thermodynamic and atmospheric processes, with all their intermittency, variation and inherent messiness. This also means there is no ongoing coordination of stages of transport, movement or processing in becoming useful energy, stripping out the rhythms inherent to the political economy of fossil fuels as high-value commodities that move and are exchanged between geographies of production and consumption (as made clear in chapter 5). This also importantly means there is much less geopolitical entanglement or scope for disruption of wind-generated electricity, as inherent in the supply chains of fossil fuels.

Solar photovoltaic–generated electricity shares this tight coupling of natural and technological rhythms, with an even more immediate spatiotemporal relation between the energy received in sunlight and its conversion in PV cells into electricity. Solar radiation itself cannot be stored and then released at will. Rather, PV panels are positioned to best capture the spatially and temporally varying patterns sunlight—in some systems with panel orientation closely tracking the rhythmic cycling of the sun during the day. As discussed in chapter 4 in relation to the rhythms of natural light, the movement and strength of solar radiation and the diverse energetic work of which it is capable is predictable in its general patterning, with a strong diurnal rhythm that shifts seasonally according to physical location, but also mediated by the more chaotic and variously predictable patterns of cloud cover (see figure 6.1). Solar PV electricity can never be generated when sunlight is entirely absent, but the temporal shape of its potential during daylight hours is subject to repetitive and predictable rhythmic interrelations in the atmospheric environment. And again, in common with wind energy, there are no supply chains rhythms involved between resource making and electricity generation.

Tidal energy is rhythmically quite different, having its primary energetic foundation in the gravitational effect of the cycling of the moon in relation to the earth on ocean water (and to a lesser extent the gravitational attraction of the sun). Its rhythmicity is therefore entrained to a combined planetary-cosmological rhythm distinct to that of solar cycling alone, and not synchronised with it (see box 3.1). A given body of ocean water bulges as the moon becomes more proximate and then more distant in its cycling around the earth, creating high and low tides, with that movement intensified by the geography of particular estuaries and bays with a large tidal range. The rhythm and intensity of tidal water movement is predictable within each tidal environment (as specified in local tide tables) and moves and varies from day to day, with a flux that predominantly follows the lunar cycle. The temporality of the conversion of the energy in ocean water movement to electricity within turbines depends on the

Figure 6.1. Solar panels and wind turbine over a supermarket car park in New York.
Photo by the author.

type of tidal technology, but it is episodic and restricted to particular periods of the day when there are strong tidal currents, or when water at high tide is held back by a tidal barrage and released at low tide. Tidal energy therefore has a complex and locally situated rhythmicity that structures its potential to contribute to electricity generation. And again, in common with wind and solar energy, there are no supply chains rhythms involved between tidal resource making and electricity generation.

Biomass energy forms are a materially diverse set and rhythmically distinct from other renewables, depending to an extent on which particular type of biomass is involved. As a set they do share some similarities with fossil fuels in having their energetic foundation in the growth of organic matter (plants, crops, trees), driven by photosynthesis over seasonal cycles. They are also similar to fossil fuels in typically having a chain of managed steps in their making into an energy resource (harvesting, transport, processing and storage), before then entering into variously scaled technological systems for conversion into electricity; and also in their generation of variously polluting emissions where combustion is involved. However, the crucial rhythmic distinction from fossil fuels is the short term rather than geologic timescale of their becoming an energy resource, moving from living organic matter to resource over a growth/life cycle (of various but relatively short durations). Biomass energy forms

> have a cyclical rhythmicity therefore, which also enables replacement rather than depletion (as well as carbon neutrality over the short term), and a potential managed constancy of flow of energy into electricity making. That flow may be variable and interrupted, for example by drought or excessively wet conditions restricting growth of energy crops, or by transport failures, labour disputes (as with fossil fuels) or even geopolitical conflict where supply geographies are more extended, but the potential for constancy is there.

These four types of renewable energy resource and electricity generation have significantly distinct and contrasting polyrhythmic qualities (summarised in table 6.1, along with other renewable energy forms), which are important to how they can contribute to the managed generation and availability of electricity. Evidently, a solar PV panel cannot directly provide electricity when it is dark, a wind turbine is dormant when the air is still, tidal energy contributes power in surges, and each of these distinct rhythmicities, entrained to the beats of planetary cycles and environmental processes, are variously able to be anticipated and predicted. The fact that these diverse rhythmic qualities are in many respects strikingly different to those of established big power coal, nuclear and HEP generation has significant implications for how electricity supply and grid functioning at scale is managed. As will be argued later, with a greater penetration of renewables supplying into electricity grids, grid management certainly becomes rhythmically even more complex, but not as inherently unstable and unreliable as critics invested in incumbent infrastructures and business logics like to make out.

A crucial disruption for established networks of actors is that most renewable energy resources cannot become embroiled in the rhythmic coordinations of commodity flow through sites of value extraction, or in the structures of economic and geopolitical power that have been so central to carbon economies. Without the trading and transport of oil, gas and coal, geopolitics is recast, and there are securities that come from the rhythms of renewables, in part through opportunities to radically remake and rescale the politics of energy production. Following Mitchell's (2013) argument that the materiality of energetic flows and the possibilities of democratic politics are closely related, this opens up the potential, at least, for low carbon energy-making being enacted in more democratic and less destructive formations. As he cautions though, 'one cannot predict democratic possibilities directly from the design of socio-technical systems. . . . The point rather is that in battles over the shape of future energy systems the possibilities for democracy are at stake' (ibid.: 266–67).

Table 6.1 includes entries in the 'after-life' column, and it is important to recognise that low carbon, sustainable and renewable technologies do have material environmental consequences, including in the form of potentially

Table 6.1. The Rhythmic Qualities of Different Low Carbon Energy Resources for Electricity Generation, from 'Pre-life' to 'After-life'

Energy Resource	*Pre-life Rhythms*	*Rhythms within Energy System before End-use*	*Rhythms in Energy Delivery*	*After-life Rhythms*
Wind and Wave	Very short duration, contemporary solar	Momentary at point of conversion in turbines	Intermittent variously predictable, some seasonality	Short-term land- or seascape disruption, and wastes
Solar	None, contemporary solar	Momentary at point of conversion in PV panels; storage with solar hot water	Intermittent, strongly diurnal and seasonal, variously predictable	Short-term landscape disruption and wastes
Tidal	Very short duration, contemporary lunar	Momentary at point of conversion in turbines; storage in tidal lagoon systems	Episodic, lunar, very predictable	For large-scale projects, midterm local ecological change; social impacts
Geothermal	Very long geologic duration; inner earth heat, radioactive decay	Extraction and movement through water and steam systems; momentary at point of conversion in turbines	Managed constancy, with potential for disruption	Short-term and limited long-term landscape and environmental impacts
Water (in streams, rivers, lakes)	Within working of hydrological cycle; various temporalities short to long	Flow management and storage in reservoirs; momentary at point of conversion in turbines	Variable, variously predictable seasonal flow and managed constancy	Large-scale projects, long-term river/landscape change and social impacts
Biomass feedstocks	Short- to midterm growing cycles, recent solar	Harvesting, movement, storage; momentary combustion and conversion in turbines	Managed constancy, with potential for disruption	Short- to midterm emissions and landscape change
Waste feedstocks	Short durations of sewage making, of divested things and other combustible unwanted products	Collection, movement, storage and short duration/momentary combustion and conversion in turbines	Managed constancy, with potential for disruption	Short- to midterm emissions and wastes

lingering and problematic wastes. Cross and Murray (2018) provide an excellent account of the challenges of dealing with such solar power ‘after-lives’ in Africa. These are nothing like the scale of hydrocarbon fuel after-lives, either in their intensity or in the spatial and temporal reach of their polluting consequences, but still demand recognition and careful management.

De-centralised Rhythms and Alternative Geographies

It is important to think about the implications that flow from the rhythms of renewables in their spatial as well as temporal manifestation. It was stressed in chapters 2 and 3 that rhythms are spatiotemporal phenomena, materialising and repeating in space and over time. In the discussion of big power grid–based electricity provision in chapter 5, it was made clear that while the demand rhythms of electricity consumption are radically dispersed and distributed across space, the rhythms of electricity supply have been traditionally centred on only a small number of power station locations, generating massive, variously dynamic flows of electricity into the grid from sites typically linked to the history of local resource extraction (coal mining in particular), fuel importing, and/or the geography of regional intensities of demand. The ‘big carbon power’ polyrhythmic assemblage is formed therefore from a particular geography of spatially distributed demand rhythms, and spatially centralised supply rhythms (fed by coordinated chains of resource flows), a geography which also demands capital investment, management and governance at scale, by big power utilities that are either publicly or privately owned.

The spatiality of renewable electricity generation is strikingly different with important consequences for the polyrhythmic assemblage(s) in which it can become embedded. In nearly all cases, because of the temporal characteristics summarised in table 6.1, and, in particular, the tight coupling between natural resource rhythms and the technological rhythms of electricity generation, the site of generation *has* to be the site of the available resource; where the tidal pulse is, where the stronger winds are, where the sunlight rhythm falls and the shade does not, where the water flow gradient is larger and so on. All energetic places across a polyrhythmic landscape of power generation potential. Biomass fuels and wastes are distinct in having a looser rhythm-energy coupling, being transportable as resources to generation stations, accumulated and concentrated before their conversion into electricity, but no other renewables share this quality. This means the rhythms of renewable electricity generation are both spatially diffuse and particular, spreading their energy-seeking geographies across diverse rural and coastal landscapes, into marine environments, across the rooftops of buildings, both more isolated and more concentrated into urban space (Walker and Cass 2007). The rhythms of such electricity generation are made in situ and in place, extracting energetic flows from macro- and micro-environments, pulsing in varied quantities and intensities (from 100s of megawatts to 10s of kilowatts).

Where renewable energy rhythms are fed into big grid infrastructures, this means that these networks will have a much more varied spatiotemporal patterning of electricity supply to integrate, aggregate and manage than under old big power geographies (discussed further below). However, the diffuse geography and 'size-ability' of renewables (ibid.: 461) also means that renewable-made electrons are not only tied to becoming distributed inputs into national or regional grids, or to being the product and property only of big-scale utilities. Other geographies of assembled elements and of relations between supply and demand are also available. A much simpler 'system' can be, for example, one that operates entirely off-grid with the generation rhythms of a solar panel, wind or hydro turbine supplying a particular electricity-powered technology, a singular home, or a set of buildings, and their limited set of rhythms of electricity use. Or one that is networked but locally bounded, electricity generation feeding into an infrastructure that distributes electricity across a rural village, or organisational complex (and their associated sets of electricity demand rhythms), but no further. Or it could take the form of a hybrid arrangement that is both locally bounded and grid connected, with the potential to work as both on- and off-grid. And across these different arrangements, electrons can be generated, owned and managed by individuals, households, communities, schools, universities, individual businesses and so on (Walker and Cass 2011), opening up a plethora of organisational and political possibilities for becoming involved in the rhythms of electricity-making.

Such varied spatial, institutional and political arrangements are becoming more realised and experimented with in many parts of the world. For example, in Germany the 'Energiewendie' (Gailing and Moss 2016) is materialising a transformed energy system through multi-scaled initiatives that include big-scale offshore wind farms, but also urban-scale municipal energy companies and community renewable projects organised around 'energy democracy' principles (Becker and Naumann 2017). In Africa, the open-access 'least cost electrification tool' made available through the United Nations[1] is intended to help guide strategies for expanding electricity access, through spatially evaluating the relative cost of three alternative electrification strategies—national grid, mini-grid and stand-alone devices—in relation to available resources, population density and other spatial parameters. It is not only therefore the established national grid model that is seen

1. See https://unite.un.org/sites/unite.un.org/files/app-desa-elec.trification/index.html.

as the way to do electrification, and much potential is particularly seen in mini or micro grids (Moner-Girona et al. 2018).

Such spatial flexibility has important implications, first for the complexity or simplicity of the polyrhythmic assemblage that is so formed, second for who and what is involved in making electricity flow happen, and third for the 'level' at which the relations between supply and demand become critical. In the latter respect, the polyrhythmic isorhythmia of balance between generation and use can be enacted very locally, within a household or an organisation, or across a network of limited spatial extent. Crucially, it also need not only be oriented towards a big-grid 'ideal' of a functional continuity that is achieved by only ever meeting demand rather than managing it. However, before exploring such 'flexibilities' further, we need to first consider how future demand rhythms in low carbon transition processes might take on new shapes and intensities.

NEW ELECTRICITY DEMAND RHYTHMS

Electricity demand is always changing and evolving in its makeup, its aggregate total and its timing; it is in this sense a living phenomenon with structure and regularity, but still constantly in the process of formation and therefore open to change (Walker 2014). Chapter 4 laid out some of the longer-term history of how new patterns of energy expenditure have introduced new rhythmic patternings and polyrhythmic interactions into practices and orderings in the social world; and in chapter 5 some of the contributory processes leading to the rhythmic profile of electricity load curves shifting over time were also discussed. Demand dynamics are therefore an important agentive force within the contingency of the electricity system assemblage, with energy policy makers and grid managers attempting to accommodate and anticipate these dynamics and plan for them over short- to longer-term time frames.

While then the rhythms of future electricity demand will always repeat differently to those of today, some of the dominant trajectories of low carbon transformation are intent on bringing significantly new and potentially disruptive demand rhythms into the electricity system. Potentially most significant are shifts away from the direct combustion of hydrocarbon fuels—gas, petrol, oil, butane etc.—and their replacement with the use of electrical power. In other words, burning fuels in situ being substituted by a stream of electrons flowing over networks, powering technologies designed to provide a similar energy service (heat, movement, light), but through a different means of energy conversion. This raises some key questions. What new demand rhythms does such energetic substitution introduce? What new pulses could emerge in the temporal and spatial patterning of future demand, are existing infrastructures able to carry these, and what discordant or disruptive interactions could emerge?

Answering such questions depends both on what the existing landscape of hydrocarbon use in a particular setting looks like—where the carbon dependencies currently reside—and what trajectory of change away from these is imagined and pursued. The two illustrative, but particularly significant cases (in a UK context, but also elsewhere) of space heating and car-based automobility demonstrate both the scale of new patterning of demand rhythms that could be involved and the importance of situated differentiations and distinctions in how they come to matter.

Electrifying Space Heating

The demand for artificial (techno-energetic) space heating (discussed in chapter 4) has become what it currently is through the development of situated, cultural ideas of thermal comfort, building design and indoor living, co-evolving with the development of (and active promotion of) particular infrastructures and heating technologies (Shove 2003, Shove et al. 2014a). The extant rhythmic structures of heating—and not heating—in any one setting, diurnally and across the seasons, reflect this history, closely entwined with the rhythms of local climatic and environmental conditions. It follows that the assemblage of rhythms that generate a profile of heat demand over time is made differently from place to place; and the extent to which these rhythms are carried by electricity systems or other forms of heat-making is also place dependent.

It was noted in chapter 5, and specifically in relation to figure 5.4, that the electricity demand load curve in France has a noticeably different daily and seasonally varying shape to that of the United Kingdom, in part because of the much greater use of electricity for space heating in France under a government policy deliberately designed to build up the demand for nuclear-generated power. The rhythms of electricity demand in France therefore *already* have the demand for space heating as a significant constituent element. In the United Kingdom in contrast, there is much greater use of gas-fired space heating, a historical pattern that became widely embedded with the exploitation of natural gas from the North Sea. Over a ten-year period starting in 1967, an extensive pipeline network was laid out across the country connecting more than 13.5 million customers into one gas grid, and about 35 million devices already using manufactured town gas were converted to work with natural gas, a massive state-led intervention in the materiality and infrastructure of energy supply (Arapostathis et al. 2019). In the United Kingdom, therefore, the rhythms of heat demand are currently carried largely by the gas network; with 67 per cent of all demand arising from heating met by natural gas and only 13 per cent by electricity (Department for Business Energy and Industrial Strategy 2018).

For the United Kingdom, moving away from the familiar use of gas-fired space heating and towards alternative low or zero carbon-powered arrangements therefore raises a host of issues, including some that directly arise from and for demand rhythms. One of the proposed strategies is to shift to electric heating, primarily through heat pump technologies that are already widely used in other countries, meaning that rhythms of gas demand will, with some modification, become rhythms of electricity demand. Most important in this rhythm removal and re-attachment is that the demand for gas is very seasonal, with a surge of demand over the winter and some very strong daily peaks, moving in a counter-rhythm to the falling of outside air temperature. Furthermore, this synchronization between gas demand rhythms and the rhythms of natural heat flow is deeply embedded in the working of tens of millions of thermostats scattered across the buildings of the United Kingdom, all locally set to try to sustain a particular indoor temperature. Thermostats act in effect as automated thermodynamic 'rhythm-linkers', tying together the dynamics of local external temperature and internal room temperature, making heating technologies work harder when it's colder outside. They are agentive therefore, both rhythmically and energetically. Box 6.1 conveys something of the interwoven polyrhythmic structure of home heating, with thermostats playing a monitoring and controlling role. Much in the specific dynamics of this rhythm-linking depends on the thermal performance of buildings, but when thermostats are involved there will always be some degree of responsiveness to the temperature of the external environment.

The problem for this strategy for decarbonising heat is that the UK electricity grid currently deals with nothing like the seasonal intensity of the rhythms of gas demand. Figure 6.2 shows a comparison between the total daily demand for gas and electricity in Great Britain across eight years. Electricity demand has a repeating seasonal shape, increasing in the winter, but in a relatively shallow and regular pulse. Gas demand has a far more intense and spiky beat, peaking very strongly in the winter (up to seven times higher than in the summer) and with significant variability both because of the messy variation of rhythms of outdoor temperature over any one season and between different years, and the tightly automated rhythm-linking in thermostat functioning.

Such a rhythmic profile has far more acute real-time consequences for the temporally ultra-sensitive electricity system than for the gas system, which (as explained in chapter 5) has more 'give' and temporal buffering within the

BOX 6.1.
A Polyrhythmia of Household Heating

It begins with the timer, a click, pulsing the heating on to a clock schedule, to somehow, precisely or imperfectly, fit the daily anticipations of the household. The timer makes rhythms in sequence, in whirring boiler and circulating pump, heated water sliding and gurgling through pipes and radiators, warming the floorboards, sometimes creaking, groaning, cracking; and, in turn, the air of rooms and corridors and their inhabitants, bodies and other organisms, yielding, resisting, uncurling, emerging. Thermal rhythms that shift slowly, with lag and inertia, as heat conducts and convects, warming, accumulating and dispersing between things of different constitution, position and location. And the thermostat knows it all. It knows the thermal beats of the timer, boiler, pump and radiator are never alone. Always accompanied by the repetitions of atmosphere, seasonal and diurnal, shafts of sunlight into the home, air and energy trailing in and out, through doors and windows. Other inside-heats pulse and pattern, cookers, lights and appliances switched on and off, bursting and trickling therms in their functioning; human bodies, variously still and energetic, warmth making and releasing, always while alive. The thermostat knows it all, adds it all together, conducts the mass, in concert a chaos of rhythms entwining and thermally interacting. And, click, it says enough work has been done, for now.

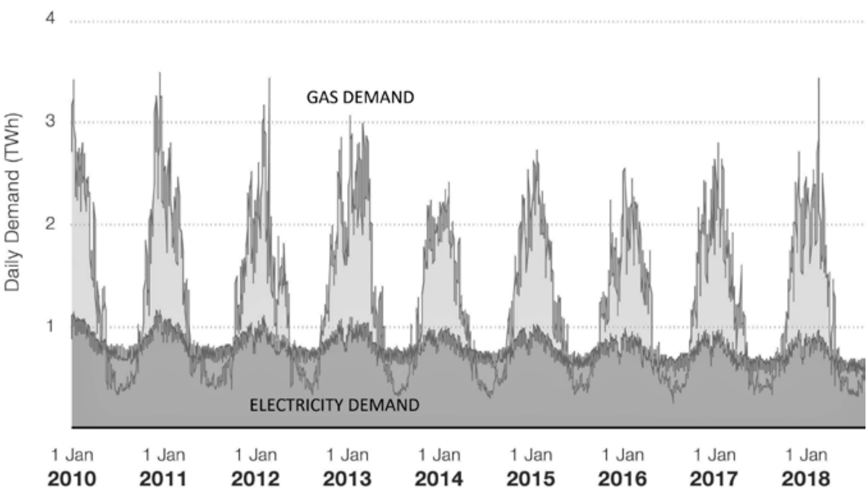

Figure 6.2. Gas demand and electricity demand for Great Britain 2010–2018.
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materiality of its energetic flow and infrastructure. There is much uncertainty about exactly how severe these consequences could be. Some see the existing infrastructure as acting to *resist* the rhythmic intensities that would be produced, predicting that peak electricity demand could more than double, threatening to destabilise networks and generate arrhythmic shocks to system functioning. To carry these demand pulses, much expensive network 'reinforcement' would be needed; along with the prospect of needing power generators that are on hold and silent for much of the year, being brought into action only to provide a blast of additional power on particularly cold winter days (Department for Business Energy and Industrial Strategy 2018: 76). Others, however, argue that smart flexibility and storage, of both heat (short term and inter-seasonal) and electricity, could do much to smooth rhythms out (discussed further below), along with a more mixed portfolio of energetic substitutions that keep a substantial proportion of heat demand rhythms out of the electricity system all together.

Electrifying Automobility

Decarbonising mobility is a vital part of any decarbonisation strategy. There are different modes of hydrocarbon-powered movement—including air, rail and sea travel—but specifically here I will consider the undoing of the domination of the hydrocarbon-fuelled car in everyday patterns of mobility (as briefly discussed in the history of combustion and heat in chapter 4), with a focus, for the moment, just on electric vehicles (EVs). As many writers have made clear, the existing 'automobility' system (Urry 2004) is deeply embedded, held together through economic, cultural, political and infrastructural forces that produce strong lock-in and inertia, and 'automobility is deeply embedded in Western life styles, and stabilised through sunk investments, interests vested in its continuation, and taken-for-granted beliefs and practices' (Kemp et al. 2012: 3). It is also a system, or in more dynamic terms a polyrhythmic assemblage, that has a particular rhythmic structure, including within and between four key types of rhythm:

1. *rhythms of oil extraction, processing, transport and storage* held together in tightly coordinated logistical patterns (Haarstad and Wanvik 2017) and managed such that that a stabilised and concentrated form of liquid hydrocarbon energy is available to be purchased and consumed by end-users, and profit and tax returns generated. These chains of interlinked rhythms are stretched out across space (nationally and internationally) and oriented towards ensuring a coordinated eurhythmia of continuity, security of supply and moneymaking.

2. *rhythms of vehicle fuelling* structured by the geography of and distances between fuelling station locations, the speed with which the refuelling of the vehicle can take place, and the energetic capacities of vehicle fuel tanks and fuel efficiencies in relation to distance travelled. Fuelling rhythms are practically managed by the vehicle user to ensure that the store of energy carried by the vehicle does not run out—that their own mobility rhythms embedded in sequences of activities do not fall into arrhythmic disruption—and that refuelling can take place at petrol stations encountered within journey patterns. A very mundane and familiar management of rhythmic interrelations and orientations to infrastructural provision.
3. *rhythms in and of the movement of vehicles, and the people and things they carry,* functionally achieved through the expenditure of energy in fuel tanks, applied to the production of heat in combustion engines, making wheels turn in order to travel through space and time. Which movements and rhythms of mobility are performed fits within the time-structuring of everyday activity—home life, work, leisure, shopping—linking vehicle use to the interconnection and sequencing of particular practices in time and space (Mattioli and Anable 2017, Mattioli et al. 2016), which have been iteratively shaped by the material-spatial arrangement of road infrastructures and land uses within urban and rural space (Shove et al. 2015).
4. *rhythms of pollution*-making as engines in use turnover, generating gases and particles (and soundwaves) that spill into the air, into breathing bodies and other organisms (Walker et al. 2020), and ultimately into the shifting rhythms of the climate (as conceptualised rhythmically in chapter 3).

These four rhythm types are tightly interrelated—the rhythms of vehicle use, produce and are enabled by the rhythms of refuelling, which in turn are enabled by the coordinated sets of rhythms of fuel supply, which all add into to the rhythms of pollution production. Making everyday mobility low carbon means, therefore, intervening in some way into a set of rhythmic associations and relations, acting on particular rhythms—modifying, recalibrating, removing or replacing—but with potentially significant consequences for the polyrhythmia as a whole.

Whatever strategy is followed, certainly the rhythms of the hydrocarbon fuel supply system (type 1 above) have to be curtailed, and within a strategy of shifting to EVs, this means their replacement with the very different polyrhythms of a low or zero carbon electricity system. However, as with heating, taking new mobility demand rhythms into the electricity system is not a simple matter of removal and re-attachment, with much resting on exactly how the rhythms of vehicle fuelling (type 2 above) also become reconfigured. If there is a wholesale movement from hydrocarbon to electric fuelling, this will mean significant new aggregate loads on electricity grids. However, the rhythm of electric vehicle charging cannot (as yet) simply mirror the rhythm of hydrocarbon refuelling, in relation to distance travelled, speed of refuelling and tank/battery capacity. The inherent 'vital' rhythms of current EV batteries (see later discussion) resist the rapid speed at which a fuel tank can be re-energised, and generally do not release their energy over as long a period of driving; the relation between type 2 and 3 rhythms is necessarily different.

The current focus is therefore on charging where and when vehicles are already static and/or parked for a stretch of time—at home, at work, while shopping—meaning that the rhythm of re-energising a vehicle in time and space becomes recalibrated with the rhythms of car use and non-use, and therefore with the patterns of everyday practices and how these are, and are not, sequenced around the use of the car (Mattioli et al. 2016). But how well charging and the time-space of car non-use can synchronize neatly together is very unclear, with evident scope for discordances, clashes and arrhythmic mismatches between charging opportunities and expectations of both everyday and more non-routine journey-making by car.

This all makes the likely patterning of the rhythms of electric vehicle charging hard to predict or plan for, given also that what is (and is not) predicted and planned for will shape the patterns that in the end do emerge. Recent studies have attempted to track and analyse the charging patterns of EV owners, suggesting what might be the key explanatory variables of charging behaviour (e.g., Franke and Krems 2013), or have modelled and developed charging scenarios for the future (e.g., Azadfar et al. 2015) and what these mean for load on electricity systems. But given the interwoven rhythmic complexities involved and their emergent and situated character, possible indicators of future patterns are only beginning to emerge (Ofgem 2018).

In the United Kingdom, where a ban on all new diesel and petrol car sales is due to come into force in 2030, National Grid currently presents a rather relaxed view of the degree of likely exact synchronization of charging patterns, referring to the multiple rhythms of routine, movement and being at home that are relevant to factor in:

> If every consumer chose to charge their vehicle after getting home from work at 5pm, as System Operator we would face runaway peak demand to manage. The consumer would still have the choice of when and how to charge. In reality, there is already diversity of demand. People arrive home at different times and have different routines, with only one in five expected to charge at peak times. It's a little bit like every home having a kettle, but we don't all make a cup of tea at the same time (National Grid 2019).

Their perspective also relies on the development of ways of managing charging rhythms to avoid excessive peak load and overloading of local networks, assuming that 'chargers will be smart-enabled—in other words they can talk to each other, helping consumers, if they would like to, and potential service providers manage demand in the most effective way' (ibid.). They also note the attempted development of 'flash charging technologies' that could mimic far more directly the current experience of fuelling up at petrol stations, with such technology clearly oriented towards leaving the rhythms of type 2 and 3 intact, enabling the space times of electrified mobility to mirror their hydrocarbon form. Whether this is the way to go is not, however, just a question of technology and cost, but rather whether it is right to attempt to sustain the rhythms of a regime of mobility that is problematic for a host of reasons beyond just the carbon-related (Kemp et al. 2012). The case for challenging the domination of car-based flows of movement and for focusing on what should come 'after the car' (Denis and Urry 2009) will be discussed further in chapter 7.

SMART POLYRHYTHMIA

Through considering the rhythms of renewable energy forms and the type of new demand rhythms that could emerge as part of low carbon transition, it has become clear that the polyrhythmic assemblage of the low carbon electricity system is going to have quite a different symphonic form to that of the carbon-dominated past. There will be different and far more diverse and distributed resource beats and pulses feeding into generation at a multiplicity of points in infrastructural networks, coupled in varied ways to the distributed repetitive cycling and chaotic variation of rhythms in the environment (sun, wind, tides) and its thermodynamic patterning. There will also be new beats and pulses of demand drawing electric current out of the system to work newly electrified ways of doing things and realising energy services, in patterns of spatiotemporal repetition that will be different, but in ways that we cannot yet be clear about.

In combination, this adds up to a potentially major disruption in the polyrhythmia of big grid electricity. If the logic of big power grid systems remains that the system will provide, and it will provide wherever and whenever, in the instant, electricity is demanded, then the isorhythmic synchronization between aggregate future supply and demand comes under enormous pressure in the types of low carbon re-rhythmising laid out above. Similarly undermined is the established model of an electricity infrastructure built on sets of interrelations between the rhythms of commodified energy resources and their assumed neatly functioning supply chains, and the particular ordering and disciplining of rhythms in grid operation. Within the materiality of the grid itself there can also be a threat of discordance, as capacities of local network infrastructures to carry specific rhythmic-energetic intensities are exceeded; for example, when attempting to carry either surges of demand that come from locally structured EV charging synchronizations; or surges of supply from areas with a high density of solar generation (Palmer et al. 2017).

As emphasised earlier, however, not all of what is in transition has to be thought about in terms of 'big grid'. Low carbon transition can mean very different scales of infrastructure, and it follows very different scales and techniques of keeping electricity flow in balance. In low carbon grids, there is the potential for much *less* spatial dislocation between the rhythms of generation and consumption than in the big (carbon) power model; rhythms made in proximity, rather than at a distance from each other opening up new possibilities for how the relations between supply and demand are managed. The impossibility of dislocations in time are still present for low carbon electricity systems of any scale to function smoothly, given that the electricity that is available has to match the electricity that is used; but that does not mean that the old dominant discipline of keeping electricity isorhythmia in balance cannot be rethought and other ways found of working with the repetitions and anticipations that are inherent to the energetic-rhythms of environments and social activity.

The notion of the smart grid is a way of capturing how the management of electricity infrastructure is being reimagined and reorganised, as part of what Strengers (2013: 1–2) sees as a 'distinctive ontology in which smart technologies perform and establish a highly rational and rationalising form of social order'. Much reliance is being put on low carbon electricity systems (at different scales) becoming smart ones, layering new data infrastructure flows over electricity flows in order to (i) know more about the movement of electrons in wires and cables—more precisely and with more granularity (Kragh-Furbo and Walker 2018) —and (ii) achieve a new sophistication of rational management and control over how these flows are moving, in what directions and to what ends. Much of what is smart is also intrinsically rhythmic (Coletta and Kitchin 2017), involving knowing, intervening in and governing rhythms in various ways. This is particularly clear in the search for flexibility and responsiveness in demand rhythms that, under the established disciplining of rhythm management within big grids, have previously been considered largely untouchable (as discussed in chapter 5). While this is a burgeoning area of research and innovation, at least some of the envisioned ways in which the future management and functioning of electricity system polyrhythmias might evolve, and how smartness fits within this picture, can be sketched out.

Conducting the Low Carbon Orchestra

In chapter 5, the traditional managed ordering of power stations into baseload, daytime and peak load plant was characterised in musical terms—a continual drone, daily chorus and occasional extra loud blast of sound. To continue the analogy, in the fully low carbon orchestra this ordering becomes far more polyrhythmic and polyphonic, formed of multiple waves and blasts of sound as the possibility of renewable energy generation comes and goes, fading and rising across the sonic landscape of the electricity network, sometimes in patterns that follow a score (the tidal pulse, the solar silence in the dark), but also in abstract, self-forming swirls and shafts of complex sound (wind energy as free jazz). How (or indeed whether) the conductor can keep this orchestra under some degree of managed control in order to stop the performance collapsing is the subject of much disagreement. Some feel the need to hang onto the drone of some form of substantial baseload (gas generation as marginally lower carbon, nuclear as claimed low carbon), as a background 'lift music' over which more complex rhythms can then be managed. Others argue that the whole concept of baseload is defunct, that the drone has had its day, and a smart grid will be clever enough to keep track of the polyphony and sustain the isorhythmic performance of grid balancing in a harmonic condition. These more positive views of how smart grid management can work include, amongst the mass of proposed innovations, some working with the spatiality of implicated resource rhythms, as well as with how these can be anticipated as knowable repeating phenomena.

One of the characteristics of spatially extended electricity grids is that they have the possibility of drawing different sets of situated rhythms and rhythmic interactions into their infrastructural assemblage of social, technological and material elements—a more varied jumbling together of musical styles and patterns to continue the analogy. In chapter 5, we saw how historically grid developers had deliberately capitalised on how rhythms vary across space in order to 'capture' different demand rhythms into their networks, with the consequence that differently timed peaks and troughs in demand would, when combined together in real time, create a smoother (and more profitable) demand curve. For low carbon electricity systems, the distributed geography of renewable energy technologies and their coupling with diversely patterned environmental rhythms (of solar, wind, water flow etc.) becomes similarly advantageous. In simple terms, if the wind is not blowing in one location, it may well be in another and the more that wind turbines are geographically scattered across land and seascapes the more likely, in general, that is to be true. Similarly for solar power in relation to both different length days from North to South and variations in cloud cover; for wave power driven by different wind systems; and, to some degree, for hydroelectric systems when distributed across different rainfall regimes. As Heptonstall et al. (2017: 19) describe in more technical language:

> Variance may also be reduced through geographical dispersion of plants (which has the effect of smoothing outputs), and by having different types of intermittent plant on a system. This is because different types of renewable resource fluctuate over different timescales, which also has the effect of smoothing outputs such that overall variation decreases.

There is therefore some benefit to low carbon systems being both poly-energetic in the diversity of energy resources that are generating electricity, and polyrhythmic in the spatial patterning of this electricity production. How much having a poly-energetic and polyrhythmic geography can be relied on to sustain sufficient flows of electrons across a grid network is a complex and situated question of (a) how weather patterning relates to the locations of different generation technologies, and (b) how these energetic rhythms relate to the rhythms of collective demand (diurnally and seasonally) and also to the capacities of local networks and bigger scale transmission systems. For example, in places where there is a heavy load of peak electricity use for air conditioning, there is the possibility of a localised and productive rhythmic correlation between high demand and strong solar PV generation, at least during the daytime. In other settings, there may be no such 'natural' linkage between demand and generation rhythms, rather significant disconnections, or more chaotic interrelations. In the United Kingdom, for example, wind farms are geographically spread across the country and increasingly into marine spaces, providing some degree of smoothing of the continuity of overall generation, and wind speeds are generally higher in the winter when peak demands also occur (ibid.). However, at the tighter temporal scale of day-to-day rhythms, there is no natural interlinkage between the timing of peak demand and wind speeds. It follows that rare but recurrent periods of very still weather covering most of the country (as well as offshore) are frequently highlighted by sceptics (and protectors of incumbent interests) as instances in which security of supply cannot be secured without conventional baseload in place (Gosden and Spence 2014).

Exactly how far grid geography extends across physical space is important though, and there are benefits that can come with interconnections between separate grids to form bigger managed entities. For example, an analysis of energy policy scenarios (Nagl et al. 2011) to achieve the ambitious Energiewende transition in Germany (Gailing and Moss 2016) concludes that the progressive formation of a European supra-national grid with higher capacity interconnectors between systems and more integrated management is key to sustaining a well-functioning and secure power system. Specifically, it is noted that:

> the grid extension and Europe-wide network enables electricity transfer from solar sites at the Mediterranean and wind power stations in Northern Europe. This allows compensating or supporting conventional generation by imports from wind and solar power stations in periods with high demand (Nagl et al. 2011).

A report focused on the implications of the expansion of wind energy for the UK electricity system (Royal Academy of Engineering 2014) also notes the importance of interconnections into the European system in extending the geography of environmental rhythms that matter to electricity generation. German and British wind rhythms, situated in relatively disconnected weather systems and wind regimes, are largely uncorrelated in time, giving more scope for 'mutual smoothing' if wind-generated electricity could be traded across international space. German and Danish wind rhythms in contrast are more correlated given their spatial proximity. Imaginaries of even grander transcontinental systems, such as DESERTEC connecting PV and wind generation in the Sahara to a European-African supergrid system, or the 'Northern Atlantic Energy Network' (Orkustofnun et al. 2016) linking up Arctic, Nordic and Northern European regions, are therefore about the total generation potential they can tap into, but also the distinctive rhythms of generation that they could carry.

Whatever the particular geography of varied energetic rhythms that provides low carbon power into an electricity network, being able to *anticipate* these rhythms—anticipate what beats of what musical polyphony are about to materialise—is crucial. In chapter 5, the significance of technologies of rhythmic prediction in predicting demand rhythms was emphasised as being integral to both the practicalities of grid balancing as well as the profit-making of those involved in electricity markets. With greater renewable energy penetration, this predictive work becomes necessary also for anticipating supply rhythms—from the easily known rhythms of tidal power, to the more difficult anticipation of rhythms of solar radiation and wind, in relation to the distributed geography of where hundreds of thousands of solar and wind installations are located. Quite different, therefore, to anticipating the generally easily known rhythms of generation at only a handful of big power stations.

As Haupt (2018: 98) comments, 'Although weather impacts all types of power production, it actually also drives the renewable units. It is important to be able to forecast the wind, solar and hydro power available the next day, or often over the next several days too'. In this respect, the supercomputer–powered technologies of weather forecasting, which have become more accurate and available at greater spatial and temporal resolution through statistical learning and advanced modelling techniques, are becoming an integral part of the smart polyrhythmia of electricity grid functioning. For wind energy in the United Kingdom, predictive methods have been developed to the point that 'its level of output can be predicted to a high degree of accuracy' and within the current tolerance levels required for the ongoing management of the grid (Royal Academy of Engineering 2014: 33). Buontempo (2018: 32) observes that 'different from the traditional energy mix where climate represents simply an external factor, in the context of renewable energy the climate often represents the valuable asset itself', meaning that for both long-term investment strategies in generating capacity and short-term orientations to changing weather conditions, being able to anticipate the situated rhythms of environmental systems has become a rapidly emerging commercial opportunity. That these systems are rhythmic—they exhibit patterns of repetition including in thermodynamic terms—is important to how their energetic flows and capacities to do work can be anticipated, planned for and, in market-based systems, profited from. Although with already occurring climatic change, it is becoming increasingly difficult to assume that weather patterns in the past will necessarily define the parameters of the future.

Battery and Storage Rhythms

While one strategy of low carbon grid balancing is to take advantage of the spatial diversity of energetic rhythms in the environment and to as much as possible anticipate these, another is to 'dampen down' or smooth out these rhythms once they become electron flows within the electricity system. In chapter 5, being able to store energy—in a woodpile, fuel tank or gas pipe—was characterised as a form of temporal buffering between the rhythms of supply and demand, in effect removing the need for their tight, real-time synchronization. Through storage, the energetic potential to supply is held static and in place, ready and waiting for when it is to be drawn on to do work in end-use technologies.

Whilst in small amounts electricity has long been storable in batteries and integral to its scattered mobility in portable devices, this has only recently become feasible at scale and seen as a potentially significant part of grid management. An avalanche of advances in battery technology are now in play, seeking to bring down costs, but also to scale up storage capacity (in terms of total storable energy) and improve the rhythms of battery operation. Any one battery technology has both a charging rhythm in the conversion of electrical to chemical energy (as discussed earlier in relation to EVs) up to its maximum capacity, and a discharge rhythm of deliverable power (energy over time) in converting back to electricity and running down the store, and each of these parameters can shift over the longer-term rhythm of a battery's lifetime. Batteries are therefore devices whose vital rhythms are important in how, when aggregated en-masse into battery farms, they can then be put to the service of the functioning grid.

The same is true across the range of other storage technologies that have been and are being developed to convert electricity into various temporary energetic forms, including the pumping of water to an elevated reservoir, conversion to hydrogen, to liquid or compressed air, or into stored heat. Each of these have materially embedded rhythmic parameters, which have various degrees of fit with the temporalities of grid management, for example, being able to respond very rapidly to drops in system frequency, to contribute to peak load for a sustained period, or to store electricity from low cost, low carbon generation when supply exceeds demand. For example, the Dinorwig pumped storage scheme in the United Kingdom—which in effect makes a pulse of demand in time, which can then be returned as supply with a timing that suits the purposes of grid management—has a very acutely configured rhythm, being able to ramp up from zero to 1.32 GW of output in just twelve seconds. Whilst originally used as part of meeting peak load, it now operates as a 'fast response plant', with its speed and power enabling it to rapidly fill in unexpected gaps in the synchronization of supply and demand curves; its rhythmic capacities therefore aligning in a particular way to the temporalities of system management. Conversion of the energy in electricity to hydrogen through electrolysis, if implemented at scale, could provide a different temporal role, enabling the making of a storable fuel at times of plentiful low carbon generation, which can then be burnt in power stations at times of peak load, or to fill in longer gaps in the rhythms of wind or solar generation. Energy storage in batteries and other forms therefore has a potentially crucial role in the overall 'smart' orchestration of low carbon electricity flows, although not without costs, both economic and environmental, that necessarily constrain the potential of storage as the ready 'solution' for low carbon rhythm challenges.

Smart Meters as Rhythms Revealers

Smartness, as noted earlier, now covers a vast field in which visions of a future 'smart utopia' are mobilised, replete with both smart technologies and infrastructures, and with smart managers and consumers (Strengers 2013, Levanda 2019). For electricity systems, the key innovation is to layer flows of data alongside and in relation to flows of electricity; data flowing in different directions between technological elements of networks and between involved actors. In 'smart grid' strategies, experiments and imaginaries, much of what has already been discussed in relation to the rhythms of generation, demand

and storage is becoming managed through such digital infrastructures and control systems. Bringing together, for example, information on the real-time rhythms of generation of particular wind or solar farms, on future expected environmental conditions, on the level of storage available and on how different parts of networks are performing, so that the polyrhythmic smart grid can be responsive and orchestrate the rhythms of its different elements into a coherent and rational whole.

Alongside these types of information flows, much attention is also being given—under the general heading of smart metering—to making new data about electricity consumption, including in order to better reveal its rhythmic structures. In Kragh-Furbo and Walker (2018) we conceptualised all electricity metering as a form of 'quantification work' (Espeland and Stevens 2008), in which the flow of electrons hidden in cables and wires is measured, made knowable and turned into data; also arguing that all metering is enacted within a particular spatial and temporal configuration that determines exactly what about electricity flow is made knowable, where and when. In the pre-digital era (see figure 6.3), electricity meters were almost entirely located to generate customer bills, demarcating the boundary between flow as consumption (behind the meter) and flow as supply (in front of the meter). All the rhythmic workings of electrified devices (fridges, lights, computers etc.) located

Figure 6.3. From the temporally imprecise and infrequent data making rhythms of manually read meters, to the high precision and high resolution rhythms of smart meters.
Photos by the author.

'behind' the meter, and run by a paying consumer were aggregated together in the measurement of flow at that one metered point. This made an aggregation in space matched by an aggregation in time, in which the meter was only 'read' in accordance with the rhythms of needing to produce customer bills, enacted through a labour-intensive process involving manual transcription by travelling supply company employees, or consumers themselves. In, for example, 'quarterly billing' there was a rhythm of just four readings being taken from the meter per year, with the exact periodicity subject to locally contingent practicalities. The meter produced a kilowatt hours (kW/h) trace of everyday electricity-using practices and associated technologies, but in such aggregated spatial and temporal terms that nearly all the detail of the rhythms of work done by which devices and to what ends remained hidden.

With digitalisation and the development of advanced or smart meters (see figure 6.3), it has become possible to know, observe and represent the rhythms of electricity flow in ways that more precisely capture their patterning in space and time. Data can be released from digital meters at minute down to second and potentially subsecond intervals, this data pulsing instantaneously over wired or wireless data infrastructures. Hundreds of data points on electricity flow can be generated per hour or day from each meter—a major rescaling of the beat of data making when compared to the rhythms of manual meter reading. The imprecise repetitions of manual reading are also replaced by an exactly calibrated metronomic rhythm of time-stamped data. In homes and small businesses, smart meters are still generally being positioned where they always have been at the customer/supplier boundary. However, in many workplaces, there has been a proliferation of 'sub-metering' recording the kW/h rhythms of particular buildings, floors of buildings, workgroups, or even particular devices or sets of devices, using technologies and data infrastructures that are relatively cheap and easy to install, or to commission as a service.

There are various claims made about the value of knowing the rhythms of electricity flow with such temporal and/or spatial granularity. One, common to both domestic and organisational settings, is that knowing the rhythms of electricity consumption in close to real time, being able to visualize its dynamics through display screens and devices and track what is happening at different times of day, or when particular appliances are switched on, will incentivise users to reduce consumption and take responsibility for what they are consuming (Levanda 2019). This linear and rational model of information exchange, assuming that 'knowledge leads to action' and to new forms of 'good electricity conduct' (Bulkeley, Powells and Bell 2016), has been roundly critiqued for multiple reasons (Naus et al. 2014, Grandclément 2019), not least its constitution of consumers as self-governing, calculative

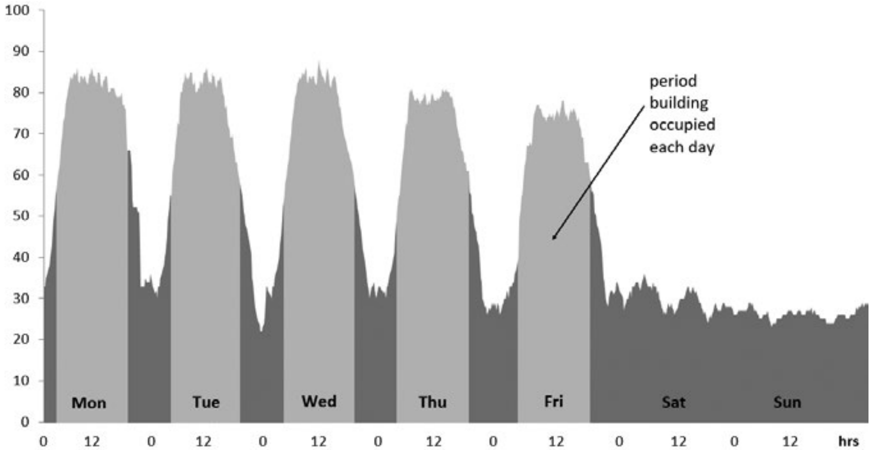

Figure 6.4. Example of visualization of half-hourly measured electricity flow (in kW) across days of a week in relation to times at which a workplace building is occupied.

agents. Accordingly, in domestic settings, empirical evidence from smart metering trials finds that they have only relatively marginal and short-lasting impacts on patterns of consumption (Hargreaves et al. 2010, Strengers 2013, Klopfert and Wallenborn 2011). In organisational settings in which there is more capacity to act, in particular in relation to reducing energy costs, there is more persuasive evidence that being able to track the rhythms of consumption with more precision, and make comparisons between rhythms over time can be productive. A recurrent example takes the form of a so-called 'top hat' diagram (see figure 6.4), which visually aligns the rhythm of electricity consumption over time with the rhythmic structure of the working day, and the opening/occupied and closing/unoccupied times of businesses or particular buildings. By comparing between these different categories of rhythm, electricity use 'out of hours' can then be targeted as 'waste'; as unproductive or unnecessary flow that can be acted on.

Such overlaying of rhythmic structures and analysis of patterns of repetition is taken further in software systems designed to produce automated 'alerts', 'alarms' or 'exception reports' when patterns in the measured flow data are judged to warrant intervention. These draw on the fundamental expectation of rhythmic repetition in how energy is used (that we have already seen is crucial for grid management), in assuming that what has been measured as normal before (averaged over a specific temporal granularity) should be repeated in equivalent time periods—equivalent Sundays, lunchtimes, or weekday evenings, for example. In the research we carried out (Kragh-Furbo and Walker 2018), the forms of abnormality in the data that could be spotted were described expansively by one company interviewee as 'negative readings, high readings, low readings, zeroes, spikes, missing data', with these constituting traces of both technical and human failings, or in rhythmic terms instances of problematic dysrhythmia, or bad elements; for example, equipment breaking down or malfunctioning, electricity-using devices being switched on when they should normally be switched off (or vice versa), and employees opening windows or propping open doors.

In these ways therefore, smart meters are 'rhythm-revealers', both in terms of what they directly measure as electricity flow, but also what is meant to be acted on from this measurement. They are more than this though, being also integral to moving into what has for a long time been forbidden territory, that of actively and routinely managing the rhythms of demand.

Flexible Rhythms and Demand-Side Response

In chapter 5, it was explained how within traditional 'big (carbon) power' electricity systems (at least those able to be well resourced and managed) the rhythms of energy demand have been seen as largely independent of system governance. Under the 'modern infrastructural ideal' (Luque-Ayala and Silver 2016) of always on-call provision, demand rhythms in the aggregate were considered an emergent outcome of economic and social progress, self-forming and a dominant force. They were not rhythms to be intervened in as part of achieving the moment-to-moment synchronization between supply and demand. That was a matter solely for the orchestration of supply.

With the pressure for low carbon transition, however, intervening in demand rhythms is now being seen very differently. Instead of supply rhythms always being entrained to demand rhythms, sometimes, under these new logics, isorhythmic synchronization is to be achieved by shifting demand rhythms in time, making them both flexible and responsive (Curtis et al. 2018) to the balancing needs of the electricity system. These system 'needs' fall broadly into two general categories: (i) shaving peaks of demand, making its aggregate maximum less intense, as generated through various existing and newly forming social and natural dynamics; and (ii) filling troughs, actively encouraging more demand during periods when there is more low carbon generation than demand to be satisfied, thereby actively coupling demand rhythms to, for example, the variously cyclical and chaotic rhythms of solar and wind energies. In figure 6.5, we can see an example of how the smart management of the timing of demand from the charging of electric vehicles is presented as being responsive to such ends, leading to a variety of system and user benefits compared to a 'dumb' approach (Ofgem 2018).

Flexibility, in this context, conveys that energy use does not always have to happen in unchanging, or pre-determined patterns of repetition; that it

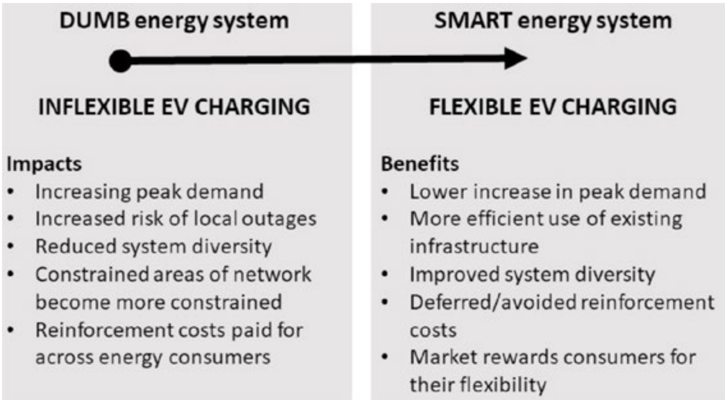

Figure 6.5. Benefits of smart flexible electric vehicle charging compared with 'dumb' inflexible charging.
Adapted from Ofgem (2018).

is not necessarily firmly locked into the social rhythms of electricity-using practices positioned in time and in sequence, or the automated technological rhythms (see chapter 5) of devices doing energetic work to provide energy services. Responsiveness is about making this flexibility something that can be moulded and managed in time by grid operators, effectively extending the boundaries of grid management into the very distributed and situated settings and personal, shared and organisational lives, from which energy demand first emerges. This reorientation to the possibility of managing demand rhythms is becoming more developed in relation to some categories of consumers, or consumption settings, than others; as well as more in relation to turning down or switching off to manage peaks, than 'turning up' to fill troughs. Different means of flexing and re-rhythmising demand have also been pursued.

Most common is to approach rhythm modification as a matter of money, either through 'time of use' pricing (electricity prices varying by time of day/week/year); or by specific demand-side response (DSR) payments being made to end-users to switch things off in response to the signalling of a grid-system need. An example of a fairly complex time-of-use pricing structure in use in Ontario, Canada, is shown in figure 6.6. This sets price rhythms in relation to seasonal rhythms (defined as summer and winter) and cultural rhythms (weekdays, weekends and statutory holidays), and how these combine to make daily rhythms of aggregate load on the electricity system (divided into 'off-peak', 'mid-peak' and 'on-peak'), with this varying through the year. The timing of peak demand is markedly different in the summer to the winter, with no peak at all at weekends or on statutory holidays. Here, in

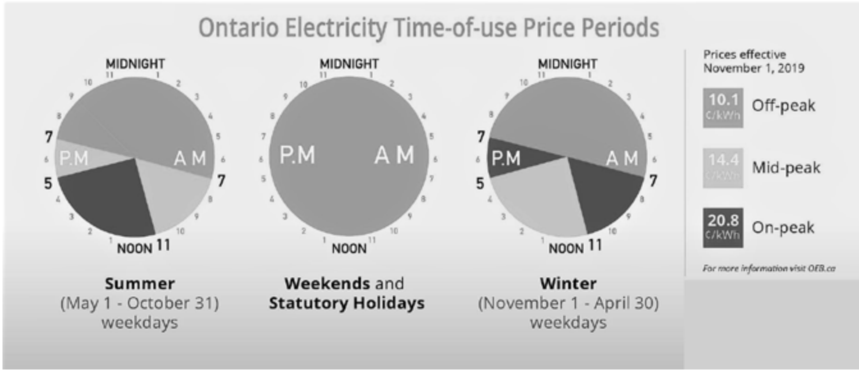

Figure 6.6. Electricity Time of Use Price Periods in Ontario, Canada.

Source: Ontario Energy Board www.oeb.ca/rates-and-your-bill/electricity-rates/managing-costs-time-use-rates. Reproduced under Open Government Licence–Ontario.

a compact form, we can see how a set of rhythmic interactions, as relevant to this particular setting and its seasonal cycling of temperature and light, have been made integral to the attempted price-based choreography of electricity flow through the grid.

Payments for DSR responsiveness have been more focused on businesses and large organisations than household consumers (Grunewald and Torriti 2013). For example, in the United Kingdom, National Grid runs a series of DSR schemes through which big energy users are paid to cut back consumption when asked to and 'aggregators' are contracted to package together the potential for flexibility across sets of smaller-scale businesses and organisations (Curtis et al. 2018). Aggregators hunt out mundane electricity-using devices (air conditioning systems, freezers, industrial heaters, pumps etc.) already pulsing on and off across the national electricity landscape, recruiting them into synchronizing their combined switching off to signals sent out by National Grid. This is not at all straightforward. Prospective clients have to be persuaded that some of the devices they use can be switched off without introducing any significant dysrhythmia into their operations, and details of timings matter, for example, devices need to be switched *on* and part of the functional polyrhythmia of the organisation at the relevant moment in time, if they are then to be available to be switched *off*. For domestic consumers, various experiments and trials of DSR schemes have been carried out and many proposals have been debated (Abi Ghanem and Mander 2014), but finding flexibility in the extraordinarily distributed rhythms of household energy use (and making it pay) is as yet less developed (see further discussion below on resistances).

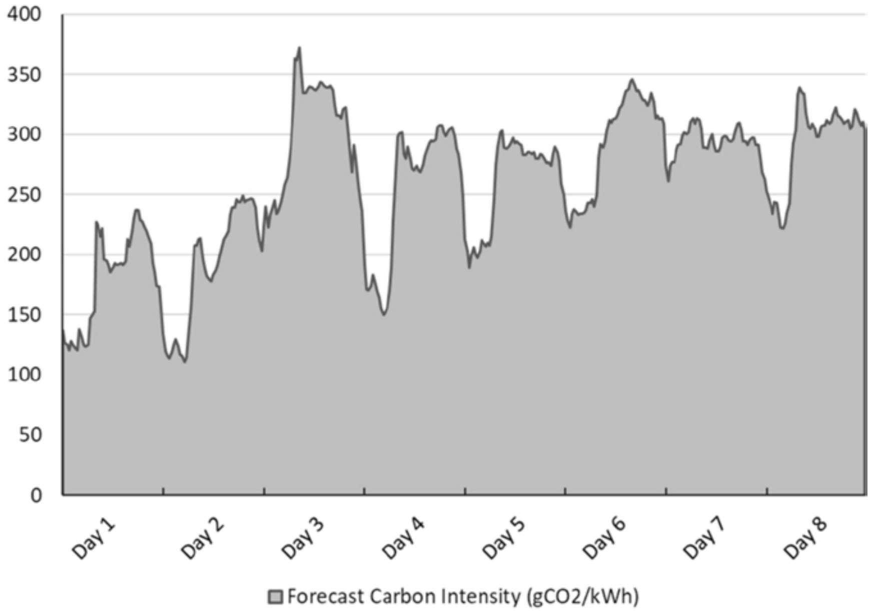

Figure 6.7. Forecast carbon intensity of the National Grid in Great Britain for 8 days in November 2019.
Data from carbonintensity.org.uk/

Some initiatives have also tried to use nonmonetary values to incentivise flexibility, instilling a sense of responsibility to act in the common good when grids are under the most severe pressure (Strengers 2013), or to orient rhythms of consumption towards times when the electricity flowing in the grid is full of low, rather than high, carbon electricity. Figure 6.7 shows an example of predicted 'carbon intensity' rhythms for the Great Britain National Grid over an eight-day period, taken from a website with various resources intended to help consumers time their use of appliances (such as washing machines) for when the carbon intensity of the grid is low. In this graph the trace of a diurnal rhythm to carbon intensity can be picked out (similar roughly in shape to the repeating daily load curves in figures 5.2 and 5.3), reflecting the influence of overall demand on the grid's carbon footprint (carbon intensity typically being higher when demand is high). However, this diurnal repetition is modified and cut into by how the real-time balance between low and high carbon generation plays out, with carbon intensity much lower at times when there is a lot of wind blowing for wind farms and/or a lot of sunshine for solar panels. Through such data, an attempt is made to make the rhythms of fossil fuel pollution within the polyrhythmia of the grid visible rather than hidden—by giving the rhythms of generated electrons a carbon identity—and through their visibility making them agentive in stimulating electricity demand rhythms to be coordinated in synchrony.

Along with different methods for incentivising flexibility, different approaches to enacting responsiveness have also been experimented with and deployed (Grandclément 2019). Relying on users to respond to price signals, carbon intensity data or the 'common good' by manually switching things off or deciding, to say, shift the rhythm of doing the vacuuming into 'off peak' hours, is technologically simple and cheap to enact, but is unreliable in its outcomes and can have problematic knock-on consequences. An alternative is to install automated systems that, without consumer intervention, more tightly and precisely couple the moments of system need to a responsive rhythm in connected devices. For example, there are 'smart thermostats' that turn up, down, or off cohorts of heaters, air conditioners, freezers or fridges in rhythms that ensure that there is minimal consequence for their performance; and smart algorithms that can be used to automatically switch on and off electric vehicle charging within an area to keep local infrastructural load under control (see figure 6.5) and minimise charging costs under variable tariff regimes. Automated technological rhythms in both cases are entrained to a polyrhythmic logic embedded in software that is purposefully attuned to the 'rational' management of demand.

While different approaches are being taken to enacting the smart management of demand rhythms, any attempt to intervene to actively change, disrupt or re-calibrate rhythms can encounter significant resistances (Edensor 2010b, Jalas et al. 2016, Murray and Doughty 2016). These can take a material form relating to the energetic characteristics of particular thermodynamic flows and conversions, they can be due to how rhythms are always interrelated and sometimes held together in strong couplings (as in the case of automobility discussed earlier), and also arise from how interventions into particular categories of rhythms are interpreted normatively and politically.

Materially there are resistances, for example in the dynamics of how particular technologies function, how rapidly they can be switched on and off without damaging their technological integrity, and also in the tightness of the coupling between the rhythm of their being on and the service or energetic outcome that they are designed to produce (Curtis et al. 2018). The rhythmic relations set in train by particular thermodynamic conversions (as discussed in chapter 4) can be crucial here with, for example, light (and visibility) being lost very rapidly when a lighting system is not functioning, whilst the cooling or heating of space, or of contained materials, has more inherent inertia, the energy service being only slowly diminished over time after the heating or cooling device has been turned off.

Resistances related to rhythmic interconnectedness, or the temporal qualities of the 'connective tissue' between practices (Blue and Spurling 2017) can also arise in different forms. Blue (2018) explores how in a hospital setting the timing of use of particular energy-consuming technologies is caught up in how different hospital-based practices are interconnected and held together within the rhythms of sociotemporal structures (such as sequences of admitting, assessment, scanning, operating, monitoring etc.), but also by how interconnections run through material layouts and professional boundaries between different work tasks. This creates fixities in the temporal arrangement of hospital life, as well as instances of flexibility that offer some opportunity to reorder what is done when in order to align with demand response objectives. In home settings, Strengers (2012) similarly emphasises that whilst the rhythms of practice routines can appear tightly sequenced, interconnected and coordinated, it is also the case that minor to more significant disruptions to the playing out of domestic life are quite normal, with flexibility very much part of everyday improvisation. How, when and whether incentives, signals or forms of feedback can tap into this already practiced flexibility to the ends of energy system governance becomes the pertinent question (Higginson et al. 2014).

Resistances that are political or ethical in character relate to how end-users judge the appropriate boundaries of intervention into the normal playing out of rhythms, as well as who should have knowledge of the rhythmic patterns that underpin energy use. In seeing households, in particular, as a private space with private sets of rhythms, there have been resistances to anyone other than those occupying this private space having any control of what happens within it, including over the working rhythms of electrified technologies (Fell et al. 2015). There have also been resistances to any external organisation being able to access information about how these devices are being used, as generated in real time and with some temporal granularity by smart meters (McKenna et al. 2012). There is therefore a politics to intervening in the rhythms of demand, which also necessarily centres on questions of inequality—who is more or less able to be flexible and benefit from, or be punished by, schemes that seek to incentivise being responsive. In Powells and Fell's (2019) terms, this is a question of who does and does not have 'flexibility capital', with better-off consumers being able to invest in smart systems and appliances, while an 'energy underclass' (Walker and Cass 2011) of low-income and fuel-poor households are excluded from such innovations, or further disadvantaged.

Localising Rhythmic Interrelations

While mainstream strategies for working differently with the polyrhythms of electricity systems continue to focus on big grids, and sometimes on making these even bigger to gain the rhythmic benefits of forming low carbon supergrids (as discussed earlier), there are also strategies that go in exactly the opposite direction. As discussed earlier, generating low carbon electricity and doing electrification is now being quite routinely implemented both without any network connection at all, or only within the restricted spatial configuration of local micro grids. Sometimes such material setups are deployed for largely practical or economic reasons (such as the cost of connecting up to a distant big grid), but they can also be integral to an ethos of collective community action, taking local control of energy generation, and/or developing self-reliance and resilience (Walker and Cass 2011).

Amongst the many things that are different about off-grid and local grid assemblages are the implications for where and how the rhythmic relations between electricity supply and demand come to matter. In off-grid configurations, at their most basic, electricity can only be consumed when there is sufficient power being generated to work a particular device or appliance, or as Strengers (2013: 147) puts it, 'microgeneration brings specific spatial and temporal constraints to practices of making energy and to the practices that use these energies. Time and space are coupled and tightened'. The rhythms of electricity-using practices are therefore, in very material and practical terms, bounded by and entrained to the rhythms of generation, which, depending on the resource flows being tapped into (in space and time), may have a very regular or more chaotic structure (see further discussion of off-grid rhythms in chapter 7). Small-scale battery storage in off-grid and micro-grid configurations is able to break into this tight coupling and bounding. Figure 6.8 shows the temporal patterning of solar generation and total electricity demand for an example of a PV-based micro grid in Africa (Moner-Girona et al. 2018). PV output has a very elliptical shape tracing the cyclical movement of the sun through the day, whilst the load of electricity use has a different, quite spiky profile, with some increase in the middle of the day when PV output is highest, but a much stronger peak in the evening when there is no PV generation at all. Integrated battery storage, holding in place the energetic work done by the PV panels until its release later in the day, is what enables this rhythm of evening demand to be powered and therefore possible.

Systems assembled in such configurations are not only sensitive to generation-use synchronisations, but also to how many devices are simultaneously switched on, the intensity of the load pulse that any one device produces and how frequently over a period of time these pulses occur. Rhythmic patterns in each of these parameters, individually and in combination, can overload the material capacity of the local network to carry electricity flow, and/or they can rapidly drain battery storage. This means that the self-management of the rhythms of electricity use to stay within capacity constraints is necessary,

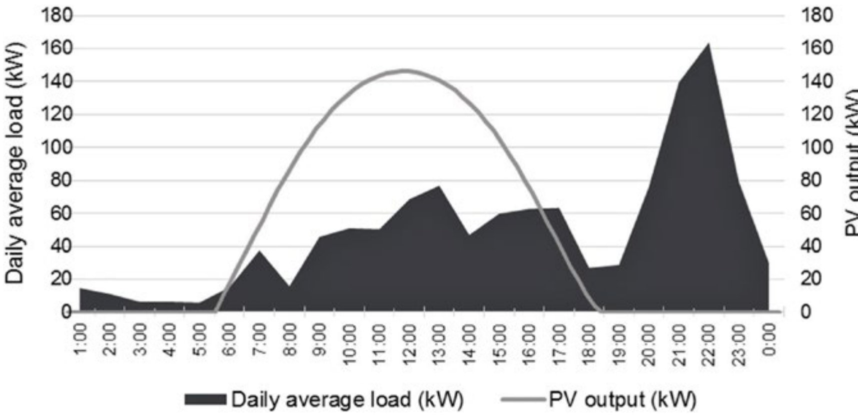

Figure 6.8. Example of electricity load profile and PV output for a specific PV/hybrid mini-grid location.

Reproduced from Mirona-Girona et al. (2018) under licence CC-BY.

or in a local micro grid some form of collective governance or regulation to keep the grid functioning is required. Infrastructures in such situations 'organize time and produce collective rhythms' (Jalas et al. 2016: 17), through both how they enable but also crucially how they constrain. In box 6.2, I reflect on two places in which my own access to infrastructural capacity was temporarily constrained, set against a normality in which such boundaries are rarely encountered; The first is where there was a contract signed up to with the local electricity supplier in Lisbon, Portugal, which limited how much power could be used at one point of time (a very standard arrangement in some countries); the second where there was no grid connection at all at a cottage in Wales, only local PV panels and a small battery.

Even in material configurations that encompass both local microgeneration and a grid connection (potentially for both consuming electricity and supplying it to the grid), there can still be motivations for the local synchronization of rhythms of generation and use. The value to be gained by so-called 'prosumers' (Olkkonen et al. 2017, Smale et al. 2019) can be both from directly using the electricity from their local PV panel (for example) when it is available rather than buying it from the grid, and from being paid for surplus electricity generated that they are not directly using. Generally, the value of the former is greater than the latter. There is a logic therefore for such prosumers to time household electricity-using activities for when the sun is shining. Prosumers, it is argued, can also be motivated by climate concerns to first use their local low carbon electricity, rather than draw from carbon-heavy grid supply; being responsive to the carbon identity of electrons (as discussed

BOX 6.2.
Living Temporarily within the Rhythms of Infrastructural Constraint

In Lisbon, in a fourth-floor apartment, enjoying the rhythmicity of a southern European city, bathed in cyclical flows of light and warmth. Looking out over the patterning of river boats, the hum of traffic across the bridge and airplanes skimming the rooftops. All energised, on the move. In the apartment a discordant moment. All silenced, the fridge, the CD player. Electricity disappeared, overloaded by the synchronisation of boiling kettle, vibrating washing machine and steaming iron; the attempted simultaneity of tea-making, clothes washing and crease removing. Rhythm interrupted by a contract and a device that says only so much and no more. From then on, I take care with the energetic rhythms I set in motion.

In Wales, staying in a cottage, on a hillside, enjoying the western rhythms of mist slowly swirling, revealing and concealing, the trees, the sheep and the track. A still, solitary wind turbine across the valley, unmoved, unspinning in the absence of air on the move. Our solar off-grid electricity struggles to find its power, to bring the battery to its peak before its potential drains away in rhythms of making brightness and entertainment. We limit our technological dependence, our indoor dispersal and separation, join together our activity, our space, the span of our day. Sleep comes sooner. Rhythms re-made. Charged particles, absent now; but maybe back again tomorrow.

earlier), but through a very local mechanism. The evidence that consumers do act in these ways to purposefully flex and re-rhythmise their consumption again raises questions about which rhythms dominate and structure patterns of electricity use. The rhythms of routine, habit, feeding, cleaning and so on, or potentially the rhythms of price, carbon and sunshine? Some empirical studies find that consumers can be motivated to re-rhythmise aspects of their electricity use, while others find resistances of the various forms discussed earlier, and that apparently rational reasons for shifting consumption in time are ignored, or fade in effect over time. In drawing conclusions from this body of work, Strengers (2013: 152) argues that 'tangible, temporal and limited energies potentially reorder temporal routines . . ., in ways that may serve to reduce and shift energy demand', but she also recognises the dangers of romanticising such potential given the transient meanings that low carbon energy may only temporarily carry and the 'things have nothing to do with energy at all' that shape the ongoing rhythms of how energy is used.

SOME REPETITIONS AND REFLECTIONS

Working through the ways in which various of the rhythms of electricity systems need to be modified, replaced, newly managed and coordinated in transitioning away from their high carbon and polluting forms has demonstrated the importance of not just engaging with rhythms, but with their interrelation and interaction. Conceptualising electricity systems as vast and complex polyrhythmic assemblages with infrastructures of energetic flow and conversion at their core means that a substantial change in one rhythm, or set of related rhythms, will often have consequences for the shape, repetition and constancy of others. Consequences that have the potential to disrupt established synchronicities, couplings and entrainments, break up existing hierarchies of rhythmic domination and subordination, and redirect the direction and intensities of thermodynamic entanglements.

There have been many examples of such consequential shifts in this chapter as we have moved from the rhythms of renewables, to new pulses of demand, to the smart orchestration of low carbon grids. Removing the rhythms of fossil fuel combustion from the electricity system breaks apart the sequenced and closely coordinated chains of carbon commodities, replacing them instead with rhythms tightly coupled in space and time to the thermodynamics of environmental and planetary processes. Introducing the rhythms of solar power into electricity-making synchronises generation with the rhythms of some electricity demands, for example in daytime air conditioning, whilst de-coupling resolutely from others. Transferring the rhythms of heating and mobility from direct combustion of hydrocarbons into the rhythms of demand on the electricity system introduces new peaks, troughs, intensities and unpredictabilities into the already complex task of orchestrating the rhythms of generation capacity. When the rhythms of energetic storage at scale enter the mix, real-time sensitivities in relations between supply and demand begin to diminish. Rescaling and redistributing the rhythms of electricity generation across a much more diverse physical and social landscape opens up the possibility of demand and supply coordinations becoming localised rather than aggregated, breaking away in effect from their enrolment into the mega-assemblage of the grid. In these and many other ways, all of the social, cultural, technological, environmental and cosmological rhythms that give the electricity system its polyrhythmic form start to beat together differently when removing carbon becomes a primary aim.

As made very clear in both this and the previous chapter, the active management and coordination of rhythms is always in the polyrhythmic mix, making and keeping electricity infrastructures operational and functional (at whatever scale they may be realised); very much, therefore, *part of* the assemblage, rather than acting on it. Low carbon systems demand even more active management and coordination of rhythms, including in the previously untouched territory of the temporal patterning of demand, with smart infrastructures and technologies expected to do much of the new work involved. Through knowing the multidimensional and even more distributed rhythms of supply and demand with more reliability, specificity and granularity, and deploying that knowledge into data processing and algorithms, feedback to consumers and automated control systems, smartness is tasked with making and sustaining a new isorhythmia of managed grid continuity. A version of what Coletta and Kitchin (2017) have termed algo*rhythmic* governance. However, as I and many others have emphasised, the much-hyped, techno-optimism of the smart ontology (wherever it is deployed) has to be approached carefully and critically. The rationalities, logics and techniques of smart rhythm management, as, for example, applied to shifting the timings and intensities of demand, encounter resistances of multiple forms (material, social, ethical) that 'act back' against attempts to reorder how energy is used in line with smart rationalities. And while there is undoubtedly much discursive enthusiasm for seeing wind turbines, solar panels, tidal power and other low carbon resource rhythms feeding into grids that are full of smart knowledge and rhythmic coordination, there is still much holding onto old ways of making electricity, achieving continuity and keeping power (of different forms) in place. As Boyer (2015: 534) comments, deploying the notion of 'energopolitics' to capture the power conflicts that run through energy systems:

> Renewable energy production is quite openly coded as a threat and disturbance in the baseload discourse of grid engineers and administrators: the resistance of grid and its cultures to renewable energy forms a relatively invisible frontline of energopolitical conflict in the struggle to escape the Anthropocene.

Such conflicts and resistances are playing out around the world with much differentiation. Some, maybe only a handful, of national electricity grid systems are already well on the way to embracing new low carbon energies, integrating new rhythms and managing new calibrations between rhythms. Many others remain wedded to their traditional polyrhythmic form with only incremental and marginal concessions to change. Similarly, micro grids, community energy systems and other versions of electricity provision rescaling are taking low carbon electricity into new infrastructural configurations, but doing so with much discontinuity and unevenness from place to place. Understanding such variation and the different shapes and speeds of innovation and diffusion is directly in the analytic space of transition studies, which has done much work to build on the multilevel perspective (Geels and Schot 2007), to examine how low carbon transitions are playing out (or failing to) across different techno-energy sectors in different contexts and at different scales (e.g., Bulkeley, McGuirk and Dowling 2016, Gailing and Moss 2016, Verbong and Loorbach 2012, Verbong and Geels 2010, Hodson and Marvin 2010). I have not gone down the route of applying rhythmanalytic thinking to the dynamics of transition, although there is undoubtedly potential to do so, including by linking to Chen's (2017) conjunctural rhythmanalysis to understand key moments of change. Instead, in moving to the final chapter and the last of the different strategies for rhythmanalytical investigation that I have pursed, I will ask further questions about how low carbon futures should entail polyrhythmic and poly-energetic transformation. This involves returning to the interrelations of energetic and rhythmic change that featured in chapters 3 and 4, in order to focus on undoing some of the interlinked processes of change in rhythms and techno-energetic dependencies that emerged during the long (and not yet defunct) era of carbon power.

Chapter Seven

Rhythms without Techno-energies

Bodies, Homes and Cities

> A symphony of rhythms and temporalities . . . underpins our development as human and as living organisms. It marks us as creatures of this earth, as beings that are constituted by a double temporality: rhythmically structured within and embedded in the rhythmic organization of the cosmos (Adam 1998: 13).

> All his life he had been inside machines, whether he realised it or not. Modern houses were machines. Shopping centres were machines. Schools. Cars. Trains. Cities. They were all sophisticated technological constructs, wired up with light and motors. You switched them on, and didn't spare a thought while they pampered you with unnatural services (Faber 2015: 228).

Rhythms and energies are ubiquitous and inescapable, but which should dominate, which should be diminished and which should be curtailed? Through the six preceding chapters, I have made the case for bringing the study of energy and rhythm together, and for doing so through the ideas, concepts and multidisciplinary methodology of rhythmanalysis and its grand ontological scope and ambition. I have followed the injunction to find the rhythm in all things, from corporeal to cosmological, engaging simultaneously with how rhythms are intrinsically energetic, involving expenditures, conversions and exchanges of energy in space and time taking both natural and techno-energetic forms. I have engaged with the living earth as a vast polyrhythmia of cosmological, environmental and ecological rhythms, and it follows of cycling, beating and pulsing energies; meaning that as human beings and as human societies, we are rhythmically and energetically immersed and entangled. From this starting point, I have turned my rhythmanalytic microscope and wide-angled lens to focus on a series of rhythm-energetic questions that matter to the role of techno-energetic expenditures and infrastructures in society, and thereby to the global climate crisis.

In chapters 4 and 5, I considered the dynamics of this rhythm-energetic condition, and the implications of new forms and patterns of techno-energetic expenditure being added into the modern polyrhythmic mix. We saw looking back at the development of society and economy, that there has been a co-dependency between rhythms and energies, with new patterns of energy expenditure co-evolving with shifts in social, economic, cultural and technological rhythms and their polyrhythmic interactions. As a consequence, techno-energetic rhythms, largely powered by carbon fuels, have for much of the wealthier world become deeply embedded in the rhythms of society, in the spatiotemporal patterns, sequences and synchronisations of being together, in the energy infrastructures that power the beats and pulses of everyday life, and even in the bodies that we inhabit. This has produced a deeply rooted techno-energetic dependency (and potential fragility) in the social order, and, most critically, a radical proliferation and escalation of ever-accumulating carbon pollution into the cycles, patterns and repetitions of the global climate.

We saw in chapter 6, how in principle there are ways in which both the obvious and more hidden rhythms of electricity systems can be modified, replaced, newly managed and coordinated in transitioning away from their high carbon and polluting forms; including through putting the complex and distributed rhythms of wind, solar, wave and tidal resources at their low carbon core, through smart rhythm management and rescaling electricity-making and demand-supply synchronisation across a far more fragmented geography. However, despite all of what *could* be achieved by decarbonising the polyrhythmia of electricity and other energy systems, I argue in this final chapter that on its own this is not enough. That there is a need to engage with our immersion and entanglement in rhythms and energies in more fundamental terms, in order to address not only the carbon that is released, but also the techno-energetic expenditures and dependencies that continue to evolve and reproduce in high-energy contexts in the Global North. Decarbonisation, in other words, needs to be accompanied by (techno) de-energisation.

Engaging with de-energisation in rhythmic terms means rearticulating some of the basic propositions of earlier chapters, in order to pose a series of questions:

1. Given that energy and rhythm have an intrinsic relation, they beat together, how can the rhythms of social reproduction be structured and enacted differently so that they are less techno-energetically intensive and dependent?
2. Conversely, as everyday life is shot through with rhythms and energies that are both social *and* natural in their making, how might (re)connections and (re)couplings to natural rhythm-energies be strengthened?

3. As our immersion in rhythms and energies matters also to bodily, ecological and environmental health, are there ways in which de-energisation can serve to sustain or improve eurhythmic formations and resist dysrhythmic elements and arrhythmic fractures?
4. In summary, can we live in ways that are less entangled with techno-energetic rhythms, more connected with rhythm-energies outside of these energy systems and more synchronized with times, temporalities and rhythms that have the capacity to counter patterns of fracture and harm in human and ecological life?

These are challenging questions, which I will only begin to answer in this final chapter. A full exposition would mean giving attention not only to the particularities of rhythm-energy relations in many specific sites, settings and contexts, but also crucially to how different rhythms are valued and others are diminished and how power plays out in polyrhythmia such that some rhythms are dominant while others are marginalised or required to 'keep in step'. In chapters 4, 5 and 6, I argued that contemporary energy and carbon problems were inherent to how rhythms have been seen selectively viewed, through lenses that foreground the eurhythmic circulations of economic growth, energy commodities and capital, while backgrounding the increasingly dysrhythmic circulations of environment, climate and bodies. It was made clear that to realise low carbon transition, dominant ways of valuing locked-together rhythms within fossil fuel infrastructures had to be challenged, with sets of rhythmic interactions taken apart in order to disrupt their structuring effects and incumbent momentums. The same applies to rhythms outside of energy systems, which are just as full of hierarchical entrainment, selective evaluations and dominant expectations of how rhythms will repeat and be ordered and powered. Bringing into being alternative patterns of repetition and different anticipations of how everyday life will play out, as part of realising de-energisation at scale, is therefore a daunting ambition; but also one that many commentators, campaigners and activists, largely on the margins, have been engaged with arguing for and attempting to enact, if not explicitly through a rhythmic framing.

To enter into this involved territory, I first lay out why de-energisation is a necessary counterpart to decarbonisation and has to be understood within the guiding principles of a just transition (Bickerstaff et al. 2013, Newell and Mulvaney 2013, Hall et al. 2013, Routledge et al. 2018) and briefly discuss the challenge that is necessary to the established politics of energy demand. I then discuss four general principles of de-energisation that can be understood in rhythmic terms—deceleration, reconnection, localisation and sharing—considering their relevance, scope and contingencies. Finally, I move through three sites of polyrhythmic formation—the body, the home and the city—in order to exemplify how de-energisation can be engaged with through rhythmanalysis. This will by no means cover all of the ways in which the re-making the rhythms of societies, economies, organisations, cities, households and human bodies have roles in de-energised and low carbon futures, but a start is made.

DE-ENERGISATION, INEQUALITIES AND POLITICS

The Case for De-energisation

Focusing on de-energisation as a mode of climate action is to resist the seduction of supply-dominated decarbonisation. Make energy production low carbon, remove the constant spinning out of rhythms of pollution into the atmosphere from energy systems, the seduction goes, and we can carry on using as much energy as we do now; maybe even more. The examples of the few countries that have seemingly all but achieved this nirvana makes it seem all the more possible. Iceland, for instance, is already in the virtuous position of generating all of its electricity through low carbon means (hydro and geothermal) and having 90 per cent of its homes geothermally heated (Jónsson et al. 2019). Hence, its electricity and heating system carbon emissions have plummeted since the 1970s as coal-fired power generation has been eliminated.[1] Iceland represents a way of thinking about an energy future that strips carbon out of supply to the extent that energy use, and the rhythms of society and economy it is integral to, appears unproblematic. So why can we not *all* be focused on heading towards this goal?

First, and most evident as a basic problem is the temporal disjunction between the speed of emission reduction needed and the relatively slow speeds at which de-carbonising supply has progressed to date. Anderson et al. (2015) stress this in making their case for prioritising demand reduction, arguing that just the long planning, construction and commissioning schedules for new energy supply infrastructures—the rhythms of their material coming into being—are too slow for the speed of transition that is needed. Whether the beat of transition can be substantially accelerated, pushed on by the politics of climate emergency, is unclear. As noted in the previous chapter, internationally there is much differentiation in level of commitment to decarbonisation, much rhetoric but comparatively little real and substantial transformation. What is certain, however, is that an energy supply system with much less recurrent and repeating energy demand to satisfy can only be easier and quicker to de-carbonise. De-energisation

1. Transport fuels are still heavily carbon-based and combined with mega-scale aluminium production; this mean that, in per capita terms, total carbon emissions are not as low as may be imagined.

gives decarbonisation a less daunting and also less expensive target to aim at, given the major costs that have to be carried if decarbonisation of energy supply is to progress at pace (Rosen and Guenther 2015).

Second, and for social justice reasons, a good amount of the investment in bringing low carbon supply rhythms into play needs to be in the Global South, addressing the ‘right to energy’ for much of the global population whose access to energy is insufficient and/or unstable. I have argued elsewhere (Walker 2015b) that the ‘right to energy’, whilst compelling in its simplicity, becomes far more involved in the working out of exactly what this means (what form of energy, how much, on what terms etc.). This means there is also a danger that the space for political work that this opens up is co-opted by those wanting to roll out further forms of big power, carbon-based energy infrastructure into ‘new markets’. Far better for newly developed infrastructural assemblages to ‘jump over’ the carbon-era and into the diversity of scales and modes of low carbon polyrhythms discussed in chapter 6.

Third, and again for climate justice reasons, de-energisation has to be focused on the Global North because of the asymmetry in who is responsible for bringing arrhythmic fractures into the global climate, and who is most vulnerable to, and least able to adapt to, their impacts (Schlosberg and Collins 2014). De-energisation, it follows, needs to be enacted in societies, economies and sectors of the population with the heaviest energy-carbon footprints (Soytasa et al. 2007, Brand and Boardman 2008, Hubacek et al. 2017, Oswald et al. 2020), whilst simultaneously securing at least minimum quality-of-life standards for those already living in poverty and with insufficient basic energy services (Walker, Simcock and Day 2016). Combining this and the previous point in simple terms, de-energising the rhythms of the Global North creates space for *energising* without carbon the rhythms of much of the Global South.

Fourth, as discussed in chapter 6, it would be naive to approach renewable energy technologies as resoundingly virtuous without recognising the problematic impacts and injustices they can still carry (Newell and Mulvaney 2013). This is most clearly the case with nuclear power, which is shamelessly presented as part of de-carbonising supply with little proper recognition of the unremittingly unresolved matter of how to deal with the extraordinarily stretched ‘after-life’ rhythms of radioactive wastes (as explained in chapter 5), let alone the many other forms of risk and injustice that the industry presents along its geographically extended fuel cycle (Butler and Simmons 2013). Similarly, in Iceland, hydro-power might provide low carbon electricity, but its expansion in sensitive highland areas in order to power aluminium production has been deeply controversial (Benediktsson 2007, Saethorsdottir and Saarinen 2016, Sheller 2014). Editing out some low carbon technologies because of their wider implications, or at least using them sparingly and cautiously, serves further to underpin the reasoning of points one and two above.

There are therefore multiple reasons for pursuing de-energisation in techno-energy intensive settings in the Global North, including others more conventionally deployed in arguing for energy efficiency as a repeatedly undervalued domain of energy and carbon policy (Creutzig et al. 2018). But in positioning de-energisation within the case for a just transition, there are further matters to consider, in particular how this relates to sustaining, or, for much of the global population, achieving a baseline of well-being and human flourishing.

If techno-energy use is to be cut back in ways that protect well-being and human flourishing, we would need to have sense of where a 'baseline' of essential or necessary techno-energy use might be—or at least a way of trying to work that out. Various approaches have recently been developed, including by looking to the substantial literature on basic needs and working through how these can be satisfied with less energy demand and related carbon emissions (e.g., Brand-Correa and Steinberger 2017, Steinberger and Roberts 2010, Gough 2017). In my own writing with colleagues (Walker, Simcock and Day 2016), we have suggested that the 'capabilities approach' (Sen 2009) provides a coherent and generally applicable foundation for conceptualising how (domestic) energy use relates to the energy services this produces, and in turn how these services matter to well-being. Focusing on capabilities—what people are able to do or be—and on outcomes, rather than say an amount of energy, makes it possible to centre in on exactly why techno-energy use matters, how essential it may or may not be, and also to look 'for alternative means to support capabilities, that do not necessitate a specific energy service at a household level' (Walker, Simcock and Day 2016: 262). For example, this might include ways of synchronizing the rhythms of sharing and collective provision (as discussed further below in relation to homes and cities). The capabilities approach also provides a necessarily situated and flexible approach to defining what a 'right to energy' should mean in different environmental, social and cultural contexts around the world, and for people in different circumstances, and will be a reference point for later discussion. Within such thinking, it is also relevant to ask how capabilities and rhythms are related. In chapter 4 various ways in which energetic-rhythmic relations mattered to well-being were considered, such as how rhythms of overnight shift working problematically bring discordances into the chronobiology of sustaining bodily health; and how the introduction of artificial light has been beneficial to home studying and therefore to being educated as a basic capability. Looking for so-called 'co-benefits', or enhancement of capabilities across multiple dimensions, within the dynamics of de-energisation is therefore important and will feature in later discussion.

The Politics of Demand

While there is a strong case for de-energisation, it involves a significant re-orientation to conventional ways of thinking about (techno) energy demand. Conceptually I have argued in chapters 3 and 4 that demand derives from the very many social practices in which the use of powered technologies is integral, and, in chapters 5 and 6, that understanding the temporal patterning of energy demand therefore involves stepping back from energy itself to examine how energy-using practices are positioned in time, how they are bundled, sequenced and synchronized together in shared routines. However, it was also made clear that the demand that emerges, in the aggregate and in its temporal variation, has been viewed politically and institutionally through a particular and restricted lens (Hui et al. 2018, Rinkinen et al. 2019, Willis 2012). Energy demand, in all its distributed complexity, has been considered an indicator of economic strength, an inevitable and emergent outcome of a well-functioning society and growing economy. Something therefore to be met and matched, with the expectation that it would grow in aggregate scale over time, with demand trajectories that readily elide any distinction between the 'need' for energy and the predicted scale of expected consumption. In other words, assuming all that will be demanded will be needed.

Such a perspective has served the interests of those already invested in the rhythms of energy supply and benefiting from these growing in scale, and has fitted tightly into neo-liberal models of how to be a 'successful' economy; a set of interests that the substantial attention to energy efficiency over past decades, as a way of reducing demand, has done little to challenge. As made clear in chapter 6, for a long time, demand rhythms were not something to be intervened other than to build them up, and steps towards beginning to shift them in time through demand-side response measures have been limited and controversial, particularly in their movement into domestic spaces.

Seeking to go further and significantly strip techno-energy use out of potentially all sorts of routine ways of doing things, out of expectations of 'the good life', and out of the rhythms of energetic flows that are embedded in how—and how much—we produce, consume and move around, is another step again. It means changes in rhythms and polyrhythmia beyond energy systems, extending into areas of 'non-energy' policy (Royston et al. 2018), and re-orientations to how different types of rhythms are valued. There are many complexities, tensions and dilemmas wrapped up in moving into this territory, which can be represented in unhelpfully simplistic terms; by critics as a return to the slow and dark rhythms of the past, and by advocates as an inherently positive, meaningful and progressive direction of travel, without engaging with questions of contingency, difference and inequality. In what follows, I will try not to be guilty of the latter failing.

RHYTHMS AND DE-ENERGISATION: FOUR PRINCIPLES

In keeping a focus on rhythms and the energetic possibilities of their disruption replacement, modification and changing interrelation, a first step is to identify some general principles that can guide the finding of opportunities for de-energisation. Principles of sustainability, green development, low-energy societies and similar have been widely articulated and debated. Little of this discourse engages directly with rhythm, but there are related strands of thinking concerned with time and temporality. These include Adam's (1990, 1998) extensive writing on timescapes and social-natural temporal relations, and work concerned with temporalities in relation to sustainability (Held 2001, Aldrich 2005), environmental research, policy and politics (Wood 2008, Szerszynski 2002, Jalas 2006) and escapes from the 'modern socionature regime' (Kolinjivadi et al. 2020). The substantial body of research approaching sustainability through a social practice perspective has also drawn on various temporal frameworks and concepts in seeking to go beyond individualised behaviour change approaches to shifting patterns of resource consumption (Shove and Spurling 2013, Southerton et al. 2012, Strengers and Maller 2015, Hui et al. 2018). Furthermore, looking beyond academic writing there are also principles to be found articulated in activist discourses and grassroots initiatives, including those focused on low-carbon communities, transition towns and forms of 'sustainable materialism' (Schlosberg 2019); as well as in deep ecology (Naess 1984) and radical frameworks for de-growth and alternatives to dominant capitalist models of economy and development (Demaria et al. 2013, Kallis 2018). Importantly, such thinking is often focused on different ways of evaluating human flourishing and well-being, alongside stripping out pollution, resource degradation and ecological damage from economic activity. A thorough review is not attempted here, but from my reading there are four relevant general principles.

Decelerating Rhythms: Slowing the Energetic Tempo

Many writers and analysts have diagnosed and critiqued manifestations of the increasing speed of social, economic and cultural phenomena, with accelerations associated with various phases of modernity, industrialisation and/or globalisation (Wajcman and Dodd 2017, Rosa 2015, Aldrich 2005, Adam 2004). In rhythmic terms, speeding up can mean either a rhythm having a shorter duration or a higher tempo of repetition, or both combined; slowing down therefore the reverse. Within a polyrhythmia, a shift in either the duration or tempo of a given rhythm is likely to have knock-on consequences, for example, a faster rhythm entraining others into a faster pulse, or arrhythmically clashing with those that remain slower tempo or longer duration. In chapters 3 and 4, it was noted that often (but not necessarily) the outcome of more energetic expenditure, or more intense thermodynamic conversions, has been an increase in speed. For Rosa (2015: 73), social acceleration, in its 'technical' dimension, is about 'the more rapid production of goods, the speedier conversion of matter and energy'. He also sees energy as wrapped up with accelerations in the 'pace of life'—as both a measurable phenomenon and a feeling of being time-pressured (Southerton 2003)—but in a paradoxical relationship with energised innovations that have meant to 'save time'. As Christiansen and Gebauer (2019a: 9) put it in rhythmanalytic terms:

> The faster technology works, the less we feel we have time. Paradoxical, because the intention is the reverse: faster technology should free up our time to do other things. Of course, this is a classic example of Lefebvre's arrhythmia when two (or more) rhythms intersect. Technological rhythms are accelerating but our biological rhythms are not.

Rosa, along with many others, also critiques the increasing tempo of material, social and cultural obsolescence and the speed with which shifts in consumption take place. In modern capitalist society, he argues, structure and order is predicated on both growth and a constant acceleration in the speed of innovation and novelty, with a pervasive valorisation of speed and the efficiencies and profit it implies (Adam 2004). In energetic terms, such acceleration has relied on the ever-escalating meeting of new energy demands, with faster rhythms of obsolescence generating more energy expenditure in production systems churning out new products to make and meet expectations of a faster tempo of novelty and replacement; with much of that production now 'off-shored' and spatiotemporally distanced from the site and moment of consumption (Barrett et al. 2013, Oswald et al. 2020). De-growth discourses encompass a similar critique.

In the face of such accelerations of many types of rhythms and their knock-on consequences within polyrhythmic relations, slowing down is frequently advocated as a response to socio-ecological crisis, as well as to the observation that faster ways of living are not obviously happier ones. Slow design, 'more time less stuff' (Jalas 2006), slow travel and slow food (Hsu 2014) are each examples of slogans advocating forms of deceleration, as are narratives of 'flight shaming' seeking to undermine fast and frequent flying as a normalised rhythm of mobility (for those more wealthy). There is therefore much to work with. However, there are also contingencies in applying deceleration as a general principle of de-energisation, particularly given that acceleration has not taken place everywhere or been a common experience, with its pace and manifestation strongly differentiated across aspects of social experience, across geographies and between social groups. For Rosa (2015: 21), 'forces of acceleration and deceleration do not balance out, but are instead very unequal in distribution', meaning that there is no one common starting point for change, or simple way in which less speed necessarily means more equality, as Illich (1978) would have it. Digital technologies are also an example of how *more* speed in the pulsing rhythms of communication can support de-energisation, if they are virtually substituting for physical co-presence and powered travel, and can be part of 'de-growth' futures if they are deployed in ways that are open, democratic and enable diverse forms of conviviality (Pansera et al. 2019). Deceleration as a principle therefore has much relevance to de-energisation, but it has to be approached with some care and differentiation.

Reconnecting Rhythms: Social and Natural Coupling

As with social acceleration, the disconnection of the rhythms of society, economy and everyday life from the rhythms of natural cycles, ecologies and organisms has also been the subject of much analysis and critique. As discussed in chapter 2, Adam (1990: 74) makes much of the essential rhythmicity of nature, in all its forms, and is critical of how social scientists ignore that humans as biological entities, and therefore part of nature, are 'timepieces that beat the multiple pulses of our earth and oscillate in synchrony with nature's rhythms'. Clock time, she argues, represents 'a technological time created to human design' in which 'the variable times of nature—of day and night, seasons and change, growth and ageing, birth and death—are objectified, constituted independent of life and cosmic processes, of human activity and social organisation' (Adam 2004: 4). This means that discordances and dissonances with the imposed linear and mechanical beats of modern, industrial sociotemporal orders demand close and critical attention. Other commentaries contrast clock time to the temporal regimes of traditional and indigenous cultures that 'regard time as inseparable from nature' (Griffiths 2005: 54) with the imposition of the linear time of modernity a form of 'cultural imperialism and racial and religious subjection' (ibid.: 59). Others focus on how various forms of disconnection from 'natural clocks' have harmful consequences on health and happiness (Prance 2005), as discussed in chapter 4; or on how the imposition of industrial rhythms on agricultural production clashes with the natural times of animals and ecologies (Held 2001). For Rosa (2015), there are links to social acceleration, given that speeding up inevitably implies discordances with the slower, more constant times of natural systems.

Advocacy for reconnecting to the times of nature emerges from such critique, including in relation to living more harmoniously with energy, weather and climate. Returning to the rhythms of natural energetic flows encompasses generating electricity from renewable resources (chapter 6), but is more fundamentally about a poly-energetic (and thermodynamic) understanding of interweaving rhythms of the planet, ecologies, societies and bodies. As explained in chapter 3, energy is defined by physicists as the 'ability to do work', and a compelling ethical question at a time of climate crisis is to ask what work *really* needs to be done by techno-energies, and what can be achieved through other means and in other ways, including by drawing far more directly and substantially on the vast energetic flows outside of energy systems. Energies that were doing agentive rhythm-energetic work—warming, illuminating, flowing, eroding—long before artificial technologized energies came into being, and that are inherently part of the times and rhythms of nature; as well as the metabolic rhythms of human bodies. This brings into critical focus substitutions between natural and techno-energetic energies, ways of achieving valued outcomes without techno-energetic expenditures, and ways of recalibrating social and bodily rhythms to the timings of natural energetic beats and pulses. However, here again close attention has to be given to the practical workings of a general principle of reconnection and return to natural rhythm-energies. There can be an over-romanticised view of being close to the rhythms of natural processes that can manifest in brutal, dangerous and unreliable forms, and to an idea of doing without techno-energies through frugality that can be blind to the realities of living in energy poverty (Walker 2013). Making reconnections with care, in context and with awareness of different circumstances, is therefore necessary.

Localising Rhythms: Proximity and Attunement

Closely aligned to discourses of reconnection are those that, in various ways, seek to make life more local. This a strong theme in much environmental activism—although not without critique (North 2010)—with various groundings, including, for example, resistance to the 'distances travelled' by commodities in global production networks (Cleveland et al. 2015) and the search for communality in local environmental action with strong connections to place (Schlosberg 2019). In rhythm terms, localisation can be most obviously about simplifying and radically shortening the sequential chains and pulses of movement between points of production and points of consumption, by making in situ or sourcing products from the local area. The energy implicated in the rhythms of extended transnational movement is therefore stripped out. Localisation can also in more polyrhythmic terms be about attuning the interaction of social, bodily and ecological rhythms to those of place and situation. This can include recognising, as discussed in chapters 4 and 6, how landscapes and places are poly-energetic in which rhythms of different natural energy flows intermingle, exchange and interact, varying over space and time, in both regular and more chaotic patterns of repetition. This was important in chapter 6 to the tight coupling between natural resource rhythms and the rhythms of (most) renewable energy resources, such that the site of conversion into electricity or other energy form *has* to be the site of the available resource. Attunement to local poly-energetic landscapes also, though, matters to making ways of life that are less dependent on techno-energies and more aligned with rhythms of natural light, heat, air movement and other aspects of environment and ecology embroiled in making places energetically what they are. This has been an important theme, for example, of building design for some time, in both vernacular and more high-tech forms, and for some versions of place-making and city planning. Attunement to how bodies, as rhythm-energetically constituted organisms, are part of polyrhythmic and poly-energetic sites (including through the type of lay thermodynamics characterised in box 4.2) are also relevant here.

Sharing Rhythms: Synchronizing and Sequencing

Sharing is connected quite directly to localisation but has emerged as a general principle of sustainability more recently than others, in concert with notions of the sharing economy (Martin 2016), circular economy (Geissdoerfer et al. 2017), collaborative consumption (Leismann et al. 2013) and sharing cities (McLaren and Agyeman 2015). Sharing in rhythmic terms encompasses both sharing in synchrony and in sequence. Synchronized sharing involves activities being carried out together, with the same rhythm in space and/or time, often involving a collective orchestration of making use of an infrastructure or a particular material arrangement of functional things. Such synchronizations are entirely familiar, arguably an 'evolutionary trait' (McLaren and Agyeman 2017: 323), and were very much in view in the discussion of both the regular and more sporadic rhythms of electricity demand in chapter 5. However, there has been much debate about changes in the patterns and rhythms of 'doing things together', for example in relation to concerns about more people living alone, the fragmentation of family life and greater social differentiation in access to public spaces. For de-energisation, the physical synchronization of shared social rhythms matters because of how the outcomes of the energetic-rhythmic work of technologies can have an economy of scale, and of spatiotemporal concentration (Isaksson and Ellegård 2015). In simple terms, energised technologies in principle will support the energy-demanding practices of multiple people at a lower level of energy use than a more distributed, asynchronous pattern of similar performances. As Yates

(2016: 449) points out, various historical trends have moved against such (energetic) economies of sharing, including 'the transition from launderettes, shared taps and laundry services to washing machines' and processes of personalisation that 'extend the process of domestication of services and goods by allocating them per person (as with telephones, televisions, cars, computers and bathrooms) or per room (television, heating sources and electricity points) rather than per household'.

Sharing of material things can also include sharing in sequence, a type of sharing that is again very normal and familiar. In rhythmic terms this means something being in use in a pattern that links to the practice rhythms of multiple 'users' and therefore being used at a higher tempo or frequency or over a greater longevity than would otherwise be the case. For example, a (power) tool that is borrowed from a collective tool store, rather than purchased to be used infrequently and sit idle most of the time; clothing that is given to a charity shop to be worn by another person, entering into the rhythms of their dressing, rather than a garment being made, transported and sold anew. The energetic benefits of this form of sharing come from the energy embedded in the making of products and the energetic proliferation and waste that comes with not sharing, and some sharing initiatives express a sense of resistance to such 'over-consumption' (Ozanne and Ballantine 2010). Here the metaphors of the circular economy connect quite closely to a vocabulary of rhythm, including in notions of materials (re)cycling and being sustained in a rhythm of circulation, repair and reuse (Geissdoerfer et al. 2017).

As with deceleration, reconnection, and localisation, we have to exercise some caution in following rhythm-sharing as a general principle of de-energisation. Yates (2016: 449) argues 'what counts as doing something together with somebody else is far from straightforward, encompassing a mosaic of different forms of communality', meaning that distilling its energetic implications can be particularly complex. There is also a necessary resistance to some high-profile manifestations of sharing in sequence (such as AirBnB) being seen as productively aligned with sustainability objectives (Voytenko et al. 2017). As Martin (2016: 159) argues, the sharing economy has 'the paradoxical potential to: promote more sustainable consumption and production practices; and, to reinforce the current unsustainable economic paradigm'.

Exemplifying the Principles

These four principles provide a foundation for now engaging with de-energisation in more specific rhythmic terms. I have outlined the relevance of deceleration, reconnection, localisation and sharing to thinking with both energy and rhythm, explained something of their scope in relation to de-energisation and made clear some of the contingencies and complexities involved in their application. Over following sections a series of examples of how these principles, and in some cases multiple principles in concert, play into de-energisation strategies are explored. The approach used is to centre in turn on three sites of polyrhythmic formation—the body, the home and the city. While these can be used analytically as distinct polyrhythmic sites (Chen 2017), they are also obviously interconnected. As Lefebvre and Régulier argue, there are in rhythmic terms multiple transitions and imbrications between inner-private and external-public rhythms, between 'the bedroom, the apartment, the house, the street, the square and the district'. Whilst such interrelations will become apparent, the approach is broadly similar to chapter 5, in beginning with a polyrhythmic site rather than a particular rhythm, in order to then identify rhythmic relations within and beyond this. However, here the analysis will be lighter and less systematic, involving characterising each site in both rhythmanalytic and energetic terms before then focusing on some specific examples of de-energisation that connect to both the four principles and the questions posed in the introduction to this chapter. None of the examples I work through are intrinsically novel, and some are very familiar, but the intention is to demonstrate a way of working with an energetic rhythmanalysis that might be developed further and with more innovation in the future.

BODY RHYTHMS AND DE-ENERGISATION: MOVEMENT AND REST

The body features quite centrally in the foundational rhythmanalysis writing and in its subsequent extensions and applications. As discussed in chapter 2, this is in part because of the methodological orientation to using the body as a way of observing and sensing rhythms, and judging the relative speed of different beats and pulses beyond the body itself. The body is also conceptualised as a polyrhythmic site and is referenced in exemplifying the contrast between healthy, eurhythmic and pathological, arrhythmic conditions. In rhythmanalytic terms, therefore, there are distinctly corporeal rhythms, but also always intersections between these and rhythms beyond the body, including the rhythms of everyday social practices and of cosmological cycles experienced physiologically in entraining, bio-rhythmic effects (Adam 1990). As Chen (2017: 42) states, 'the site of bodily rhythm is distinguished, yet it orchestrates a multiplicity of rhythms which actively work on the body'. In energy terms, the body is also a site in which the energetic constitution of rhythm is readily apprehended. In chapter 3, it was argued that bodies are both polyrhythmic and poly-energetic, as experienced through everyday bodily sustenance, activity and performance, and that in combination the rhythmic and energetic are so closely entwined that they define what it means (physiologically) to be a living human organism. In starting from this rhythm-energetic conceptualisation of the human body and its wider entanglements, how might we then find examples of its enrolment into the dynamics of de-energisation? Two are outlined here related first to the rhythms of bodily movement, and then, in contrast, to those of bodily inactivity.

Muscle Rhythms and Re-making Mobility

In being made animate through the rhythmic, repeating conversion of calorific energy into corporeal beats and muscular movements (as outlined in chapter 4), the body evidently does thermodynamic ‘work’ that is outside of the realm of techno-energetic systems. A relevant question is therefore to what extent dependencies on techno-energetic expenditures can be replaced by expenditures of energies of the human body, and be seen as equivalent in terms of the outcomes they enable? Historically, much brute, dangerous, draining and tedious human labour-work has been replaced by the work of powered machinery, and it follows that in reflecting on the balance of human well-being, a ‘return’ to the energetic body has to be approached with some caution. However, it is also clear that as the energetic rhythms of bodies—of muscles, heart and lungs—have become less intensively deployed in the doing of everyday life, this has increasingly eroded, across many populations, the eurhythmic qualities of bodily ensembles. An array of health conditions (both physical and mental) are associated with bodies that are rhythmically and energetically inactive, less fired up to function and make productive use of energy ingested as calories; bodies that as a consequence can readily falter from a eurhythmic condition into damaging arrhythmia.

Hence, there is a role in de-energised futures for substitutions of the techno-energetic with the human-energetic. That is most clear in seeing walking and cycling as alternatives to powered forms of mobility. There is a basic need for local mobility to get from place to place, to provision, to access key services and thereby realise core capabilities (Mattioli 2016). Achieving this through the rhythmic repetitions of muscles of the body can replace (with some important conditions and caveats) the rhythmic repetitions of combustion, cylinders, axles and wheels (as captured succinctly in figure 7.1). Such rhythm-energetic switching is not only about purposefully (re)activating bodily energies, but necessarily also about the complex and extended

Figure 7.1. Car fuelling versus bicycle fuelling.
Photo by Carlton Reid www.flickr.com/photos/carltonreid/4646637491, Reproduced under Public Domain License.

polyrhythmia of systems of mobility (as discussed in chapter 6 in relation to the transition to electric vehicles). Journeys, Hui (2013: 90) argues, are 'outcomes of the specific ordering and organization of practices', including their rhythmic relations, meaning that it is not only the journey that is rhythmically recalibrated when the mode of movement changes. Walking rather than car driving, for example, entails a different fitting together of rhythms, a slower speed and potentially (but not necessarily) a longer duration of movement, with implications then for what else, within polyrhythmia, walking is part of.

The sets of 'systemic sticking points' (Watson 2013) that differentially enable and limit the possibilities of different forms of mobility (as discussed later in city contexts) include, therefore, how expectations of rhythmic durations, speeds and repetitions become held together. However, the beneficial outcomes of reforming mobility polyrhythmia extend well beyond the stripping out of techno-energies; as Chen (2017: 77) argues, walking is an integrative activity, 'the practice of walking is essentially a way of weaving a plethora of rhythms that orchestrate at the site of the bodily'. Rhythmanalytic, as well as other writing, typically casts walking and cycling rhythms in a positive light (e.g., Spinney 2010, McCormack 2013, Sarmento 2017), arguing that connections can be formed with the local rhythms of place, social interaction, nature and community (although they can also be anxious and intimidating experiences). In these and other ways therefore, including the better breathing of less polluted air (Walker et al. 2020), the rhythms of walking and cycling align well with the co-benefits of de-energising societies that have become heavily hydrocarbon dependent.

Sleep, Entrainment and Thermoregulation

Whilst how the body is energetically active in moving from place to place is relevant to de-energisation, so in contrast are rhythms of its activity and inactivity. Sleeping in particular stands out in analyses of the energy expenditures associated with patterns of time use (what is being done when at different times of day) as being, in relative terms, an activity with a low techno-energetic footprint (Anderson and Torriti 2018, Durand-Daubin 2016). Hence the recurrent overnight troughs in electricity demand curves seen in chapter 5. Sleep is a practice that 'involves both biology and sociality' (Maller 2019: 96), with much diversity in how it is performed in relation to culture, age/life stage, health status and income. However, many studies have problematised declining durations of sleep and increased incidence of sleep deprivation particularly within high-income countries (Ferrie et al. 2011), seeing this as a further general symptom of processes of social acceleration, but also linked to other dynamics (including recently the effects of climate change (Rifkin et al. 2018)). Assertions of the need for an adequate amount of sustained bodily rhythms of rest, relaxation and sleep align therefore to some degree with the dynamics of de-energisation.

Timings of 'being at rest' are also important, though, in relation to natural cycles of light and heat and their locally experienced manifestation. Questions of synchronization between solar time and the delineation of time zones and schedules of clock-shifting (discussed later in relation to city rhythms) are relevant here, as well as the attunement of rhythms of the body in relation to its local thermal environment. In chapter 4, we saw how bodies can be conceived as polyrhythmic assemblages of thermal flows and accumulations (Oppermann et al. 2020) in which the rhythms of activity and internal heat generation, as well as those of heartbeat, breathing and perspiration, are interwoven within the mechanisms of bodily thermoregulation. Another strand of de-energisation therefore focuses on the relations between bodily capacities to thermoregulate and the use of techno-energies to create controlled climates for bodies to inhabit (Shove et al. 2014a). The largely abandoned rhythm of the 'siesta' in Spain (termed differently in other cultures), in which the social synchronization of resting bodies aligns with the hottest part of the day, is an example of a collective mechanism of working with bodily rhythms and bodily energies in some degree of harmony and attunement with the rhythms of environmental conditions. Similarly, the adaptive and attuned rhythms of dressing the body with clothing, to either retain or lose heat depending on the variability of anticipated thermal conditions (de Vet and Head 2020), is another of way working with the rhythm-energetic constitution of the body; rather than monotonously dressing for the types of homogenised and energised indoor climates discussed in chapter 4. With a helping hand, and within certain important bounds (including those related to age, health status and climatic extremes), the body as a polyrhythmic assemblage can self-manage its thermal energies.

There are therefore various ways in which the rhythm-energetic constitution of human bodies can be articulated with the dynamics of de-energisation. In principle, bodies can be better rhythmed and their energies better deployed in ways that bring social and environmental co-benefits. However, there are many challenges and tensions in such energetic-rhythmic recalibrations. *Crucially*, not all bodies are equally able to be energetic, to move and do without the techno-energetic support of powered technologies, and such capacities change over the rhythms of life-course. Stoekl's (2007: 274) bold assertion that 'since the imminent depletion of fossil fuels' means that 'muscle power, body power will be a, if not the, major component in the energy mix of the future' is, for a number of reasons, strikingly simplistic. The principle of equalising capabilities to function—to be mobile, to able to interact with others, to be sufficiently warm, to be well fed and nourished—is therefore particularly important in seeing the potential of embodied rhythms in de-energisation processes.

HOME RHYTHMS AND DE-ENERGISATION: HEATING AND LIVING TOGETHER

Homes and home-spaces are relatively rarely encountered as a chosen site of polyrhythmic assemblage, the rhythmanalyst's lens having typically rested in more public spaces or been aligned to more specific strands or settings of activity. A number of studies have, though, conceptualised homes as constituted of multiple temporalities and rhythms in space and time (Lee 2014, Nansen et al. 2009, Carr et al. 2017, Power 2009), as flows of activity that move around the home-space, that have a repeating temporal order as routines play out, and members of households synchronize and desynchronize their patterns of activity and their bodily rhythms over diurnal, weekly and seasonal repetitions, and over life-course dynamics. Non-human rhythms are also implicated. As Power (2009: 1031) argues, 'nonhuman animals that visit home and the broader environmental context outside home, bring different embodied times, rhythms and temporalities to home that shape the ways that people use, make and experience home'. The materiality of the home also matters to its polyrhythmicity (Carr et al. 2017) and is crucial to the energies that flow through the home-space. In a number of my own reflections and rhythm-energetic vignettes that have featured in previous chapters (for example, in boxes 4.2, 4.3, 5.1 and 6.1), the rhythms of energised domestic technologies have figured—washing machines, toasters, kettles, fridges, heating systems, radiators—all of which have patterns of repetition in their use. Therefore, both the sociality and the materiality of the home are integral to its polyrhythmic patterning, as well as to the techno-energetic resources this enrols. There are, in other words, interdependencies constantly at work between the lived and the built or made. As I have argued in previous writing with colleagues, a home's energy (and carbon) performance is 'a function of both how a building is designed and formed (its fabric, technologies, layout and so on) *and* how it is lived in, the practices that are performed on an ongoing basis' (Walker et al. 2015: 495). How then might the lived-in home, as both a sociomaterial and rhythm-energetic entity, be drawn into the dynamics of de-energisation? Two examples are examined, those of domestic thermal rhythms and sharing rhythms.

Thermal Rhythms at Home

Like bodies, home-spaces are also full of thermal flows, beats, pulses and exchanges, as captured in discussing the dynamics of indoor climates in chapter 4, the rhythms in demand for energy for heating and cooling in chapter 5, and the UK transition from gas to electric heating in chapter 6. Along with the polyrhythmic account of a home heating system in box 6.1, this all made clear that very substantial techno-energetic expenditures can be enrolled into managing the dynamics of domestic indoor temperatures; for example, in the United Kingdom 55 per cent of residential energy consumption[2] is currently devoted to space heating. Better management of the thermal performance of housing has therefore long been a key target for cutting energy use and, in more thermally demanding contexts, also addressing the scourge of fuel poverty, which is itself a dynamic and temporally structured phenomenon (Day and Walker 2013).

While any improvement to the techno-energetic load involved in indoor climate control can be interpreted as a modulation of rhythmic interconnections, this is most apparent in passive house design, which is rhythm-energetic at its core. Passive design enacts indoor heating through harnessing the heat-emitting rhythms of functioning technologies (such as cookers, fridges and televisions), the heat-emitting rhythms of human bodies (and other living inhabitants such as pets), and the day-to-day and seasonal cycles of received solar radiation. In passive houses active heating or cooling technologies are designed out, replaced by the choreography of pulses and cycles of other thermal flows in order to achieve an acceptable level of comfort and only a very slowly changing rhythm of room temperature (Muller and Berker

2. Data for 2019 from www.gov.uk/government/statistics/energy-consumption-in-the-uk.

2013). Whilst this involves high standards of house construction and use of ventilation and heat-recovery technologies, it necessarily also integrates the bodies and practices of inhabitants into achieving a carefully calibrated thermal polyrhythmia, able to achieve up to 85 to 90 per cent[3] reduction in energy consumption (Stephan et al. 2013). A eurhythmia (at least in principle) of house design from a thermal perspective, without anything like the normal techno-energetic load.

To what degree passive homes, and other variants of low or zero carbon homes, should also enrol significant shifts or disruption*s* in the rhythms of domestic life (what inhabitants are doing where, when and how) in order to 'perform well' is less clear. In researching this question with those designing, building and selling homes to satisfy an eventually aborted requirement for zero carbon performance in the United Kingdom (Walker, Karvonen and Guy 2015, 2016), we found contradictory evidence. Some, in interviews and documentation, referred to 'new normals' of home living and to 'building new lifestyles' as well as new homes. Far more dominant though was a resistance to any expectation of needing to live 'differently', including to reform the rhythmic ensemble of day-to-day home-life. For example, as representative of a housing association explained, 'these properties are designed to be as simple and easy to use as a normal house . . . they're not alien houses, it's a bit different how people should live in the properties, but not vastly'. An architect made a similar comment, using the example of allowing the normal rhythms of drying clothes through tumble-drying to proceed without 'restriction':

> people are buying these houses to live in and you've got three hundred houses, you might only get five or six eco activists who want to live there, you might want to get another twenty people who like their towels tumble dried. So we always said these houses should be able to be lived in by anyone, we shouldn't restrict how people live.

Clothes drying is a good example of an apparently simple practice that can be readily de-energised—through the provision of a clothesline to enable drying by the rhythms of sun and wind, potentially with sequential use by different residents (see figure 7.2). It is, however, entangled with the orchestration of other rhythms—clothes washing, hanging out, collecting in, as well as the rhythms of changing clothes, dressing for different activities and so on (de Vet and Head 2020). The rhythms of the tumble drier fit differently into the beats and pulses of everyday life to those of the clothesline, as well as into images of the modern household and the rhythm-energies through which it

3. Although taking account of embodied energy in construction and transport use if located away from urban centres can be significant.

Figure 7.2. Clothes drying infrastructure in Shanghai, China.
Photo by Dai Luo. www.flickr.com/photos/dailuo/7278634890 Reproduced under licence CC-BY-2.0

functions. Tumble drying is not a necessity, drying clothes can be done otherwise, but it has become to some degree locked in and difficult to extract.

The figure of the 'eco-activist', used rather dismissively in the interview quoted above, points however to approaches to de-energisation that very much *do* see the need to recalibrate the rhythms of home living in relation to their techno-energy dependencies, connecting to all four rhythmic de-energisation principles. In chapter 6, it was discussed how techniques for achieving flexibility and responsiveness in the rhythms of energy use are being developed both to respond to the needs of electricity grids, but also in more local alignments between renewable energy production and consumption. However, truly off-grid living extends further into synchronizing the rhythms of 'what is done when' with the availability of local energetic flows of both light and heat, allowing different pace-makers to dominate and have entraining effects. Vannini and Taggart's (2015: 639) research with 'off-gridders' in Canada engages with the 'temporal dimensions of renewable energy lifestyles', and how these contrast with grid-tied homes 'which can operate in relative asynchrony with the weather, the seasons, and with natural cycles of light and darkness'.

The limited and varying power made and held in PV-battery systems mean that off-grid lives are typically led more slowly, electricity dependencies are circumvented with other available devices such as outdoor ice boxes, indoor lighting is used sparingly, and running more energy-intensive devices such as washing machines, vacuum cleaners or power tools is avoided on 'dark days'. Off-gridders also anticipate the rhythms of daily cycles and darker days as the managers of grid systems in chapter 6 do, although more intuitively and within only their specific locality. The limits of infrastructure emerge as actively reshaping both the energetic and rhythmic content of everyday life, in ways that are concordant with ethical commitments; 'their experiences, motivations and relational position informs the conscious efforts they make to slow down and to live in synchrony with varying textures of grey and radiant skies and the technological and meteorological duration patterns their life is enmeshed within' (ibid.: 646).

Sharing Home-life

Such enactments of resistance to the speed of techno-energised ways of living and intent to recouple to the variabilities of natural cycles lie outside of the norms of more widely shared and 'modernised' polyrhythmic structures and relations. They are 'disorderly' in relation to standard rhythmic orders (Edensor 2010b). However, in principle, and in variants of practice, they demonstrate how social rhythms can become differently entwined with those of infrastructure, environment and atmosphere, and how hierarchies of rhythmic domination and subordination can be challenged and restructured. The same is true of other examples of living differently, for example in intentional communities, eco-communities, cooperative housing and similar arrangements (Chatterton 2013, Dawson 2006, Jarvis 2015). Here rhythms of sharing come into view, specifically modes of 'living together' through inhabiting and making use of spaces and their affordances through both degrees of synchrony and/or coordinated sequencing (Yates 2016). There are many different forms this can take, including the classic family home, shared flats and houses, sheltered housing for older people, and co-housing spaces where there are individual homes but some purposeful sharing of communal spaces, facilities and infrastructures. Across this range, the degree and particularities of synchronizations in the rhythms (in space and time) of what people are doing can be very diverse, with variation in how much, for example, there is a rhythm of shared cooking and eating, shared doing the laundry, shared leisure-time and shared moving to and from the home-space.

This makes the energetic implications of 'living together' different to generalise. Studies examining the sustainability implications of the rising numbers of people living by themselves do show that this increases per capita energy consumption (Bradbury et al. 2014, Yates 2016). For example, in the United States, where average household size has decreased significantly since 1950, a study found that the carbon footprint of a representative person cohabiting with others was 23 per cent less, on average, than if that same person lived alone (Underwood and Zahran 2015). A recent pan-European study estimated that the average carbon and energy footprints of an EU household of five or more people are about 50 per cent that of a one-person household (Ivanova and Büchs 2020). It is important not to approach such statistics too bluntly and to over-romanticise the notion of shared living, particularly where this is forced by circumstance and means overcrowding in poor-quality accommodation. Experience also shows that even in intentional, co-housing communities, there can be tensions around how much communality is sustained with 'much private property, personal space and "alone time" . . . retained by individual residents in these arrangements, demonstrating that the economies of scale achievable in larger households are only ever partially realised' (Yates 2016: 436). However, there are many ways in which the rhythms of 'sharing space and sharing time' (Jarvis 2011) are talked about positively beyond their environmental potential, for example in terms of conviviality, shared purpose and mental health, so in principle there are significant co-benefits that can be achieved (Jarvis 2015).

Another way of thinking about sharing and rhythmic patterning is in terms of the range of practices that the home-space accommodates and that therefore the domestic polyrhythmia includes; particular practice rhythms sharing space and sometimes overlapping in time. Most striking in recent dynamics is the rise of home working, such that there is no neat separation between the rhythms in space and time of home and work, but rather degrees of sometimes messy overlap facilitated by the connectivity and mobilities of digital technology (as captured in the 'charging rhythms' of box 5.2). For Nansen et al (2009), domestic rhythms are substantially 're-constituted', perturbed and remade by the proliferation of digital connectivity and associated media, with consequences for home-life that have become the subject of much debate and critique. Work rhythms can problematically inhabit and disrupt what were solely domestic time-spaces, but if one of the outcomes of the melding of the rhythms of work and home is that the journey to and from work is removed, or diminished in frequency, then various studies show that significant de-energisation gains can be achieved (e.g., Fu et al. 2012). There is much contingency in such analysis, for example in relation to patterns in how the home-as-work-space is heated, lit and powered, and what mode and length of anticipated rhythm of travelling is 'removed'. There is also much complexity in how flexibility in working practices and the demand for travel are related

(Burkinshaw 2018), but there is undoubtedly a space in which the trajectories and possibilities of re-rhythmising the future of work and its relation to everyday life are significant for the dynamics of de-energisation at a wider scale.

The home as a polyrhythmic site can therefore be more or less techno-energy intensive in its material functioning, in how it is inhabited and in how in spatiotemporal terms it fits with rhythms of practices beyond the home. Other examples could also be added in. There is much scope for imagining, designing and materialising de-energised domestic polyrhythmia, but also real challenges for disrupting the accumulated momentum of rhythms that orient towards energetic consumption opportunities for profit; challenges that are materially, politically and institutionally structured (Horne 2018). Much more could be explored along these lines, but I will now turn to the spaces and temporalities of the cities, in which the majority of homes are now located.

CITY RHYTHMS AND DE-ENERGISATION: MOBILITIES, TIMINGS AND ECOLOGIES

Lefebvre is perhaps best known as an urban theorist and this is reflected in his rhythmanalysis writing. In the most well-known passage in the main rhythmanalysis text, Lefebvre gives a rhythmic account of what is 'seen from the window' of his apartment in the centre of Paris, and in an earlier essay with Régulier, they compare and contrast the rhythms of Mediterranean cities in their historical and political context, showing how 'urban, which is to say public, space becomes the site of a vast staging where all these relations with their rhythms show and unfurl themselves' (Lefebvre and Régulier [1986] 2004: 102). Rhythmanalytic work that has followed has included analysis of the rhythms and 'chronotopes' of particular urban settings (Osman and Mulicek 2017, Mulicek et al. 2016, Nkooe 2018, Lehtovuori and Koskela 2013, Sgibnev 2015), rhythmised accounts of differentiated experiences of urban mobility, tourism, shopping and leisure (Jones and Warren 2016, Schwanen et al. 2012, Antchak 2018, Edensor and Larsen 2018, Lager et al. 2016, Prior 2011, Sarmento 2017, Simpson 2008), and of longer-scale rhythms of urban history and heritage (Hetherington 2013, Hornsey 2012).

In such work, certain urban spaces are characterised as more rhythmically complex, more densely animated, some made up of multiple clashing rhythms, others more synchronous or harmonious. Such rhythmic qualities shift between day and night, from day to day, from weekday to weekend, over historical time-spans, and in relation to particular city 'events', both planned (Edensor and Larsen 2018) and unplanned (Thorpe 2015). Hence the urban for Crang (2001: 189) is 'the site where multiple temporalities collide', in patterns of repetition, but always emergent and with difference and dynamism (Edensor 2010b). As rhythms are also energetic expenditures, it follows that urban polyrhythmia, or what Brighenti and Karrholm (2018) extend into 'territory-rhythm complexes', are thoroughly thermodynamic, full of environmental flows and cycles of heat and light, but also of massive techno-energies pulsing through high densities of infrastructure (for both static and mobile uses) and powering a multiplicity of energy-using practices. Cities account for around 70 per cent of global energy consumption (Creutzig et al. 2015), hence are crucial sites for rhythm de-energisation. This means giving attention to rhythm-energetic questions in how cities are laid out, made and managed, given that, as Jalas (2005: 73) states, bringing environmental concerns into 'spatial planning implies nothing less than temporal planning'. Held (2001: 356) similarly argues 'if we ignore climatic and other relevant context-variables with their rhythms and *eigenzeiten* [embedded times], as we have done for a long time in planning our settlements, architecture and construction, we cannot be on a sustainable energy path'. Three, out of many potential examples relevant to the dynamics of de-energising cities are considered here, relating to mobility, solar time and urban ecology.

Rhythm-energies of City Mobility

In Lefebvre's account of the rhythms of Paris looking out from his apartment, flows of energised mobility through space and time are centre stage. For example, in this passage he gives attention to the rhythms of traffic and pedestrians, their speeds, intensities and interactions:

> At the green light, steps and words stop. A second of silence and then it's the rush, the starting up of tens of cars, the rhythms of old bangers speeding up as quickly as possible. At some risk: passers-by to the left, buses cutting across, other vehicles . . . On this side, people walking back and forth . . . a mix of young and old, alone and in couples, but no cars alongside culture. After the red light, all of sudden it's the bellowing charge of wild cats, big or small, monstrous lorries turning towards Bastille, the majority of small vehicles hurtling towards the Hotel de Ville. The noise grows, grows in intensity and strength, at its peak becomes unbearable, though quite well borne by the stench of fumes . . . Hard rhythms: alternations of silence and outburst, time both broken and accentuated, striking he who takes to listening from his window (Lefebvre [1992] 2004: 38–39).

Traffic is noisy, risky and dominating in this account, and its intensities mark out the daily rhythms of the Parisian streets. Elsewhere, Lefebvre develops a critique of automobility as part of his conceptualisation of 'social space' (Murray and Doughty 2016), with implications for diminishing its role in the polyrhythmia of city life. The most fundamental transformation, as discussed earlier, is to replace the rhythms of powered mobility with the rhythms of the energised body, a shift that needs much action and normalisation at an urban scale. Urban infrastructures channel rhythms of movement, to enable mass commuting practices (Edensor 2011), prioritising some modes of mobility, frustrating or obstructing others. As Spinney (2010) argues, the hegemonic domination of road traffic acts to segregate public space, defining key beats and pulses of urban life, including (for many) the necessary rhythmic structure of moving between home, work, education, care and leisure settings, as well as the mundane pauses, durations and deviations of navigating around and across major roadways.

These are disciplining effects that the low carbon transition to electric vehicles does little to challenge. As argued in chapter 6, transitioning to electric cars means intervening in an assemblage of tightly held together rhythmic relations; but EVs are necessarily still energised vehicles, marketed and conceived as such (Hui 2019), and their infrastructures can still dominate and circumscribe the rhythms of public space. It can however be otherwise. In cities where mobility hierarchies have been significantly reordered in favour of walking and cycling, such as Copenhagen in Denmark (see the rhythm-energetic vignette in box 7.1), we get a good sense of how the polyrhythmia of city life can look,

BOX 7.1.
Cycling Rhythms in Copenhagen

A bicycle for one, Danish, borrowed and shared, wheels turned by muscle, metabolic energy stored, to be expended and depleted. I set off, my pulse rising as I follow signs, lines and paths, with others and yet more others. A busy route, one way this side, one way the other, a discipline unfamiliar but routine for the rhythms of residents. Pausing, surging from lights, in front of hydrocarbon cars waiting to turn, even lorries not so dominant in this city. A whir of wheel and pedal, gravel crunch, brake squeal, past factory, through park, by water. Faster and slower, older and younger, a stately rhythm, a racing rhythm, a rhythm synchronised to chat together. I arrive to meet the timetabled train that has carriages for bicycles and riders. Fifteen, twenty, quietly sit and stand together, shared electrified mobility for a while, before leaving, past bicycles resting in hundreds. I push to the street, setting off, accelerating, dispersing, following signs, lines and paths, now sometimes improvising my route, my beat. Finding my way to a restaurant to park, lock, talk, drink, refuel. Someone told me the cycle tracks are the first to be cleared when it snows.

feel and sound quite different to Lefebvre's Paris. To some degree decelerated, but also restructured in terms of how the beats and durations of movement relate to the sequencing and synchronization of other activities. Making such polyrhythmic forms needs spatial planning that not only lays out urban public space to facilitate muscle-powered movement, but also gives close attention to the demand for mobility and therefore to matters of density, mixed land uses and trip distances (Dujardin et al. 2014, Owens 1992, Hodson et al. 2013). City planning is in this way a key tool in the governance of both the generation of mobility rhythms and the techno-energies these enrol.

Enacting sharing as a principle of rhythm de-energisation is also central to challenging car-based mobility. Public transport is a long-standing mode of synchronised sharing in which traveller's distinct space-time pathways converge at points and moments of departure, are held together within an energised infrastructure, before then dispersing at the journey's end. Within an ecology (and economy) of shared-synchronized movement, there is a familiar carbon/energetic scaling; a shared train or tram is (generally) better than a shared bus, a shared bus better than a shared car, a shared car better than an unshared car. Affordable shared public provision in various forms is also important to realising social justice goals tied to the need for mobility (Simcock and Mullen 2016), enabling people on low incomes to connect into the rhythms of educational and economic activity (Cheyne and Imran 2016). Furthermore, in terms of how cities orientate themselves to the rhythms of longer-distance travel, a shared train is also (much) better in energy terms than a shared airplane (even more so when the sharing is in a private jet). The rhythms of a de-energising city are therefore oriented to its railway stations as hubs of synchronized convergence, not to airports and all that coordinates in, on and around them. And similarly oriented to its bus and tram stops, rather than to its highways and car parks.

At a local scale, bike-sharing schemes also support de-energisation (Fishman et al. 2014), in this case through the rhythms of sharing in sequence. When shared, the rhythm of the bike 'in use' becomes part of the muscular rhythms of multiple users over time, with the convenience of its picking up and leaving intended to fit easily and flexibly into the time-space rhythms of potential cycle users. And the success of such schemes relates in part to how well the rhythms of intended movement by potential users from place to place are predicted in the placement of docking stations, the movement of bikes between docking stations as part of scheme management and so on. Anticipating and provisioning the repeating rhythms of demand is important to keeping forms of shared mobility functioning; just as such tasks are crucial for sustaining the operation of electricity systems discussed in chapters 5 and 6.

City Time and Solar Rhythms

Whilst the rhythms of mobility within bundles of social practice constitute much of the more obvious frenetic activity of urban polyrhythmia, longer cyclical rhythms of days and seasons also structure patterns of repetition. Accounts of the rhythms of urban life explicitly and implicitly engage with its daily structure, the surges of activity as the city 'wakes up', the start and end of work and schooling, the evening rush hour, the nighttime leisure economy and so on, all differentiated to some degree from setting to setting. In energetic terms, this patterning matters to when over a diurnal temporality the use of techno-energy happens, making, for example, the peaks and troughs of electricity load curves featuring in chapters 5 and 6. However, the intensity of this techno-energetic demand is also dependent on how closely the rhythms of city activity are matched or synchronized with the diurnal cycling of natural solar radiation and thermal energy in which the city is always immersed. Key rhythms of energy demand are socio-natural hybrids, it was argued in chapter 5, raising questions about the coupling between the rhythms of social activity and those of natural energetic flows. Important in the dynamics of (de)coupling are shifts away from the sun operating as a locally defined source of sociotemporal order (as discussed in chapter 4), towards the use of nationally and internationally standardised clock times to schedule and synchronize social activity.

How clock time is set is a national-level question of time zone delineation and clock-shifting protocols (e.g., distinguishing winter from summer time), but the geographical positioning of individual cities in relation to clock time regimes has specific local consequences for rhythm-energetic relations. A logic that sees the setting of time zones driven by an optimum synchronization of social with solar rhythms would materialise a geography of twenty-four equally spaced time zones around the world, such that for cities at a given latitude sunrise and sunset happens at approximately the same clock time. However, the reality is far more chaotic and discordant (Green 2014). This is most clear in situations where time zones are set primarily for political reasons. In China there is just one official time zone of Beijing or China standard time, despite its territory covering fifty degrees of longitude and in theory three time zones, producing an increasing misalignment between daylight and time schedules in cities towards the west of the country. Similarly, there is only one time zone across the geographical expanse of India, set during British colonisation, spanning nearly thirty degrees of longitude. The consequence is higher demand for techno-energetic illumination, and to some degree heating or cooling, where the coupling of social and solar rhythms is most misaligned. Implications then follow for how peak demand across national or intranational grids is structured, for the spatial distribution of consumer energy costs, and for the timing of PV electricity generation (see chapter 6). How much difference both the setting of time zones and use of clock-shifting protocols makes to energy consumption is much studied and disputed (e.g., Ahuja and SenGupta 2012, Hill et al. 2010). Ideally, however, in de-energised cities there would be consistently closer couplings between the rhythms of clock time and solar time in relation to diurnal and seasonal cycles, mobilising principles of both reconnection and local attunement.

Ecological Rhythms in the City

While the rhythms of cosmological cycles are part of city polyrhythmia, so are the rhythms of ecology and non-human organisms. There are non-human agencies at work in how such rhythms become manifest in urban settings—through the growth and movement of weeds, seeds, insects, urban wildlife and so on (Maller 2018) —but what is purposefully allowed or enabled to be part of urban landscapes circumscribes this agency. In energetic terms urban ecologies are integral to how thermodynamic flows move in city space and, in particular how patterns of cooling of both bodies and buildings can be achieved with less use of techno-energies (Norton et al. 2015, Bowler et al. 2010). In terms of de-energisation principles, this is a question of both socio-natural rhythm coupling and local attunement to the climate and to the thermal micro-geographies of city environments. Urban spaces respond to solar heating in strongly differentiated thermal rhythms over diurnal and seasonal timescales, as measured quite strikingly in remotely sensed satellite analysis of temperature gradients for different types of urban surface (Chudnovsky et al. 2004). Many studies have shown both direct and indirect effects on the urban micro-climate of integrating various forms of green surface and infrastructure into its built form. Urban trees reduce air temperature through a diurnally and seasonally structured rhythm of evapotranspiration and release of water vapour (Moss et al. 2019), as well as provide a shading effect damping down the heating rhythm of received solar radiation for buildings.

City parks and green spaces (see figure 7.3) provide spaces for the rhythms of being in the city to periodically slow down, for people to relax, be cooled by breezes and shaded from the sun during hotter parts of the day. Enabling photosynthetic growth rhythms to proliferate on green roofs and building can contribute to a 'nature-based' thermoregulation of indoor environments, also limiting the expelling of heat from air conditioners into the urban heat island. In such ways, integrating ecological rhythms into the energetic relations of city polyrhythmia can have valuable de-energising outcomes, as well as many co-benefits for physical and mental health, including the vulnerabilities to more frequent repetitions of extreme heat events due to climate change.

Figure 7.3. Ecological shade in Taipei, Taiwan.
Photo by the author.

How well such measures support the doing of de-energisation in socially and environmentally just ways is a key issue. Green gentrification (Gould and Lewis 2016, Anguelovski et al. 2018) has been recognised as having potentially corrosive effects on low-income, minority and disenfranchised neighbourhoods, bringing the rhythms of ecology into such communities—along potentially with redesigns to enable the rhythms of walking and cycling and of the thermodynamics of low energy housing—but in the process changing the existing rhythms of property markets and pushing out existing residents and businesses. The de-energised polyrhythmia acts therefore to include the rhythms of some bodies and ways of living while excluding others. All the more important therefore to follow principles of just transition in city spaces, and to see Lefebvre's 'right to the city' in rhythm-energetic and low carbon terms, as well as in its more established formulations. Articulating the 'right to the low carbon city' or the 'right to low energy living', I have argued at greater length elsewhere (Walker 2015a), is one way of making clear the crucial role the state and other actors have in enabling de-carbonised and de-energised ways of being, whilst ensuring that a foundation of achieving basic capabilities is available to all.

SOME FINAL REFLECTIONS

Rhythmanalysis has, from its inception, been about both analysis and critique. Looking back to the writing of Lefebvre and Régulier, their objective was in part to take forward lines of Marxist thinking to build a rhythm-critique of the trajectory and experience of everyday life under capitalism. My critical orientation has been to bring rhythmanalysis to bear on the conjunction of energy, carbon and climate change, and, as indicated at the start of this book, to follow through on Lefebvre's ([1992] 2004: 15) intent that rhythmanalysis should be 'a new science, a new field of knowledge . . . with practical consequences'. Having built an approach to understanding rhythm and energy together, and applying rhythmanalysis to examining the rhythms of energy in society—its infrastructures, everyday patterns, synchronizations, repetitions, anticipations, dynamics and arrhythmic fractures—I have in this and the previous chapter considered a diversity of practical ways in which both carbon and techno-energy is, bit by bit in some places and contexts, being removed from the polyrhythmia of high carbon, techno-energy-dependent societies.

This has involved tracking the rhythmic reconfigurations and new modes of rhythm management already materialising in (some) decarbonising electricity systems, and then going beyond this to find the rhythmic possibilities in more fundamentally de-energising how moving, warming, cooling, illuminating, working and much else are routinely done. Rather obsessively I have been at pains to follow Lefebvre's urge to find rhythm pretty much everywhere—both in the obviously pulsing and repetitively beating, and the seemingly inert and unmoving—adding to this a continued energetic orientation very deliberately extending across diverse and interacting natural-energetic and techno-energetic forms. In centring in this chapter on bodies, homes and cities as interrelated polyrhythmic sites, I have explored how tempos can be slowed down, social and natural rhythms reconnected and local attunement and shared rhythms enacted, in order to contribute to de-energisation in diverse ways. This has not been a complete or consistently detailed analysis of rhythms and energies, but in its ontological starting point, its scope and pluralistic rhythmanalytic method, my intention and hope is that it provides a foundation on which others may build.

I cannot claim, however, to have provided new answers to how these different beats and pulses of rhythm-energies should come about across a much wider field and with more urgency. My largely implicit orientation to purposeful change, more clearly articulated elsewhere (Walker 2013, Walker 2014, 2015a, Shove and Walker 2014), has been to seeing this happening not simply or primarily by demanding more of personal action and the agencies of 'right thinking' individuals. Rather, the change that really matters has to be collective and structural and therefore demanding much more of governance, politics and democratic practice than we have seen to date. This orientation to change aligns with understanding temporality and rhythm in structural and ordering terms. As Rosa (2015: xxxviii) argues, 'the question how we want to live is equivalent to the question how we want to spend our time, but the qualities of "our" time, its horizons and structures, its tempo and rhythm, are not (or only to a very limited degree) at our disposal'. And while Harvey (1990: 432) asks us 'what would the space and time of a socialist or ecologically responsible society look like?', it is self-evident that taking apart the space and time of the societies we have now is not just a matter of knowing where we want to go.

I have moved to a 'triadic analysis' (Lefebvre [1992] 2004: 22) of the space, time *and* energies, in other words the rhythms, of carbon-rich, energy-dependent ways of living, and mapped out some of what would, could and should be different in low carbon, de-energised futures. This has shown that there is much that is deeply embedded and tightly ordered, with resistances that hold established forms of rhythmic repetition and polyrhythmic interaction in place. But, a constant refrain of rhythmanalysis is that repetition is always open to difference, and that the disorderly coexists with the orderly (Edensor 2010b), which includes the possibility of rhythm-energies pulsing differently with radically less carbon and techno-energetic intensity. Difference often emerges only slowly, but can speed up as discontinuities and fractures emerge. For Lefebvre (ibid.: 53), 'Disruptions and crises always have origins in and effects on rhythms: those of institutions, of growth, of the population, of exchanges, of work, therefore those which make or express the complexity of present societies'. It has been central to my argument that the climate crisis has its origins in rhythms and their energies, but whether this is an unfolding crisis that has the power to 'act back' to address the rhythms of its making is at yet unclear. Rhythms and energies are visceral and existential, mundane and profound. The future will be rhythm-energetic but there is still much to do to steer away from the incessant beats of its current carbon-accumulating trajectory.

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