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Structuring Energy:
Politics of the Energy Concept in Nineteenth-Century Physics, Literature, and Infrastructures

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DEDICATION

For Nick and Molly

ABSTRACT OF THE DISSERTATION

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Even as we urgently need to transition to sustainable energy sources, shifting fuel types alone will not address the persistent structural inequalities of our infrastructures. This dissertation theorizes energy's infrastructure, which emerged contemporary to classical energy physics in the nineteenth century and naturalized western assumptions about bodies, movement, resources, and possibilities. I argue that the Victorian period is crucial to understanding how certain energy modalities are embedded in our cultural imaginaries, literatures, infrastructures, and sciences. Because energy deals in conversions and relationalities, strategies of representation such as models, fictions, figurative language, and infrastructural forms produce a version of modernity that we recognize while obscuring other possibilities. By studying energy's nineteenth-century emergence as a scientific concept, therefore, we can approach a twenty-first century energy transition from a culturally responsive, sociopolitical perspective.

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> What I'd like to do is get back to what I consider the regular definition of infrastructure, in terms of job creation. So that's roads, bridges, ports, airports, and including broadband into that, water infrastructure.
> - Shelley Moore Capito, quoted in "Republicans prepping smaller counteroffer to Biden's infrastructure Plan," *Politico* (2021)

> President Biden believes that the market-based shift toward clean energy presents enormous opportunities for the development of new markets and new industries.
> - "Fact Sheet: The American Jobs Plan" *Whitehouse.gov* (2021)

When the Biden administration unveiled its infrastructure bill in March 2021, Republicans opposed the two trillion-dollar plan on the grounds that the bill stretched the traditional definition of infrastructure. In addition to expanding and repairing physical critical infrastructures, like roads and pipes, the bill includes initiatives for social programs designed to upgrade healthcare, childcare, and education infrastructures, especially in lower-income communities and communities of color.[1] Republican lawmakers continue to argue that social concerns, racial and economic inequalities, and caregiving systems are not part of the nation's critical infrastructure, and therefore should not be lumped into legislation designed to fund, as Shelley Moore Capito put it, "the regular definition of infrastructure."

Just what the "regular definition" of infrastructure is, though, is a matter of critical interpretation. Infrastructures *are* roads, bridges, waterways, and ports; but they are also

[1] "Fact Sheet: The American Jobs Plan," whitehouse.gov, last modified March 31, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/3/31/fact-sheet-the-american-jobs-plan/.

forms that circulate or constrain, that supply or cut off, that connect or separate. They are material and sociopolitical arrangements that link or divide us, that impose order on our world, and that can expose the inequalities embedded in the architectures of modernity. In this dissertation, I propose that one such way to lay bare the deep-seated ideologies and inequalities hardened into infrastructures, and why they are hidden or obstructed from a "traditional" definition, is to examine how the emergence of energy as a scientific concept in the mid-nineteenth century has restricted our ability to imagine the infrastructures of modernity as anything but extractive, productive, fuel distribution systems. Tracing energy back to its initial codification in thermodynamics reveals an interlinking of this new science with industrial capitalism and patterns of extractive imperial violence.

Energy is often the product that circulates in infrastructural space, and also the modality of infrastructural conveyance. Flow, field, transfer, conversion: these are all energy's terms. Infrastructure and energy are both protean, manifold, and performative. Indeed, Brian Larkin has described infrastructures as "things and also the relation between things,"[2] the kind of capacious ontology that energy shares. I argue that, because energy is a concept so capacious and abstract, we *must* give energy structure, linguistically and materially, because it otherwise exists without recourse to a stable signifier. And, crucially, we are tempted to fall in line with energy structures as they naturalize without considering their affordances or operations of governance. Our fossil

[2] Brian Larkin, "The Politics and Poetics of Infrastructure," *Annual Review of Anthropology* 42 (August 2013), 329.

fuel infrastructures, for example, are forms that have hardened a version of modernity licensed by a Victorian concept of energy.

Defining energy was a political and historically specific act, not purely the outcome of detached, scientific investigation. Energy had no formal place in physics until the late 1840s, prior to which it was a poetic and rhetorical term with a Greco-Roman heritage[3] we can trace back to Aristotle's *energeia*.[4] As Crosbie Smith has shown, a group of north British scientists[5] appropriated the term, *energy*, to unify a range of natural phenomena – including heat, light, and electromagnetism – while securing institutional authority for their mostly Scottish Presbyterian cohort. The process of codifying energy wedded the political and theological agendas of these scientists to an emerging concept of how fuel and labor should be managed. In its scientific usage, energy is defined as the ability to perform work.[6] But, during the early stages of theorizing energy in scientific terms, energy's pre-scientific, humanistic meanings layered into its embryonic technical definition.[7] Energy was defined as work, but the thermodynamics laws qualified work and exhaustion, productivity and dissipation, across moral and poetic registers. North

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[3] Aristotle's *energeia* is the foundation for the Latin word *energia*, the French word *énergie*, and the English word *energy*. The latter two originated in the sixteenth century and connect work to virtue and goodness. None of energy's pre-1840s definitions is scientific, but all bear traces of scientific energy's commitment to vigor, transformation, and movement. For more on the etymology of energy, see Cara New Daggett, *The Birth of Energy: Fossil Fuels, Thermodynamics, and the Politics of Work* (Durham and London: Duke University Press, 2019), 17-19.

[4] "energy, n.". OED Online. March 2021. Oxford University Press. https://www.oed.com/view/Entry/62088?redirectedFrom=energy (accessed May 14, 2021).

[5] As I discuss in later chapters, this group included William Thomson (known later in his life as Lord Kelvin), James Clerk Maxwell, Peter Guthrie Tait, and their colleagues.

[6] "energy, n.". OED Online.

[7] For more on energy's humanistic origin and its role in allegory, see Bruce Clarke, *Energy Forms: Allegory and Science in the Era of Classical Thermodynamics* (Ann Arbor: University of Michigan Press, 2001).

British scientists took charge of the new word. They infused energy with a Scottish Presbyterian desire to industrialize, economize, and direct the earth's fuel reserves.

Moreover, because the concept of energy unified units of work across organic and inorganic systems, the concept of labor was bound into standardizable metrics used to govern workers' bodies, the machines they operated, and the resources they processed.[8] It is precisely because energy is so capacious that its framers could claim energy as a universalizing, humanistic logic while simultaneously routing it through the exclusionary politics of imperialism, globalizing industry, and Presbyterian work ethic. Though our primary fuels have shifted over time, these values tied energy to globalizing capitalism and infrastructures that abet energy inequality and a fossil fuel-intensive landscape.

In the nineteenth century, energy reoriented physics because, unlike the Newtonian term, *force*,[9] it encompassed all the areas of research that deal in transformations and potentials. Conversion, transformation, and universality are qualities that make energy recognizable to us, but they also left energy too abstract to be useful without forms, structures, and a governing logic. Because energy, itself, cannot be seen directly, early thermodynamicists relied on figurative language to model it, or to guide energy into workable representations. Thermodynamics needed laws, and ways of visualizing the unseen modalities of transfers and potentials that energy promised. But garnering authority for a new scientific regime meant convincing an existing intellectual public to

[8] Anson Rabinbach argues that the science of energy brought machines and workers under a single set of natural laws. Fatigue was perceived as a quantifiable, measurable, and ultimately optimizable state shared by humans and industrial machines. Anson Rabinbach, *The Human Motor: Energy, Fatigue, and the Origins of Modernity* (Berkeley and Los Angeles: University of California Press, 1990).
[9] Barri Gold discusses Isaac Newton's preference for "force" over "energy," since the latter was perceived as a poetic term. Barri J. Gold, *ThermoPoetics: Energy in Victorian Literature and Science* (Cambridge: MIT Press, 2010), 4.

get behind a heterodox, non-Newtonian program. And, as Smith has convincingly shown, advancing one's intellectual property in a scientific marketplace of ideas often meant developing "an economic model of scientific activity" by cultivating one's symbolic capital.[10] Energy physics emerged with these barriers in mind.

Whereas scientific energy desired the centuries-long pedigree of Newtonian *force* (the term that energy was designed to supplant), the pre-scientific version of energy had already earned its legitimacy. It was not uncommon for nineteenth-century scientists to use poetry to shore up support for their burgeoning theories, so early thermodynamicists leveraged the authority of poetry to shift power away from *force* and towards *energy*. For example, Scottish physicist and mathematician James Clerk Maxwell parodied Shelley's *Prometheus Unbound* in a paper he delivered at the British Association for the Advancement of Science in 1876. He wrote his own poem about energy dethroning force and shedding its Newtonian limitations, as Shelley's Prometheus escapes Jupiter's captivity.[11] By choosing a poetic term, early energy physicists were able to rhetorically unify phenomena that were hard to grasp without linguistic modeling. Of course, one cannot look directly *at* heat or electromagnetism. Instead, their effects are observed or felt, and then often translated into language as well as mathematics. Additionally, by choosing a word with a Greco-Roman, then Latin, then Romantic lineage, a word whose etymology suggested movement and transformation, these scientists strengthened

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[10] Crosbie Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain* (Chicago: University of Chicago Press, 1998), 3.
[11] Clarke, *Energy Forms*, 19-20.

scientific energy with a timelessness and sense of universality that would remain crucial to the project.

Whether energy shows up in Romantic-era poetry, infrastructural planning, or classical energy physics, transformation remains key. Energy is about preference for movement, a principle which primed its application in governing fuel sources. We know that infrastructures move or transform energy so that it is available in certain locations when consumers need to access it. But energy is also a literary term, even after its shift towards thermodynamic language, because it is fundamentally about representing transformations. When we consider that energy physics required models, language, and other representational forms to coax energy out of its abstractions, it becomes clear how much the transformations of figurative language complement the transformations of energetic phenomena.

Figurative language often transforms one thing into another. So, too, does energy describe transfers and relationalities in states of being. Figurative language is fundamental to nineteenth-century physics because its objects are not dimensionally difficult to access, like tiny microbes or faraway planets, but rather conceptually abstract notions like Faraday's web-like, invisible electromagnetic field lines. The Victorians applied analogy and metaphor (*i.e.*, the language of transformation) to define and describe energetic phenomena (*i.e.*, the physics of transformation). They illustrated the laws of thermodynamics with allegory and thought experimentation. Maxwell's Demon, covered in chapter four, was a thought experiment popularized by North British physicists towards the end of the century. The demon was Maxwell's strategy for visualizing the statistical limitations of the second law, and William Thomson exploited the demon's figurative powers because he relied on the allegory to demonstrate his own Scottish Presbyterian interpretation of energy. In his study of allegorical forms in classical energy science, Bruce Clarke reminds us that "[f]igurative processes are called forth at the limits of comprehension, staging an uncertain confrontation between the actual and the possible, the virtual and the real."[12] In many cases, energy phenomena arrived somewhere between orthodox, legitimized science and the limits of comprehension. Figurative language was there, as Clarke describes, to "mediat[e] the gap."[13]

Language, therefore, served at least two important functions in structuring the concept of energy in the nineteenth century. First, language gave energy form and mediated the gap between unseen, sensory, ambient phenomena and measurable, supposedly standardizable natural law. Energy had accumulated centuries of rhetorical and poetic meaning before physicists appropriated it for the new science of thermodynamics, so energy already had a working lexicon: movement, transformation, conversion, work. Energy was also, before and after its scientific origin, moralistic. It gestured to the spirit of an individual, the locus at the human core that produced a "spontaneous overflow of feelings" that Wordsworth told us are recollected in tranquility, or that give us the Victorian discipline to govern those feelings, that overflow, and channel it into productive work. Energy was also a recognizable word, a fact that remained significant to the task of unseating "force" from Newtonian physics. Second,

[12] Clarke, *Energy Forms*, 99.
[13] Clarke, 99.

the language chosen to formulate the laws of energy physics aligned with the industrial, imperial, and theological agendas of their framers. As chapter two explores, Victorian energy scientists selected words like “dissipation,” specifically, to name the phenomena they studied because dissipation carried heavy moral and economic connotations. To the Scottish Presbyterians writing these laws, dissipation and decay were morally equivalent with waste and depravity.[14] The energy laws, therefore, linguistically linked scientific findings to a vision of the universe that seemed to resonate with the project of imperial expansion, efficient resource extraction at the expense of the earth and especially peripheral regions, and the growth of modern infrastructures built to enforce and further this vision.

Considering that energy is an overdetermined term whose meanings extend from the physical and scientific to the poetic and metaphysical, its technical definition, or “the ability to do work,” feels inadequate. And yet, as Cara Daggett has argued, the western concept of energy is all about work, or “the gospel of labor and its veneration of productivity.”[15] Indeed, the violence of fossil fuel capitalism is obscured by energy’s apparently universal laws about work production. As Daggett explains it, the ruling logic of energy science mandated that we *must* put the earth, its resources, and its humans to work for profit, or else we risk wasting the natural bounty that God intended industrially minded nations to enjoy.[16] As we will see in later chapters, Victorian science often

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[14] Smith, *The Science of Energy*, 124.
[15] Daggett, *The Birth of Energy*, 5.
[16] Daggett, 4.

exploited economic language to discuss the potential waste and decay of leaving energy resources in the ground.

Because this ruling logic undergirded technical designs for emerging industrial and imperial infrastructures, like mill technologies, steam engines, and undersea telegraphy, I propose that infrastructural design helped generate an enduring energy concept that now makes us question the degree to which critical infrastructures are matters of social and cultural concern. We ask, "What do care workers have to do with a bill about fixing pipes and bridges?", and "Why is partnering with Tribal Nations of concern as we repair our crumbling infrastructures?".[17] Or, at least some of our politicians ask us these questions and perpetuate these narratives. By limiting energy's critical infrastructures to a set of fuels and a system to circulate, distribute, and manage them, those of the "traditional definition" camp are performing the long-enduring, Victorian vision of energy as value one can extract and direct. The infrastructures of modernity, as forms that enforce a physical sense of order for the energy concept, have helped link energy and capital. They have also kept this vision of energy in place.

Yet, the American Jobs Act, too, carries its own traces of Victorian energy language. The epigraph at the beginning of this introduction evidences the deep impact that productive labor and economic growth have made on energy and its infrastructures. The Biden administration's infrastructure legislation describes a transition to clean energy as a "market-based shift" that will create jobs and expand the economy. On this count,

[17] The American Jobs Act promises to center Tribal Nations and rural communities in infrastructural overhaul, both to stimulate economic growth in these areas and to position the agricultural sector as a leader in America's shift to net-zero emissions. "Fact Sheet: The American Jobs Plan."

Daggett argues that fossil fuel capitalism has historically been so successful because its proponents augur poverty, social unrest, and economic downturn if we simply left carbon in the ground.[18] Those who seek a net-zero emissions energy shift must adjust their arguments to the dominant energy logic, the basic assumption that energy means critical, (mainly) fossil fuel infrastructures, jobs, and economic growth. It may not surprise us that goals for a clean energy transition are couched in the terms of Business as Usual, but there is an urgent need to interrogate why the infrastructures that govern our access to basic resources, that supposedly connect us to the ideals of accumulation, communication, and movement, emerged from a Victorian vision of energy.

The Victorians certainly did wed energy to labor, and labor to capital, but not all labor was valued equally. Because energy supposedly universalized units of work across all domains, organic and inorganic, the Victorians used energy science to standardize and industrialize labor. Energy's basic transposability was assumed as natural law and used to support and enforce western hierarchies of race, class, and gender. However, there are plenty of examples where humans and natures viewed as capital's "potential energy" forms refused energy's reductive categorization as either productive labor or waste. As chapter three details, the colonial plantation system's scaling, or ability to expand without a change in framing, did not map to the ecological particularities of the only Southeast Asian tree sap that had been standardized for telegraphic insulation material. The Victorian vision of energy made value judgements about what counted as productive labor, productive land, productive fuels, and productive humans. The infrastructures

[18] Daggett, *The Birth of Energy*, 187.

designed by Victorian scientists sedimented these assumptions, though it is clear through examples of resistance that other possibilities exist.

Exactly how we imagine energy depends on its cultural reception and circulation. The structure energy adopts is material and linguistic, a real thing and a figuration. Because defining scientific energy relied on figurative language, and because infrastructural forms and literary forms contributed to a vision of energy we now recognize, this project combines literary analysis of Victorian novels with political readings of energy physics to examine how fictions and language were integral components in producing energy's infrastructural and ideological forms. In other words, science, literature, and infrastructures co-structured an enduring energy concept through performative acts of definition, modeling, and representation. Joining recent projects in Victorian studies,[19] this dissertation is motivated by our current ecological crisis, and our own warped sense of the indestructibility and timelessness of energy as a concept. Victorian literature and culture are vital touchstones for investigating the political history of energy because the Victorians grappled with their own ecological and infrastructural shifts. The nineteenth century developed a unique imaginary of anthropogenic climate disruption, even though the coal-centered landscapes of London, Glasgow, and Manchester seem to us like a far cry from today's petro-modernity. The laws of thermodynamics, themselves, spell out conservation Londoners mapped to their waste recycling systems, as well as a mood of cosmic decay that scientists linked to the moral responsibility of fuel efficiency.

[19] For some examples, see Allen MacDuffie, *Victorian Literature, Energy, and the Ecological Imagination*; Jesse Oak Taylor, *The Sky of Our Manufacture*; Nathan K. Hensley and Philip Steer (ed.), *Ecological Form: System and Aesthetics in the Age of Empire*.

The Victorians did have a sense that they could change and were changing their planet. The material changes are evidenced most obviously by infrastructures that enforced fossil fuel capitalism, but they also appear in the energetic and ecological language of the Victorian literary archive. This project emphasizes the language that variously supported or resisted the burgeoning scientific concept of energy, from the mid-nineteenth century to the fin de siècle. I also argue, however, that Victorian novels and mainstream periodicals actively contributed to generating the western energy imaginary. When we examine the literature of this period, not all energy language aligns with the moral, theological, and cosmological registers of contemporaneous thermodynamics. Nevertheless, the scientific and literary texts share figurative language and an imaginative scaffolding that reinforced energy's core forms, such as flow, fields, influence, transformation, and circulation.

My argument draws from, and builds on, questions of form that Victorian studies scholars have tracked through the Victorian novel and coeval scientific discourses, including the formative projects of George Levine, Gillian Beer, and Sally Shuttleworth. More recent contributions have shifted the field's literary readings towards ecocriticism and energy science. Allen MacDuffie has argued that the form of the Victorian novel, itself, mimics the economy of an energy system. Novels such as *Our Mutual Friend* and *The Strange Case of Dr Jekyll and Mr Hyde* figuratively enact the conservation of the first law of thermodynamics, and the dissipation of the second law. He surmises that, though the Victorians understood that their actions registered on the scale of deep, ecological time, classical energy science never underscored the significance of human interference in the environment because the framers of thermodynamics amplified their own economic and theological goals.[20] MacDuffie proposes that Victorian literary texts function as "*alternative thermodynamic narratives*"[21] because their forms variously support and depart from the burgeoning western energy concept. Jesse Oak Taylor, too, has suggested that the Victorian novel serves as a model for manufactured climates, or that the climate of the novel models a nested energetic system resembling the porous ecologies and assemblages that comprise our own cities, atmospheres, and natures.[22] Taylor, MacDuffie, and other nineteenth-century literary scholars view the organization of the Victorian novel as a symbol of ecological structure, and of the Victorians' perception of distributed networks and forces, of cosmic time and gradual change, that emerging sciences revealed to them.

I have also drawn on historical studies of energy physics and Daggett's recent "genealogy of energy."[23] Daggett's argument insists that we can unhitch energy from its single-minded work definition by tracing energy back to the origins of thermodynamics and exposing the conditions that created a work-energy rationality. A post-work energy imagination is possible, Daggett reasons, but only if we unveil the historical reasons why work and energy are linked in the first place.[24] The foundation for a history of energy physics and its principal actors was created by Crosbie Smith and M. Norton Wise, whose biography of Lord Kelvin covers the work and aspirations of William Thomson

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[20] Allen MacDuffie, *Victorian Literature, Energy, and the Ecological Imagination* (Cambridge: Cambridge University Press, 2014), 13.
[21] MacDuffie, 15. Emphasis in original.
[22] Jesse Oak Taylor, *The Sky of Our Manufacture: The London Fog in British Fiction from Dickens to Woolf* (Charlottesville and London: University of Virginia Press, 2016), 27-33.
[23] Daggett, *The Birth of Energy*, 3.
[24] Daggett, 11.

and his colleagues. In his book, *The Science of Energy*, Smith focuses on the North British cohort of scientists whose guiding beliefs and commercial ambitions ushered in a new age of physics. This dissertation has benefited from such historical footing, and explores further links between literary texts and developing scientific and infrastructural patterns. As we will see throughout this study, infrastructure is an ideal intersection between the cultural production of energy in the Victorian period and the politics of energy's material distribution. The way that we interpret infrastructures, or the way that we envision how they should operate and what they should look like, has much to do with how we imagine energy. If we have not imagined energy as anything but an economic stimulant, a set of fuels to be harvested and monetized, and a universal unit of labor, then it is difficult to imagine infrastructures that create space between energy and capital accumulation.

"Structuring Energy" begins by connecting the pre-thermodynamic water infrastructures of the early nineteenth century to the logic of flow "ownership" in riparian doctrine and heat theory. The first chapter studies the isomorphisms between water and energy flow, and proposes that early thermodynamicists used water as a model for resource flow and ownership. Scottish scientists William and James Thomson combined energy's pre-scientific connotations as a personal quality with energy's nascent scientific definition. They observed water flows in mill and canal machinery, and then moralized the objective of maximizing work production by preventing water spills or run-off. Chapter one argues that the physical characteristics that make water unstable as individuated property also resemble energy's transformative qualities. The feeling of flow also echoed in self-help literatures that encouraged individuals to tame their overflow of passions into productive outlets, or productive work. George Eliot's *The Mill on the Floss*, however, adopts a counter aesthetics of feeling and water management. Eliot links energy and water in figurative combinations that gesture to those of energy scientists; yet she ultimately underscores the artifice of flow ownership in large, distributed systems of natural violence.

The second chapter traces a connection between thermodynamic language and Charles Dickens's representation of the mid-nineteenth century dust economy. This "dust," which was mostly coal ash from domestic hearths, features prominently in *Our Mutual Friend*. Contributors to popular Victorian middle-class periodicals used imagery from Dickens's novel as a common grammar to connect readers with journalistic reports of dust yards; yet, by doing so, their accounts are riddled with the politics of what I call "the efficiency narrative," or the misguided belief that recirculating energies or materials will result in less accumulation and overall energy expenditure. Because recent studies of waste recycling in the twenty-first century have identified the nineteenth-century dust yard as an exemplary model of efficiency, I argue that it is necessary to return to the dust economy as a way of unsettling the stories about waste and recycling infrastructures that we continue to perpetuate.

The third chapter follows by studying the history of electromagnetic field theory and telegraphic infrastructures. I explore a link between the natural Southeast Asian latex used nearly exclusively as an insulation for nineteenth-century British telegraph cables, and the development of field theory. Field theory demonstrated that the energy in telegraph cables is located around, rather than within, the conducting wire. I use this information to argue that telegraphic infrastructure is not simply the cables and signaling systems developed by the British, but also the knowledge, resources, and cultures of Southeast Asian Indigenous communities, including lifeways that resisted the western energy project. Britain's global telegraphy enterprise relied on enormous quantities of gutta percha, the tree sap procured only by Indigenous collectors and that refused settler colonial agricultural practices, like the plantation model. I read two late-nineteenth century novels, *Dracula* and *The Beetle*, and argue that these texts are representative of a culturally perceived threat to the British empire and its vision of energy. The counter-colonial invaders in these novels dismantle British colonial authority by turning settler capitalism against the metropole and mobilizing the distributed supply chains on which empire depended. Britain's invaders in both novels also possess characteristics that resemble the ambient, uncategorizable energy of field theory.

My final chapter concerns the attempt of North British scientists to structure energy from the ground up by introducing a universalizing theory for the structure of ether and matter, and by controlling the narrative of entropy as cosmic heat death. Although the North British group of energy physicists generally dominated the science of energy in the nineteenth century, their theological interpretation that the second law of thermodynamics augured inevitable cosmic heat death encountered resistance from other intellectual schools. In part to secure their worldview within a universal energy narrative, the North Britishers dispatched a series of rhetorical and speculative strategies that would index energy in its most basic, elemental forms to their own ideologies. These included the vortex theory of ether and matter, and Maxwell's demon. When William Thomson popularized Maxwell's demon, he intended the thought experiment to cast doubt on the conservative forces and deterministic reversibility claims that his adversaries adopted to the entropy law. This chapter reads Edward Bulwer-Lytton's *The Coming Race* as a satire of demon-like negative entropy and a world of limitless energy. The North British scientists would not have wanted a boundless, inexhaustible energy source because, they argued, energy followed a teleology of dissipation. It was placed by God in reserves for successful nations to use mindfully. In other words, they linked the entropy law to the Presbyterian work ethic and industrial logic that has since impacted our mindset about energy distribution and management.

Finally, the dissertation concludes with a coda that extends some of the key arguments of this project, and that explores how understanding the Victorian vision of energy can help us interrogate our own, twenty-first century infrastructures. As we deal with climate change and an urgent need for infrastructural transformations that will lead us into a more energy-secure and equitable future, our mindset will require adjusting what energy means to us.

Chapter 1:

Owning the Flow: Waterpower, Heat Engines, and *The Mill on the Floss*

In an undated notebook entry titled "'A Fine Excess.' Feeling Is Energy," George Eliot meditates on what she calls "the efficacy of feeling in stimulating to ardent co-operation,"[25] arguing that calculated, outcome-driven efforts are neither sustainable nor resonant within the social body. To build her argument, Eliot centers water in figurative language that evokes both forceful overabundance and narrow management. "'A Fine Excess'" concludes:

> No doubt the passionate inspiration which prompts and sustains a course of self-sacrificing labor in the light of soberly estimated results gathers the highest title to our veneration, and makes the supreme heroism. But the generous leap of impulse is needed too, to swell the flood of sympathy in us beholders, that we may not fall completely under the mastery of calculation, which in turn may fail of ends for want of energy got from ardor. We have need to keep the sluices open for possible influxes of the rarer sort.[26]

This passage binds what Michael Tondre calls Eliot's "general economy of feeling"[27] to the imagery of natural disaster and infrastructural management: the uncontrollable excess of flooding as well as human-built channels for harnessing waterpower. The surge and flow of water, the struggle for its control, and the productive work of channeling it bespeak Victorian values of emotional regulation and calculated effort. But for Eliot, overindulging the passions of futile feeling is not merely wasted effort. Instead, such acts

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[25] George Eliot, "'A Fine Excess.' Feeling Is Energy," in *Essays and Leaves from a Note-Book* (New York: Harper & Brothers, 1884), 294.
[26] Eliot, 295.
[27] Michael Tondre, "George Eliot's 'Fine Excess': *Middlemarch*, Energy, and the Afterlife of Feeling," *Nineteenth-Century Literature*, 67, no. 2 (September 2012): 204-233. http://jstor.org/stable/10.1525/ncl.2012.67.2.204.

of feeling register beyond the threshold of calculable outcomes. “I really believe and mean this,” Eliot insists, “- not as a rule of general action, but as a possible grand insistence of determining energy in human sympathy, which even in particular cases, where it has only a magnificent futility, is more adorable, or as we say divine, than unpitying force, or than a prudent calculation of results.”[28] Thus, futile emotions do not dissipate into obscurity simply because their results are not measurable; but they leave finer, ghostlier traces on the landscape of society.

While Tondre points out that “’A Fine Excess’” complements the argument of historical loss and gain at the end of *Middlemarch*, I want to focus on Eliot’s earlier work, and to her attraction to water as she reveals the value of excess, waste, violent overflow, and pleasure. This chapter examines the water management infrastructures that preceded and assisted industrial steam power, and that inspired models of early thermodynamic systems. Early energy scientists aligned waterpower and its infrastructures with the Victorian values of channeling excess, eliminating waste, and working productively. As the science of energy burgeoned, Scottish scientists combined pre-thermodynamics notions of energy as a personal characteristic with its developing definition as the capacity to produce mechanical effect. They observed water flows in mill and canal machinery, and attached a moral imperative to extract the maximum work from the flow by preventing it from spilling or dissipating. By possessing a flow, they reasoned, one could channel energy to produce work and contribute in aggregate to the growth of the nation. This chapter argues that energy science emerged under the

[28] George Eliot, “’A Fine Excess.’ Feeling Is Energy,” 295.

influence of water power as a model for the flow and government of resources. Moreover, the physical characteristics that make water inherently unsuitable for individual ownership also resemble energy's transformative qualities. Therefore, water's energy-like characteristics predicated the possibilities for a science of energy.

Because energy also resonated in cultural discourse as a personal quality of intensity, vigor, or feeling, the logic of flow productivity mapped to a Victorian ethics of governing the self and channeling one's feelings into productive outlets. By the mid-nineteenth century, the concept of "owning" a flow by maximizing work output also circulated in the literatures of self-help culture, which reinforced the idea that the individual was a machine whose energies threatened wild self-destruction if not channeled into productive work. Although self-help texts adopted the figurative language of steam technology, industrial water flow underpins the energy analogies in texts like Samuel Smiles's *Self-Help* (1859) because early thermodynamicists relied on isomorphisms between water and energy to formulate their theories of how to improve thermodynamic productivity. Smiles reasons that the flow of will, specifically, can be owned and directed by the individual, and should be governed into productive work lest it dissipate into self-destructive outlets.[29] Water, like steam power and Smiles's interpretation of willpower, might overwhelm an apparatus if it is not monitored and economized. And, like emotional excesses, water threatens to overwhelm and destroy if it is not channeled into productive work.

[29] Samuel Smiles, *Self-Help; with Illustrations of Character, Conduct, and Perseverance* (1859; London: John Murray, 1868), 224-228.

Eliot, however, resists such straightforward associations. She builds similar analogies between water structures and early energy theory, but she centers her model on the aesthetics of excess rather than the virtues of economy. Floods leave their own fine traces on Eliot's notion of the social body, and within the energies that circulate for generations. Eliot's research on waterpower peaked in the late 1850s when she was writing *The Mill on the Floss*. During this period, she and George Henry Lewes visited the Rivers Wey and Trent, where Lewes chronicled Eliot's archival work and intensive study of hydraulics and energy conversion.[30] She studied accounts of floods archived in the British Museum,[31] and referenced Thomas Lauder's *Account of the Great Floods of August 1829 in the Province of Moray*, which details the destruction of waterpower infrastructures in Scotland.[32] By the 1850s, thermodynamics had emerged as the new science of heat and energy conversion. *The Mill on the Floss* blurs pre- and post-thermodynamics temporalities: it was published after thermodynamics emerged, but it is set in the 1820s, before formal energy science and during the era of industrial waterpower. Eliot therefore looks back on an era when the structures of waterpower and flow ownership primed the convergence of thermodynamic energies and their self-help analogs in the ethics of productivity and self-denial.

This chapter uses the dual temporalities of *The Mill on the Floss* to challenge the familiar, contemporaneous Victorian associations of motive power, masculine self-government, and steam productivity. Eliot's novel centers the fictional Rivers Floss and

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[30] Tamara Ketabgian, *The Lives of Machines: The Industrial Imaginary in Victorian Literature and Culture* (Ann Arbor: University of Michigan Press, 2011), 120-121.
[31] Gordon S. Haight, ed., *Selections from George Eliot's Letters* (New Haven and London: Yale University Press, 1985), 221.
[32] Ketabgian, *The Lives of Machines*, 120.

Ripple; and the narrative chronicles their periodic flooding, conflict over control and ownership of waterpower, and the productive use of waterpower in riparian mills. Eliot's figurative and literal uses of flow in this novel converge on questions of ownership and control: controlling the flow of energy in water alongside that in feeling. Because *The Mill on the Floss* was published after the emergence of thermodynamics and during the height of Victorian self-help culture, the novel works with the same figurative language scientists used to establish an ethics of productivity, and that self-help authors used to structure personal patterns of routinization that mimicked thermodynamic machinery. However, Eliot applies water and energy forms to a different ethics from that of early energy scientists, who deliberately aligned the science of thermodynamics with the industrial and affective registers of water.

In particular, brothers James and William Thomson spent the 1840s studying the symmetry of heat engine cycles and the function of waterwheels. James was an engineer with practical training in the Glasgow shipbuilding industry. William, known later in life as Lord Kelvin, was heavily influenced by his brother's work on steam engines and their inconvenient consumption of power, or power that could not perform productive work. Such industrial questions infiltrated William Thomson's contribution to the initial framing of thermodynamics, a narrative we will visit in chapter two. In the early 1840s, however, James was fixated on the isomorphisms between power loss in water structures and heat engines, and he involved his brother in theoretical questions of economy and waste.

The Thomson brothers were concerned with the power "consumed" by heat engines. In an engine, heat moves from a high temperature to a lower temperature, and the engine performs useful work in the process. However, running an engine always results in some waste, or some heat that can never become motive power. James Thomson was fascinated by waterpower's analogous problem: in structures like mills, canal locks, and sluices, the water's flow loses its momentum. But James could not square water's "wasted" power with that of engines because there was no friction or electrical resistance involved, no alteration of a material substance into heat.[33]

To resolve this question, the Thomsons relied on a rare text published by French engineer and military scientist Sadi Carnot. Carnot's 1824 *Reflexions on the Motive Power of Fire* constructed an analogy between water wheels and heat engines. According to his argument, frictional and conductional power losses were exactly analogous to the work "wasted" when water falls through a height without harnessing waterpower with a wheel.[34] Carnot had died of cholera in 1832 and would have disappeared into obscurity were it not for another French scientist, Émile Clapeyron, who published an interpretation of Carnot's work in his 1834 "Memoir on the Motive Power of Heat." It was from *this* text that the Thomson brothers drew most of their inspiration, until William finally acquired and reviewed the original Carnot text in 1849.[35]

Carnot's *Reflexions* was as much a political economy treatise as it was a scientific text. Because France lacked Britain's access to fruitful coal mines, Carnot recognized that

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[33] Crosbie Smith and M. Norton Wise, *Energy and Empire: A Biographical Study of Lord Kelvin* (Cambridge: Cambridge University Press, 1989), 286.
[34] Smith and Wise, 295-96.
[35] Smith, *The Science of Energy*, 52.

the French required superior steam engines to compete with Britain. Acknowledging access to natural resources as the seat of Britain's prosperity, Carnot opened his *Reflexions* by arguing that France, too, needed steam ships and superior commercial circulation. "To take away today from England her steam-engines would be to take away at the same time her coal and iron," he explained. "It would be to dry up all her sources of wealth, to ruin all on which her prosperity depends, in short, to annihilate that colossal power."[36] Carnot's motivations for perfecting steam engines therefore aligned with the Thomsons' preoccupation with productive labor and furthering the wealth of their nation.

This chapter studies Carnot's theoretical engine cycle, which sets up a relation between the quantity of water cycled during its fall through a height differential and the quantity of heat cycled in an engine as the heat "falls" from a higher temperature to a lower one. I examine how James and William Thomson applied Carnot's results to their own Presbyterian virtues of self-government and productivity, virtues that seeded William Thomson's future work on thermodynamics. Finally, this chapter studies *The Mill on the Floss*'s resistance to the narrow and occasionally dangerous coupling of thermodynamics and self-help. By applying similar energy and water analogies to those of the Thomsons, Eliot shows how water infrastructures are connected to larger, more distributed systems whose forces cannot be governed into mere productive work in the service of Britain, or even of humans.

By the time that Eliot had written "'A Fine Excess,'" she had also developed her economy of feeling into a web of interconnecting individual actors and collective social

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[36] Sadi Carnot, *Reflexions on the Motive Power of Fire and on Machines Fitted to Develop that Power*, trans. R.H. Thurston (1824; New York: Dover Publications, 1960), 4.

structures. As Tondre argues, Eliot shows us how "the value of excess feeling lies in its power to extend beyond the boundaries of the immediate self," unfettered by pragmatism and economized emotional effort.[37] *The Mill on the Floss* also ventures into this territory, though it was written before her note-book entries. *The Mill* charts a landscape of water infrastructures and energy transfers different from those of contemporaneous steam power and self-help novels like Dinah Mulock Craik's 1856 *John Halifax, Gentleman*. We know that Eliot studied physics and researched waterpower. She was an avid reader of Mary Somerville's work, and she even hosted the esteemed physicist John Tyndall at her home.[38] Moreover, her first article for the *Westminster Review* argued that human behaviors are controlled by "undeviating laws," much like those of physics, and which structure the development of individuals as part of larger systems.[39] Therefore, we can interpret *The Mill on the Floss* as staging its own argument alongside other models of water infrastructures in the language and literatures of energy, a science focused on transformation and interconnectedness.

I have broken this chapter into two core sections. The first section covers the history and technicalities of nineteenth-century British water management; and the second section analyzes Eliot's engagement with water infrastructures and the economy of feeling in *The Mill on the Floss*. I gloss the challenges of organizing a doctrine of water rights in the nineteenth century, and of adjusting the law to suit technological

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37 Tondre, "George Eliot's," 210.
38 Selma B. Brody, "Physics in *Middlemarch*: Gas Molecules and Ethereal Atoms," *Modern Philology*, 85, no. 1 (August 1987): 44. http://jstor.org/stable/437748. Tyndall and the mathematician William Clifford were regular houseguests at Eliot's and Lewes's home, though it should be noted that their visits began in the 1860s, when Eliot was writing *Felix Holt*. *The Mill on the Floss* was published in 1860.
39 A.S. Byatt, introduction to *The Mill on the Floss*, by George Eliot (1860; London: Penguin Classics, 2003), xxiv.

changes as the century progressed. The Thomsons' concern with power loss is at the heart of these questions of how to govern, or how to "own," water flow.

In a later, fossil-fuel-dominated economy, even when water is no longer a primary energy source, the questions of flow management and ownership remain. Revisiting the history of pairing hydraulic structures with early energy physics is crucial, therefore, because energy and water are both spatially unsuited as property yet figure in legal and technological property conflict. In Eliot's novel, riparian law drives the plot forward, but it is ultimately the conflict of scales that threatens water ownership. Tulliver is rash and litigious, but he loses his mill because 1829 riparian law has no precedent for irrigation cases. This business of litigation and water ownership turns out to matter little in the end. After all, the mill is *destroyed* because a catastrophic flood washes it away. Even Tom Tulliver, who masters his own feelings and channels his personal energies into repossessing his father's mill, is overpowered by the wild, destructive energies of natural disaster. In *The Mill on the Floss*, Eliot shows us the differences between the responsibility of energy management, and the artifice of energy ownership in a system of natural violence.

Controlling River Flow: Riparian Doctrine and Waterpower Infrastructures

Water's physical characteristics challenge traditional questions of property ownership and commercial use of natural resources. Waterpower is viable because water exists in a constant state of flux: a river must flow to turn wheels and other machinery. However, that flow also creates conflict of two varieties. First, riparian landowners and industries must compete for space along a river. Once situated, each property owner's water management strategies have consequences for those sharing access to the river's flow. Riparian doctrine, or the law of water rights, shifted and developed rapidly in the period between 1785 and 1825, when England experienced an uptick in industrial water structures.[40] Mill technologies required access to waterpower, so it is unsurprising that competition for geographic location and legal battles for river control were interlinked during this period. Second, technological improvements to water wheels and other river machinery turned the crude watercourse infrastructures of earlier periods into a science. As Joshua Getzler explains it, "between 1750 and 1850 there were vast investments in river-widening, wells, weirds, dams, sluices, bridges, leets, and mill-races, allowing engineers to bring a steady and controlled water-stream to mills and mines miles away from water sources."[41] Riparian doctrine and the technological improvement of water infrastructures are intersecting strategies because they each deal with questions of managing flow to extract the most useful work possible.

In this section, I examine the scientific and legal approaches to controlling water flow, a natural resource that is not stable and cannot be "owned" in a straightforward sense. James and William Thomson were fascinated by the energy transfers of water infrastructures, and they drew inspiration from Sadi Carnot's analogy between heat engines and water falling through a wheel. Carnot's analogy is important, first, because William Thomson applied Carnot's theory to his contribution to the foundation of

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[40] T.E. Lauer, "Common Law Background of the Riparian Doctrine," *Missouri Law Review,* 28, no. 1 (1963): 80. https://scholarship.law.missouri.edu/mlr/vol28/iss1/7.
[41] Joshua Getzler, *A History of Water Rights at Common Law* (Oxford: Oxford University Press, 2004), 36.

thermodynamics; but it is also important because Carnot's commitment to France's global dominance resonated with the Thomsons' British nationalistic values. William Thomson updated and extended Carnot's argument for a mid-nineteenth-century British audience whose chief industrial concerns combined the challenges of waterpower with the promises of steam.

Carnot's original text does not address riparian law, nor does it suggest steam as a possible solution for water rights conflicts. However, William Thomson's 1849 assessment of Carnot was motivated by Thomson's personal desire to eliminate power loss in water machinery and its steam components. I argue here, therefore, that early-to-mid-nineteenth century riparian doctrine buttresses technological questions of water infrastructure productivity. Steam power did not replace waterpower so much as complement it: by the end of the 1850s waterpower declined only fourteen percent in Britain due to steam substitutions.[42] Therefore, we can consider Britain's waning watercourse access points and the questions of flow "ownership" implicated in an energy crisis that drove up the value of riparian rights.

The Thomsons' work draws out these connections. By using Carnot's theory to trace a common thread through water and heat cycling, the Thomson brothers suggested that water and heat were Nature's great energy stores awaiting man's responsible innovation. Channeling excess and economizing flow to the advantage of industry would minimize waste, serve the nation and its growing consumerist requirements, and resolve the difficulties of riparian law. In his work on water infrastructures and heat theory,

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[42] Getzler, *A History of Water Rights,* 25.

William Thomson set up binaries like “economy” and “dissipation.” In the later 1840s and 1850s, such concepts framed his theory of thermodynamics. Moreover, I want to suggest in this section that water’s physical characteristics, *i.e.*, flow, constant change, and the inevitable extension of effects beyond any individual “owner” or “right-holder,” resemble energy’s transformational qualities. These similarities, and their commercial affordances in industry and riparian rights, modeled what was possible, or desirable, for a science of energy physics.

British riparian doctrine, or the law of water rights, was notoriously unstable during periods of industrial change and population growth. Prior to the industrial revolution, upstream mill sites had long been occupied.[43] However, the late eighteenth and early nineteenth centuries saw a massive demand for running water to power mechanical equipment. The history of British water law, therefore, reveals a mutual development of riparian doctrine and water infrastructures. As the courts adjusted to growing competition for water access, riparian law remained volatile, or in a state of consistent and fundamental development that attorney T.E. Lauer has described as “embryonic.”[44] Undoubtedly this is because water conflict differs from that of other natural resources. To possess a “flow” is, itself, an unstable circumstance.

Early nineteenth-century industrial and commercial development required British courts to reexamine the parameters of flow ownership and right to water flow. Consequently, technological changes to watercourses and riparian rights were mutually

[43] Carol M. Rose, “Energy and Efficiency in the Realignment of Common-Law Water Rights,” *Journal of Legal Studies*, 10, no. 2 (1990): 268. https://www.jstor.org/stable/724422.
[44] Lauer, “Common Law Background,” 63.

influential forces. On the one hand, nineteenth-century mills placed a greater demand on watercourses than did their eighteenth-century counterparts. By altering a stream's flow, new machinery dampened the power available for other riparian right-holders. Water conflict in the courts now dealt mostly in right-to-use, as opposed to strict protection of ownership.[45] On the other hand, legal changes also motivated technological improvements. By granting water rights to more individuals, the courts provoked intense competition to capture water flow more productively.

By 1800, all potential mill sites in England were occupied.[46] Because additional watercourse access points no longer existed, mill owners retrofitted their machinery with "micro-inventions that continuously refined the ancient macro-invention of the water wheel."[47] Such micro-inventions included turbines and other sophisticated designs that focused straying water into single channels. Eventually mills added steam power as another mechanical assist. Steam was intended to complement, rather than replace, waterpower. The result was that scientists and engineers applied the problems of waterpower to the design objectives of steam engines.

James Thomson was one such engineer. Thomson devoted his career to Glasgow's industrial problems, and all his inventions concerned economy of operation.[48] Because the Clyde Valley was the seat of Britain's iron shipbuilding industry, Thomson spent his youth observing ships' paddle wheels and other combinations of steam and water power. In particular, he was vexed by structures that seemed to "waste" water's

[45] Anthony Scott and Georgina Coustalin, "The Evolution of Water Rights," *Natural Resources Journal,* 35, no. 4 (1995): 851-52.
[46] Getzler, *A History of Water Rights*, 40.
[47] Getzler, 37.
[48] Smith, *The Science of Energy*, 32.

power by letting it dissipate into eddies, or by otherwise failing to channel and harness it for work production. It seemed to him that surges of waterpower were wasted in filling canal locks when they could have been channeled into turning a wheel, thereby performing useful work. Water might as well do something useful in its travels downstream. According to James's Scottish Presbyterian values, allowing the flow to dissipate into rivulets and eddies was a waste of the great power reservoirs that God bestowed upon mankind.[49]

James found the "consumption" of waterpower even more vexing. Later in life, he recalled this fascination with waterpower consumption in a letter to his brother William: "Even you and I at Walsall (in 1842 I think) when watching the consumption of power in the flow of water into a canal lock were speculating on what became of the power as we could not suppose the water *worn* and therefore altered like as solids might be supposed to be when power is consumed in their friction."[50] In the late 1840s, this question evolved into a disagreement between William Thomson and James Joule that ended in the formal framing of thermodynamics. Thomson contributed his two laws of thermodynamics after he satisfied his own observations of power consumption with Joule's argument that work and heat are interconvertible. While I will cover this debate in detail in chapter two, it is important to understand here that the Thomson-Joule controversy was resolved when William Thomson reconciled Joule's theory of heat-work equivalency with Sadi Carnot's theory of what Thomson called "perfect" heat cycles, or cycles without waste.

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[49] For more on the Scottish Presbyterian concern with directing the irreversible transformations of energy stores bestowed upon mankind by God, see chapter four of this dissertation.
[50] In Smith, *The Science of Energy*, 39. Quoted from James to William Thomson 1863, T119, Kelvin Collection, ULG.

Sadi Carnot's work, therefore, influenced William Thomson's fundamental understanding of how heat falls through temperature extremes in an engine to produce motive power, and why some degree of power is always consumed by that fall. James Thomson's work as an iron shipbuilding and marine engineer introduced William to Carnot's theory. In August 1844, James wrote a letter to his brother that discussed the "mechanical effect," or work, lost during the passage of heat from a hotter temperature to a cooler one.[51] James had finally located a theory that combined the notion that work is lost during heat cycling with the Thomsons' questions about waterpower loss. The problem was that no one could find a copy of Carnot's original text.

In this letter, James referred to Émile Clapeyron's 1834 *Memoir on the Motive Power of Heat*, a text which recast Carnot's *Reflexions on the Motive Power of Fire and on Machines Fitted to Develop that Power* into graphical and mathematical notation. Carnot's original text is well-reasoned, but it also relies on verbal arguments. In fact, Clapeyron concedes that Carnot "arrives by a chain of difficult and elusive arguments" which, he proposes, might be more convincing when cast into mathematical form.[52] Carnot's is a short but dense treatise that Clapeyron propelled into the general scientific community by supplying its missing mathematical analysis. And, had Clapeyron not taken on Carnot's work, *Reflexions* might have remained an obscure book, lost after its author's early death.[53]

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[51] Smith and Wise, *Energy and Empire*, 289.
[52] Émile Clapeyron, *Memoir on the Motive Power of Heat*, trans. R.H. Thurston (1843; New York: Dover Publications, 1960), 74.
[53] I take up the question of "translating" scientific treatises into the language of mathematical notation in chapter three. There, I discuss how Michael Faraday's electromagnetic field theory was not only recast into mathematical form, but also altered from its original theoretical foundation. Because Sadi Carnot was an

As a mining engineer, Clapeyron was familiar with graphical approaches and knew it would be helpful to formulate a graphical representation of Carnot's original heat cycle. Although scientists had already forgotten or dismissed Carnot's original insights, Clapeyron argued that Carnot's theory seemed unimpeachable: "both fertile and beyond question."[54] He was therefore committed to convincing the scientific community to reexamine Carnot. By graphically plotting the changes in pressure and volume as an engine's working fluid completes a single heat cycle, Clapeyron demonstrated that "there is a loss of force whenever there is a direct communication of heat between two bodies at different temperatures,"[55] a result that gestured to the Thomsons' question about the mysterious loss of mechanical power. Until William formulated his law of dissipation in the 1850s,[56] Carnot's explanation for power loss remained the most fruitful response to this gnawing question.

For the time being, though, James Thomson was pleased to have acquired Clapeyron's insight. The key to Carnot's theory was an analogy between the "fall" of heat from a high temperature to a lower temperature, and the literal fall of water through a height differential. James explained to his brother:

> The whole subject you will see bears a remarkable resemblance to the action of a fall of water. Thus we get mec[hanical] eff[ect] when we can let water fall from one level to another or when we can let heat fall from one degree of intensity to another. In each case a definite quantity is given out but we may get more or less

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elite French military scientist and engineer, the same questions of class and privilege do not apply. Moreover, Carnot's work remained obscure for a time after his death because most of his belongings were burned to eradicate any traces of illness and contagion.

[54] Clapeyron, *Memoir on the Motive Power of Heat*, 74.

[55] Clapeyron, 75.

[56] William Thomson's law of dissipation of energy, later known as the law of entropy, was introduced in "On the Dynamical Theory of Heat," published between 1851 and 1855. I cover the history and politics of this theory in chapters two and four.

> according to the nature of the machines we use to receive it. Thus a water mill wastes part by letting water spill from the buckets before it has arrived at the lowest level and a steam engine wastes part by throwing out the water before it has come to be of the same temperature as the sea. Then again, in a water wheel, much depends on our not allowing the water to fall through the air before it commences acting on the wheel… If we had a water wheel sufficiently high to receive the water of a stream almost at its source we would waste all the tributary streams which run in at a lower level.[57]

In Carnot's analogy, an engine produces work because heat falls in intensity. Through this fall, the machine harnesses some amount of power, though another fraction is unavoidably lost. The engineer's objective, then, is to maximize the heat captured by that fall in intensity from a high temperature to a low one. Per Carnot, waterpower is exactly analogous: an ideal water mill minimizes spillage, and it does not waste any tributary water sources that might contribute to flow velocity.

Clapeyron's analysis of Carnot's work was useful, but James preferred to examine the original text. He therefore tasked his brother with finding Carnot's *Reflexions* during William's 1847 visit to Paris.[58] Still, William had no luck until 1849, when he finally located Carnot's original text and published an appraisal in *The Proceedings of the Royal Society of Edinburgh*.

In "An Account of Carnot's Theory of the Motive Power of Heat," Thomson not only assesses the efficacy of Carnot's work, but also stitches together the significance of a theory of heat. Although Carnot and Thomson both believed in economizing heat engines to extend useful work production, I argue that Thomson's interpretation of Carnot's "ideal," yet physically impossible, heat engine attaches the operation of water

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[57] In Smith and Wise, *Energy and Empire*, 290. Quoted from James to William Thomson, 4th August 1844, T402, ULC.

[58] Smith, *The Science of Energy*, 44.

infrastructures in Carnot's original analogy to standards of moral and functional perfection. Functional perfection acquired a specific, technical definition;[59] but the moral connotations of approaching that perfection picked up the Victorian virtues of self-government, self-denial, and productive labor.

While Thomson's ideal engine emphasized managing heat flow with as little waste as possible, Carnot's original theory underscored re-establishing a natural balance of *caloric*, or what was believed to be imponderable heat matter,[60] after allowing heat to "fall" down a temperature gradient. Like falling water,

> the motive power of heat depends also on the quantity of caloric used, and on what may be termed, or what in fact we will call, the *height of its* fall, that is to say, the difference of temperature of the bodies between which the exchange of caloric is made. In the waterfall the motive power is exactly proportional to the difference of level between the higher and lower reservoirs. In the fall of caloric the motive power undoubtedly increases with the difference of temperature between the warm and cold bodies; but we do not know whether it is proportional to this difference.[61]

Reflexions thus explored what occasioned engines to produce work in the first place. Carnot posited that work results when caloric fluid is transferred from a heat source to a heat sink, or when it "falls" through a temperature differential. He determined that what makes heat engines run is a "re-establishment of equilibrium," or the cycle of moving heat from a hot temperature to a cold temperature, and then back again. In Carnot's

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[59] Thomson defines the ideal engine as such that "whatever amount of mechanical effect it can derive from a certain thermal agency; if an equal amount be spent in working it backwards, an equal reverse thermal effect will be produced." William Thomson, "An Account of Carnot's Theory of the Motive Power of Heat;* with Numerical Results deduced from Regnault's Experiments on Steam," *Earth and Environmental Science Transactions of the Royal Society of Edinburgh,* 16, no. 5 (1849): 545. https://doi.org/10.1017/S0080456800022481.
[60] In the eighteenth and early nineteenth centuries, the caloric theory of heat held that heat was a subtle fluid called "caloric." Carnot refers to this theory in *Reflexions*.
[61] Carnot, *Reflexions on the Motive Power of Fire*, 15.

words, “the production of heat alone is not sufficient to give birth to the impelling power: it is necessary that there should also be cold; without it, the heat would be useless.”[62] According to this principle, the difference in temperature between the heat source and heat sink propels the caloric fluid, chemically bound to the steam, down a gradient. Like water falling through a wheel, the engine exploits that momentum to move its piston.

When Thomson evaluated Carnot’s theory, he did not merely echo Carnot’s argument that an engine re-balances caloric fluid. Instead, he concluded that the usefulness of the theory lies in our calculating just how much work we can extract from “the *letting down*” of heat from a high temperature to a low temperature.[63] For this, Thomson applied Clapeyron’s graphical method, which plots the pressure of the engine cycle as a function of its volume, and calculates work by approximating the area underneath the resulting curve. Thomson’s synthesis of Carnot and Clapeyron amplified *Reflexions* on a Scottish, and later an international, stage. But like Clapeyron, Thomson adjusted Carnot’s principles to highlight the importance of quantifying the work we can extract from what he calls an “ideal” engine.

In *Reflexions*, Carnot does not explicitly define what he considers a “perfect” or “ideal” engine. Instead, he describes the conditions which would render heat engines superior to existing models. For example, he notes that “*superiority lies essentially in the power of utilizing a greater fall of caloric*”,[64] or that superior steam engines should harness the power that results from a large temperature difference. He also suggests that

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[62] Carnot, *Reflexions on the Motive Power of Fire*, 7.
[63] Thomson, “An Account of Carnot’s Theory,” 547.
[64] Carnot, 50.

"a good steam-engine… should not only employ steam under heavy pressure, but *under successive and very variable pressures, differing greatly from one another, and progressively decreasing.*"[65] Carnot makes these suggestions, but he does not outline the essential heat engine as a Platonic ideal against which manmade machines are pale imitations.

Thomson, by contrast, carves out what he calls "a *perfect* thermo-dynamic engine."[66] Crosbie Smith points out that in Thomson's "Account of Carnot's Theory" he uses the term "thermo-dynamic" for the first time.[67] In fact, Thomson introduces this term by using Carnot to define his own parameters of heat flow management. He begins by acknowledging that heat is everywhere, and that its transformations in natural phenomena are difficult to isolate. But he argues that, to lay "the foundation of a physical theory of any of the effects of heat", we must focus on "work performed" or "mechanical effect."[68] To Thomson, the most important element of a theory of heat is how much useful work we can extract from heat operations. Focusing on the outcome of work production channels our efforts into designing machinery that will enrich the nation and avoid wasting any of its natural resources.

On the one hand, it is easy to see how Thomson's sentiments aligned with Carnot's vision of putting natural resources to work. *Reflexions on the Motive Power of Fire* also opens by arguing that a theory of heat is useful only when we apply it to extending a nation's influence. But on the other hand, as Smith points out, Carnot's

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[65] Carnot, *Reflexions on the Motive Power of Fire*, 50.
[66] Thomson, "An Account of Carnot's Theory," 545.
[67] Smith, *The Science of Energy*, 93.
[68] Thomson, 541.

treatise emerged from late-eighteenth century Enlightenment values like harnessing gifts of Nature to elevate mankind. When Thomson interpreted *Reflexions* and extended its arguments for a (mainly) British audience, he also injected Carnot's theory with his own Scottish Presbyterian values. Subsequently, Thomson's "Account" maps Carnot's vision of political economy on the nineteenth-century British virtues of minimizing waste, controlling natural resources for the benefit of the nation, and governing the personal energies of individuals. These virtues link scientific energy in its earliest formation to both the gospel of capitalism and the unobtainable, productive ideal of a "perfect thermo-dynamic engine."

For example, Carnot's argument treats natural disasters as sources of heat, and therefore power, that mankind has not yet learned to harness. "To heat also are due the vast movements which take place on the earth," he declares. "It causes the agitations of the atmosphere, the ascension of the clouds, the fall of rain and of meteors, the currents of water which channel the surface of the globe, and of which man has thus far employed but a small portion… From this immense reservoir we may draw the moving force necessary for our purposes."[69] Heat thus threatens to overwhelm, but it remains an essentially never-ending resource. Thomson translates heat's bounty into a moral imperative: heat's "all-pervading influence"[70] in nature generates the obligation of finding a "perfect theory of heat," or of determining "the degree of perfectibility which cannot be surpassed" in practical engine construction and economy.[71] Therefore, once we

[69] Carnot, *Reflexions on the Motive Power of Fire*, 3.
[70] Thomson, "An Account of Carnot's Theory," 541.
[71] Thomson, 546.

establish a theory of heat, any imperfections that remain in engine design are the fault of the human designer. Natural laws place limitations on the efficiency of energy transfers, but it is the responsibility of the engineer to make sure that energy is transferred economically. Then, humans do what they can to extract as much as possible, with as little waste as possible, from the stores of energy at their disposal.

We can see the foundation of William Thomson's thermodynamic laws already present in his differentiation of productive and unproductive labor. Political economists and practical engineers alike considered productive labor that which contributed to the wealth of the nation. As Smith and Wise put it, unproductive labor was "consumed in the doing,"[72] which included power consumed by water infrastructures and their steam components. Industrial waterpower relied on the caprices of weather, in addition to the unstable foundations of British riparian doctrine. Unlike Carnot's vision of steam engines, in which steam would "carry the fruits of civilization over portions of the globe where they would else have been wanting for years" and "unite the nations of the earth as inhabitants of one country,"[73] the Thomsons imagined that improved steam engines would assist Britain's commercial agenda by easing the burden of riparian conflict, watercourse congestion, and the poor economy of existing water infrastructures.

But water infrastructures, and the flow of water that operates them, create new zones of contact, movement, and disruption that combine the individualism of property ownership with a sense of wholeness only in aggregate. We refer to right to *flow*; we do not commonly speak of owning this or that water droplet. Therefore, as energy science

[72] Smith and Wise, *Energy and Empire*, 287.
[73] Carnot, *Reflexions on the Motive Power of Fire*, 4.

came into existence in the late 1840s and early 1850s, it did so under the influence of water as a model for resource flow, management, and ownership. Because it moves, we can channel it, divert it, dam it, or dissipate it. For the Thomson brothers, Carnot's falling water analogy solidified the connection between water's unstable characteristics and what would become known as "energy."

As I argue throughout this dissertation, the word, "energy," belonged to the domains of both psychic and physical force. Therefore, the forms of water and its infrastructures supported a common language of emotional control and energy management. Combinations of physic forces and industrial imagery appear in mid-century literature from Thomas Carlyle to Charles Dickens; but what makes George Eliot's contribution so crucial to this archive is that she applies the same water forms as do the Thomson brothers to draw forth a completely different emotional sensibility and ethos of collective responsibility. The next section examines how the characteristics of water mapped to the logic of energy resource management, and how the Victorian language of emotional control bound the figurative structures of water to bourgeois, masculine self-help virtues. George Eliot's *The Mill on the Floss*, however, suggests a different emotional economy by using the same water structures as an anchor for psychic and physical energies that defy William Thomson's economy-dissipation binary.

"A NARROW SELF-DELUSIVE FANATICISM": WATER, ENERGY, AND SCALE IN ELIOT'S ECONOMY OF FEELING

So far, we have established that the dynamic properties of water resemble energy's volatile characteristics, namely flow, movement, and evasion of stable ownership. Waterpower's commercial challenges led to two developments: first, the integration of assists like steam engines, which managed water flow and helped to avoid riparian conflict; and second, the formal binding of heat theory to water analogies. From his perspective as a Scottish engineer, James Thomson observed what he called the "consumption" of waterpower as a problem of wastefulness. He and his brother William embraced Carnot's waterfall analogy as William worked on his own theory of heat. Eventually William Thomson's dynamical theory of heat became one of the first texts to establish the science of thermodynamics. I have argued, therefore, that the commercial affordances of waterpower, and the unstable characteristics of water flow, modeled the possibilities for a bourgeoning science of energy.

And yet, water flow is also a figurative stand-in for the language of emotions. Water is life-giving and cleansing. But water also destroys: natural disasters remind us that a single flood can bury the imprint of generations on a landscape. Apropos of the Thomsons' fascination with water, we can make water perform work to our advantage, so what might have been a danger or a waste is now a tool of capital, a source of enrichment and growth. Victorian self-help culture affixed these notions to the idea that discipline, self-denial, and steady work were virtues of social mobility. Self-help discourse also absorbed the figurative language of steam, especially the combination of steam power's structured, mechanical routinization and the underlying threat of explosion. The individual was envisioned as a unit whose energies threatened wild, passionate self-destruction, but that might also be governed into productive labor. Water flow underpinned such language, not only because water and affects are old bedfellows, but because thermodynamics emerged from isomorphisms between water and energy.

Self-help texts thrived mid-century, when thermodynamics settled into British vernacular. In particular, the Scottish journalist Samuel Smiles's *Self-Help* (1859) achieved international success and was revised for a second edition in 1868. Smiles argues for an ethics of "energetic individualism"[74] which, in aggregate, "constitutes the true source of national vigour and strength."[75] The energy of each individual who helps himself, in turn, helps the nation, for "the nation is only an aggregate of individual conditions, and civilization itself is but a question of the personal improvement of the men, women, and children of whom society is composed."[76] One's individual decisions, therefore, contribute to collective national triumph, or collective national decay.

Smiles combines the pre-scientific qualities of energy as a psychic force with its newer thermodynamic definition. In *Self-Help*, energy is a personal quality one can shape, channel, dissipate, or waste; but, through the collective work of individuals, it is also a motive force in the service of Britain. The word, "energy," appears seventy-five times in the 1868 edition of *Self-Help*, and "energetic" appears an additional thirty times. The first part of this section studies self-help literatures and their reinforcement of the word, "energy." We find in *Self-Help* Thomsonian thermodynamic virtues of an "ideal" engine, mapped to the affective obligations of the bourgeois, masculine subject. Such didacticism also infiltrated popular mid-century novels. In Dinah Mulock Craik's *John*

[74] Samuel Smiles, *Self-Help*, 6.
[75] Smiles, 1.
[76] Smiles, 2.

Halifax, Gentleman (1856), steam power appears as both the solution to hydraulic management and the figurative masculine energies of its eponymous hero. It is easy to locate William Thomson's politics and Smiles's celebration of energetic individualism in *John Halifax*, whose plot centers on riparian conflict and the transformative powers of self-denial and perseverance.

The second part of this section explores George Eliot's ironic treatment of hydraulic management and steam power as fixtures of self-help culture. In *The Mill on the Floss* (1860), Eliot seems to deliberately unsettle the conventions that *John Halifax* promotes. However, Eliot does not simply refute the figurative associations of water management, self-help, and emotional regulation. Instead, she applies the same forms of water, flow, and riparian infrastructures to uncouple energy from such moral-material attachments as those championed by the Thomson brothers.

In *Self-Help*'s eighth chapter, "Energy and Courage," Smiles insists on what he calls the "energy of will" as the protean force within man that may drive him either towards uprightness and individual industry, or towards misguided and wasted effort. Will here is defined as "force of purpose,"[77] giving "impulse to [man's] every action, and soul to every effort."[78] However, each effort does not produce equally beneficial results. Smiles continues: "As will, considered without regard to direction, is simply constancy, firmness, perseverance, it will be obvious that everything depends upon right direction and motives. Directed towards the enjoyment of the senses, the strong will may be a demon, and the intellect merely its debased slave; but directed towards good, the strong

[77] Smiles, *Self-Help*, 226.
[78] Smiles, 224.

will is a king, and the intellect the minister of man's highest well-being."[79] We find traces of hydraulic management and its links to thermodynamics in this language. Energy of will, Smiles argues, is like *flow*. It exists as a force within us, and we can choose to channel it industriously, allow it to dissipate into uselessness, or divert it for misguided efforts. The key is to discipline the self into directing that energy of will towards what will elevate our social status and benefit the nation meanwhile.

With the direction of will and steady self-application, Smiles tells us, any man might invoke his own powers to work towards an energetic individualism that benefits Britain in aggregate. Although Smiles, himself, glosses the biographies of recent and historical "men of industry" to evidence his argument, Dinah Mulock Craik's fictional John Halifax is also often referred to as a hero of Smilesian self-help.[80] *John Halifax, Gentleman* launched Craik's success as a career writer. When she published the novel in 1856, her middle-class readership generally celebrated her representation of self-reliant masculinity, even as her female contemporaries criticized her overdependence on trite sentimental formulas and "flimsy" plot structures.[81] As Elaine Showalter argues, most of Craik's work belonged to her general recommendation for women: "she presented them with a program of self-reliance and self-development, rational and thoroughly British."[82] By constructing male heroes like Halifax, therefore, Craik projected her ideals for women onto an appropriate domestic convention. John Halifax might embody resignation, steady

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[79] Smiles, *Self-Help*, 228.
[80] Ketabgian, for example, argues that "In *John Halifax*, Craik traces the path of hydraulic power through her Smilesian hero…". *The Lives of Machines*, 113.
[81] Elaine Showalter, "Dinah Mulock Craik and the Tactics of Sentiment: A Case Study in Victorian Female Authorship," *Feminist Studies*, 2, no. 2 (1975): 18. https://search.proquest.com/docview/1295919351?accountid=14521.
[82] Showalter, 13.

productivity, and eventual success, if Craik could not bestow her female characters with such qualities. Per Showalter, Craik belongs to a cohort of Victorian women novelists and poets[83] whose body of work seems to oppose organized progress towards women's equality, yet simultaneously undermines women's domestic confinement by devising "strategies of adjustment."[84] In Craik's case, such a strategy was building her own ideals into the masculine, Smilesian hero.

John Halifax, Gentleman traces out the life of a young man who gradually improves his lot as an orphaned farm laborer by transforming himself into an industrial capitalist. The novel opens in fictional Norton Bury in 1794, when the Quaker tanner Abel Fletcher pays a young John Halifax to help his invalid son, Phineas, walk back to their house. Phineas, the novel's narrator, quickly establishes a bond with Halifax, and he remains an adoring friend who chronicles Halifax's successes over the course of their lives. During his adolescent years, Halifax works for Abel Fletcher in the tanyard while teaching himself to read and write in his spare time. His literacy earns him a position as clerk, the first in a series of job promotions.

As time passes, Halifax and Phineas travel to the countryside where John meets and falls in love with Ursula March, a young heiress. Ursula's family resent her unconventional marriage to Halifax, and the trustee of her inheritance withholds her property. Therefore, she and John live rather meagerly until a local mill owner, Lord Luxmore, offers to both lease Halifax his mill and persuade Ursula's family to release her inheritance in exchange for Halifax's promise that he will influence the local tenants to

[83] In addition to Craik, these include Margaret Oliphant and Charlotte Yonge.
[84] Showalter, "Dinah Mulock Craik," 5.

vote in favor of Luxmore's preferred Parliamentary candidate. Halifax agrees, but he ends up reassuring the tenants that they should vote as they like.

Luxmore retaliates by diverting the watercourse that runs through his property and Halifax's mill, thereby intercepting the flow needed to power the waterwheel. Because Halifax has economized his free time by making models of steam machinery, he saves the mill by introducing steam power as an assist for the waterwheel. The remainder of the novel follows John Halifax into his new life of wealth, during which he becomes a magistrate, rescues a bank from financial crisis, and remains an influential bridge between the upper and lower classes.

Even after Halifax escapes poverty, the novel waxes philosophical on the virtues of a parsimonious life. No passions, material or affective, should be stoked, and it is John Halifax's particular brand of sentimental tight-fistedness that ensures his success. Halifax is not a stingy miser: he pays his mill workers full wages even when work is scarce, for example. But he also allows few pleasures for himself and his family. Early in the novel, Phineas recalls an anecdote of one of his father's attempts to improve "what he persisted in considering [his] 'infant' mind."[85] His father recounts the cautionary tale of a girl, evidently the young Ursula March, who "in some passionate struggle had hurt herself very much with a knife."[86] Abel turns to Phineas and cautions, "Let this be a warning to thee, my son, not to give way to violent passions."[87] John Halifax remains Phineas's

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[85] Dinah Mulock Craik, *John Halifax, Gentleman* (London: Hurst & Blackett, 1856), Kindle, 17.
[86] Craik, 17.
[87] Craik, 17.

paragon of virtue and steadiness throughout the novel. He neither acts on strong feeling nor allows his passions to overwhelm him.

Like a good Smilesian, Halifax channels his fascinations into work that will offer him a return for his efforts. In particular, he spends a great deal of time thinking about the River Severn, which flows through Norton Bury. Like the Thomson brothers, he confesses, “I could stand for an hour watching a mill at work, especially if it’s worked by a great water-wheel.”[88] The river often functions as a metaphorical stand-in for Halifax’s inward life. Phineas compares his friend’s humility and circumspection to the river he admires: “like our own silent Severn, however broad and grand its current might be, that course seemed the natural channel into which it flowed.”[89] Nowhere in the constructions of Halifax and his kinship with water does the narration suggest water’s violence, disobedience, or power of destruction. Instead, *John Halifax, Gentleman* only casually references floods of the past[90] or involves Halifax in heroic scenes of mastery over water.[91]

Halifax’s pastime ruminations on steam engines and waterpower culminate in his introduction of steam power to the Luxmore mill, which is what ultimately secures his fortune. When Halifax discloses his plans to add a steam engine to the mill, his workers react with skepticism. A mid-century text, *John Halifax, Gentleman* invites readers to praise Halifax’s foresight and to laugh at the mill-workers’ contempt for the machines

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[88] Craik, *John Halifax, Gentleman*, 74.
[89] Craik, 155.
[90] For example, Phineas tells John, “Oh, we at Norton bury are used to floods.” When John asks if the floods are serious, Phineas answers, “Have been – but not in my time.” Craik, 26.
[91] For example, Halifax single-handedly rescues several men from “a whirl of conflicting currents, in which no boat could live.” Craik, 27.

that, they perceive, threaten their hand labor. Similarly, readers are expected to enjoy Halifax's sentimental influence over these workers, who eventually embrace the steam engine that will release Lord Luxmore's oppressive control of the water flow. Indeed, Halifax reminds Luxmore that the steam engine "renders me quite independent of your stream."[92] He thanks Luxmore for his intended cruelty because the ironic and felicitous outcome has been "one of the greatest advantages"[93] of his life.

The scenes that occasion John Halifax's momentous reveal of his steam engine entail what mid-century readers might have considered an amusing series of exchanges between the mechanically savvy Halifax and his apprehensive Luddite employees. For example, one man points to the steam engine and addresses Halifax: "They say there's six devils inside on her, theer."[94] In another passage, "one village oracle" visits the mill "to prove how impossible it was that such a thing as steam could work anything."[95] Tamara Ketabgian has discussed these scenes as the novel's celebration of steam "as a mysterious and near-demonic source of energy."[96] Indeed, the machinery apparently acquires a soul of its own once Halifax sets the engine in motion. Phineas even exclaims, "The monster was alive!"[97] All of this, however, functions only to elevate Halifax in his employees', and in our, estimation. We are told that "they all looked with great awe at the master, as if he were something more than man."[98] This, of course, is the point. John

[92] Craik, *John Halifax, Gentleman*, 204.
[93] Craik, 204.
[94] Craik, 203.
[95] Craik, 202.
[96] Ketabgian, *The Lives of Machines*, 114.
[97] Craik, 203.
[98] Craik, 203.

Halifax is the Smilesian gold standard: simultaneously the model of middle-class virtue and an everyman we might embody if we simply do as Halifax does.

Despite the novel's sentimental representation of domestic, middle-class industriousness, Sally Mitchell has pointed out that *John Halifax* embeds political commentary on the shift of power away from aristocrat-controlled elections to an extended franchise after the reform of 1832.[99] By wresting the power of commerce away from the landed gentry (*i.e.*, Lord Luxmore), Halifax essentially enacts "the real transfer of power" that "the Reform Bill simply ratified."[100] Seen this way, steam power is a deciding technological and political factor in riparian conflict and watercourse congestion. However, this kind of technological determinism, where steam simply replaces traditional waterpower infrastructures and radically shifts the course of socioeconomic development, is the target of *The Mill on the Floss*'s irony in 1860, several years after Craik's success with *John Halifax*. Where Craik finds genuine consolation in marrying the linear narrative of steam's ascendency to that of the middle-class hero, Eliot undercuts that notion, and its associated energy-laden and affective baggage, by structuring her own narrative around the limitations of hydraulic and emotional confinement. Some energies, Eliot suggests, are embedded or distributed in systems beyond our ability to manage them.

Maggie Tulliver's unbridled passions and conflicted, polar energies, like an extension of the River Floss, would not do for Craik. She disliked *The Mill on the Floss*

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[99] Sally Mitchell, "John Halifax, Gentleman: Epitome of an Age," *The Victorian Web*, accessed Jan. 3, 2021, https://www.victorianweb.org/authors/craik/mitchell/3.html.
[100] Mitchell.

and attacked the novel in an anonymous essay that defended Tom Tulliver as *The Mill*'s true hero.[101] In Craik's defense, Eliot had also criticized Craik and was annoyed when a French journalist compared them in 1860.[102] Eliot did not consider herself in the same register of authorship as Craik, simply because the two novelists were similarly English, women, and writers.

In spite of Eliot's insistence on retaining a worthy critical distance from "Miss Mulock – a writer who is read only by novel-readers, pure and simple, never by people of high culture,"[103] I will spend the next part of this section exploring *The Mill on the Floss* as an alternative to the affective and material energy politics of self-help literatures like *John Halifax, Gentleman*. I do not intend to compare the formal properties of the texts so much as I am interested in how they do or do not support the rising British energy agenda contemporary to their respective publications, and the Thomsons' advancement of water infrastructures as part of heat theory. As we have seen, Craik's case is straightforward. *John Halifax* extolls the idea that heat power, like water flow, must be harnessed and channeled towards individual work in the interest of improving the nation. Part of this program is learning to direct the will away from sensory pleasures and towards productive transformations of power. *The Mill on the Floss*, on the other hand, is far more ambiguous about the virtues of personal energies, the opaqueness of water ownership, the function of steam power in riparian mill technologies, and the long-term efficacy of calculated or economized efforts.

[101] Showalter, "Dinah Mulock Craik," 18.
[102] Showalter, 6.
[103] In Showalter, Quoted from Letter to Francois D'Albert Durade in *The George Eliot Letters*, ed. Gordon Haight (New Haven: Yale University Press, 1954) vol. 3, 302.

Like *John Halifax*, *The Mill on the Floss* is a mid-century novel looking historically backwards to reflect on water conflict, riparian mills, and infrastructural changes to the English countryside. Both novels test their protagonists in times of hardship, but they take decidedly different routes in addressing that conflict. Most obviously, John Halifax lives to a ripe old age while both of *The Mill*'s young protagonists die in a catastrophic flood. Any narrative parallels or departures I note here, however, are not meant to say that *The Mill* simply negates Craik's pairing of hydraulic management and energetic individualism. Instead, when Smilesian characters do succeed, Eliot's narrator invites us to celebrate those characters with a sense of sympathetic irony, rather than earnest admiration. Eliot acknowledges the British tradition of bourgeois, masculine self-advancement; and then she embraces an aesthetics of "unproductive energy,"[104] centering water structures in examples of "painful collisions"[105] that occur, not for want of better hydraulic control, but because water connects to larger natural systems where cycles of flooding and destruction do not make considerations for human-scaled industrial progress.

The novel's characters model energy on various levels of scale and management. For instance, *The Mill on the Floss* takes great pains in setting Maggie Tulliver apart from the novel's "narrow" characters associated with a traditional industrial imaginary. However, Eliot never meant to vilify Maggie's foils. In response to a review of the novel that described the Dodsons as "odious" and "stingy," she defended these characters to her

[104] Tondre, "George Eliot's," 205.
[105] George Eliot, *The Mill on the Floss* (1860; London: Penguin Classics, 2003), 248. Citations refer to the Penguin edition.

publisher John Blackwood: "So far as my own feeling and intention are concerned, no one class of persons or form of character is held up to reprobation or to exclusive admiration. Tom is painted with as much love and pity as Maggie, and I am so far from hating the Dodsons myself, that I am rather aghast to find them ticketed with such very ugly adjectives."[106] Therefore, we are not expected to despise Maggie's relatives as we root for her, even if their conduct seems anathema to Maggie's ideas of happiness, virtue, and respectability.

Indeed, Maggie and Tom complement each other because they are unalike, even if their differences are sometimes painful to Maggie. Physically, Tom's fair complexion aligns him with his Dodson relatives, whereas Maggie's dark hair and eyes arouse suspicion in her family that such a complexion might "stand in her way i' life, to be so brown."[107] But Maggie also possesses an emotional intensity that her relatives do not. The narrator explains that, whereas "tom had very clear prosaic eyes not apt to be dimmed by mists of feeling or imagination,"[108] Maggie felt and imagined everything. She "rushed to her deeds with passionate impulse,"[109] often giving in to violent outbursts of feeling. Whatever Maggie feels in this novel, whether in happiness or in sorrow, she allows herself to be swept up in it. In Smiles's terminology, Maggie wastes her psychic forces by indulging her senses, turning a naturally "strong will [into] a demon."[110] Indeed, Maggie considers herself somewhat demonic, as fits of anger towards her family

[106] George Eliot, Letter to John Blackwood in *Selections from George Eliot's Letters*, ed. Gordon Haight (New Haven and London: Yale University Press, 1985), 246-47.
[107] Eliot, *The Mill on the Floss*, 73.
[108] Eliot, 288.
[109] Eliot, 70.
[110] Smiles, *Self-Help*, 228.

"flow out over her affections and conscience like a lava stream" to "frighten her with the sense that it was not difficult for her to become a demon."[111] In the school of self-help, Maggie is therefore both energetic and wasteful. Or, like James Thomson described to his brother, she acts like a mill that lets water spill from its buckets before it can act on the wheel and transform that stored energy into productive work. She does not direct her energy flow, but rather wastes her potential in passionate raging, venting, and feeling overall too much.

Eliot's narrator aligns the psychic energies of the Tulliver siblings with the forces and checks of the River Floss. Their mother fears that Maggie, who is always swept up in her own feelings and passions, will similarly be swept away by the Floss. The text returns repeatedly to Mrs. Tulliver's fear that Maggie will "be brought in dead and drownded one day,"[112] which ultimately comes to pass with the deaths of her children in the novel's final scenes. Maggie, like the Floss, exists in extremes. Until it floods, the "dear old Floss" is a placid fixture of St. Ogg's, which, as Maggie watches from a distance, "seem[s] to be sleeping in a morning holiday."[113] Maggie, too, tends to settle at one pole or the other. As a child, for example, she spends a morning grinding the head of her fetish doll in the attic as punishment for her own misfortunes, until she suddenly rushes downstairs to sing and dance in celebration of Tom's coming home from school.[114] Later,

[111] Eliot, *The Mill on the Floss*, 299.
[112] Eliot, 110. *The Mill*'s narrator shows us four separate occasions where Mrs. Tulliver worries that her children, particularly Maggie, will drown in the Floss before Maggie and Tom do drown in the river.
[113] Eliot, 389.
[114] Eliot, 31-32.

when Tom and Maggie are young adults, he accuses her of inconsistency,[115] that she is "always in extremes" and has "no judgment and self-command."[116]

These latter regulatory traits, and particularly what Eliot calls "narrowness," likewise connect Tom to the Floss. Tom aligns with the language of water management and commerce, as opposed to the "strong tide[s]"[117] which characterize his sister. Tom may be stubborn and single-minded, but that willful inflexibility equips him with "a distinctive discernment of what would turn to his advantage or disadvantage."[118] Eliot's narrator encourages us to think of Tom's narrowness as a kind of intelligence, albeit intelligence with limitations and blinders. *The Mill* sympathetically critiques a handful of narrow-minded characters, including the Reverend Stelling, who ironically overlooks Tom's intelligence because of his own shallow notions of education. Similarly, Mr. Tulliver never considers his son "'cute… like the little wench,"[119] though Tom ultimately recovers his father's property losses by applying his unimaginative narrowness to business. *The Mill on the Floss* is not unfeeling towards the industrial work ethic espoused by novels like *John Halifax, Gentleman*, but the narrator cautions against the limitations of confining the mind, and the forces of nature, to a limited range of experience. During times of hardship such routinization may be a balm; but in perpetuity "the same scenes are revolved over and over again" as if narrow minds "were machines set to a recurrent series of movements."[120]

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[115] Eliot, *The Mill on the Floss*, 356.
[116] Eliot, 408.
[117] Eliot, 289.
[118] Eliot, 70.
[119] Eliot, 23.
[120] Eliot, 291-292.

Eliot uses Mr. Tulliver's own narrow prejudices to explore the novel's legal and historical structures. When the narrative opens, we learn that Tulliver had been involved in a lawsuit to defend his water rights against a neighboring riparian landowner. In that case, Tulliver's opponent had built a dam and the lawsuit had been settled by arbitration in Tulliver's favor.[121] Later in the novel, however, the litigious Tulliver returns to the courts when Mr. Pivart, another neighbor higher on the River Ripple, plans to irrigate his lands. Unlike *John Halifax*, in which Lord Luxmore indeed disturbs Halifax's waterpower, Pivart's irrigation system may or may not threaten Tulliver's grist mill. But, "confident as Mr Tulliver was in his principle that water was water and in the direct inference that Pivart had not a leg to stand on in this affair of irrigation,"[122] Tulliver proceeds with his lawsuit and loses.

Tulliver's circular principle that "water was water" repeats in his ruminations during both lawsuits. From his narrow perspective as a miller who must have water to turn his wheel, Tulliver feels that riparian doctrine should be straightforward enough. Even so, he notices how water seems spatially unsuited to any straightforward ownership, so far as the lawyers are concerned. He remarks, "water's a very particular thing – you can't pick it up with a pitchfork. That's why it's been nuts to Old Harry and the lawyers."[123] Tulliver cannot square the uncertainty of water flow, and the respective uncertainty of legal attempts to control it, with his unwavering certainty in himself.

[121] Eliot, *The Mill on the Floss*, 17.
[122] Eliot, 167.
[123] Eliot, 164.

Poor Tulliver must forfeit Dorlcote Mill and all his property after this crushing lawsuit, which serves a final, shattering blow to his character. In the immediate aftermath of the lawsuit, however, Tulliver's frantic energies vent themselves in searching for an escape hatch. Once he has exhausted all hopes of recovering his family's losses, Tulliver's energies have dissipated completely, and he exists only as a shadow of the old inflexible miller his children remember. Eliot's narrator returns to the language of energy management to structure Tulliver's emotional state: "All the obstinacy and defiance of his nature, driven out of their old channel, found a vent for themselves in the immediate formation of plans by which he would meet the difficulties and remain Mr Tulliver of Dorlcote Mill in spite of them."[124] When the failed lawsuit drives Tulliver's obstinacy out of its old channel, his single-minded energies flow into other eddies and rivulets, leaving him to scramble from one potential solution to another. He considers applying to Mr. Furley, who holds the mortgage on Dorlcote Mill. Tulliver is convinced Furley "would be glad not only to purchase the whole estate including the mill and homestead, but would accept Mr Tulliver as tenant."[125] This request is not only unreasonable but also impossible because Furley has recently signed over the mortgage to Tulliver's legal antagonist, the lawyer Wakem. By the time he learns that Wakem is current master of his mill and lands, Tulliver's energies have exhausted their escape channels and are quite dissipated. He falls too ill to recover.

The Mill's treatment of water ownership is the novel's central conflict, subordinating its protagonists to an uncertain future where the narrator's observations

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[124] Eliot, *The Mill on the Floss*, 205.
[125] Eliot, 206.

reveal flow-like limitations and affordances of their character traits. But Eliot's choice to explore the particularities of riparian law during the late 1820s also reveals what Jules Law argues is "Eliot's early and intense preoccupation with the circulation of fluids – and with attendant issues of property, transfer, reciprocity, and blockage."[126] In this case, setting the novel in the late 1820s becomes a crucial narrative choice because, in the history of riparian doctrine, there was no legal precedent or standard for a technology like Pivart's irrigation system. Moreover, Pivart's apparent need for irrigation in a naturally wet British climate seems strange. Agricultural irrigation was rarely necessary,[127] and therefore irrigation rights and technologies remained underdeveloped in England throughout the nineteenth century.[128]

Because Eliot chooses this underdeveloped technology and its respectively inchoate legal doctrine, the novel does not present the reactions of its characters to what, for them, might be a predictable outcome, but rather drops them into the tumult of what Law calls "radical uncertainty."[129] Law argues that this "represents the displaced responses of characters and language to historical circumstances that are genuinely, objectively uncertain."[130] Eliot's narrator places the question of uncertainty somewhat less comprehensively, in the terms of charting or mapping a river. "Maggie's destiny, then, is at present hidden, and we must wait for it to reveal itself like the course of an unmapped river," she writes. Looking forward from Maggie's perspective, "we only

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[126] Jules Law, *The Social Life of Fluids: Blood, Milk, and Water in the Victorian Novel* (Ithaca and Cambridge: Cambridge University Press, 2010): 72.
[127] Getzler, *A History of Water Rights*, 38.
[128] Law, 80.
[129] Law, 84.
[130] Law, 80.

know that the river is full and rapid, and that for all rivers there is the same final home."[131] The narrator is looking backward in time, and thus Maggie's destiny is hidden only to her and to *The Mill*'s readers, but it is not indiscrete. Through the narrative, we simply follow what are, to Maggie, uncertain twists and bends until we arrive at the inevitable final home, the mooring we all expect at the end of life.

What, then, are we to make of each character's choices and the onus of directing personal energies productively on their way to that final home? Eliot's appeal to expansive, distributed natural forces in *The Mill on the Floss* suggests two things. First, the novel supposes that a purely individual and even human perspective places limitations on our ability to comprehend the scope of energetic systems. As Elizabeth Miller puts it, "[h]umans are ill-equipped to understand the longer temporal arcs of the energy systems they use, Eliot suggests, because of their short lifespan and transient memories."[132] Karen Gindele frames the restrictions placed on Eliot's characters as a kind of immanence: "the fact of a body, which occupies space and exists during time in the world, and a mind which cannot know everything."[133] Read this way, Maggie's destiny, like the energy systems distributed across time and space,[134] is material, yet remains too tenuous for her to grasp. The narrator homes in on her life through a different, wider perspective.

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[131] Eliot, *The Mill on the Floss*, 418.
[132] Elizabeth Carolyn Miller, "Fixed Capital and the Flow: Water Power, Steam Power, and *The Mill on the Floss*," in *Ecological Form: System and Aesthetics in the Age of Empire*, ed. Nathan K. Hensley and Philip Steer (New York: Fordham University Press, 2019), 93.
[133] Karen C. Gindele, "The Web of Necessity: George Eliot's Theory of Ideology," *Texas Studies in Literature and Language* 42, no. 3 (2000): 256. https://www.jstor.org/stable/40755310.
[134] Timothy Morton has argued for a theory of "hyperobjects," or "things that are massively distributed in time and space relative to humans," that enables us to conceptualize our limited geographical and temporal perspective. We only see or experience pieces of hyperobjects, which makes our being relative to them difficult to comprehend. Humans' perspective relative to climate is an example of this. Timothy Morton, *Hyperobjects: Philosophy and Ecology after the End of the World* (Minneapolis and London: Minnesota University Press, 2013), 1-4.

Maggie's failure to economize her own energies, viewed through such a wider lens, matters little. Overzealous attempts to manage hydraulic systems and their energy outputs are similarly misguided. Water management infrastructures and thermodynamic systems emerge from a fantasy of channeling, or narrowing, networks of forces too diffuse, perhaps, to even conceptualize. There is danger in such a narrow vision of control. Miller argues that, after all, if rural waterpower in *The Mill on the Floss* is destroyed by natural catastrophe, the Victorians could not have imagined the delayed violence of steam power.[135]

And how *does* steam power figure in this novel? If steam appears as the solution to riparian conflict in *John Halifax*, it makes only a quiet entrance or two in *The Mill on the Floss*. As the plot unfolds in the foreground, we see signs of change across the landscape in the background. For instance, the narrator opens *The Mill* with a description of the Floss, where "the black ships – laden with the fresh-scented fir-planks, with rounded sacks of oil-bearing seed, or with the dark glitter of coal – are borne along to the town of St Ogg's."[136] In this pastoral, riparian setting, the Floss ferries the beginnings of an energy regime transition. But this is not the swift replacement of waterwheels for steam engines. Even when Tom discusses adding steam power as a mill assist with his Uncle Deane, the conversation only serves as speculation on these matters.[137] By the time Tom recovers the mill, he scarcely has time to install new technologies before a flood levels his property.

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[135] Miller uses Rob Nixon's terminology here to explain the catastrophic violence of flooding versus the "slow violence" of coal. 92. Rob Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge and London: Harvard University Press, 2011).
[136] Eliot, *The Mill on the Floss*, 9.
[137] Eliot, 256.

Eliot thus prompts us to broaden our perspective, to refuse settling into complacency about our own energies and the energy systems we inhabit. The townspeople of St. Ogg's, too, have settled into complacency about the floods of yore; although when the signs of flooding appear, the oldest townsfolk do know how to read them. They shake their heads, the narrator cautions, remembering the equinoctial floods of sixty years ago. "But the younger generation," we are told, "who had seen several small floods, thought lightly of these sombre recollections and forebodings," because their perspective does not accord with town legend. The narrator consults her "private hagiographer" for an account of Ogg the son of Beorl, namesake of the town. According to legend, St. Ogg's boat was blessed by the Virgin Mary so that he might ferry townsfolk to safety during the periodic flood times.[138] This is the town lore, yet at present, "[t]he mind of St Ogg's did not look extensively before or after. It inherited a long past without thinking of it, and had no eyes for the spirits that walked the streets."[139]

But the spirits *do* walk the streets, so to speak, regardless of their being invisible, which brings us to what I interpret as Eliot's second suggestion about personal choice in a decidedly constrained human existence. We can return to Eliot's note-book entry, "'A Fine Excess.' Feeling is Energy," where Eliot writes, "The impulse and act made the

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[138] Eliot's records of research for *The Mill on the Floss* reveal her familiarity with Thomas Lauder's *Account of the Great Floods of August 1829 in the Province of Moray*, which provided Eliot with historically accurate accounts of flood destruction in Scotland. The novel's climactic, equinoctial flood also seems to reference the folk belief in a regular "equinoctial storm," which was disproven later in the century by the improvement of meteorological science. For more details, see Tamara Ketabgian, *The Lives of Machines*, 120. Elizabeth Carolyn Miller, "Fixed Capital and the Flow: Water Power, Steam Power, and *The Mill on the Floss*," 89.
[139] Eliot, *The Mill on the Floss*, 126.

heroism, not the correctness of adaptation."[140] In other words, the key event of a sympathetic act is the instinct behind it, as opposed to whether the act guarantees palpable returns. Eliot's narrator suggests that the spirits of the town's past do linger on some level; that the town "carries the traces of its long growth and history, like a millennial tree";[141] that, in Tondre's words, "sentiments that do not signify at the threshold of social utility… can influence society in spite of their shortcomings."[142] Excess, "wasteful," or unchanneled energies here are not futile because, perhaps, we register their value on a finer scale than the coarseness of daily life permits. What does not get channeled, then, or what dissipates into wasted potential, finds an afterlife beyond the scale of calculable outcomes.

The Mill on the Floss incorporates hydraulic energetic systems and their affective counterparts on at least two scales: the narrow, commercial, and governable; and the scattered, wide, and geological. Moreover, the novel does not hold energies or forces separate across scales and systems, but rather suggests that they are simultaneously at work, within and beyond the individual. Maggie and Tom both struggle to balance the impulses of their energies with the restrictions of their environments. Impulses, as we have seen, are not demonized by Eliot as wasteful energies to be buried or redirected. Where John Halifax seems to exist simply to uphold energetic prudence and firmness of character, Eliot's most Smilesian protagonists struggle with inward conflicts of resentment and desire, even if they do choose the "correct" application of will. Tom bears

[140] Eliot, "'A Fine Excess.' Feeling is Energy," 295.
[141] Eliot, *The Mill on the Floss*, 123.
[142] Tondre, "George Eliot's," 209.

his family's poverty by turning his "natural inclination to blame… into [a] new channel."[143] What those around him witness as "a remarkable manifestation of self-command and practical judgment in a lad of fifteen"[144] is not the simple self-renunciation of *John Halifax*, but the "productive" and gender-appropriate re-channeling of blame. Tom can do this, Eliot suggests, not because he simply masters his passions, but because Tom is dreadfully ordinary, because his "was a nature which had a sort of superstitious repugnance to everything exceptional."[145] Tom's self-mastery is not valorized here; it is simply that his inward conflicts are less fierce than those of his sister.

As for Maggie, she, too, tries to redirect her energies into self-denial, giving up her modest aesthetic and intellectual pleasures. Maggie thus begins what Philip Wakem calls her "narrow self-delusive fanaticism,"[146] or her unsuccessful attempt to overcompensate for feelings that both overwhelm and constrain her. Unlike Tom, Maggie cannot work for her Uncle Deane to help pay off their family's debts. Moreover, Tom insists on her staying home, amid the oppressive despair of her mother and vacant hopelessness of her father. Maggie decides, therefore, to renounce her old pleasures of reading, to do what she can to embrace their new life in all its spareness. So, when Philip implores her to at least read something for pleasure, she refuses: "I was never satisfied with a *little* of anything. That is why it is better for me to do without earthly happiness altogether…".[147] Still, we find that even in her asceticism, Maggie is indulgent. "From what you know of her," the narrator tells us, "you will not be surprised that she threw

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[143] Eliot, *The Mill on the Floss*, 215.
[144] Eliot, 224.
[145] Eliot, 353.
[146] Eliot, 340.
[147] Eliot, 341.

some exaggeration and wilfulness, some pride and impetuosity even into her self-renunciation: her own life was still a drama for her, in which she demanded of herself that her part should be played with intensity. And so it came to pass that she often lost the spirit of humility by being excessive in the outward act."[148] Characters like Maggie and, to a degree, Philip Wakem,[149] are marked by their powers of emotional excess, where even feelings leave flood marks.[150] Such marks are simultaneously records of inner conflict and omens of the energies that might surface in the future.

Eliot suggests that forces withheld too narrowly in an individual like Maggie are bound to eventually shatter their container. As mill machinery is no match for a catastrophic flood, the "painful collisions" within Maggie originate from forces "which will make a way for themselves, often in a shattering, violent manner."[151] And so it seems fitting, if improbable, that Maggie perishes in the novel's climactic flood. Just before the flood arrives, Maggie is tested by temptation, renunciation, and disgrace. She and her cousin's fiancé, Stephen Guest, grow fond of each other, despite Maggie's best attempts to resist his advances. Maggie rejects Stephen, but only after they have left St. Ogg's together in a rowboat. When Maggie returns to town, she faces the consequences of her social indiscretion. Although Maggie sets to work immediately to do right by Lucy and

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[148] Eliot, *The Mill on the Floss*, 305.

[149] Critics have compared Philip Wakem to *John Halifax*'s Phineas, suspecting that Eliot designed Philip in repudiation of Craik's sentimental representation of the effeminate invalid narrator, fawning on the Smilesian hero. In *The Mill*, Philip retains the qualities that Craik presents as feminine, but he never admires or submits to Tom Tulliver. Philip has nearly every advantage over Tom, excepting his health and appearance. For more details on critical reception, and on Eliot's potential response to *John Halifax*, see Elaine Showalter, "Dinah Mulock Craik and the Tactics of Sentiment: A Case Study in Victorian Female Authorship," 18.

[150] Eliot, 349. Eliot's narrator remarks that Maggie's time spent with Philip in the Red Deeps included "dangerous moments," as when "feeling, rising high above its average depth, leaves flood-marks which are never reached again."

[151] Eliot, 248.

the rest of her family, these challenges end in the equinoctial flood and her death. In what Eliot calls "The Last Conflict,"[152] Maggie erupts with emotional and physical power, exhausting all her energies. She does not channel, direct, or economize her energy, but rather exerts herself until the moment of her death.

Maggie is not killed by overexertion, of course; she drowns in the flood. But the novel collapses the language of Maggie's emotions into the flow of water, first from the rain and then from the river. The narrator pairs the flood's arrival with Maggie's final temptation: Stephen has written a selfish, maudlin letter to Maggie, asking her to join him once again. The weather has changed suddenly, and "Maggie was again sitting in her lonely room, battling with the old shadowy enemies that were for ever slain and rising again."[153] As she contemplates Stephen's words, water pours into the house from under the door. Then, with the sensation of the water around her knees and feet, Maggie settles into a new sense of purpose. She plunges into the water, fetches Bob Jakin's boat,[154] and heads for Tom.

As Maggie maneuvers the boat into the Floss's current, her wasteful, energetic impulses drive her forward, as if the flood has amplified her natural tendencies towards excess and overflow. "More and more strongly the energies seemed to come and put themselves forth," the narrator describes, "as if her life were a stored-up force that was being spent in this hour, unneeded for any future."[155] As opposed to the Thomsonian ethos of control, where one guides energy surges to develop productive work, Eliot's

[152] The final chapter of the novel, excepting the conclusion, is titled "The Last Conflict."
[153] Eliot, *The Mill on the Floss*, 531.
[154] Eliot, 537.
[155] Eliot, 539.

flood folds waste and excess into overwhelming natural power. Here, Maggie's overflow of work and feeling become part of the natural destructive forces of the flood. If Sadi Carnot argued that natural disasters are "immense reservoirs" of power we may learn to tap for our benefit,[156] Eliot explodes that notion into the stuff of industrial fantasy. As Tom and Maggie hold each other in the little rowboat, they see only "Death rushing on them" in the form of dismantled wooden machinery.[157]

We know that Eliot took great pains in considering the machinery that upsets the Tullivers' boat. She wrote to John Blackwood that she had been lying awake, mulling over the last eleven pages of the novel, and that she wanted to be sure he inserted the word, "wooden," before "machinery," if she had not already done so in the manuscript. It was important to her that huge fragments of *wooden machinery* upset the boat to drown the Tulliver siblings.[158] And so Tom regains his father's mill through self-advancement and steady work,[159] only to lose his life months later when the shattered fragments of riparian machinery rush on him as the grim augur of Death.

Eliot is not an enemy of progress, of course; and so *The Mill on the Floss* ends with the narrator's reassurance that Dorlcote Mill was soon rebuilt. In fact, Maggie and Tom seem to be the only casualties of this recent equinoctial flood, whose traces on the

[156] Carnot, *Reflexions on the Motive Power of Fire and on Machines Fitted to Develop that Power*, 3.
[157] Eliot, *The Mill on the Floss*, 542.
[158] George Eliot, Letter to John Blackwood in *Selections from George Eliot's Letters*, ed. Gordon Haight (New Haven and London: Yale University Press, 1985), 241.
[159] Critics have noted the irony of Tom's success. His cousin Lucy uses her influence with her father to finesse businesses opportunities for Tom. Perhaps most crucially, Dorlcote Mill's current occupant is thrown from his horse and dies just as Tom acquires the funds to recover the property. Eliot therefore casts an ironical slant to Tom's self-made heroism, where *John Halifax* plays it straight.

landscape are subtle yet material.[160] With this in mind, I want to return to Samuel Smiles to point out key differences between Eliot's notion of subtle influences and Smiles's ethics of energetic individualism. Smiles, celebrating the great men of industry, makes his own case for smallness and obscurity. He argues:

> Many are the lives of man unwritten, which have nevertheless as powerfully influenced civilization and progress as the more fortunate Great whose names are recorded in biography. Even the humblest person, who sets before his fellows an example of industry, sobriety, and upright honesty of purpose in life, has a present as well as a future influence upon the well-being of his country; for his life and character pass unconsciously into the lives of others, and propagate good example for all time to come.[161]

Smiles appeals to the average reader here, underscoring the importance of small, everyday acts that, in aggregate, build our collective contribution to the nation's energy. He returns to a similar argument later in the text, where his language acquires an Eliot-like tone: "human character is moulded by a thousand subtle influences."[162] But the minutiae here, the influences that Smiles references, are not the same as those of Eliot's economy of feeling. For Eliot, the subtle influences that "pass unconsciously into the lives of others," as Smiles puts it, are not the means to some decided end. They are not energies to channel into a calculable outcome. Instead, they alter the landscape of life and feeling beyond the utility of daily operations.

The Conclusion of *The Mill on the Floss* bears out Eliot's view on devastation and renewal, and the influences that endure as subtle yet indelible markers of energy's violence. The narrator proclaims that "Nature repairs her ravages – repairs them with her

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[160] Eliot, *The Mill on the Floss*, 543.
[161] Smiles, *Self-Help*, 5-6.
[162] Smiles, 26.

sunshine, and with human labour."[163] New growth and human effort suture the trauma of natural disaster. We learn that the Floss bustles once more with commercial activity, that the devastating flood "had left little visible trace on the face of the earth" only five years after the deaths of Maggie and Tom. But Eliot's narrator famously retraces her phrase, adding, "Nature repairs her ravages – but not all."[164] We can reclaim or restore a landscape, but we do not erase the history of its injury.

Indeed, it is worth quoting this passage in its entirety: "Nature repairs her ravages – but not all. The uptorn trees are not rooted again – the parted hills are left scarred; if there is new growth, the trees are not the same as the old, and the hills underneath their green vesture bear the marks of the past rending. To the eyes that have dwelt on the past, there is no thorough repair."[165] There is a comforting sense of cyclic return here, but also an unsettling sense of impermanence. We see trees again, but the particular trees uptorn by the flood are gone forever. Beneath the grass that grows in the spring lie the scars of natural disaster. Dorlcote Mill is rebuilt, but it is not the same mill.

Energy is the science of cycles and transformations, but not of the Enlightenment-style conservation of Carnot's day. Carnot believed that heat cycles mimicked water cycles, where both caloric fluid and water were respectively restored to their original amounts, even with the power loss that vexed the Thomsons. As we have seen, William Thomson's post-caloric theory intervention was that we must economize our efforts to ensure the best possible outcome. But Eliot suggests that the forces of restoration and

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[163] Eliot, *The Mill on the Floss*, 543.
[164] Eliot, 543.
[165] Eliot, 543.

destruction are bound up together. There is little use in struggling to preserve the "narrow self-delusive fanaticism" of owning or governing our power of will in this transient, human way. Instead, we might trust that the surge and flow of even our most futile impulses leave their own subtle traces on the social landscape.

CONCLUSION

By the early nineteenth century, all potential mill sites along Britain's watercourses were occupied. More than ever, riparian law struggled to adjudicate conflicts over the control of water flow. The Scottish brothers William and James Thomson were fascinated by the question of water infrastructure productivity because, from their vantage point on the Clyde, solving the problem of power loss would address riparian congestion and further the nation's industrial progress.

In particular, the Thomsons extended Sadi Carnot's analogy between water falling through a height differential in a waterwheel and heat falling through a temperature differential in an engine. As a relic of post-Napoleonic France, Carnot's treatise emphasized the massive potential energy stores of natural disasters, and suggested that humans might learn to harness that power to spread knowledge and European influence across the globe. William Thomson's 1849 assessment of Carnot abandons the original text's Enlightenment spirit, but updates the scientific theory for a Victorian audience by arguing that Carnot's theory models a "perfect" thermodynamic engine. Thomson attaches British values of minimizing waste, controlling resources, and economizing personal energies to the productive ideal of a thermodynamic engine. Later, Victorian self-help culture affixed these notions to the idea that discipline and steady work were the keys to social mobility.

I have argued that energy's intersections across psychic and physical force allow us to see the figurative connections among water, affects, and energy management. Carnot's falling water analogy modeled the link between water's flow and the unstable characteristics of energy. When William Thomson built the virtues of flow management into the laws of thermodynamics, he naturalized what was possible, or desirable, to characterize the qualities of energy that are not, on their own, individualistic or discrete. Water *flows,* and so we *must,* Thomson argued, channel it. We *must* divert it into useful transformations. We *must not* dissipate it into waste. This applies to water, to energy, and to the will of the individual.

Eliot, on the other hand, applies many of the same figurative structures to dislodge emotional, hydraulic, and energetic flow from their Thomsonian associations. *The Mill on the Floss* espouses an aesthetics of unproductive energy, or energetic wastefulness. The novel locates water, and the personal efforts and affects of humans, in larger energy systems beyond the narrow control of human-built infrastructures. The fantasy of channeling is shattered in *The Mill* by small, inward "painful collisions," and by large-scale natural catastrophe. Still, even the most diffuse efforts or impulses matter in Eliot's economy of feeling, as we are reminded that the minutiae of our lives exist beyond our ability to calculate them.

In chapter two, we will take a closer look at William Thomson's involvement in framing the two laws of thermodynamics. As we have seen, Thomson was concerned with productivity and resource management. Indeed, he took great pains to write these virtues into thermodynamics and thus transform them into natural law. By the time Charles Dickens published *Our Mutual Friend*, contributors to popular middle-class periodicals were using the language, and the contradictions, of thermodynamics to discuss the famous Dickensian dust yards and its workers. Because recent studies of waste and recycling have identified the nineteenth century dust yard as a model of efficiency, it is necessary examine what I will refer to as the "dust economy" as a way of unsettling the stories about waste recovery that we continue to perpetuate.

Chapter 2:

Hacking the Loop: Energy Politics in Narratives of Efficiency and *Our Mutual Friend*

Efficiency is a double-edged sword. Although we tend to align energy efficiency with environmentalism, efficiency cannot be uncoupled from capitalism's predatory relations, including its insistence on using the planet as a cheap resource for accumulation. Modern recycling infrastructures exploit efficiency's ideological contradictions by turning waste into another cheap resource. Waste-centered critiques are therefore essential to the story of energy science its operation in fossil fuel capitalism. By the early nineteenth century, urban recycling programs had adopted efficiency rhetoric now recognizable in Big Oil's twenty-first century advertising. This chapter takes on the Victorian quest for work/energy efficiency, and the traces of Victorian efficiency narratives we can find in today's recycling infrastructures.

In October 2019, BP released plans to construct a pilot plant for its new plastic recycling technology, BP Infinia, a depolymerization process that deconstructs plastic waste into monomer building blocks for new plastics.[166] Two months later, BP announced its involvement in a consortium of corporations joining forces to create a "value chain" for the "closed loop recycling" promised by BP's technological innovations. Rita Griffin, chief operations officer of Petrochemicals, claims that Infinia will keep plastics in an infinitely-recyclable loop, thereby reducing landfill waste, as well

[166] "BP's New Technology to Enable Circularity for Unrecyclable PET Plastic Waste," BP.com, October 24, 2019, https://www.bp.com/en/global/corporate/news-and-insights/press-releases/bp-new-technology-to-enable-circularity-for-unrecyclable-pet-plastic-waste.html.

as minimizing oil extraction for new plastics. The technology is but one node in the network required to ensure what she calls plastic's circular economy. "You also need to collect and sort the waste," she explains, "then supply our recycled feedstock to companies that make new products from it."[167] In short, this kind of recycling may indeed reduce some landfill waste, but it also relies on perpetuating capitalism's status quo of boundless economic growth and commitment to market-based solutions.

BP's recycling agenda is easy to take for granted, or perhaps even to praise, when we operate from within the comfort zone of a twentieth- and twenty-first century energy regime. For instance, we might say that energy companies are adjusting to shifting markets and planetary damage by choosing to underscore efficiency and recycling. We might even argue, following the logic of some politicians, that we shouldn't concern ourselves with the private sector's bottom line when companies are actively reducing their carbon footprints. BP's Infinia program demonstrates the possibilities for an energy-efficient future as imagined by an oil giant, and it perpetuates an eco-conscious image that has paid off in the company's net worth. As law professors Miriam Cherry and Judd Sneirson point out, we sympathize with a company actively trying to manage waste in a decaying world: "For whatever [consumers'] own carbon footprints might be, for whatever gas-guzzling SUVs they or their neighbors might own, for however many trips consumers made in their cars, they at least aspired to be kinder to the environment."[168] It

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[167] "Helping to Reduce Plastic Waste," BP.com, January 23, 2020, https://www.bp.com/en/global/corporate/news-and-insights/bp-magazine/rita-griffin-coo-petrochemicals-on-bp-infinia.html.

[168] Miriam A. Cherry and Judd F. Sneirson, "Beyond Profit: Rethinking Corporate Social Responsibility and Greenwashing after the BP Oil Disaster," *Tulane Law Review* 85, no. 4 (March 2011): 1007, accessed January 26, 2020. HeinOnline.

is easy to stabilize capitalism's status quo when you justify accumulation with efficiency narratives. As this dissertation continues to argue, nineteenth-century Britain is a key historical period for the critique of a dominant energy logic and the way infrastructures transform, distribute, and obstruct energy.

This chapter furthers the dissertation's broad assertion that nineteenth-century energy forms produced many political and economic configurations of our current global energy crisis. Despite our relatively recent admission of anthropogenic climate change, the Victorians felt the scale of industrialization's environmental disruptions and invoked the new science of thermodynamics to manage their changing planet. While energy's metaphors have evolved with time and changes in science, we can trace enduring notions of efficiency back to the initial emergence of thermodynamic laws and the culture that produced energy's legibility. Because Britain's growing empire depended on the strength of its industrial and commercial centers, it is no surprise that energy science synthesizes rhetoric from political economy and engineering in its treatment of work and waste, labor and value, economy and dissipation.

Therefore, the analysis here centers on what I call the "efficiency narrative," or the expansion-motivated fiction of conservation, and on recycling infrastructure in mid-nineteenth century London. North British energy physicists framed an industrially favorable rendering of contradictions they observed in work/energy relations. By the time energy science reached the public, London was transforming its urban space to accommodate population growth and commerce. The social and material challenges of London's slow, chaotic, yet efficiency-driven improvement programs adumbrated contradictions in energy discourse. By examining how London coupled massive infrastructural expansion with programs aimed at containment and recirculation, I show how major shifts in the urban aesthetic were coextensive with an uptick in written representations of energy, both literary and journalistic.

The previous chapter focused on the isomorphisms of water flow and heat flow in producing motive power. While the Thomson brothers seemed wedded to Carnot's falling water analogy, James Prescott Joule threatened the model by suggesting a new hypothesis: heat and motion are interconvertible. William Thomson was initially unable to reconcile Joule's theory with Carnot's. It did not seem possible that heat and motion could be interchangeable if heat was also limited, as Carnot insisted, by "falling" from a hot temperature to a cold one. By the mid-nineteenth century, however, Thomson, Rudolf Clausius, and other notable (mainly North British) scientists had combined Carnot's logic with Joule's to their satisfaction. Thermodynamics emerged from this synthesis, simultaneously universalizing energetic transactions and placing limitations on their work production. The language of efficiency subsumes this simultaneous universality and limitation. Efficiency claims containment yet often implicitly seeks expansion. By examining the birth of the thermodynamic laws, this chapter exposes their contradictions and their now nearly invisible but potent hold on modern efficiency rhetoric.

As Britain transitioned to a coal-based economy, the energy transition released rural areas from their previous responsibility of primary energy production. Urban spaces and population growth were no longer limited by energy supply, and London experienced the growing pains of a nation adjusting to its now cheap and available resources. As energy's definitional ambiguity entered the public sphere, London witnessed an onslaught of metropolitan development designed to manage the waste products of, and to ease, rapid growth by applying market-driven efficiency logic.

In what follows, I pursue three threads to show how narrative was a political force in shaping energy's infrastructural space. First, I trace a brief political history of the thermodynamic laws and the efficiency logic derived from them. When we learn them now, basic thermodynamics concepts often appear to us in their sparest form, denuded of their cultural and historical associations. The laws' original framers did not simply discover a universal truth in nature. They were telling a story about the universe: how their new scientific word, "energy," complemented its non-physics definitions, and how humans *should* behave as actors in natural systems. Moreover, even though many of the classical energy physicists hailed from North Britain (thus limiting energy's scientific origins by geographical location), they encountered conflicts of worldview that affected the overall language of the thermodynamic laws. The contradictions of our efficiency narrative emerged through the politics of thermodynamics.

Second, I examine the operations of London's nineteenth-century dust economy. Middle-class periodicals published accounts of energy science and urban improvement side by side. In many of these narratives, authors route their impressions of dust yards and dust labor through Dickens's well-known imagery and through thermodynamic language. By attaching the dust yard to *Our Mutual Friend* (1863-65), writers preserve the romantic aura of transforming trash into new materials, even as they personally encounter decay and degeneration. In the new era of thermodynamics, waste recirculation permitted the fantasy of endless consumption without the consequences of energy loss, unchecked pollution, and filth. The romance of waste recycling included conceptualizing a self-sustaining system where energies are recirculated, rather than dissipated, and the city (or the nation) need not rely on outside input to sustain production. In this fantasy, the minutiae of each energy transfer are flattened into universal conservation. However, representations of workers' bodies, effaced in scientific literature on energy transfer, reappear in middle-class accounts of dust work. Here, dust workers' bodies are fraught with contradiction as middle-class observers find it difficult to determine whether dust workers are energized or dissipated by their labor.[169]

Such thermodynamic contradictions matter not just for their historical significance, but because twenty and twenty-first century waste management literature misleads us into collapsing economic and energetic waste into one sustainability model. This perpetuates a narrative that allows corporations and nongovernmental mega-organizations to standardize waste management using language that obscures the linked violence against workers and the environment. Because recent waste studies[170] have praised the nineteenth century dust yard as a model of efficiency, it is necessary to return to the dust economy, its controversies, and its contradictions, as a way of unpacking the stories about waste recovery that we now live by. In many ways, recycling continues to be a romantic fiction.

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[169] While this chapter covers the romance of efficiency and the fantasy of recycling's endless loops, chapter four discusses a North British romanticized interpretation of entropy, or the dissipation law. These conflicting illustrations of energy logic underscore the unstable foundation for energy, and show us that energy acquired a multiplicity of forms as it took shape in western culture.
[170] Refers broadly to integrated disciplines concerned with waste management, economic analysis, recycling, waste treatment, science and technology, and other assessments of waste.

The final thread of this chapter studies the energetic systems of Charles Dickens's *Our Mutual Friend*. Controversial as dust work was, Dickens's imagery turned it into what Emily Hobhouse called a "veritable romance."[171] Dickens published this novel more than ten years after the codification of thermodynamics, when the new science of energy had ensconced itself in the public imagination. Although many have pointed out *Our Mutual Friend*'s almost obsessive motif of waste's lively transformations, the novel is equally concerned with, and indeed almost relishes, moments of wastefulness. Dickens foregrounds the materiality of the dust economy as a contrast to the abstract and capricious "Economy of Shares." Dust makes its most romantic appearance when the novel's wealthier characters spin the story of John Harmon into the stuff of myth. Otherwise, it stands to disappoint and exhaust characters who sift through dust or examine it with rapacious eyes. When mid-century journalists appropriated *Our Mutual Friend*'s imagery, they reproduced romantic narratives of containing waste in closed systems, recycling it to generate raw materials and recover hidden treasures. However, Dickens's novel, itself, is more critical of London's dust economy, suggesting that the mythology of efficiency matured unevenly among London's social classes, much like its urban development.

[171] Emily Hobhouse, "Dust-Women," *The Economic Journal* 10, no. 39 (September 1900): 412.

The Laws of Thermodynamics: Restoration, Dissipation, and the Moral Imperative of Efficiency

The two laws of thermodynamics are now a catechism of modern physics: 1. In a closed system, energy can be neither created nor destroyed. It may transfer between forms yet remains consistent in amount. 2. The amount of concentrated, work-available energy in a closed system decreases as entropy tends towards a maximum. In other words, while the *amount* of energy remains consistent, it moves down a natural gradient from availability to diffuseness. This is why restoring a closed system to a higher state of order requires an external source of energy; or, taking the universe as a closed system, this is why the universe naturally works towards a state of cold, workless equilibrium.

If these laws now sound authoritative or even common-sensical, I want to challenge our complacency by briefly sketching out a history that highlights the cultural, economic, and political forces that structured the logic of energy. By sketching a history of the thermodynamic laws, I am underlining the conflicting worldviews of their framers, as well as their deep reliance on figurative language. At the end of this section, I will restate the two laws of thermodynamics by situating them within their cultural concerns, rather than extracting them from their human associations. Codifying energy science was a political act: because energy is not an object one studies with indexical vision, scientists relied on theological, social, and economic analogies to model energetic relations. Some scientists even claimed that such analogies indicated universal truths across nature, and that energetic equivalencies connected the social and material spheres. As we will see, contemporary infrastructural developments, including urban recycling, supported those models and buried their contradictions.

The Two Worldviews of James Joule and William Thomson

Recall from the previous chapter that water mill analogies structured early nineteenth-century models of heat transfer and motive power. In the 1840s, William Thomson and his brother James remained wedded to Carnot's view that work resulted from the "fall" of caloric from hot to cold temperatures. Under this analogy, more work results when caloric falls through a greater temperature differential, just as more work results when water falls from a greater height to turn a wheel. James Thomson's practical training in marine engineering and steam engines directed both brothers to the problem of waste, or machine power consumption. Besides its theoretical interventions, Carnot's research on heat engines was a civilizing mission for imperial France. With better engine efficiency, France might "carry the fruits of civilization over portions of the globe where they would else have been wanting for years,"[172] and like England, profit from "the revival of the working of the coal mines."[173] Carnot, then, was a favorite among scientists and engineers who puzzled out the problem of industrial work losses.

To investigate this problem, the Thomsons continued their work on waterwheels: the motive power "consumed" in turning a waterwheel was analogous to the motive power "consumed" by engines when heat falls, as Carnot argued, from a heat source to a

[172] Carnot, *Reflexions on the Motive Power of Fire*, 4.
[173] Carnot, 4.

heat sink without performing useful work.[174] The Thomsons were Scottish Presbyterians who subscribed to the worldview that God maintains order through progression. Therefore, as Crosbie Smith and M. Norton Wise have persuasively shown, William Thomson assimilated directionality into his thermodynamic worldview long before he confronted James Prescott Joule about Joule's new idea that heat and motion are interchangeable.[175]

While scientific histories usually credit Thomson with reconciling Joule and a newly resurrected Carnot to establish classical thermodynamics, they less frequently deconstruct how Thomson staged this reconciliation. Here, I emphasize the highly politicized actions involved in constructing our thermodynamic laws. First, Joule presented a paper at the Oxford meeting of the British Association for the Advancement of Science in 1847.[176] His ambitious ideas about heat/motion interconvertibility encountered so much skepticism that the British Association let him read only a portion of his paper.[177] Nevertheless, Thomson attended Joule's session and concluded that Joule's equivalency ideas were only half correct. Whereas Joule insisted beyond doubt that heat becomes motion *and* motion becomes heat, Thomson agreed with the former only. In other words, Thomson contended that motion becomes heat, but heat absolutely does not become motion. How else could one explain the consumption of motive power when heat drives work? Joule accepted that any losses in his calculations were due to

[174] Smith and Wise, *Energy and Empire*, 286.
[175] Smith and Wise, 318.
[176] James Prescott Joule, "On the Mechanical Equivalent of Heat, as determined by the Heat evolved by the agitation of Liquids, By J.P. Joule," *Report of the Seventeenth Meeting of the British Association for the Advancement of Science*, 55. London: John Murray: 1841. HathiTrust.
[177] Daggett, *The Birth of Energy*, 36.

experimental, rather than theoretical, error.[178] But Thomson, who had already assimilated directionality into the reality of heat engines, refused to accept Joule's theory as written. Because Thomson already operated from the standpoint that there was natural order and progression, he did not simply combine Joule and Carnot; he was also reconciling them within his own worldview.

Although they disagreed, Thomson's interest in Joule's work all but rescued the interconvertibility theory from academic insignificance. Joule's 1847 paper captured Thomson's attention for its insights into heat created by hydrodynamical friction.[179] After the BAAS meeting, Joule became Thomson's regular interlocutor on matters of heat and work. Joule even left copies of his 1843 and 1844 papers with the porter at Oxford College where Thomson was a professor in residence.[180] Equally impressed and frustrated by Joule's work, Thomson independently investigated the mechanical equivalency of heat. These different approaches to the same problem are significant, and both approaches left lasting impressions on the outcome of Thomson's eventual reconciliation of Joule and Carnot.

Differences in worldview prohibited Thomson from simply assimilating Joule's equivalency theory. For one thing, Joule was a staunchly conservative Anglican, and he bolstered his scientific reasoning with theological conviction. Although Thomson shared concern for God's place in the universe, he refused heat/motion reciprocity because it guaranteed complete conservation. Joule's 1847 lecture titled "On Matter, Living Force,

[178] Daggett, *The Birth of Energy*, 36.
[179] Smith, *The Science of Energy*, 79.
[180] Smith, 79.

and Heat," expresses a commitment to unity and conservation by uniting the equivalency theory with God's maintenance of natural forces. In Joule's universe, energetic conversions sustain regularity: "Thus it is that order is maintained in the universe – nothing is deranged, nothing ever lost, but the entire machinery, complicated as it is, works smoothly and harmoniously… the most perfect regularity preserved – the whole being governed by the sovereign will of God."[181] Here Joule can praise divine machinery as complicated yet harmonious, and thus write off any losses in his experimental data to complications beyond human comprehension. Thomson, on the other hand, allowed his God the ability to transfigure and destroy. There was no room for limitless conservation in that universe.[182] Smith and Wise describe two of Thomson's deepest commitments as "the universal rule of natural law within a material world created and governed by divine power, and… the progressive development of that world towards an inevitable end."[183] There was no end for Joule. If work or heat seemed lost, they were certainly restored somewhere else.

Moreover, Thomson derived his insights from political economy, as did many nineteenth century scientists. In his Cambridge engineering manual, for instance, William Whewell uses the labor theory of value to explain "laboring force," a term we would now define as the energy transferred to perform work. Whewell defines laboring force in two ways: first, as the agency producing the effects of change or movement; or, "work done

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[181] James Prescott Joule. *The Scientific Papers of James Prescott Joule* (London: Taylor and Francis, 1884), 273.
[182] This is a narrative I expand in chapter four.
[183] Smith and Wise, *Energy and Empire*, 317.

by labour."[184] Second, "*Labouring Force is the labour that we pay for.*"[185] By using the language of political economy to support his other, exclusively Newtonian, definition of this term, Whewell binds engineering examples ("to draw a carriage along a road, to bend springs, to move stones or masses of wood or metal"[186]) to economic examples ("Labouring force enters into the prices of articles produced by man"[187]). And, because the labor theory of value argues that we can price commodities using labor as an elemental unit, we can suppose that Whewell's definitional equivalency is literal.[188]

Another section of Whewell's text addresses the engineer's problem of inefficient labor. The method one chooses to do work is irrelevant, he claims, because laboring force is constant regardless of the approach taken. In physics, the term "displacement" typically trumps "distance" when we discuss work. This is because, for example, if I wish to push a large box from point A to point B, I have many choices of approaching my destination. I might push the box halfway to point B, return it to point A, and then push it all the way to point B. That choice seems ridiculous, of course, when I could push the box in a straight line from A to B. Though I cover a greater distance in my first trajectory, my displacement nevertheless remains constant. Additionally, I must apply more overall

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[184] William Whewell, *The Mechanics of Engineering* (Cambridge: Cambridge University Press, 1841), 145.
[185] Whewell, 148.
[186] Whewell, 145.
[187] Whewell, 148.
[188] Eighteenth-century and nineteenth-century political economists argued that, according to the labor theory of value, the value of commodities was objective. The basic unit for pricing commodities was therefore human labor. Under this model, value does not depend on how much time production actually takes, but rather on how much time production *should* take, given the level of productivity possible in society. We can directly connect this to the engineer's problem of displacement versus distance, where distance refers to how much ground an object has covered in its movement, whereas displacement is only the change in position. You can move back and forth one mile having a displacement of zero, for instance, if you end up where you started. Somewhat analogously, you might toil all day at a task requiring ten minutes of labor, but your additional labor does not increase the value of the commodity.

force to the box to take it on a longer journey, but the force *required* to simply move it from A to B never changes.

Whewell thus explains, "When a certain quantity of work is to be done, the labouring force which is requisite is the same, whatever be the mechanism by which it is done, except so far as the mechanism is bad, and consumes labouring force uselessly."[189] This is a problem for the engineer and the capitalist alike. In the engineering world, you certainly do not want to design systems that ask people to push boxes back and forth when they are energetically *required* to simply push boxes in straight lines. Inefficient box-pushing expends energy we might wisely use elsewhere, like additional box-pushing (in straight lines). Similarly, actual labor time does not change the value of a commodity because its price indicates only the labor socially necessary to produce it. Therefore, machines and workers who consume more than they output are operating at a loss; or, they expend more force than is necessary to cover the system's displacement. The direction of a process matters, and thus both Whewell and Thomson concerned themselves with matters of directional transformation, and with influence of efficiency on industry and market value. It is easy to see why Joule's limitless conservation has little place in this worldview.

We see how Whewell's *The Mechanics of Engineering* frames its language based not on isomorphisms but on physical equivalencies among energy, labor, and capital. In her discussion of Maxwell's "mathematical analogies," Barri Gold describes the contradictions of such sweeping generalizations: "At the same time it becomes

[189] Whewell, *The Mechanics of Engineering*, 148.

increasingly clear that we don't know what mechanical explanation means. Can we – should we – make claims that our explanations are actually descriptions? …And what does it mean when we do the math? Is that a description? An analogy?"[190] When dealing with objects too numerous to count, too far away to directly observe, or too tiny to access, how do our mathematical and representational aids participate in producing the knowledge we accept as truth? Ironically, attempts to describe energy in mechanical terms only generated figurative language. Carnot deliberately invoked images of waterpower when he described the "fall" of heat from high to low temperatures; but does heat literally fall? And if it does, as caloric theory claimed, how can it possibly transform into work, as Joule argued? That would require, per Carnot's analogy, somehow working against gravity to "fall up" the waterwheel.

We might object to such a literal equivalence. Heat and gravity, after all, do not operate identically. However, energy's fungibility suggested to Victorians that ostensibly separate entities like heat and gravity might literally fall subject to identical and consistent natural law. In the nineteenth century it was not uncommon to extend analogy into scientific truth claims. Physicist Balfour Stewart and astronomer Norman Lockyer took these analogies very seriously. In their article, "The Sun as a Type of Material Universe," Stewart and Lockyer argue that analogies among different branches of knowledge "ought to be not fictions but truths,"[191] a claim they evidence by using energy in the social world to explain energy in the physical world. "Energy in the social world is

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[190] Gold, *ThermoPoetics*, 119.
[191] Balfour Stewart and Norman Lockyer, "The Sun as a Type of Material Universe," Part II, *MacMillan's Magazine* 18 (1861), 319.

well understood," they observe, and so "[w]e shall venture to begin this article by instituting an analogy between the social and the physical world, in the hope that those more familiar with the former than the latter may be led to clearly perceive what is meant by the word ENERGY in a strictly physical sense."[192] Beginning with the premise that analogies are truths, Stewart and Lockyer use a variety of social class-based metaphors to both frame "energy" as a scientific term, surely for some readers to encounter for the first time, and to explain the two laws of thermodynamics.

According to Stewart and Lockyer, we can learn how energy operates in the universe by considering the dynamics of social position and individual initiative. A man's energy is "the power which he possesses of overcoming obstacles; and the amount of his energy is measured by the amount of obstacles which he can overcome, by the amount of work which he can do."[193] The analogy here, of course, is an object at rest overcoming inertia to move over a distance and perform work, not unlike Whewell's definition of laboring force. "Nevertheless," they continue, "such a man will sometimes be defeated by an opponent who does not possess a tithe of his personal energy. Now, why is this? The reason is that, although his opponent may be deficient in personal energy, yet he may possess more than an equivalent in the high position which he occupies, and it is simply this position that enables him to combat successfully with a man of much greater personal energy than himself."[194] Their physical-world equivalent of a man whose personal energy is overcome by social rank is a man who throws stones from the ground versus the

[192] Stewart and Lockyer, "The Sun as a Type of Material Universe," 319.
[193] Stewart and Lockyer, 319.
[194] Stewart and Lockyer, 319.

advantageous position of a rooftop. No matter how forcefully you hurl rocks from the ground, the opponent who simply drops a rock on you from above has every advantage.

In this analogy, there is no strict divide between physical position and social position. Even though the rooftop opponent lacks energy, "at some remote period a vast amount of personal energy was expended in raising the family into this high position. The founder of the family had doubtless greater energy than his fellow-men, and spent it in raising himself and his family into a position of advantage."[195] In other words, because an exceptionally energetic man propelled his family into a position of social privilege, his lazy descendent gets to drop a stone off of the roof with all the advantages of gravity. Because the article claims self-similarity between social and physical energies, relative physical position and relative social position are two manifestations of the same system.

We can also see how Stewart and Lockyer agree with Whewell's engineering manual. A man's having an abundance of personal energy does not guarantee that he will accomplish a great deal of work. To return to the box-pushing example, an energetic man might push boxes around all day through the same displacement as a man who stands still and then moves the box in a straight line. What's more, if his social position permits, perhaps he hires someone to move it for him and consequently expends no personal energy. Stewart and Lockyer therefore apply Whewell's economics-physics to the social domain.

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[195] Stewart and Lockyer, "The Sun as a Type of Material Universe," 319.

Thomson and Joule appear in the foreground of this article. Joule becomes the father of the conservation law, and Thomson the father of the law of "dissipation."[196] By 1868, when the article appeared in *MacMillan's Magazine,* Thomson had long since found a way to incorporate Joule's theory to his liking, but only after spending a year in dialogue with William John Macquorn Rankine, a Scottish mechanical engineer. Like the Thomsons, Rankine had practical training in steam machinery. In 1850, he introduced a paper which, among other things, argued that a "dynamical theory of heat" could explain the conversion of heat into work: the part of Joule's theory that Thomson did not yet accept.[197] The missing link was a modified version of Carnot's principle. Both Rankine and Thomson studied German physicist Rudolf Clausius's 1850 research on joining heat/work equivalence to an update of Carnot's original theory.[198] Rankine and Clausius, who both incorporated Joule's conservation principle and a new-and-improved Carnot, convinced Thomson that he could find experimental evidence for the conversion of heat into work. He found this evidence in steam engine boilers and felt satisfied.[199] Thomson was assembling evidence into a worldview he already held. Therefore, when Thomson carved out the two laws of thermodynamics, we should read the physics alongside its carefully-chosen language.

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[196] Stewart and Lockyer, "The Sun as a Type of Material Universe," 321-322.
[197] Smith, *The Science of Energy*, 105.
[198] Rudolph Clausius, *The Mechanical Theory of Heat, with Its Applications to the Steam-Engine, and to the Physical Properties of Bodies*, ed. T. Archer Hirst (London: John Van Voorst, 1867), 270-272. Clausius based his research on the axiom that heat cannot spontaneously move from a colder body to a warmer one.
[199] William Thomson, "The Dynamical Theory of Heat. (Selected Portions.) By William Thomson (Lord Kelvin.)," in *The Second Law of Thermodynamics: Memoirs by Carnot, Clausius and Thomson*, ed. W.F. Magie (New York and London: Harper & Brothers Publishers, 1899), 144.

What remained was for Thomson to formally synthesize his findings with those of Joule, Clausius, and Rankine. In early 1852, he presented a short series of papers to the Royal Society of Edinburgh, clarifying what he now called the "dissipation" of mechanical energy as a universal tendency in nature. As Joule demonstrated, energy was conserved in quantity; however, as steam engines evidenced daily, only God could restore that energy to a useful form.[200] It was therefore man's duty to harness and direct the energies available to ensure society's progress. "Whatever be the nature of these means [energetic agencies]," Thomson argued, "consciousness teaches every individual that they are, to some extent, subject to the direction of his will."[201] It was man's job to ensure these energies were "directed to produce the desired mechanical effects."[202] Thomson listed the forms of energy available on earth: food, heat, elevated positions, the movement of air and water, natural combustibles (e.g., wood and coal), and artificial combustibles (e.g., hydrogen and phosphorus).[203] All these resources owed their energy to sun, whose heat enabled all forms of mechanical potential through energetic transformation.[204] Poorly-directed transformation created energetic waste, but never altered the quantity of energy in the universe.

Having worked through this history, we now have two mid-nineteenth century thermodynamic laws. 1. All energy in the universe is conserved. Only the Creator may

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[200] William Thomson, "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy," *The Philosophical Magazine* 4 (1852): 304, HathiTrust.
[201] William Thomson, "On the Mechanical Action of Radiant Heat or Light: On the Power of Animated Creatures over Matter: On the Sources available to Man for the Production of Mechanical Effect," *The Philosophical Magazine* 4 (1852), 259.
[202] Thomson, "On the Mechanical Action," 259.
[203] Thomson, "On the Mechanical Action," 260.
[204] Thomson, "On the Mechanical Action," 260.

create and destroy energy. If we suspect that a system has lost energy, the missing amount will appear elsewhere and in a different form. 2. There is a universal tendency towards energy's dissipation. Energy transfers result in progressively less concentrated forms. Only the Creator may restore energy to its original concentration or position. Therefore, we must use our natural energy stores judiciously, directing each transfer to most productive outcome.

My explicitly theological second rendering of the thermodynamics laws also implicitly combines the transcendental logic of Whewell, Stewart, and Lockyer (among many others). Thomson selected the word, "dissipation," to describe the energetic tendency towards diffuseness; but dissipation was also a common nineteenth century term used to describe wasteful, unproductive, morally depraved, or frittered out individuals.[205] For example, Thomson's father wrote him a letter in 1842 disparaging a Glasgow student who was found "to have been attending the theatre and other amusements from night to night – to have been indulging in habits of dissipation."[206] The second law therefore attaches wasteful and morally degraded connotations to heat diffusion and power loss.

Thermodynamics' combination of circulation and directional transformation bound the sun and the earth's energy stores to a moral, even cosmological, imperative to "conserve" energy. This is the efficiency narrative we should recognize: efficiency means focusing energy wisely so that we may use available fuel sources without wasting them.

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205 "dissipated, adj.". OED Online. December 2019. Oxford University Press. https://www.oed.com/view/Entry/55494?rskey=WnAif7&result=2&isAdvanced=false (accessed February 03, 2020).
206 Smith, *The Science of Energy*, 124.

Efficiency also means minimizing loss to further expansion. Thomson intended for natural energy stores to assist Britain's progress as a nation, and energetic efficiency – social, economic, and mechanical – is vital to that vision. Because scientists assumed that unifying natural laws governed the social and material spheres, nineteenth-century infrastructural developments grew out of a moral imperative to identify and root out waste, and to capitalize on efficiency by maximizing growth and resource power. As we will see, urban recycling programs did not, in fact, reduce energy consumption. Instead, the industrial processes of reincorporating waste as serviceable materials increased overall fuel expenditure. London's rapid expansion required an efficient infrastructure for dealing with the dust and smoke from domestic hearths, as well as other waste products. However, improving the city's organization of refuse only permitted London's growth at the expense of its surrounding system.

DUST AS AN INDUSTRIAL RAW MATERIAL: URBAN RECYCLING PROGRAMS UNDER THE REIGN OF ENERGY

Nineteenth-century dust yards are perhaps best known for their appearance in Dickens's *Our Mutual Friend*, and for their representation in art. E.H. Dixon's 1837 painting of the dust heap at King's Cross[207] (Fig. 1) gives us a glimpse of this bygone phenomenon: a mountain of dust dwarfs buildings and merges with treetops. Tiny human figures labor at the foot of the mountain and on trails winding up its sides. Although art

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[207] E.H. Dixon, *King's Cross, London: the Great Dust-Heap, next to Battle Bridge and the Smallpox Hospital*, 1837, watercolour painting, 17.8 cm x 27 cm, Wellcome Collection. https://wellcomecollection.org/works/ssu37wed#licenseInformation.

and literature capture their aesthetic strangeness and almost sublime vastness, dust yards have not gone unnoticed by recent waste studies that examine the efficiency of the Victorian dust economy. One study even argues that Victorian waste processing serves as a model for private sector recycling in currently developing countries.[208] Besides this study's absurd stadial development assumptions, modeling London's dust recycling means that there is continued value in that model's methodology. I urge us to dispute these notions by pointing out how the sociopolitical foundations of thermodynamics underline the dust economy's efficiency fantasies. Modern recycling claims to confront climate change by reducing primary resource extraction; yet, when unpacked, we find that market mediated waste programs rely on distinctly Victorian ideas about energy.

Figure 1. "King's Cross, London: the Great Dust-Heap, next to Battle Bridge and the Smallpox Hospital," by E.H. Dixon, 1837, Wellcome Collection

[208] Costas A. Velis, David C. Wilson, and Christopher R. Cheeseman, "19th Century London Dust-Yards: A Case Study in Closed-Loop Resource Efficiency," *Waste Management* 29 (2009), 1288. https://doi.10.1016/j.wasman.2008.10.1018.

The system of recycling "dust," or generalized refuse collected from London homes, developed in response to changes in the market value of constituent waste products. Industrial processing used coal dust as a raw material for building resources like bricks, and for agricultural fertilizers. Some manufacturers incorporated non-coal refuse into various luxury commodities, including jewelry, dyes, soaps, and perfumes.[209] The system was profitable for London, whose population had surged in response to Britain's increased reliance on coal energy. More people in the city meant more domestic coal expenditure, leaving London to deal with the "nuisance" of smoke and coal dust. Since smoke was notoriously difficult to measure and govern, particularly because legislation did not regulate domestic smoke production, the smoke nuisance was ineffectively handled by those who argued that "the evolution of black smoke could be stopped with profit, simply by taking care to burn the coal scientifically."[210] Coal *dust*, on the other hand, could be swept up, collected, and thus regulated. Those with the startup capital therefore obtained permission from local parishes to collect the city's garbage and turn it into wealth.

Such dust contractors had already raked in fortunes by the time Thomson, Clausius, Joule, Rankine, and the rest of the early energy physicists arrived at a comfortable foundation for thermodynamics. However, just because energy laws did not prescribe the rules of dust does not mean that urban improvement infrastructures were not at work, mutually reinforcing energy logic and dust logic when thermodynamics did emerge. Written accounts of urban improvement and the new science of energy were

[209] "Out of the Dust-Heap," *Cassell's Magazine* 2 (1867): 474-475.
[210] Minutes of the Smoke Abatement Society, 1898, Wellcome Collection.

mid-century hits: popular periodicals published dust and energy narratives side by side while Dickens was gaining momentum for his last completed novel. Popularized accounts of energy science appear throughout the 1850s and 1860s in both of Dickens's weekly magazines, *Household Words* and *All the Year Round*. And, apparently enchanted years later by Richard Henry Horne's fanciful article in *Household Words*, "Dust; Or, Ugliness Redeemed," Dickens devised the premise for *Our Mutual Friend*.[211]

By examining how popular culture adopted energy science during this period, we can also see how recycling programs stand out as structures that actively reproduced an early thermodynamic worldview. At the same time, scientists continued to merge social and physical spheres, and they doubled down on the economic, moral, and cosmological connotations of Thomson's dissipation law. This section rounds out three argumentative threads, organized by subsection. I first explain the operations and basic economic structure of the nineteenth century dust yard; I unpack early thermodynamic logic from influential scientific and mainstream literature; and finally I extend these connections into what is now commercial recycling, an industry that continues to profit from thermodynamic contradictions. Current waste recovery programs rely on the vestiges of Victorian energy contradictions to perpetuate the infrastructure of fossil fuel capitalism.

[211] Heather Tilley, "Ashes to Cashes: The Value of Dust," *Dickens* Our Mutual Friend *Reading Project*, July 17, 2014, Accessed February 4, 2020, https://dickensourmutualfriend.wordpress.com/2014/07/17/ashes-to-cashes-the-value-of-dust/comment-page-1/.

The History of Refuse Is a Veritable Romance

The ability to turn a vast profit from other people's garbage began with London's coal dust problem: mass inward migration and population growth in London caused a boom in coal consumption, and the city's environment could no longer accommodate London's growth rate. Historians trace modern mass politics[212] and ways of living to industrial organizations of fossil fuel energy. England burned coal as early as the thirteenth century, but coal demand was modest and varied with timber availability.[213] Much earlier than that, agricultural civilizations around the globe had consumed fossil fuels for thousands of years. What we call the industrial revolution represents a watershed for energy's infrastructure because coal became a cheap natural resource during that period. Until the early nineteenth century, steam engines consumed more fuel than they could extract from England's water-filled coal mines; but after improved engines abetted mining and industrial iron production, England began to harness its network of waterways to cheaply transport coal. This self-reinforcing system of geography and industry is why, rather than superior technology or innovative ability, Britain's development "diverged" from other parts of the world such as China, Japan, and India.[214]

Coal abundance in Britain freed up agricultural populations whose land had previously supplied fuel and food. Unfettered by the seasonal and geographical limitations of waterpower, industry thrived in urban locations, where populations now grew dense. In this case two things happened. First, as labor forces turned increasingly to

[212] Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (London and New York: Verso, 2011), 12.
[213] Daggett, *The Birth of Energy*, 28.
[214] Kenneth Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton and Oxford: Princeton University Press, 2000), 32.

producing industrial goods, Britain relied on its peripheral territories for food and raw materials. As Timothy Mitchell explains it, "Coal made available thermal and mechanical energy in unprecedented quantity and concentration, but this energy was of no benefit unless there were ways to put it to work."[215] Without uncompensated labor and lifeways, Britain could not have sustained its growth nor, as we will see in chapter three, even claimed scientific developments like electromagnetic field theory. Second, cities needed to adapt to population growth by assembling the infrastructures of modernity. Urban improvement initiatives therefore subsumed energy science into plans for dealing with population growth and waste removal. Recycling programs, particularly dust contracting, committed to efficiency rhetoric by applying conservation in thermodynamics' first law in order to transmute the consequences of dissipation into fuel for still more growth. In other words, the dust economy did not conserve resources to limit expenditure; rather, it turned dust into a cheap raw material to further accumulation. And, the more London grew, the more dust there was to collect. Dust contracting became a very lucrative enterprise.

As Henry Mayhew famously describes them in *London Labour and the London Poor*, dust contractors were "generally men of considerable wealth."[216] Contractors bid for yearly rights to collect household waste, or "dust," from London's parishes. Emphasizing the urgency of waste collection, Mayhew explains the endlessness of coal production and dust removal: "Now the ashes and cinders arising from this enormous

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[215] Mitchell, *Carbon Democracy*, 16.
[216] Henry Mayhew, *London Labour and the London Poor*, 1850-52, 1861-62, Introduction and notes by Robert Douglas-Fairhurst (Oxford and New York: Oxford University Press, 2010), 193.

consumption of coal would, it is evident, if allowed to lie scattered about in such a place as London, render, ere long, not only the back streets, but even the important thoroughfares, filthy and impassable. Upon the Officers of the various parishes, therefore, has devolved the duty of seeing that the refuse of the fuel consumed throughout London is removed almost as fast as produced…".[217] The system profited the city by keeping its thoroughfares accessible to traffic, and by collecting the highest bids of contractors. In turn, contractors exploited market demands for raw materials and enjoyed an enormous profit margin until the dust market collapsed in the second half of the nineteenth century.

Still, dust needed an interim storage location, and it required massive amounts of manual processing to sort out its constituent elements. Contractors kept their dust on plots of land strategically located to minimize distance between collection sites and the Thames or canals, where barges could easily transport dust to various British and international destinations. The dust shown in Dixon's painting, for example, traveled as far as Russia, where it aided Moscow's reconstruction after the French invasion.[218] And, while accounts of dust yards make frequent use of words like "volcanic,"[219] "mountain-side,"[220] and "avalanche"[221] to illustrate the enormous scale of the mounds, nineteenth century authors also take care in parsing out the minutiae of dust's components, which ran the gamut from animal carcasses to silver spoons.

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[217] Mayhew, *London Labour and the London Poor*, 193.
[218] Richard Henry Horne, "Dust; Or, Ugliness Redeemed," *Household Words* 1 (July 1850): 384. Hathi Trust.
[219] Mayhew, 195.
[220] "At Mr. Boffin's," *Cassell's Magazine* 3 (1867): 136, HathiTrust.
[221] "At Mr. Boffin's," 135.

Dust work became an established profession for working-class individuals because coal ash needed to be carefully separated from other types of refuse. Such labor required dust workers to remain outside all day and in all seasons. There, exposed to the elements, they sifted out dust's oversized material (the "breeze") from its underflow (the "soil").[222] All other constituents had their own "departments": decomposing and other organic matter fell under "soft-ware," while "hard-ware" designated broken items which could be sold to make new roads.[223] Dust mounds also enticed scavengers who either already subsisted by recovering street objects or were seduced by the potential of finding someone's mistakenly discarded treasures.

The glamor of finding a will, precious metals, or a bank note hidden in mountains of garbage attached itself to middle-class narratives of dust work. These accounts foreground both the immense potential of dust to uplift and transform, and its equal power to degrade. Because Dixon's watercolor shows us how massive and incongruous the King's Cross dust heap appeared against London's modernizing landscape, it is easy to imagine these mounds as urban eyesores that confronted all Londoners. Strangely enough, middle-class accounts of dust heaps record them as hidden in plain sight. One Dickens fan and anonymous contributor to *Cassell's Magazine* ventures to the suburbs in search of a dust yard, hoping that doing so will conjure up fanciful imagery of Boffin's Bower. He and his party lose their way and ask suburban locals for directions. Once he does find a dust yard, it is apparently less charming than Dickens's dust: "After a

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[222] Costas A. Velis, David C. Wilson, and Christopher R. Cheeseman, "19th Century London Dust-Yards: A Case Study in Closed-Loop Resource Efficiency," 1283.
[223] Horne, "Dust; Or, Ugliness Redeemed," 380.

bewildering direction about 'turnings' to the right and left, we quitted the main road and plunged into a squalid region of half-demolished houses, where small trades seemed to flourish well amongst the dirt and filth around. Huge railway buildings were in progress here, and had evidently crept, glacier-like, over what must have been – what was – a very ant-hill swarming with London's poorer inhabitants."[224] Like a tourist in his own city, this author goes in search of "Mr. Boffin's." Instead, he gets lost in the labyrinthine streets of London's poorer quarters, and is overwhelmed by the sights and smells of the dust yard. Most of all, he is repulsed by the "swarms" of London's poor.

It is in the contrast between dust workers and the materials they process that middle-class dust narratives issue their most forceful thermodynamic language. The author of "At Mr. Boffin's" describes the directed transformation and dissipation he witnesses in the dust yard. Before cataloging the items that dust reincarnates, he proclaims that "there is no waste in Nature, and soon it may be repeated that there is no waste in Art."[225] On the other hand, the individuals of dust work are expressly *degraded* by their environment: "It is the human helps whose appearance most strikes the eye. Hair, skin, clothes – everything is of the ash, ashy; and as they toil on amongst the refuse, in appearance a more degraded looking set is impossible to conceive. There is something inexpressibly repulsive in seeing women and young girls engaged in such toil, a hundred times worse from its filth and surroundings than that of women in the farmers' fields."[226] The mountain in front of him, immense as it is, is somehow less arresting than the

[224] "At Mr. Boffin's," 135.
[225] "At Mr. Boffin's," 136.
[226] "At Mr. Boffin's," 138.

debasement of dust labor. And, as Tina Choi points out in her work on sanitary reform, waste objects climb the social ladder yet humans seldom do.[227]

Dust work was controversial labor for many middle-class observers. In her piece on "Dust-Women," Emily Hobhouse assesses the popular opinion that women were unfit for such unclean work.[228] Indeed, because Victorians believed that environmental conditions influenced social circumstances, one reason for the dust economy's decline was London's sanitary reform,[229] which gained momentum as the value of coal dust depreciated with decreased demand. Nevertheless, Hobhouse's language is laden with contradictions. "Dust-Women" cannot affirm whether dust work is salubrious for women, or harmful to their health and social prospects. The dust women are ruddy, sturdy, and bright-eyed, for instance, and Hobhouse contrasts their constitution with "the pallor and haggard looks of the ordinary London worker."[230] Yet, they also suffer from constant exposure to the elements, and from sore throat and eyes.[231] The dust erodes these women at the same time that it rejuvenates them; it dissipates them at the same time that it revitalizes them.

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[227] Tina Choi, "Radical Solutions, Conservative Systems: Narratives of Circulation and Closure," in *Anonymous Connections: The Body and Narratives of the Social in Victorian Britain* (Ann Arbor: University of Michigan Press, 2015), 89.
[228] Emily Hobhouse, "Dust-Women," *The Economic Journal* 10, no. 39 (September 1900): 418-420.
[229] Joanna Hofer-Robinson, *Dickens and Demolition: Literary Afterlives and Mid-Nineteenth Century Urban Development* (Edinburgh: Edinburgh University Press, 2019), 27.
[230] Hobhouse, "Dust-Women," 415.
[231] Hobhouse, 415.

Yet, somehow dust yards are glamorous. Hobhouse routes her own description through Dickens's imagery, which has transformed dust labor into a "veritable romance," despite its controversy:

> Since the days when we first learnt to love Mr. Boffin and wondered over the great black mounds from which the Golden Dustman's fortune sprang, a certain glamour has encircled a dust-yard, a feeling that unknown possibilities lie hid in a pile of rubbish. And this is literally true. The history of refuse is a veritable romance, and women play no inconsiderable part in its changing fortunes. Daily on her knees before the grate or with the dust-pan in the rooms, the housemaid begins the story, every member of the family adds something, though the largest contributions flow from the kitchen and the cook. Leaving the house in the decaying conglomerate of the dust-bin, this refuse matter dies temporarily to all use, then passes through the hands of women in the yards, and goes forth to fresh life and service unrecognised in resurrection clothes…wall-bricks and paving stones spring from the dust heap, even the glass the careless servant breaks journeys to Sweden, returning as neat squares of emery paper wherewith she may polish the fender. But the women who handle the refuse on the wharves see neither its beginning nor its end, they deal with it only at the worst and foulest moment of its history.[232]

Dickens's novel has apparently inspired Hobhouse's romantic fiction of urban recycling. It is a story where each individual contributes some labor along a figurative assembly line that begins with an object's death and terminates in its resurrection. Hobhouse uses active language to describe the refuse: it "springs" from the heap, journeying to Sweden and back. But the dust women remain node-like in this transaction, despite their integral position on the assembly line. They abet dust's transformation, but do not inject dust with its power to evolve.

There is something deeply contradictory, then, in both the aesthetics and the physics of recycling's romance. Hobhouse and the author of "At Mr. Boffin's" each pick up on this, if not consciously. In "At Mr. Boffin's," the workers are unambiguously

[232] Hobhouse, 412.

degraded while refuse acquires new social value; but the author of this piece still searches for the aesthetic romance of Boffin's Bower. Hobhouse cannot ultimately position the dust yard as a factor of dust women's personal degeneration, or of their ruddy health. However, she also uses Dickens to situate dust work in a sentimental fiction where dust women contribute to waste's social mobility, though they, themselves, are stationary actors in that network.

How can dust be both promoting and degrading? Why is it simultaneously glamorous and repulsive? Both of these middle-class accounts discuss the *potential* of the dust to become something else, or to reveal something hidden. For instance, glamor for Hobhouse is an index of the "feeling that unknown possibilities lie hid in a pile of rubbish." The notion that some otherwise decaying object lies hidden, awaiting human discovery, follows coal from its dormancy underground to its afterlife on the dust heap. Scientific literature at both expert and popular levels bolstered recycling's contradictions by situating them within energy's already ambiguous framework. While energy scientists underscored the national priority of keeping coal a cheap and available resource, popular science writers broadcast this gospel, publishing articles alongside middle-class urban improvement pieces.

Nature's Investment

So far, we have considered the contradictions of dust's economy. According to dust logic, private contractors transformed London's refuse back into resources that extended the city's limits to no apparent energetic detriment: they stretched the value of coal and virtually every other material Londoners discarded. Recycling allowed for seemingly unlimited consumption, permitting urban expansion. Additionally, some wastes were reincorporated into building materials used in London's improvement projects and its geographical enlargement. It is a logic driven by market demand and dismissive of the energetic requirements involved in transforming waste back into useful materials. For Victorians, however, the apparent interchangeability between the social and physical realms subsumed these systemic incongruities. The laws of thermodynamics, as Thomson framed them, urged mankind to use available stores of energy in wisely directed transformations. Failure to do so would be wasteful, in both the physical and moral sense. Mid-nineteenth century science popularized the notion of universal natural law, and it used the newly-minted scientific term, "energy," to emphasize coal's role in Britain's imperial success.

Nowhere is coal energy tied so explicitly to Britain's national greatness than in William Stanley Jevons's *The Coal Question*. Jevons published the book in 1865 to caution against exhausting Britain's coal reserves. The coal question is not of an existential nature, however, but of an imperial and economic nature. In the book's introduction, Jevons joins the word "energy" to force of matter and character. He first discusses coal as a commodity, describing it as "the material energy of the country – the universal aid – the factor in everything we do."[233] Later in the introduction he switches to the social, arguing that losing access to cheap coal reserves would be to "lose that which

[233] W. Stanley Jevons, *The Coal Question; An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-Mines* (London and Cambridge: MacMillan and Company, 1865), viii.

constitutes our peculiar energy";[234] or, that which distinguishes England in its essence. Somewhere in between these two assertions, Jevons merges the social and physical connotations of energy. The question of coal is equally moral and material: "England's manufacturing and commercial greatness, at least, is at stake in this question, nor can we be sure that material decay may not involve us in moral and intellectual retrogression."[235] Exhausting English mines may take hundreds of years, but even the possibility of halting progress casts a shadow of dissipation over what it means to *be* English.

This was a matter of great concern for Britain's most distinguished scientists. Two years before Jevons published *The Coal Question*, Sir William Armstrong delivered the Presidential Address to the British Association for the Advancement of Science. Citing Thomson's dynamical theory of heat as "probably the most important discovery of the present century,"[236] Armstrong applied the first law of thermodynamics to discuss coal's derivation from solar power;[237] and he chastised Britain for its wastefulness with reminders of the growing threat of powers like the United States.[238] Armstrong underlines efficiency in this speech, urging British scientists to make it a priority in their research. He reminds them: "The greatness of England much depends upon the superiority of her coal in cheapness and quality over that of other nations… Were we reaping the full advantage of all the coal we burnt, no objection could be made to the largeness of the

[234] Jevons, *The Coal Question*, xiv.
[235] Jevons, ix.
[236] Sir William G. Armstrong, "Opening Address," British Association for the Advancement of Science, Newcastle, 1863. Wellcome Collection, archive.org/details/b30558840. Accessed August 23, 2019.
[237] Armstrong, 3.
[238] Armstrong, 4.

quantity, but we are using it wastefully and extravagantly in all its applications."[239] Coal's being a limited resource is therefore not the issue. Some amount of Britain's potential is not, and never can be, ushered towards her progress. Efficiency as a principal, then, was of great moral and national consequence.

For Thomas Henry Huxley, failing to use coal industriously was like squandering an estate that Nature had invested in the eventual progress of mankind. His lecture, "On the Formation of Coal," is a history of coal development in the carboniferous period with a compound interest metaphor. Nature very deliberately deposits coal as principal and waits for a full return on her investment:

> The English people grew into a powerful nation, and Nature still waited for a full return of the capital she had invested in the ancient club-mosses… But what becomes of the coal which is burnt in yielding this interest? Heat comes of it, light comes of it; and if we could gather together all that goes up in the chimney, and all that remains in the grate of a thoroughly-burnt coal-fire, we should find ourselves in the possession of a quantity of carbonic acid, water, ammonia, and mineral matters, exactly equal in weight to the coal… She is paid back principal and interest at the same time; and she straightaway invests the carbonic acid, the water, and the ammonia in the new forms of life, feeding with them the plants that now live. Thrifty Nature! Surely no prodigal, but most notable of housekeepers![240]

Huxley ties coal directly to the destiny of the English people. He metaphorizes Nature and her investment, but there is more to his example than figurative language. Thomson's dynamical theory of heat requires merging cosmological, moral, and physical energies. Huxley's interpretation implies that coal left in the ground is an untapped and otherwise wasted resource. Combined with Armstrong's direction to prioritize efficiency, and

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[239] Armstrong, "Opening Address," 3-4.
[240] Thomas Henry Huxley, "On the Formation of Coal," 1870, in *Discourses Biological and Geological: Essays by Thomas H. Huxley* (New York: D. Appleton and Company, 1896), 159-161.

Jevons's reminder that coal fueled Britain's superior energy, these were clear messages issuing from the scientific community that to use natural resources without reaping their maximum potential for progress would be a national disgrace.

Such lessons were not lost on scientific popularizers. Both of Dickens's weekly literary periodicals informed the public of advancements in physics, including the laws of conservation and dissipation. One *All the Year Round* article reviews John Tyndall's book, *Heat Considered as a Mode of Motion*, and praises the new theory that has "recently arisen respecting the general energies of the universe."[241] The author claims, "Heat is one of those energies, and the connexion of this agent with the rest is such, that if we master it perfectly, we master all."[242] An explanation of the boundless interconversion of energies gives way to the wastefulness of the sun, whose heat can never be harnessed by man to its full potential.[243] These articles feature the sun as paradoxically a limitless source of power and a time-sensitive waste of heat, an unattainable source of energetic potential with an expiration date. While the reviewer of Tyndall's book balances energy's universality with its inevitable wastefulness, a different *All the Year Round* contributor uses theological overtones to efface human and nonhuman labor in energetic transactions. In describing the sun as a "Great Maker of all things,"[244] this author directly echoes Huxley's compound interest metaphor. Coal is "solar light and heat put into a savings-bank ages upon ages ago. It is power and action from the sun, imprisoned in the bowels of the earth. To us nineteenth centurians falls the lucky task of

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[241] "Is Heat Motion?" *All the Year Round* 13 (July 1865): 534, HathiTrust.
[242] "Is Heat Motion?", 534.
[243] "Is Heat Motion?", 536-37.
[244] "Might and Magnitude," *All the Year Round* 15 (March 1866): 256, HathiTrust.

making it our slave, by setting it at liberty from its primeval trammels."[245] By releasing the sun from its imprisonment and setting it at liberty, humans then paradoxically enslave the sun, which labors at our will.

Notice the removal of laboring bodies in these energetic transactions: "Your sugar is crystallised sunshine from Jamaica. Your tea, quinine, coffee, and spice, are embodiments of solar influences shed on the surfaces of China, Peru, and the Indian Archipelago… But how grand and beautiful is the theory that *all* material blessings here below come to us entirely and alone from the sun!"[246] The act of acknowledging solar power as the source of all raw materials and commodities is a maneuver that applies the authority of thermodynamics to erase uncompensated labor.[247] Workers, environments, and lifeways are actors in energy transactions, but they, themselves, are not viewed as sources of power. Each worker's individual action generates some consequence, but priority is placed on whether the system, that is the nation, can grow efficiently.[248] In *Household Words*, another article mirrors this system-focused urgency by explaining, "the mechanical equivalent of heat has taught us that we burn twenty times too much coal in the furnaces of our present steam-engines, and that we must invent others on a new

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[245] "Might and Magnitude," 256.
[246] "Might and Magnitude," 256.
[247] The erasure of uncompensated labor is a notorious problem with energy as metaphysics. See Brent Ryan Bellamy, Stephanie LeMenager, and Imre Szeman, "When Energy Is the Focus: Methodology, Politics, and Pedagogy," *Postmodern Culture* 26, no. 2 (2016). https://doi.10.1353/pmc.2016.0004. Stephanie LeMenager identifies the problem of recovering laboring bodies of all kinds as part of the focus of Energy Humanities.
[248] Rabinbach, *The Human Motor*, 49. Workers' bodies were subsumed under the same universal laws of energy and society that nineteenth century scientists used to qualify and quantify mechanical systems. "Labor power" was a way of measuring the conservation principle and the principle of fatigue across mechanical and biological systems. However, I emphasize the primacy of systems over individuals here because, as Rabinbach also points out, fatigue studies often intended to maximize the individual's efficiency in order to increase overall production. In short, "Labor power represents the quantitative aspect of labor under capitalism" (74).

plan."[249] To this author, the universe is a great organism without rest: always transferring energies ceaselessly, even when our surroundings appear still. Beneath the surface, the universe is "a living creature, its heart never ceases to beat, nor the lifeblood to flow in its minutest veins."[250] Here, energy becomes the metabolism of the universe.

Situating a dynamic cosmos within the terms of organicism helps us understand energy's social and physical implications, particularly where waste is concerned. Cara Daggett argues that energy and metabolism were intertwined from their simultaneous inception in the 1840s.[251] Crucially, both thermodynamics and organicism embedded social theory into core tenets. Like the author in *Household Words* who describes energy as the lifeblood of the universe, social theorist Herbert Spencer insists that an organism's growth depends on blood's circulation to vital organs, and to the expulsion of waste. In his 1860 essay, "The Social Organism," Spencer argues that society operates under the same "principles of organization" as biology, due to self-similarity in nature.[252] In society, then, waste is a byproduct of growth, and should be handled accordingly.

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249 "Physical Force," *Household Words* 19 (March 1859): 355, HathiTrust.
250 "Physical Force," 354.
251 Daggett, *The Birth of Energy*, 115.
252 Herbert Spencer, "The Social Organism," in *A Series of Discussions* (New York: D. Appleton and Company, 1883), 401. Spencer argues that his analogy between the social organism and the biological organism sustains because "The *principles* or organization are the same; and the differences are simply differences of application."

As long as an organism has access to resources for growth and repair, it should not need to worry about the waste it produces:

> That any organ in a living being may grow by exercise, there needs a due supply of blood: all action implies waste; blood brings the materials for repair; and before there can be growth, the quantity of blood supplied must be more than that requisite for repair.
> So is it in a society…a certain expenditure and wear of the manufacturing organization are incurred; and if, in payment for the extra supply of woolens sent away, there comes back only such quantity of commodities as replaces the expenditure, and makes good the waste of life and machinery; there can clearly be no growth.[253]

According to Spencer, waste is only bad if it inhibits the growth of the social organism. Society's excreting or removing waste will benefit a nation just as it benefits an organism. But, as Daggett points out, what it means to benefit the social organism is tied directly to the nation's imperial health. She explains, "when faced with evidence that the imperial organism might not be healthy – urban smog, workers' intransigence, rampant disease in the new urban slums – it was more comfortable to tinker with waste processing than it was to question work and energy maximization itself."[254]

This helps clarify why we find so much ambiguity in dust labor. Under energy logic, dust workers responsibly transformed what would otherwise be wasted resources. At the same time, workers were subjected to a degrading and dissipative environment. As participants in waste's transformation, dust workers' bodies were sites of energetic transaction, and thus were seen as either beneficial promoters or fatigued components in a universal social-mechanical system. Ultimately, though, their individual bodies mattered

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[253] Herbert Spencer, "The Social Organism," 414.
[254] Daggett, *The Birth of Energy*, 118.

less than their composite contributions to waste recovery, particularly because, as Spencer analogizes, the nation benefits in aggregate from each individual's efficiency.

Private dust contractors benefited from these contradictions. London's transition to infrastructural modernity would assist Britain's imperial growth, and London could never sustain its population increase and maintain its position as England's center of commerce without removing its coal dust. So, contractors rode the markets for constituent waste materials while also benefitting from thermodynamic implications that recycling was morally responsible and energetically sustainable. The thermodynamic laws, of course, do not actually evidence dust recycling as a sustainable practice. In fact, the industrial processes required to convert waste into new forms required vast fuel consumption, which created even more dust, smoke, and – as we now know – greenhouse gas emissions.[255] Crucially, though, the way the laws were framed and applied buried these material realities, the consequences of which we continue to live with.

The Literature of Modern Recycling

The dust economy was more concerned with the value it might extract from London's waste, and from the potential benefits this might bring to London's infrastructural changes, than it was with its overall contribution to global damage. Allen MacDuffie argues that urban energy consumption was a question of narrative: what story did the Victorians tell "to make sense of the city's massive and growing expenditure," and is it possible to square that story with "the more teleological narrative of historical development and Providential design"?[256] Although mid-to-late century London seemed to some like a magnificent waste of energy, infrastructural and technological changes promised to contain those losses and direct energy transfer towards Britain's health and growth. The fictions we tell, and the narratives we craft for our experiences of living in the world, help shape what our built environment becomes. And, the more we live in that reality, the more we accept it as universal truth.

Twenty and twenty-first century recycling has its own literature that narrates our experience of waste removal and shapes the infrastructures of modern space. Recently published recycling literature retains elements of the nineteenth century dust economy, and current industrial standards even draw on contradictory energetic language to mask their environmental violence and to leverage recycling's market value. Industrial ecologists have been critical of commercial recycling by showing how we take for granted that recycled materials displace primary material production; that recycling many times is preferable to recycling once; and that there is a rigid distinction between what the industry calls "open-loop" and closed-loop" recycling. All three are misconceptions.[257]

Modern recycling is regulated by technical standards produced by nongovernmental and global mega-organizations such as the International Organization for Standardization (ISO). By controlling technical standards, including those of recycling, ISO has steadily and consistently governed the infrastructure of modern

[256] MacDuffie, *Victorian Literature, Energy, and the Ecological Imagination*, 60.
[257] Roland Geyer, Brandon Kuczenski, Trevor Zink, and Ashley Henderson, "Common Misconceptions about Recycling," *Journal of Industrial Ecology* 20, no. 5 (2015): 1011.

spaces.[258] Commercial recycling must follow ISO 14040, the "Life Cycle Assessment," which is a standard available for purchase only.[259] ISO profits from a virtually ubiquitous enforcement of their standards, and private organizations benefit from ISO's market-driven structuring of infrastructural space. As industrial ecologists point out, ISO's language for recycling reinforces the notions that there is an equivalency between recycled and primary materials, and that the environmental impacts of reprocessing are smaller than those of initial production.[260]

This is a misconception that even Jevons demystified. *The Coal Question* is clear that increased industrial efficiency exacerbates resource exhaustion.[261] We don't use less primary material when we recycle, or when industrial processes are more efficient. Jevons's concern was simply that we extract more economic value from the coal we use. In fact, this counter-intuitive characteristic of efficiency is sometimes called the "Jevons paradox,"[262] loosely defined as the way in which the energy and money saved by efficiency measures are used up on even more exhaustive activities. For example, we might purchase a fuel-efficient car and then drive it three times as far as we normally drive. We have seen that recycling is not exempt from this logic.

Today, part of the problem is ISO's divide between open and closed-loop recycling processes. In the former, products are converted into raw materials distinct

[258] Keller Easterling, *Extrastatecraft: The Power of Infrastructure Space* (London and New York: Verso, 2014), 171.
[259] "ISO 14040:2006 Environmental management – Life cycle assessment – Principles and framework," 2016, Accessed February 4, 2020. https://www.iso.org/standard/37456.html.
[260] Geyer, Kuczenski, Zink, and Henderson, 1010-1011.
[261] Jevons, *The Coal Question*, xiv.
[262] Gavin Bridge et al. *Energy and Society: A Critical Perspective* (London and New York: Routledge, 2018), 163.

from the pre-recycled commodity, in addition to some unrecoverable waste. In the latter, pre-recycled materials become the same or similar products after recycling. Life Cycle Assessment literature reinforces the sustainability of closed-loop logic, despite its failure to generate less waste than open-loop processes. In short, commercial recycling is market mediated, which means that recycling does not take place without profit motive; and primary production does *not* decrease as recycling increases.[263] Even state-run waste collection and recycling are influenced by the market forces of competitive bidding of contracting firms. Local governments often arrange contracts with private firms to provide waste processing service for a municipality.[264]

From the description above, it is clear that the Victorian dust economy was not a closed-loop recycling operation. However, it sustains as a model for waste management resource efficiency. In the journal *Waste Management*, for example, dust yards are praised as closed-loop systems: "Many non-governmental organisations (NGOs) regard 'zero-waste' as the ultimate goal of 21st century management… The 'dust-yard' waste management system in London in the early 19th century is one example that has approached this modern goal; it could be described as an example of 'closed-loop,' city-wide industrial symbiosis."[265] We know that dust yards did not function as ISO-specific closed loops, nor do closed loops prevent overall energy expenditure. Therefore, we should ask what is at stake in a loop's containment: energetic or economic waste?

[263] Geyer, Kuczenski, Zink, and Henderson, "Common Misconceptions about Recycling," 1011.
[264] Margaret Walls, et al. "Private Markets, Contracts, and Government Provision: What Explains the Organization of Local Waste and Recycling Markets?", *Urban Affairs Review* 40, no. 5 (May 2005), 592-93.
[265] Costas A. Velis, David C. Wilson, and Christopher R. Cheeseman, "19th Century London Dust-Yards: A Case Study in Closed-Loop Resource Efficiency," *Waste Management* 29 (2009), 1288. https://doi.10.1016/j.wasman.2008.10.1018.

As we have seen, in the nineteenth century there was little distinction. This is why these contradictions today are so troubling. BP can claim to reduce waste production by diverting currently unrecyclable plastic from the fate of landfills or incineration without disclosing the energetic requirements of their process or those of the other industrial processes in their consortium. Instead, they describe their motivation as moving from a linear to a circular economy: "We're keen to support the move to a circular economy, where everything is kept in a closed-loop system and waste is vastly reduced… We want to see plastics kept in the loop and used again and again."[266] The term, "circular economy," is troubling here because, while the circulation of plastic goods into other similar or identical plastic goods is circular, nothing else about BP's Infinia is contained, energetically speaking. Moreover, BP profits materially and ideologically from this system. In a world where fear of climate change drives many of our choices, fossil fuel companies increasingly market themselves as "eco-friendly" options for consumers who do not wish to give up modernity's comforts, but who want to care about the environment.[267]

We therefore need to be prudent about the stories we tell, or at least become more aware of their power to obscure some realities and reinforce others. This is true for the literature of energy's infrastructure, and for infrastructures represented in our most

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[266] "Helping to Reduce Plastic Waste," BP.com, January 23, 2020, https://www.bp.com/en/global/corporate/news-and-insights/bp-magazine/rita-griffin-coo-petrochemicals-on-bp-infinia.html.

[267] BP has a history of greenwashing its advertising campaigns for just this purpose. The "Beyond Petroleum" campaign in the mid-2000s was hugely successful until the 2010 Deepwater Horizon explosion in the Gulf of Mexico exposed the violent policies beneath BP's eco-benevolent advertising. See Miriam A. Cherry and Judd F. Sneirson, "Beyond Profit: Rethinking Corporate Social Responsibility and Greenwashing after the BP Oil Disaster," for a study of how American corporate law governs massive organizations like BP.

popular literatures. We have already seen how writers' appropriation of Dickens's dust yards produced romantic notions of waste recovery, even if they remained laden with the contradictions of thermodynamics. But, although *Our Mutual Friend* may have popularized the dust economy, it is also conscious of the wastefulness of modernizing London, and of how the mythology of dust, and of efficiency, developed unequally in the imaginations of London's different classes. Dickens's text, itself, offers a deeper and more complex critique of waste and energy than do the images associated with *Our Mutual Friend* that have circulated and endured in popular culture.

UNSTABLE ENERGY NARRATIVES IN *OUR MUTUAL FRIEND*

Popular science articles in the 1850s and 1860s show us that the energy concept had been percolating in the Victorian cultural imagination for roughly a decade before Dickens published *Our Mutual Friend*. Applications of the term, "energy," in this novel are deliberate and even scientific, such as when Sloppy "transfer[s] his energy to the mangle"[268] in Betty Higden's cottage. Although Dickens was not a scientist, nor did he dedicate himself to the study of scientific concepts, *Our Mutual Friend* demonstrates an insightful understanding of basic nineteenth-century thermodynamics. At the very least, Dickens kept up to date on scientific matters published in the periodicals he managed;

[268] Charles Dickens, *Our Mutual Friend*, 1863-1865, edited by Adrian Poole (London: Penguin Books, 1997), 202. Citations refer to the Penguin edition.

and, in the late 1860s he served a term as president of the Birmingham & Midland Institute,[269] a seat filled two years later by Thomas Henry Huxley.

"Energy" in *Our Mutual Friend* is a scientific term that retains all the layers of energy as a personal quality, a moral force, and an economic unit. Returning to the example of Sloppy and his mangle, the motive power to drive the mangle comes from "a polysyllabic bellow" whose momentum he transfers directly to the machine, turning it so energetically with this force of emotion that it takes "several penitential turns before he [can] be stopped."[270] Sloppy converts emotional force into motive force, indicating Dickens's understanding of the laws of conservation and energy conversion, as well as their transferability among social and physical registers. It also seems that Dickens applies the logic of Thomson's directed energy transfer. Instead of allowing his emotional energies to dissipate, Sloppy directs them into a mindful transfer, turning the mangle for Betty. This is a comical rendering of efficiency, but Sloppy and his mangle bear out many of the same considerations as those found in thermodynamics literature. Sloppy arguably, if subtly, satirizes the kind of efficiency rhetoric in nationalistic scientific treatises like Jevons's *The Coal Question* and Armstrong's BAAS address.

Because energy appears so prominently in *Our Mutual Friend*, and because the novel centers the dust economy as a foil to the tenuous "Economy of Shares," many have interpreted the novel as a system of closure and material containment, particularly adjacent to sanitary reform. Such readings rely heavily on the first law of

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[269] British Association for the Advancement of Science. Papers. Bodleian Library. University of Oxford. Parliament established the Birmingham & Midland Institute in the 1850s to make matters of science, literature, and art accessible to residents of Birmingham and Midland.
[270] Dickens, *Our Mutual Friend*, 202.

thermodynamics. Tina Choi, for instance, argues that the mid-Victorian aesthetic of closure in social novels mimics the processes of recovery and transformation in *Our Mutual Friend*.[271] Human characters and nonhuman waste endure transformations where new forms of being contain elements of the past. Choi argues that such transformations impart "a sense of legibility and finitude characteristic of the closed circle, the narrative space within which we as readers are allowed to imagine possible outcomes and alternatives."[272] In a very different reading, Jesse Oak Taylor examines the way *Our Mutual Friend* models the economy of smog. He argues that, whereas one part of the novel concerns itself with the "material substance of objects dematerialized by the exchange values of the marketplace,"[273] another part "attempts to recoup the refuse of the metropolis, both human and otherwise."[274] Therefore, waste is a source of material wealth, whereas London's banking and commerce produces wealth that, like smoke, is a type of immaterial waste.

Considering Dickens's power to cultivate or alter public reception of London – its society, its class dynamics, and its infrastructures – this section is concerned with Dickens's representation of efficiency in London's social and physical infrastructures. I argue that Dickens displays a thorough understanding of efficiency and its cultural urgency, but that *Our Mutual Friend*'s treatment of thermodynamic and efficiency imagery are unstably represented. The novel, itself, embeds more critique of these

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[271] Tina Young Choi, "Radical Solutions, Conservative Systems: Narratives of Circulation and Closure," in *Anonymous Connections: The Body and Narratives of the Social in Victorian Britain* (Ann Arbor: University of Michigan Press, 2015), 99.
[272] Choi, "Radical Solutions," 99.
[273] Taylor, *The Sky of our Manufacture*, 44.
[274] Taylor, 59.

structures than did the imagery the readerly public attached to the novel. “At Mr. Boffin’s” is an example of the latter, as is “Dust-Women,” because both pieces preassign dust work with an aura of romance, linking the fantasy of waste recycling to *Our Mutual Friend*. The public reception of Dickens’s fiction was even potent enough to transform built environments. Urban development historians have linked Dickens’s descriptions of slums to actual demolitions of those areas.[275] Fictions were so powerful, and Dickens’s especially so, because they “provided a symbolic vocabulary that later users appropriated to identify, categorise and explain why specific areas should be improved.”[276] The energy concept (and its adjacent efficiency narrative) is conducive to fictional interpretations of mid-century London because, like Dickens’s prose, it relied on figurative language to describe the mechanics of daily life.

We have already seen *Our Mutual Friend*’s influence on middle-class depictions of dust yards. Judging from those accounts, we might say that Dickens’s mythology of dust cast an aura over urban recycling, and spectators of dust work found themselves unable to reconcile their expectations with what they actually encountered. In some respects, this is true. However, while Dickens’s imagery provided a common grammar for readers to employ when talking or writing about London, *Our Mutual Friend* gave them a massive choice of imagery to pick from. Allen MacDuffie argues that the novel “resides on the very fault line of these conflicting notions of energy transformation,”[277] which is why critics tend to read the novel as a model of containment despite its

[275] Anthony S. Wohl, *The Eternal Slum: Housing and Social Policy in Victorian London* (Montreal and London: McGill-Queen’s University Press, 1977), 11.
[276] Joanna Hofer-Robinson, *Dickens and Demolition: Literary Afterlives and Mid-Nineteenth Century Urban Development* (Edinburgh: Edinburgh University Press, 2018), 4.
[277] MacDuffie, *Victorian Literature, Energy, and the Ecological Imagination*, 115.

simultaneous interest in waste and lavishness. For example, the charm of Boffin's Bower and the exceptional circumstances of the multiple Harmon wills do elevate the intrigue of dust in *Our Mutual Friend*, but they do not support dust contracting as a model of efficiency. And, although new life, resources, and identities seem to spring magically from the Thames, the novel goes out of its way to describe the labor involved in waste's transformation, and the wastefulness involved in striving for or perpetuating efficiency around London.

Starting with Dickens's descriptions of London's ongoing and often chaotic improvement projects, I point out the wastefulness of efficiency-driven transformations of the urban landscape, and the confusing temporalities nested in the narrative of linear progress. Like Stewart and Lockyer, Dickens uses physical and social position as markers of energetic state. However, Dickens seems to satirize, or at least play with, many of the same analogies that Stewart and Lockyer rely on to popularize the word, "energy," as a scientific term. The last part of my argument explores Dickens's mythology of dust. The notion of dust work seems like "a veritable romance" when Mortimer Lightwood enchants the Veneerings and their dinner guests with the legend of the "Man from Somewhere"; but *Our Mutual Friend* also dedicates detailed passages to the labor of waste recovery and the disappointment of dust's failed potential. I argue that Dickens's dust is never a symbol of unproblematized efficiency.

In many ways, *Our Mutual Friend* is about infrastructural change and the energetic systems that assist or inhibit London's modernity-in-progress. The novel's first paragraph is one sentence only, placing Lizzie Hexam and her father between two bridges, and indeed between temporalities: “In these times of ours, though concerning the exact year there is no need to be precise, a boat of dirty and disreputable appearance, with two figures in it, floated on the Thames, between Southwark Bridge which is of iron, and London Bridge which is of stone, as an autumn evening was closing in.”[278] Not only is the narrator deliberately vague concerning precise markers of period, but the histories of the bridges in question rupture the story of modernity’s linearity. Next to iron, which signals England’s coal availability and progress, stone feels like an ancient building material. Indeed, London Bridge had been, until the nineteenth century, a medieval structure that governed traffic on the Thames. But by the time of *Our Mutual Friend*’s publication, London Bridge had thirty years prior been dismantled and rebuilt.[279] The iron Southwark Bridge was constructed in the early nineteenth century and was therefore older than the new London Bridge.

By placing Lizzie and Gaffer Hexam in between these two structures, the novel opens with imagery that confuses the reader about what is new building material and what is old, what is old London and what is modern London. Such imagery immediately sets a thematic tone for the remainder of *Our Mutual Friend*: humans and materials occupy ambiguous energetic positions. The dust economy makes old materials “new,” but the question of newness complicates teleology. Recycling does not simply restore objects to newness in this novel. Like the new stones of London Bridge, the “newness” of dust’s recycled materials is layered with age and decay.

[278] Dickens, *Our Mutual Friend*, 13.
[279] Ben Johnson, “Remains of the old London Bridge,” *Historic UK*, November 15, 2015, https://www.historic-uk.com/HistoryMagazine/DestinationsUK/Remains-of-the-old-London-Bridge/.

The Hexams' boat floats between London Bridge and Southwark Bridge, but we do not know in which direction it points or if it is indeed going anywhere. Instead, it merely floats between two structures, hinting that London is in a transition period, but not quite a linear one. Dickens wrote *Our Mutual Friend* during construction of the Thames Embankment, when London was indeed in transition. Lizzie and Gaffer Hexam's boat also represents a way of life that was disappearing with London's improvement projects. After completion of the Thames Embankment, "the river would enter the city only on the city's terms, flowing between banks of concrete lined with gaslights and promenades and thus becoming a facet of the urban built environment."[280] But to Londoners, development was slow and chaotic. Unlike Haussmann's renovation of Paris, London's reconstruction was characterized by competing administrative structures, especially prior to the centralization of projects under the Metropolitan Board of Works.[281] Dickens's London revealed wastelands of liminal spaces where old London and modern London merged without regard to linear progression.

Dickens's imagery questions what it means to be "new" in London – new material, new money, new neighborhoods, new identities – when New London, itself, is a palimpsest of temporalities. Dust further destabilizes the boundaries between potential and exhaustion, newness and age because of its protean transformability, and its overwhelming filth. Moreover, before dust workers supplied the energy to sift, sort, and cart dust off to its next life, it sat stagnant on vast plots of land and rotted. The most famous description of suburban wastelands in *Our Mutual Friend* occurs as R. Wilfer

[280] Taylor, *The Sky of Our Manufacture*, 60.
[281] Hofer-Robinson, *Dickens and Demolition*, 22.

commutes back to his home in the Holloway district after work: "His home was in the Holloway region north of London, and then divided from it by fields and trees. Between Battle Bridge and that part of the Holloway district in which he dwelt, was a tract of suburban Sahara, where tiles and bricks were burnt, bones were beat, rubbish was shot, dogs were fought, and dust was heaped by contractors."[282] Here, R. Wilfer passes through a landscape not unlike that in Dixon's watercolor, which also locates its dust heap next to Battle Bridge. A "Sahara" of dust does not conjure images of productivity in the dust yard, but rather images of barrenness. The dust yard appears among other wasteful plots of land where morally degenerate activity thrives.

An 1866 article in *All the Year Round* echoes Dickens's suburban desert imagery almost exactly. The author of "Attila in London" bemoans London's improvement projects and slum demolitions, which were designed to streamline mobility and quash illicit slum activity, yet which also displaced working-class families:

> "Wonderful improvements going on everywhere, is the complacent cry as we save five minutes in a cab-ride, or are carried smoothly underground from one suburb to another. Yet many of these improvements have occasioned as much misery as a war, have brought sorrow to as many families as a pestilence, and have made the necessaries of life as unattainable as in a famine… Leaning over the narrow parapet, I see the same picture duplicated right and left. Everywhere roofless ghastly ruins, only varied by vast Saharas of brickdust, old building materials, and a repetition of the shapeless heaps of rubbish."[283]

Here, as with the description of R. Wilfer's commute, vast tracts of London's landscape are either deserts or ruins, patterns of decay amid the city's wonderful transformations elsewhere. The author is frustrated by the repetition of unequal development, the

[282] Dickens, *Our Mutual Friend*, 42.
[283] "Attila in London," *All the Year Round* 15 (May 1866), 466-467. HathiTrust.

patchwork of waste among London's modernization, and by the power of improvement projects to transform lives so unequally. The "repetition of the shapeless heaps of rubbish" and the "roofless ghastly ruins" left in the wake of modernization might have been pulled straight from *Our Mutual Friend*, where Dickens also contrasts London's transportation network with "the ragged sides of houses torn down to make way for it."[284]

Despite these connotations of moral and physical wastefulness, Dickens also gives us a more charming vision of a dust landscape by introducing Boffin's Bower. Nicodeus Boffin's nickname, the "Golden Dustman," figuratively turns dust into a symbol of wealth and moral worthiness. Mr. Boffin earns his nickname after John Harmon, Sr., the "growling old vagabond,"[285] dies and wills Boffin an enormous dust fortune upon the assumed death of his son. Whether Mr. Boffin is golden because he has suddenly acquired vast wealth, or because he is of sound morality, is a point of ambiguity. We are meant to like Mr. and Mrs. Boffin, who lovingly, if ironically, preserve Old Harmon's decaying house in its state of ruin for his son's return.[286] To Mr. Boffin, the dust mounds are beautiful. Unlike the mounds which scar the landscape of R. Wilfer's commute, Boffin believes the mounds add texture and beauty to the neighborhood. When he discusses the possibility of selling the dust, Boffin explains to Rokesmith, "I may sell *them*, though I should be sorry to see the neighbourhood deprived of 'em too. It'll look but a poor dead flat without the Mounds. Still I don't say that I'm going to keep 'em always there, for the sake of the beauty of the landscape."[287]

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[284] Dickens, *Our Mutual Friend*, 731.
[285] Dickens, 24.
[286] Dickens, 184-85.
[287] Dickens, 186.

Although Boffin earnestly believes in the beauty of dust, Dickens seems to take a more facetious position. In *Our Mutual Friend*, as was the case in nonfictional mid-century London, new structures are already decaying. The beautiful new landscape might as well be made of dust heaps: neighborhoods under construction promise to rejuvenate Old London, but are, of themselves, just heaps of trash. Bradley Headstone's school is situated in such a neighborhood, decaying before its construction has finished:

> The schools were newly built, and there were so many like them all over the country, that one might have thought the whole were but one restless edifice with the locomotive gift of Aladdin's palace. They were in a neighbourhood which looked like a toy neighbourhood taken in blocks out of a box by a child of particularly incoherent mind, and set up anyhow; here, one side of a new street; there, a large solitary public-house facing nowhere; here, another unfinished street already in ruins; there, a church; here, an immense new warehouse; there, a dilapidated old country villa; then, a medley of black ditch, sparkling cucumber-frame, rank field, richly cultivated kitchen garden, brick viaduct, arch-spanned canal, and disorder of frowziness and fog. As if the child had given the table a kick, and gone to sleep.[288]

London's construction projects aimed to reorganize the city around principles of efficiency. The repetition of the school's evidently shoddy construction indicates plans to standardize structures, thereby easing architectural labor. More efficient movement of people and goods would allow for more production and consumption as the city expanded its population and perimeter. Widening thoroughfares and demolishing old, labyrinthine streets were supposed to relieve traffic congestion and encourage London's growth as the commerce capital of the world. The dust economy implicitly contributed to London's reorganization by removing domestic waste and subsequently injecting its constituents back into production, partially as building materials for London's

[288] Dickens, *Our Mutual Friend*, 219.

demolitions and renovations. Dickens mocks urban planning in this passage, comparing it to the whims of a child and the chaos of his scattered toy blocks. Before construction has finished, the new structures are already in ruins.

Londoners bemoaned similar issues as they wrote about the supposed improvements in their city. For many, London's poor planning and execution threatened national growth. One architect and engineer correlates wider roads with accumulation, arguing, "As the strength of a chain depends on its weakest link, so the value of a thoroughfare must be measured by its narrowest straight… The obstruction of traffic, with consequent loss of time, has become more than a nuisance; it threatens to become a national loss, unless some decided steps are taken for relieving the rising tide of City street traffic, which each annual increase of surplus capital tends to swell."[289] The efficiency narrative is at the forefront of this writer's argument. London's growth simply cannot continue without streamlining mobility for people and goods. Unlike this author, Dickens is not denouncing failed urban improvement as the bottleneck of London's, and indeed Britain's, expansion. However, it is clear that he recognizes the irony of infrastructures aimed at efficiency that degrade London's power to grow and thrive. In the case of social position, too, Dickens seems to acknowledge the energetic crime of dissipation, and also to relish its extravagance.

Recall that Balfour Stewart and Norman Lockyer's "The Sun as a Type of Material Universe" analogizes physical and social position to describe energetic systems. Dickens, too, relies on figurative language to explain and intermingle physical and social

[289] "Mending the City's Ways," *All the Year Round* 15 (July 1866), 613-14.

energetic positions. There is no way that Dickens could have encountered Stewart and Lockyer's piece in *MacMillan's Magazine* before or during his writing *Our Mutual Friend*,[290] but, as we have seen, the tactic of using analogy to describe universal truth was not exceptional. Some scientists were more careful than others to fortify, or at least acknowledge, boundary distinctions between subjects of analogy. Many, however, used energy's fungibility to argue that meaning could be transferred universally across all systems. Even in *Household Words*, science popularizers went so far as to claim that "The fundamental and radical unity of all the natural forces promises even to supply a bridge which shall enable us to make a road across that profound gulf which yawns between physics and metaphysics."[291] It is safe to assume that Dickens was familiar with Victorian truth claims that relied on analogies between different branches of knowledge.

Dickens plays with energetic state and position throughout *Our Mutual Friend*, yet physical and social energies are particularly reciprocal in his contrasting descriptions of Eugene Wrayburn and Bradley Headstone. Wrayburn and Headstone may as well have emerged from Stewart and Lockyer's article to perform the social examples they use to teach readers the scientific meaning of energy. Recall Stewart and Lockyer's argument that a man with great personal energy "will sometimes be defeated by an opponent who does not possess a tithe of his personal energy," but who occupies the advantage of higher social position.[292] Bradley Headstone has devoted his life to governing his "wild

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[290] "The Sun as a Type of Material Universe" appeared in *MacMillan's* in 1868, three years after Dicken's finished *Our Mutual Friend.*
[291] "Physical Force," *Household Words*, 358.
[292] Stewart and Lockyer, "The Sun as a Type of Material Universe," 319.

energy"[293] and directing what would otherwise be an unfocused natural state into overcoming his low social position. Nothing about Wrayburn is regulated, focused, or even particularly energetic, yet he maintains an advantage over Headstone because of his social position. Unlike Headstone, Wrayburn has never needed to labor to overcome the inertia of class position. He approaches his profession as a barrister with lassitude and has not taken on significant business for seven years.[294] He has shirked responsibility for so long at his law practice that even his pen is rusty from lack of use.[295] When Mr. Boffin cheerfully proclaims that work is wonderful for persons and wonderful for bees, Wrayburn returns that bees "overdo it."[296] When he walks down London's streets, he occupies most of the sidewalk, diffusing like a gas.[297] In all manners of being, Wrayburn is shamelessly dissipated.

In most respects, Wrayburn performs the role of Stewart and Lockyer's lazy middle-class character who throws stones at his energetic opponent on the ground from the advantageous position of a rooftop. But Dickens plays with these archetypes and destabilizes them. Headstone appears to be a focused source of power who has mindfully applied his energies to overcome the social obstacles of his youth. However, we are told that Headstone is simply chaos restrained: "Suppression of so much to make room for so much, had given him a constrained manner, over and above. Yet there was enough of what was animal, and of what was fiery (though smouldering), still visible in him, to suggest that if young Bradley Headstone, when a pauper lad, had chanced to be told off

[293] Dickens, *Our Mutual Friend*, 389.
[294] Dickens, 29.
[295] Dickens, 97.
[296] Dickens, 98.
[297] Dickens, 229.

for the sea, he would not have been the last man in a ship's crew."[298] Headstone exerts enormous and perpetual effort to regulate his natural state of chaos. Where Wrayburn barely needs to lift a finger, and indeed he barely ever does, Headstone labors tirelessly to funnel the disarray of his personal energies. As he tells Lizzie, "some of us are obliged habitually to keep it down. To keep it down."[299]

Therefore, the dynamic between Wrayburn and Headstone both bears out and complicates the notions of efficiency in articles like "The Sun as a Type of Material Universe." On the one hand, Wrayburn occupies an advantageous social position, has no personal wild energies to govern, and therefore easily thwarts Headstone's plans to woo Lizzie. Despite Headstone's best efforts at mechanically routinizing his habits, Wrayburn unleashes Headstone's chaos so he can no longer perform his schoolmaster duties. It requires little personal energy on Wrayburn's part to dismantle his opponent's restraints, so we might assume that he would choose to execute energy-efficient tactics against Headstone. On the other hand, Wrayburn concerns himself with neither the labor *required* to perform a task, nor with advancing his career, social position, or even, until his near death, his relationship with Lizzie. Wrayburn occupies a position of efficiency and shirks its actualization. To return to my example from Whewell's engineering text, the capitalist and the engineer alike concern themselves with pushing boxes in straight lines, thereby minimizing distance covered through a single displacement. Wrayburn either refuses to push, or he delights in pushing his box in wasteful zig-zags from point A to point B.

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[298] Dickens, *Our Mutual Friend*, 218.
[299] Dickens, 339.

In Bradley Headstone and Eugene Wrayburn, Dickens sets up the dynamic of one highly inefficient machine striving for efficiency, and one efficient machine that performs wastefully. And, like the moral instability of the dust economy, Headstone and Wrayburn are ambiguously positioned in moral energetic systems. We delight in Wrayburn's moments of excessiveness. While his lawfirm withers from neglect, he spends entire nights leading Headstone in aimless chases through London's labyrinthine streets, profiting from the schoolmaster's paranoia. Wrayburn devotes enormous personal effort, night after night, to the cruel pleasure of driving his rival to madness. Mortimer Lightwood watches his friend work uncharacteristically hard and reflects, "what preposterous ways he took, with no other object on earth than to disappoint and punish him; and how he wore him out by every piece of ingenuity that his eccentric humour could devise; all this Lightwood noted, with a feeling of astonishment that so careless a man could be so wary, and that so idle a man could take so much trouble."[300] There is so much extravagance in this description, and yet so much labor, that we hardly know whether to admire Wrayburn for his dedication and ingenuity, or to despise the extent to which he pursues his maliciousness.

If Wrayburn is a mostly endearing character with some hateful qualities, Headstone is the inverse. He unleashes his wild energy upon Lizzie, speaking to her in threatening and energy-laden language: "I love you. What other men may mean when they use that expression, I cannot tell; what *I* mean is, that I am under the influence of some tremendous attraction which I have resisted in vain, and which overmasters me.

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[300] Dickens, *Our Mutual Friend*, 534.

You could draw me to fire, you could draw me to water, you could draw me to the gallows, you could draw me to any death, you could draw me to anything I have most avoided, you could draw me to any exposure and disgrace."[301] Headstone blames Lizzie for unraveling his hard-earned composure. It is her energy that overpowers him, and he therefore takes no responsibility for his actions. Although Headstone implies that some force of Lizzie's personality or essence has removed his agency, he chooses ambiguously scientific terms like "attraction" and "influence" to contrast his experience of love with that of "other men." He cannot find place for these emotions in the "wholesale warehouse"[302] of his mind, yet energy's slippage into scientific bounds perhaps makes love easier for Headstone to classify, not least because he can blame Lizzie for its power over him.

Despite his deeply troubling behavior towards Lizzie, Headstone is admirable for possessing the qualities that Wrayburn lacks. Indeed, Lizzie sends her brother Charlie to Headstone's school at great personal expense so he can acquire the same skillset and behaviors that Headstone has directed towards his own social mobility. Even if we do admire Headstone for his personal initiative, Dickens undermines that desire to escape class inertia and raise Lizzie with him. When Headstone attacks Wrayburn and dumps his near-lifeless body in the river, it is Lizzie's muscle memory of scavenging the Thames for corpses that saves her lover and secures her class mobility through marriage.

Only Lizzie, trained to detect corpses floating in the murky water at night, is equipped to find and remove Wrayburn from his watery grave. Dickens emphasizes the

[301] Dickens, *Our Mutual Friend*, 390.
[302] Dickens, 218.

skill and effort required for this rescue operation: "A sure touch of her old practised hand, a sure step of her old practised foot, a sure light balance of her body, and she was in the boat… Another moment, and she had cast off (taking the line with her), and the boat had shot out into the moonlight, and she was rowing down the stream as never other woman rowed on English water… An untrained sight would never have seen by the moonlight what she saw at the length of a few strokes astern."[303] In the moments before this scene, Wrayburn contemplates how to potentially terminate his relationship with Lizzie. Marriage is not a realistic option based on their class difference. After the attempted murder, however, Lizzie marries Wrayburn. Embodied knowledge from her working-class background is ironically the very thing that raises her social position.

Scholars have been critical of the two marriages that conclude *Our Mutual Friend*, writing off Lizzie's marriage to Wrayburn as a reinforcement of the middle-class marriage plot,[304] and Bella Wilfer's marriage to John Harmon as proof that calculated deceit ends in domestic bliss and wealth.[305] While there is plenty to dislike about John Harmon's protracted deception and grooming of Bella, Lizzie's marriage to Wrayburn is more complex. Dickens embeds in their union a critique of marriage as the vehicle for escaping the energetic sinkhole of a working-class background. Although Lizzie's own personal energies, the fruits of so many hours scavenging on the Thames, secure her an elevated social position, she cannot escape class antagonism. The novel's final pages depict Lady Tippins and company ventriloquizing the "voice of Society," protesting the

[303] Dickens, *Our Mutual Friend*, 683.
[304] MacDuffie, *Victorian Literature, Energy, and the Ecological Imagination*, 132.
[305] Mary Poovey, *Making a Social Body: British Cultural Formation, 1830-1864* (Chicago: University of Chicago Press, 1995), 166.

shameful union of the “brave woman…with a wonderful energy” and their respectable friend, Wrayburn.[306] Moreover, Wrayburn is practically on his deathbed when he marries Lizzie. Dickens leaves little hope that their lives together will bring enduring happiness.

The ending of *Our Mutual Friend* undermines the efficacy of sustained advantage from raising one’s energy through marriage or personal effort. By the end of the novel, Headstone is dead and Lizzie is consigned to the middle-class domestic dream of caring for her invalid husband. Wrayburn and Headstone almost seem like caricatures of Stewart and Lockyer’s analogy because they mimic the argument that social and physical position operate as one energetic system, while also subverting such a perfect model. Headstone has raised his social energy, but also seems to be merely impersonating a middle-class subject, and he exerts himself enormously to do so. Wrayburn possesses all the advantages of the middle class, yet he either lets his energies dissipate or exhausts them in wildly wasteful activities, rather than directing them mindfully. Dust, too, conjures unstable fantasies of energy transfer; and, depending on the perspective of characters, can signify an agent of magical transformations, or a source of wasted potential.

We have seen that dust sits on the fault line between conservation and dissipation, and that it evoked controversial opinion in the nineteenth century concerning the moral and physical health of its workers. The nineteenth century dust yard continues to inspire and maintain our cultural efficiency narrative, and so it serves us to consider why dust contracting remains such a romance. Despite *Our Mutual Friend*’s motif of resurrection and recycling, dust is never represented as a model of unproblematized efficiency. On the

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[306] Dickens, *Our Mutual Friend*, 794.

contrary, the novel contrasts "the legend of hidden wealth in the Mounds"[307] with the labor of its care and removal, and with the disappointment of its deflated potential.

Silas Wegg, the "literary man – *with* a wooden leg,"[308] embodies both of these extremes. Wegg is a man obsessed with potentials. He despises Boffin not only for his wealth, but because he has usurped an elaborate fantasy Wegg concocted about the mansion Boffin purchases. Wegg first encounters Mr. Boffin while selling goods from a small cart he established years ago outside a house about which "his knowledge… [is] mostly speculative and all wrong."[309] He claims intimate acquaintance with the mansion's imaginary inhabitants, but when Boffin purchases this house the potential of Wegg's fantasy disappears. We are told that, "Over the house itself, he exercised the same imaginary power as over its inhabitants and their affairs."[310] Having lost this power, he turns his romantic fantasies to the potential of dust.

Wegg convinces his taxidermist friend Mr. Venus to help him sift through the Harmon dust mounds in anticipation of finding evidence to blackmail and expropriate the Golden Dustman. Venus is less enthusiastic about this plan, arguing that he and Wegg are wasting time by "groping for nothing in cinders."[311] Like Hobhouse's explanation of the romantic "Feeling that unknown possibilities lie hid in a pile of rubbish,"[312] Wegg counters by reminding Venus of what potential awaits them if they keep searching. He asks, "What *have* we found? …Ah! There I grant you, comrade. Nothing. But on the

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[307] Dickens, *Our Mutual Friend*, 301.
[308] Dickens, 57.
[309] Dickens, 53.
[310] Dickens, 53.
[311] Dickens, 472.
[312] Hobhouse, "Dust-Women," 412.

contrary, comrade, what *may* we find? There you'll grant me. Anything."[313] Wegg reminds his accomplice of the domestic fantasy that Boffin hijacked, and is furious when Venus protests that Wegg had never known the former residents of Boffin's mansion. He cries, "No, don't say that! Because, without having known them, you can never fully know what it is to be stimilated to frenzy by the sight of the Usurper."[314]

Therefore, Wegg's dust mission is an index of his fixation on possibilites, and indeed he does discover an additional Harmon will in the mounds. But, despite Wegg's finally acquiring the object of his fantasy, dust does not live up to its potential. Instead of alleviating Wegg's burdens, the dust creates new ones. At first, simply the act of threatening Boffin is a source of physical exertion. Wegg articulates the terms of his blackmail and exhausts himself with paranoia and activity by doing so:

> At length, Mr. Boffin entreated to be allowed a quarter of an hour's grace, and a cooling walk of that duration in the yard. With some difficulty Mr. Wegg granted this great favour, but only on condition that he accompanied Mr. Boffin in his walk, as not knowing what he might fraudulently unearth if he were left to himself. A more absurd sight than Mr. Boffin in his mental irritation trotting very nimbly, and Mr. Wegg hopping after him with great exertion, eager to watch the slightest turn of an eyelash, lest it should indicate a spot rich with some secret, assuredly had never been seen in the shadow of the Mounds. Mr. Wegg was much distressed when the quarter of an hour expired, and came hopping in, a very bad second.[315]

Wegg grants Boffin the "grace" and relief of a walk around the dust yard, while the same walk leaves him hopping and expired. Wegg is bound by the possibility of unearthing something more valuable, or perhaps something more incriminating, and transfers his obsession with potentials to the motion of constant surveillance. With the repetition of the

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[313] Dickens, *Our Mutual Friend*, 472.
[314] Dickens, 484.
[315] Dickens, 643.

word, “hopping,” we are reminded in this passage of Wegg’s disability. His wooden leg remains a marker of embodied energetic transformations because, as the mounds are processed and start shrinking, so does Wegg. The possibility of unearthing valuables in the mounds deflates, and it leaves Wegg haggard and wasted.

The slow process of sifting the mounds and carting off the dust “[wears] Mr. Wegg down to skin and bone.”[316] The foreman supervising the operation drives his dust workers day and night, “in fog and rain,” and “at the most unholy and untimely hours.”[317] Such a “Demon of Unrest” burdens Wegg to the point of near death, since he tenaciously pursues the fantasy of dust’s potential. Although no valuables emerge, a rapacious Wegg observes the labor until he grows so haggard that “his wooden leg show[s] disproportionate, and present[s] a thriving appearance in contrast with the rest of his plagued body.”[318] The transformation of the mounds, themselves, is described in the terms of a state change. Dickens’s narrator explains that, from afar, the mounds appeared to be attacked by teams of dust workers, carts, and horses all day from dawn to dusk, making no impression on the mountains of waste.[319] But, as the days pressed on, the mounds appeared to be “slowly melting,” as if the labor had reached a threshold activation energy and initiated the state transformation of dust.[320]

Nowhere in the description of dust’s removal, nor in the disappointment of its potential, does *Our Mutual Friend* celebrate dust. However, when the novel’s characters of wealth and circumstance discuss Old Harmon, his unusual will, and his fortune, they

[316] Dickens, *Our Mutual Friend,* 759.
[317] Dickens, 759.
[318] Dickens, 760.
[319] Dickens, 495.
[320] Dickens, 495.

do so as if recounting a legend. These members of Society are removed from the world of dust; they know it only through Mortimer Lightwood's narration of the legal proceedings of the Harmon will and murder. Gathered at the Vennering's "bran-new" house, Lightwood entertains an enraptured dinner audience with the tale of the "Man from Somewhere," Old Harmon's son.[321] This infamous dust contractor "threw up his own mountain range, like an old volcano, and its geological formation was Dust."[322] Lightwood gives Harmon god-like agency in this story, granting him the power to will mountains into being, and effacing the labor of dust work from the myth. Young John Harmon, too, becomes the protean "Man from Somewhere," a raw material out of which any kind of identity might be wrought, and indeed it is. Harmon emerges from the Thames first as Julius Hanford, and then as John Rokesmith, before reclaiming his original identity. Dust's miraculous transformations, and a true romance of dust, develop from the perspectives of the characters most removed from it.

Dust recycling in *Our Mutual Friend* symbolizes neither an efficient model of waste containment in a modernizing London, nor a wasteful and labor-intensive enterprise whose energy requirements dissipate fantasies of resource potential. While critics have focused on the novel's motifs of regeneration and recirculation, I argue that it is equally important to distinguish how Dickens's text differs from its absorption in the public imagination. *Our Mutual Friend* retains a class-based criticism of efficiency and its romantic fantasy of closed-loop resource extraction, where journalists who cite Dickens's text and characters seem to relish the efficiency narrative. The cultural

[321] Dickens, *Our Mutual Friend*, 23.
[322] Dickens, 24.

instability of energy in this novel is important because of its power to inspire different visions of the city, the planet, and the universe.

CONCLUSION

By now it should be clear that the western energy concept did not grow out of passive scientific observation. "Energy" was structured by a group of mainly North British individuals with conflicting worldviews and political agendas. Early energy physicists also looked to problem solving in their built environments when they approached the theories of transfer and conservation. Like the water wheel inspired Sadi Carnot's caloric theory analogy, the Thomson brothers used steam engines to guide them. And, critically, both Carnot and the Thomsons were motivated by the prospect of developing coal infrastructures in their respective nations.

Figurative language structured the thermodynamic laws by providing a scaffold for their framers to build around; but words like "dissipation," now written into natural law, bolstered the case for scientists who claimed social and physical energies were interchangeable. Because energy had pre-scientific meaning, some popularizers explained its use as a scientific term by collapsing its thermodynamic and non-thermodynamic registers, arguing that all "energies" belong under one universal system. Indeed, William Thomson did intend the law of dissipation to carry the moral weight of guiding humans towards rooting out waste and maximizing resource power.

This is the origin of what I have called the western efficiency narrative, a guiding fiction that remains entrenched in our culture. Tracing a political history of the thermodynamic laws helps us understand why it seems normal for twenty-first century fossil fuel companies to market themselves as eco-conscious recyclers. Today, the infrastructure of modern space is standardized and tightly controlled by mega corporations that allow private organizations to profit from environmentally exploitative regulations masquerading as "energy efficient." Because waste management studies have recently celebrated the nineteenth century dust economy, we should ask why dust remains a model of efficiency.

Contemporary literary critics and nineteenth century writers alike have been drawn to the romance of dust. We have seen that literature both inspires public interpretation of energy systems and reveals the instability of thermodynamics in the 1860s. Dickens, himself, was inspired by Richard Henry Horne's sentimental story of dust scavenging and contracting. *Our Mutual Friend* is far less straightforward, playing with both conservation and waste in energetic systems. However, the novel has been a powerful force in producing change across London by giving readers a common iconography through which to read their rapidly modernizing city.

For the rest of the nineteenth century, coal remained at the forefront of Britain's agenda as they relied on an expanding empire for raw materials and cheap labor. The next chapter of this dissertation turns to the infrastructures of imperial expansion and the mutually generative conditions of Britain's global communications network, technologies of influence, and literatures of energy. Starting with global telegraphy, chapter three insists that the British would not have developed electromagnetic field theory without relying on non-western infrastructures.

Chapter 3:

Around the Wire: Telegraphic Infrastructure and Gothic Energies in Late Victorian Britain

By the end of the nineteenth century, the laws of thermodynamics had become common knowledge. Like gravity, energy seemed somewhat intuitive. Even those with no formal scientific training could tell you that energy conservation and dissipation registered on a common-sense level: you cannot create energy out of nothing, but you can transfer it to a finite degree. In his three-volume *Electromagnetic Theory* series (1893), physicist and electrical engineer Oliver Heaviside claimed that the principle of energy conservation felt self-evident because a new generation of learners had encountered energy's scientific definition from a young age. Scientific energy had naturalized, Heaviside argued, and the common man "goes by faith, having taken it in while young."[323] He then extended this logic to predict that, in another generation or so, energy science's latest curiosity would feel similarly obvious: that electromagnetic energy is not sent through a conducting wire, but rather exists in the space around it. "Only train up the young to believe this," he explained, "and they will afterwards look upon the notion of its going through the conductor as perfectly absurd, and will wonder how anyone ever could have believed it."[324]

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[323] Oliver Heaviside, *Electromagnetic Theory*, vol. 2 (New York: The D. Van Nostrand Company, 1893), 73.
[324] Heaviside, 73.

Heaviside's example considers how scientific knowledge is produced and naturalized. In his model, the surprising discovery of one generation becomes the natural law of the next. But his example also specifically contemplates how to normalize some of the strangest phenomena of classical energy physics: electromagnetic induction and the introduction of classical field theory. While electric current does move relatively slowly through a wire, the electromagnetic *energy* exists in the surrounding space. Consider how odd this might have sounded to a student who had visualized electricity as a fluid, flowing along a wire. Previous generations of scientists had applied just such a hydroelectric analogy: that electricity flows down a wire as water flows down a pipe. Or, they embraced the more all-encompassing imponderable fluid theories that supposed subtle fluids permeated space through the ether. Anton Mesmer's theory of animal magnetism, or "Mesmerism," argued that magnetic fluid operated this way. In the mid-nineteenth century, however, physicists explored the new idea that electromagnetic energy transformations occur along a continuum of active space, or a "field." Hans Christian Oersted was the first to demonstrate a link between electricity and magnetism in 1820, but between the 1830s and the 1850s Michael Faraday was developing a theory of *why* a moving magnet generates an electric current in a nearby wire. This phenomenon is called "induction," an electromagnetic effect that opened the doors for the technological transformations of the mid-to-late nineteenth century. Induction explains why energy does not flow linearly down a wire, but manifests in the field around it.

Despite Heaviside's prediction that electromagnetic fields would soon become a pedagogical norm,[325] flow remains embedded in our discussions of nineteenth-century telecommunications, often buttressing electromagnetic field imagery like influence and control from a distance. This chapter argues that the imaginative differences between flow and fields matter. Just as the hydroelectric analogy joined concrete fluid imagery to elusive electric phenomena, electromagnetic field theory inspired scientists to imagine what form a field of energy might take, or what it would look like. Other scientists reinserted fluid analogy into electromagnetism in order to assimilate it within preestablished scientific conventions.

The science of electromagnetic field theory, and its imaginative approaches, are situated within translation apparatuses whose universalizing program also sought to control the infrastructural configurations around the telegraph wire. Electromagnetic induction supplied vital theoretical links that determined the success of global telegraphy; but electromagnetic induction in telegraph cables was also materially linked to Southeast Asian supply chains that translated forest produce into cable insulation. Therefore, flattening acts of standardization occurred on two levels: during the development of electromagnetic field theory, and during the colonial extraction of materials to expand telegraphic infrastructure. I will demonstrate that developments in field theory revealed that global telegraphy depended on the resources and knowledge of peripheral colonial

[325] It deserves mentioning that, after Albert Einstein published his special theory of relativity in 1905, fields and field phenomena did forcefully enter the twentieth-century mainstream. However, Kieran Murphy has recently argued that Einstein's rise to prominence obscured our treatment of nineteenth-century conceptualizations of electromagnetic fields in science and literature. Kieran M. Murphy, *Electromagnetism and the Metonymic Imagination* (University Park: The Pennsylvania State University Press, 2020), 8.

subjects, and on the translation of localized agricultural and foraging practices across different stages of supply chains, from the colonial periphery into the global economy. The history of electromagnetic science shows us that, first, field theory was assimilated into the established model of energy flow, and second, developments in field theory created new market demands for colonial resources that exposed the translational failures of the plantation model.

The story of imagining electromagnetic fields and applying its concepts to telegraphy usually begins with Faraday, though many historians of science credit William Thomson and James Clerk Maxwell for making Faraday's theory accessible to scientists. Indeed, many histories note Thomson and Maxwell as Faraday's translators, yet few have interrogated the points of rupture these acts of translation produced from Faraday's original work. Thomson and Maxwell reinserted fluid imagery into Faraday's field model, despite the clear departure from fluids and ethers that Faraday's original work indicates. These imaginative differences matter not only as theoretical revisions, but also because their respective analogical approaches to fields engender different notions of influence and control from a distance. I argue that the representations of energy around the wire, the cultural narratives of foreign influence, and the colonial supply chains on which telegraphy depended all converge on the matter of employing knowledges inaccessible to the British, or approaches that traditional western science needed, but did not value. As electromagnetism developed, Faraday introduced a field model of energy that did not initially assimilate to standard scientific conventions, nor to the established models of energy flow. And then, as electromagnetic field theory changed the market forces for specialized telegraphic insulation materials, the British encountered supply chains that relied on local knowledge and agricultural practices that resisted the indiscriminate extraction and interchangeability of the plantation model.

As the science of energy matured, universality and standardization became important tools of extraction and economic expansion. What we can consider our dominant western energy concept, or energy's attachment to imperialistic, extractive values and practices that funneled peripheral labor and materials towards an imperial center, depended on appropriating, translating, and assimilating ways of life that resisted an energy-capitalism union and its flattening strategies to capture labor and eliminate waste. Cara Daggett explains this as the nexus of work and energy, that the spread of fossil fuel capitalism "conceal[ed] its violence" by spreading a gospel of productivity, and by cutting out any perceived waste or slowness.[326] To this, I would add that the energy-capitalism nexus was a complex translation apparatus that assimilated nontraditional ways of thinking about fields and forces, such as Faraday's electromagnetic field theory, as well as its consequences for colonial trade networks that sourced telegraphic insulation materials.

Electromagnetic field theory emerged from the nontraditional methods of Michael Faraday, an experimental physicist without a classical education. Eventually, the application of field theory in telegraphy required the knowledge and resources of Indigenous forest produce collectors in Southeast Asia, and contingent networks of Chinese and Malay traders linked into local and global supply chains. Faraday, who had

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[326] Daggett, *The Birth of Energy*, 5, 136.

failed to capture an enthusiastic audience for his unconventional theory until telegraphy created a commercial demand, had argued for decades that electric and magnetic "lines of force" emanate invisibly from objects with electromagnetic properties. Each line of force operates like an "axis of power," Faraday argued, polarizing the surrounding medium and conveying forces across space through contiguous action from one particle to the next.[327] When underground and undersea cable projects failed, Faraday demonstrated that global telegraphy would never succeed without managing the invisible fields around conducting wires. He argued that the material surrounding a wire, *i.e.*, cable insulation, was an active component of the field dynamic that allowed electrical signals to propagate. As British scientists and telegraph investors heeded Faraday's advice, they demanded greater quantities of gutta percha, the natural latex found only in isolated regions of Malaya, Borneo, Singapore, and Sumatra, and used to manufacture nearly all telegraph insulation. The British leveraged their colonial presence in Southeast Asia to ensure that they monopolized the gutta percha market.

Gutta percha, however, elided British control. They required it in increasing quantities for expanding telecommunications projects, but gutta percha resisted attempts to scale up proportionally with telegraphy, including ventures in plantation cropping. Such a high demand nearly drove the trees to extinction, which proved to be more harrowing for Europeans than Indigenous collectors. Yet the British blamed the Indigenous traders they relied on for the gutta percha shortage, citing what they

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[327] Bruce J. Hunt, *Pursuing Power and Light: Technology and Physics from James Watt to Albert Einstein* (Baltimore: The Johns Hopkins University Press, 2010), 76.

considered improper use of tools and unwise sap extraction methods.[328] They resented depending on the seasonal rhythms of Indigenous traders, who balanced gutta percha expeditions with other foraging and subsistence agriculture. They were skeptical of the slowness involved in culturally-specific practices like animal augury, which guided each expedition.[329] Additionally, they depended on an extensive network of Chinese and Malay intermediary traders who linked gutta percha from local economic systems to the external economy.[330] These unfamiliar methods disempowered the British, whose imperial control now partially relied on inaccessible knowledge and unruly plant life. Unlike cotton, sugar cane, and other commercial agriculture, gutta percha trading resisted the plantation formula of smooth scalability that systematically turned local peoples and plants into interchangeable industrial elements.[331]

In the mid-to-late nineteenth century, then, the British scrambled to master a science characterized by invisible electromagnetic fields. Scientists assimilated the indiscernible characteristics of electromagnetic energy to established structures and conventions, like flow. Still, scalability remained an issue: even if they could apply field theory expertly, telegraphy depended on a disappearing resource, the gutta percha tree, which only Native foragers knew how to find and manage. The story of field theory's development therefore enlarges the familiar narrative of late Victorian degeneration and imperial anxiety. Not only do the scientific renderings of field theory share linguistic

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[328] Eugene Obach, F.A., "Cantor Lectures on Gutta Percha," *Society for the Encouragement of Arts, Manufactures, & Commerce* (London: William Trounce, 1898), 44.
[329] Helen Godfrey, *Submarine Telegraphy and the Hunt for Gutta Percha: Challenge and Opportunity in a Global Trade* (Leiben and Boston: Brill, 2019), 174.
[330] Godfrey, 135.
[331] Anna Lowenhaupt Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* (Princeton and Oxford: Princeton University Press, 2015), 38-41.

similarities with representations of imperial influence, but the application of field theory in telegraphy threatened to upend the notion of British superiority due to their reliance on non-western knowledge that they nonetheless denigrated. Directing a critical gaze around the wire thus refocuses our conversations on the interplay of field models and the colonial infrastructures that sustained telecommunications technologies in late-nineteenth century Britain.

At the heart of nineteenth-century telecommunications innovations is the telegraph, which remains central to critical work on Victorian science in the era of British New Imperialism.[332] Many representations of the telegraph in media, literary, and historical studies consider the conducting wire a symbol of transforming information into an object of influence. Human bodies transmitting or receiving information are imbricated in the telegraphic apparatus when consciousness, writing, and thinking occur at a distance. Richard Menke, for instance, locates the moment of information's disembodiment in the nineteenth century, when technologies designed to encode and electrically transmit messages also prompt consideration of what consciousness looks like outside of the human body.[333] Jeffrey Sconce explores metaphors of flow and the "liveness" we perceive in media powered by electricity.[334] Sam Halliday extends his cultural analysis to electric fields, specifically, arguing that the emergence of an "electric field culture" in the nineteenth century extended the concept of influence to social

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[332] The era of New Imperialism is generally characterized as the period between 1870 and World War II.
[333] Richard Menke, *Telegraphic Realism: Victorian Fiction and Other Information Systems* (Stanford: Stanford University Press, 2012), 7.
[334] Jeffrey Sconce, *Haunted Media: Electronic Presence from Telegraphy to Television* (Durham and London: Duke University Press, 2000), 7.

environments.[335] The present chapter additionally insists that the process of parsing the ambient energy of field theory and its complementary infrastructures involved imposing deliberate energy forms on electromagnetism. As a form, the field expresses the vagueness of ambient, unseen energy that occupies space. Field energy is not discernible in the physical, infrastructural channels through which communication flows. Communication flows through a wire, so to speak, but energy does not. Energy is the ghostly, web-like influence around the wire.

As such, flow and fields are distinctive energy forms that impose different models, and different moods, on electromagnetism and telegraphic infrastructures. Moreover, it behooves us to consider Thomson's and Maxwell's reinsertions of fluid analogy into Faraday's explicitly non-fluid model. Controlling acts of scientific translation, and the subsequent resistance of gutta percha to assimilate within a capitalist apparatus, shape cultural interpretations of influence and power. Consider the imaginative differences between the field and the flow. The field is eerily both within and beyond an object, while telegraphic flow suggests a direct command of communication and movement. An energy field resists control by remaining elusive, dispersive, and atmospheric. These field-like characteristics appear in late-century gothic novels, where foreigners invade Britain and wield energy as an unmappable tool of imperial resistance, or as a counter-imperial threat. I argue that by looking at two 1897 gothic novels, *Dracula* and *The Beetle*, we can find evidence of specific field-like energy threats.

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[335] Sam Halliday, *Science and Technology in the Age of Hawthorne, Melville, Twain, and James: Thinking and Writing Electricity* (New York: Palgrave Macmillan, 2007), 51.

By the end of the nineteenth century, the gothic literature famous for conjuring the mood of fin-de-siècle degeneration had also integrated the energy politics of electromagnetic field theory and global telegraphy. Although discussions of late Victorian gothic literature observe the narrative of fin-de-siècle decay of Victorian values, fear of foreign influence, and the disintegration of British identity, there is yet little work connecting such cultural trends to the infrastructures of energy. This chapter balances my reading of field theory in British imperial infrastructures with a reading of *Dracula* and *The Beetle*. While Bram Stoker's *Dracula* is well-known and has been thoroughly scrutinized by literary critics, Richard Marsh's *The Beetle* has not achieved the same enduring cultural notoriety. Nonetheless, the novels are themed similarly, and Marsh's novel outsold Stoker's at the time of their nearly simultaneous publications. Like *Dracula*, *The Beetle* features a monstrous, ambiguously racialized character who infiltrates London to weaponize a technology of influence against the core tenets of British identity: empire, knowledge, class-position, and gender. But, unlike Dracula, who fits the profile of an eastern European, non-white threat to England, the Beetle character is a pastiche of various non-European, exaggerated physical characteristics from peripheral regions of the British empire. Additionally, this character is neither distinctively male nor female, but rather ambiguously gendered, shape-shifting between monstrous extremes, androgyny, and animal forms.

Both novels are narrated in epistolary format by (mostly) British characters. The characters variously produce and reproduce each other's voices by dictating, transcribing, and copying narrations. While *The Beetle* also challenges the assumption that the British are masters of their own superior technologies, it is in *Dracula*, particularly, that vampirism appears as an ironic technology of modernity. Count Dracula clearly appropriates ancient, occult forces beyond the pale of western "legitimate" science, but his vampirism mimics the western technologies that produce the novel's epistolary format by making his own copies of undead bodies. In this way, the form of the novel replicates the reproduction and translatability of both vampirism and modernity.

We might say that the horror of vampire capitalism is its relentless scalability. If Dracula is successful, he will create a vast race of vampires who will destroy the primacy of Britain and, eventually, the human race. But Dracula is ultimately most threatening because, unlike the British, he is able to work across value systems, translating between the enigmatic knowledges of the vampire and England's own industrial technologies. Like Faraday's lines of force, Dracula is a misty, energetic region of space. He can shape-shift, dissipate his own matter, and control bodies from a distance; yet he is also a threat to Britain's empire because he eludes the control of energetic flow and still masters the vampiric translation of capital. He translates value from his own field-like energy modality to the scalability of endless production, the manufacturing of vampire copies.

Such acts of translation are part and parcel of global capitalism. Anna Tsing's theorization of salvage accumulation insists on "acts of translation across varied social and political spaces," that capitalism functions not in spite of non-scalable, non-capitalist elements, but *because of* them.[336] Critics of capitalism often assume its systemic and even global homogeneity when, in fact, firms and investors accumulate wealth by relying on

[336] Tsing, *The Mushroom at the End of the World*, 62-65.

supply chains that translate non-capitalist lifeways and products into capitalist value systems.[337] When acts of translation break down, or when a system like the gutta percha trade proves non-translatable, energy's coupling with capitalism and the extractive logic of work is threatened. Unlike *Dracula, The Beetle*'s characters deploy translational tactics unsuccessfully when they approach a field-like, enigmatic foreign invader who seems to elude all stable classification. *The Beetle*'s narrative is unreliable, its characters do not agree on what, or who, the Beetle is, and they do not launch an organized logistical campaign to contain and eliminate their adversary. Instead, *The Beetle* uses destructive applications of energy science and its technologies to exterminate a perceived threat to the energy-capitalism nexus.

By the time *Dracula* and *The Beetle* were published in 1897, the British were grappling with their gutta percha shortage. It was clear that sourcing cable insulation was a case of salvage translation that, rather than assimilating into scalable value systems, threatened the unimpeded growth of imperial technologies. From this angle, *The Beetle*'s animal totemism, *Dracula*'s manipulation of the natural world, and the shape-shifting in both novels gesture to a command of natural forces and misty fields that threaten the prowess of Britain's great technologies of influence, not simply because they are mirrors of empire turned against the west, but because global capitalism requires their participation. Moreover, these gothic villains are reminders that Britain's energy agenda faced infrastructural, cultural, and logistical resistance from human and nonhuman life;

[337] Tsing, *The Mushroom at the End of the World*, 65. Tsing notes the work of Michael Hardt and Antonio Negri as a particularly aggressive example of theorizing capitalism without an "outside."

they are reminders that, as Daggett argues, “[d]ominant energy logics were constituted by their engagement with people and things who resisted the European work project.”[338]

This chapter narrates a political and literary history of telegraphic infrastructure and electromagnetic field theory in three parts, each with nested subsections. The first two sections approach knowledges that underpinned global telegraphy. Faraday’s theory of the field helped dismantle a long reign of Newtonian physics and inspired Einstein’s theory of relativity. But the consequences of electromagnetic induction in moving energy concerns around the telegraph wire are less well known. This chapter’s first core section discusses Faraday’s contribution to the electromagnetic field theory, as well as the imaginative differences created by Thomson’s and Maxwell’s translations of Faraday’s insights. Early submarine telegraphy projects failed until scientists took, as Heaviside put it, “the first step towards getting out of the wire into the dielectric.”[339] Therefore, the second section connects Faraday’s induction theory and the standardization of gutta percha as cable insulation with the Southeast Asian supply chains that procured what became an increasingly valuable and rarefied material. Finally, a concluding literature section links these two approaches to telegraphic infrastructure and energy science by suggesting that *Dracula* and *The Beetle* are representative of a culturally perceived threat to empire that worked across value systems, dismantling British integrity through the very settler capitalism and supply chains on which empire depended.

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[338] Daggett, *The Birth of Energy*, 136.
[339] Hunt, *Pursuing Power and Light*, 89.

ELECTROMAGNETIC INDUCTION, INVISIBLE FIELDS, AND THE PROBLEM WITH TELEGRAPH CABLES

If the laws of thermodynamics compelled scientists to revise their thinking about Newtonian force relations, then the study of electromagnetism threatened to overturn the entire basis of reality under Newtonian law. What we consider the great pre-nineteenth century scientific achievements were brought to us from a Newtonian world. However, the traditional Newtonian worldview holds that all force relations are mechanical: they operate as the mathematically predictable, clockwork motions of matter. Electromagnetism resisted this kind of mechanistic explanation. The previous chapter acknowledged that the scientific codification of "energy" in part addressed broadening the horizons of strictly Newtonian forces. The present section explores those changes in more detail, considering how such an epistemological shift tested the core tenets of conventional physics, and why those theoretical changes set the course for Britain's telecommunications agenda.

Before Britain's cables wrapped around the globe, Michael Faraday investigated a fascinating but perplexing link between electricity and magnetism. In 1819, the Danish physicist Hans Christian Oersted discovered that a current-carrying wire deflected a magnetic compass needle nearby, a finding he published in 1820.[340] Almost immediately afterward, Faraday launched into his career-long study of the interaction between electricity and magnetism, or what he later considered two linked manifestations of the same phenomenon (see fig. 2). Faraday's famous diagram of the electromagnetic link

[340] Robert D. Purrington, *Physics in the Nineteenth Century* (New Brunswick and London: Rutgers University Press, 1997), 40.

shows two joined rings, one for electricity (E) and one for magnetism (M). The rings are, as Murphy explains, "not phenomenologically the same thing, and their interaction does not derive from a simple mechanical exertion of one ring against the other. It derives from a relation of contiguity."[341] Additionally, there is a gap between the rings, indicating energetic association through spatial separation. In 1831, Faraday first reported his discovery of electromagnetic induction, arguing that electric currents were induced in a changing magnetic field, or when a conductor "cut" what he called magnetic "lines of force." These lines of force, made visible by iron filings in the space around magnets, formed the backbone of Faraday's field theory. They demonstrated physical activity in the space around current-carrying wire, and around magnets.

Faraday radically rejected several long-held Newtonian assumptions. First, he dismissed action at a distance, the notion that forces like gravity, electricity, and magnetism transmit apparently at a distance through ethereal mediation or some other agent whose action is obviated by mathematical accuracy. He did not accept the blackboxing of such phenomena and therefore developed a physical explanation to support mathematical models. Second, he eventually scrapped the need for ether, or at least argued for ether's elimination. Faraday pictured electromagnetic action as a tension across space involving contiguous particle transmission. This tempts us to also conjure up a mental picture of the ether, although Faraday was fairly convinced by the 1850s that his lines of force did not need ether mediation.[342] Third, he rejected the idea that electricity

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[341] Murphy, *Electromagnetism and the Metonymic Imagination*, 14-15.
[342] Bence Jones, *The Life and Letters of Faraday*, vol. 2, 2nd Ed. (London: Longmans, Green, and Co., 1870), 274.

was a fluid. As Faraday's theory of the field evolved, he increasingly insisted that the space *around* conductors was an active component of the electromagnetic energetic system.

Despite Faraday's insights, his background as a self-educated son of a blacksmith impeded his credibility in the mainstream scientific community. William Thomson and James Clerk Maxwell famously cast Faraday's work into mathematical notation, yet their translation of Faraday's field theory denatured some of his original intuitions, reinserting fluid analogy and mechanistic explanation where Faraday had removed it. This section lays the groundwork for my broader argument on telegraphic infrastructure and colonial influence by synthesizing the early history of classical field theory, its political situatedness in the British scientific community, and its necessity to the success of global telegraphy. Initial undersea and underground cable failures required Faraday's insight on induction phenomena, and subsequently led to Britain's massive investment in gutta percha: the insulating material around telegraph cables.

By the time scientists organized a committee for electrical standards, telegraphy and energy physics had interlocked. Thomson and Maxwell both sat on the committee and contributed to the adoption of electrical units that suited the emerging, universalizing energy regime. Energy science claims universality because energy is transferred across systems, organic and inorganic, and because energy is life-sustaining, work-sustaining, and bridges many scientific disciplines. But industrialists used energy's apparent universalism to standardize labor, police bodies, and regulate infrastructural configurations. Therefore, as we examine the conditions that led to standardization of telegraphic materials, it is important to note Faraday's distinctive theory in the history of energy physics because it disagrees with Thomson's and Maxwell's translations in prominent, imaginative ways, and because its observations sparked the boom in gutta percha, a material that resisted the precepts of energy universalism.

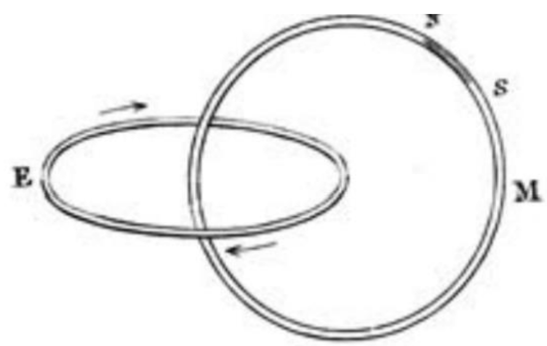

Figure 2. Faraday's diagram linking Electricity (E) and Magnetism (M)[343]

Classical Field Theory and the Persistence of Fluid Analogy

Energy science evolved out of a departure from Newtonian physics, which was governed by two intellectual trends: mechanization and Neoplatonist mathematization. In the first case, mechanical philosophers such as Descartes held that physical phenomena were the clockwork motions of matter. The Neoplatonists, like Kepler, argued that the world was structurally representational, held together by mathematical law without need to defer to physical explanation.[344] The sticking point of the Newtonian worldview was the problem of representing forces that are transmitted at a distance, like gravity, electricity, and magnetism. Newtonian scientists handled this problem variously.

[343] Michael Faraday, "On the Physical Character of the Lines of Magnetic Force," *Philosophical Magazine and Journal of Science*, Fourth Series, 3, no. 20 (June 1852): 411-412.
[344] Tian Yu Cao, *Conceptual Developments of 20th Century Field Theories*, 2nd ed. (Cambridge: Cambridge University Press, 2019), 21.

Cartesians argued for ether mediation and subtle fluids that transmitted forces across space. Alternatively, the atomists argued that void space was still possible because the mathematical models were empirically successful without describing any agent of transmission.[345]

The dawn of nineteenth-century energy physics ushered in a new era of scientific investigation during which action at a distance drew sharp controversy. Among its most relentless critics, Michael Faraday refused Newtonian action at a distance, which, as his contemporary John Tyndall explained, "perplexed and bewildered him" throughout his entire life.[346] Faraday was self-educated, and entered the scientific fold by working as Sir Humphrey Davy's assistant at the Royal Institution. Despite his humble beginnings, Faraday ultimately surpassed even Davy's expertise and matured into one of the nineteenth century's most imaginative scientific thinkers. By the 1830s, he had challenged action at a distance, uncovered electromagnetic induction phenomena, and suggested that "lines of force" conveyed invisible influences between bodies (fig. 3). Such lines of force extend beyond the physical body of a wire or a magnet, transmitting electromagnetic energies through space by the contiguous propagation of electric or magnetic "tension." The field, in Faraday's view, was the notion that two or more bodies influence each other through energies in the space around them. This is not to be confused with plenum, fluid, or ether theories, where bodies transmit forces at a distance through a medium that pervades all space.[347]

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[345] Cao, *Conceptual Developments*, 22.
[346] Jones, *The Life and Letters of Faraday*, 77.
[347] Chapter four expands the history of Victorian ether and plenum theories.

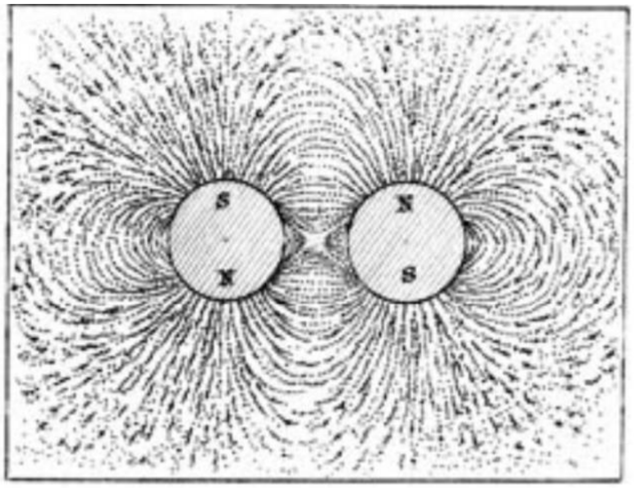

Figure 3. Faraday's lines of magnetic force[348]

Despite his experimental successes, Faraday's fresh approach to physics came at the price of his requiring "translators" for the benefit of the greater scientific community. Joseph Turner describes Thomson's and Maxwell's treatment of Faraday as "compar[ing] Faraday's lines of force to more familiar notions,"[349] that is, assimilating his theory into well-accepted scientific and mathematical conventions. I argued in chapter two that Thomson's (among others') tactic of shaping the initial thermodynamics laws relied on strategic figurative language as well as mathematical rigor. Likewise, language was no less valued in establishing electromagnetism's core conventions. As Faraday's younger and more educated contemporaries, Thomson and Maxwell were initially wary of the way Faraday "spoke" about physics.[350] Thomson even recalled that he had rejected the little he knew of Faraday's ideas in the early 1840s,[351] despite that Thomson is widely credited with understanding and employing Faraday's theory during that period. Maxwell

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[348] Faraday, "On the Physical Character of the Lines of Magnetic Force," 411-412.
[349] Joseph Turner, "Maxwell on the Method of Physical Analogy," *The British Journal for the Philosophy of Science* 6.23 (1955): 229, http://www.jstor.com/stable/685678.
[350] Purrington, *Physics in the Nineteenth Century*, 48.
[351] Jed Buchwald, "William Thomson and the Mathematization of Faraday's Electrostatics," *Historical Studies in the Physical Sciences* 8 (1977): 105, doi/10.2307/27757369.

addressed his own former skepticism in a contrite appeal to readers in the 1873 preface of his *Treatise on Electricity and Magnetism*, six years after Faraday's death, explaining,

> I was aware that there was supposed to be a difference between Faraday's way of conceiving phenomena and that of the mathematicians, so that neither he nor they were satisfied with each other's language… As I proceeded with the study of Faraday, I perceived that his method of conceiving the phenomena was also a mathematical one, though not exhibited in the conventional form of mathematical symbols. I also found that these methods were capable of being expressed in the ordinary mathematical forms, and thus compared with those of the professed mathematicians… When I had translated what I considered to be Faraday's ideas into a mathematical form, I found that in general the results of the two methods coincided, so that the same phenomena were accounted for, and the same laws of action deduced by both methods, but that Faraday's methods resembled those in which we begin with the whole and arrive at the parts by analysis, while the ordinary mathematical methods were founded on the principle of beginning with the parts and building up the whole by synthesis.[352]

As Maxwell describes it here, Faraday's methods were viable yet needed the coaxing of a trained mind into "ordinary mathematical forms." And, where Faraday saw the whole picture, mathematicians focused on parts analysis. What ultimately matters to Maxwell is the end result of his translation labors: that Faraday's method agrees with the already accepted conventions of mathematics. Although he validates Faraday, he is less concerned with the imaginative differences language produces in arriving at the convergence, the solution.

This is a statement with which some may disagree, especially considering Maxwell's famous argument for the power of knowledge creation by "Physical Analogy." Nevertheless, I maintain that this very heuristic of analogizing, on the parts of both Maxwell and Thomson, indirectly reinscribed the same conventional knowledge that

[352] James Clerk Maxwell, preface to *A Treatise on Electricity and Magnetism*, First ed., Vol. 1, 1873 (New York: Dover Publications, 2016), viii-ix.

it purported to transgress. Maxwell introduced physical analogy as a "mean" between pure mathematics and physical hypothesis. He believed that analogy closed the gap between two equally practical scientific methods, while simultaneously producing new knowledge.[353] Thomson, on the other hand, employed analogy where he needed to make sense of one branch of physics in the terms of another. Most historians of science accept that Thomson synthesized Faraday's ideas with the theory of heat flow to describe how current travels along wires. Yet Thomson swept electrostatics into a heat transfer analogy because fields provided a new way of seeing, or of knowing, a phenomenon that was not readily seeable or knowable to him. He was already involved in the study of heat transfer, and he used Faraday's research as a creative tool to serve an established epistemological framework.

As language mattered to these scientists, the distinctive way Faraday "spoke" and wrote about physics matters a great deal to the interpretation of his theory. He articulated a clear need for mathematically trained scientists to deconstruct their theoretical conjectures in terms more concrete than symbolic representations of physical phenomena. For instance, when André-Marie Ampère reduced magnetism to the motion of fluid currents, Faraday denounced Ampère's conclusion as the ad hoc outcome of mathematical discovery without recourse to demonstrating his process of investigation.[354] By contrast, Faraday did provide extensive experimental demonstration and logical reasoning for his theory, which is why Thomson's and Maxwell's return to fluid analogy is, to my mind, somewhat perplexing.

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[353] Turner, "Maxwell on the Method of Physical Analogy," 227.
[354] Purrington, *Physics in the Nineteenth Century*, 46.

In the course of translating Faraday, Maxwell turned Faraday's description of the electromagnetic field into a flux analogy, which we still employ in a traditional physics education. Maxwell asserted that "in every case the motion of electricity is subject to the same condition as that of an incompressible fluid,"[355] and further encouraged readers to consider dielectrics, or materials that resist electric current, as elastic meshes that hold this liquid in place.[356] Thomson arrived at Faraday's work earlier than Maxwell, and did not translate and extend Faraday so much as merely assimilate him into Thomson's own projects. The traditional interpretation of Thomson's work asks us to assume that he accepted Faraday's theory by the early 1840s, while working on an analogy between electrostatic "flow" and heat "flow." However, as Jed Buchwald compellingly demonstrates in his comparison of Thomson and Faraday, "Thomson in 1845 was introducing theoretical notions foreign to Faraday's theory, about which he was not altogether clear… Thomson's new formulation was afterwards seen as the essence of Faraday's electrostatics."[357]

Despite Thomson's and Maxwell's inarguably critical roles in developing electromagnetic field theory, Faraday's original ideas do differ from their translations. I belabor this point, first, to argue that the finer distinctions of imaginative strategies for making the electromagnetic field knowable extend to cultural interpretations of influence and distributed control. Visualizing electromagnetic influence as flow or flux is different from imagining an ambient field tension or contiguity in space. Science Studies scholars

[355] Maxwell, *A Treatise on Electricity and Magnetism*, 69.
[356] Alex McAulay, "On the Mathematical Theory of Electromagnetism," *Royal Society* 183 (1892): 694, https://doi.org/10.1098/rsta.1892.0018.
[357] Buchwald, "William Thomson and the Mathematization of Faraday's Electrostatics," 127.

have thoroughly discussed the machinic tendency of western science to flatten varied and layered perspectives into convention.[358] Assimilating Faraday into an already-accepted scientific tradition hammered one mode of representation into another, dominant one. While Faraday's work made space for the large-scale development of field theory, it was the translation of value from Faraday's ideas to Maxwell's and Thomson's interpretations of those ideas that cemented field theory as legitimate institutional science. Faraday was indeed employed by the Royal Institution, and operated within the structure of institutional knowledge production, but it would be a misstep not to acknowledge that his original theory emerged as a rupture in institutional thinking.

Second, Faraday's ideas are important in their unadulterated form because his insistence on incorporating the material or space around conducting wires into the electromagnetic apparatus ultimately solved signal propagation issues in global telegraphy, and later led to a massive uptick in the British demand for gutta percha. The rise of a gutta percha industry corresponded with the maturity of electrical science and its technologies. Yet, despite its widespread incorporation in global telegraphy, and indeed its indispensable role in cable functioning, gutta percha was an elusive material that resisted being flattened into a capitalist-energy regime.

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[358] Bruno Latour's work is notable here. Latour argues that inscription devices translate and flatten transverse perspectives into written documents. Bruno Latour, *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge: Harvard University Press, 1999).

Dielectrics, Induction Phenomena, and the Problem with Telegraph Signals

Opposing action at a distance, Faraday maintained that the electromagnetic apparatus includes active space around magnets and wires. In "On the Physical Character of the Lines of Magnetic Force," he explained, "the medium or space around [a magnet] is as essential as the magnet itself, being a part of the true and complete magnetic system."[359] He insisted that electric and magnetic energies were transmitted by the condition of tensions in the space and in the materials surrounding conductors, like the dielectric insulators around wires. Despite Faraday's explanation of dielectric participation in induction phenomena, mid-nineteenth century telegraph construction did not account for potential induction difficulties, and early submarine and subterranean projects experienced transmission failures, like signal lag and distortion.

In 1853, Latimer Clark of the Electric Telegraph Company invited Faraday and George Biddell Airy, Astronomer Royal, to observe some experiments on long subterranean cables. Clark noted that signals sent through long lengths of cable laid underground emerged delayed or distorted. Pending transatlantic projects would fail unless cable companies resolved their signal issues.[360] Faraday triaged the cable failure by pointing out that signal time and quality depended on how the electromagnetic energy propagated through tensions around the wire.

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[359] Faraday, "On the Physical Character of the Lines of Magnetic Force," 418.
[360] Bruce Hunt, "Michael Faraday, Cable Telegraphy, and the Rise of Field Theory," *History of Technology* 13 (1991): 2-3.

As Tyndall explained in Faraday's 1870 biography, the induction phenomena that challenged further telegraphy construction were all mentioned in his work years before a commercial need arose to illustrate them:

> This [the induction phenomena] was only a *prediction*, for the experiment was not made. Sixteen years subsequently, however, the proper conditions came into play, and Faraday was able to show that the observations of Werner Siemens and Latimer Clark on subterraneous and submarine wires were illustrations, on a grand scale, of the principle which he had enunciated in 1838. The wires and the surrounding water act as a Leyden jar, and the retardation of the current predicted by Faraday manifests itself in every message sent by such cables.[361]

Here Tyndall explains Faraday's original 1838 logical extension of the principle of induction. Faraday supposed that long lengths of cable underground or under water would act as Leyden jar capacitors, storing up charge and releasing it after long time delays, rather than allowing a signal to simply flow unimpeded.

Leyden jars were early capacitors that stored voltage, or electric potential difference, across inside and outside conducting surfaces separated by a dielectric. The dielectric, as we have discussed, resists charge that tries to pass through it. As figure 4 indicates, these capacitors were literally jars or containers with an insulating material, usually glass, sandwiched between inside and outside conducting surfaces.[362] A Leyden jar stores energy by adding charge to one conducting surface while the other surface, which has a ground connection, pulls and holds the opposite charge. A metal electrode exits the jar at the top, and a chain or wire secures the electrode's connection to the jar's inner surface. To discharge the Leyden jar, one needs a two-pronged metal rod or wire.

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[361] Jones, *The Life and Letters of Faraday*, 83.

[362] Leyden jars were the predecessors of parallel plate capacitors. In parallel plate capacitors, the dielectric material separates two conducting plates across which an electric field is induced. Both Leyden jars and parallel plate capacitors are small-scale examples of the phenomenon at work in underground or undersea telegraph cables.

One end touches the outside of the jar, while the rod's other end carefully approaches the metal electrode at the top. Across the gap between electrode and rod, a spark discharges the Leyden jar's stored energy.

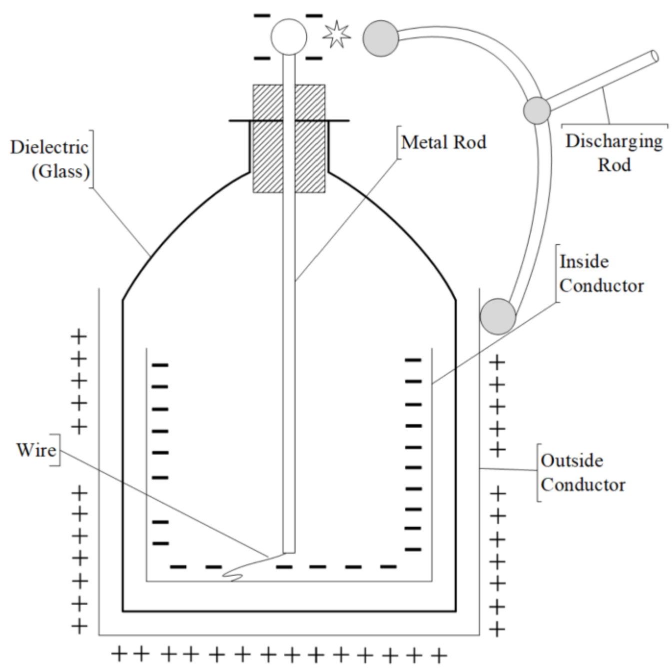

Figure 4. A basic Leyden jar capacitor

When Tyndall described the telegraph cable as a Leyden jar, he was using Faraday's reasoning to explain why signals manifested differently in cables laid underground, underwater, and in air. The Leyden jar is a metonymic stand-in for the telegraph not because of analogy, or because of metaphoric similarity, but because they are different manifestations of the same phenomenon. It was initially puzzling why there was no signal lag or distortion in cables above ground, while the signals of subterranean and submarine cables suffered. Faraday argued that the cable's dielectric material was creating a different variation of electromagnetic tension based on the cables' submersion in various external media: air, wet earth, and salt water. When Tyndall explained Faraday's argument, writing that the wires and the water "act as a Leyden jar," he meant that the same phenomenon at work in Leyden jars of different dielectric materials is responsible for signal variability in submarine, subterranean, and overland telegraph lines. If the entire telegraph cable functions as a Leyden jar, then the copper wire is its inner conductor, gutta percha is its insulating dielectric, and air, salt water, or wet earth (respective to the type of cable) is its outer conductor.

Figure 5 makes this more visible. To send a telegraph signal is to send current along the wire. However, the movement of that signal depends on an electromagnetic field created over the dielectric material. The field is induced between the outer conductor (the water, in the case of submarine cables) and the inner copper cable. Electric current can move through the copper but is stopped by the dielectric. It is easiest to think of the dielectric as an insulator, although dielectrics are of a special subset. When a dielectric is introduced to a voltage drop, notable changes do occur in the material even though current cannot pass. The electromagnetic field within the dielectric polarizes its molecules, which means that each has one side that is slightly more negative and one side that is slightly more positive. Faraday registered this phenomenon as a tension propagating through the dielectric. As Tyndall summarized, "Faraday figured their particles as polarised, and he concluded that the force of induction is propagated from particle to particle of the dielectric from the inner [conductor] to the outer one."[363] If the tension is too strong, the signal cannot move along the wire and will instead be stuck

[363] Jones, *The Life and Letters of Faraday*, 80.

until it can discharge. When Maxwell doctored Faraday's theory, he reimagined this tension as the mesh of a sponge-like substance, through which an incompressible fluid tries to escape. This analogy changes the ontological configuration of the dielectric, particularly because a mesh passively resists fluid motion while field tension in a dielectric actively restricts an electric current. The role of the dielectric in signal transmission convinced cable engineers to choose their insulation strategically because the shape and material of a wire's dielectric contributes directly to current discharge.

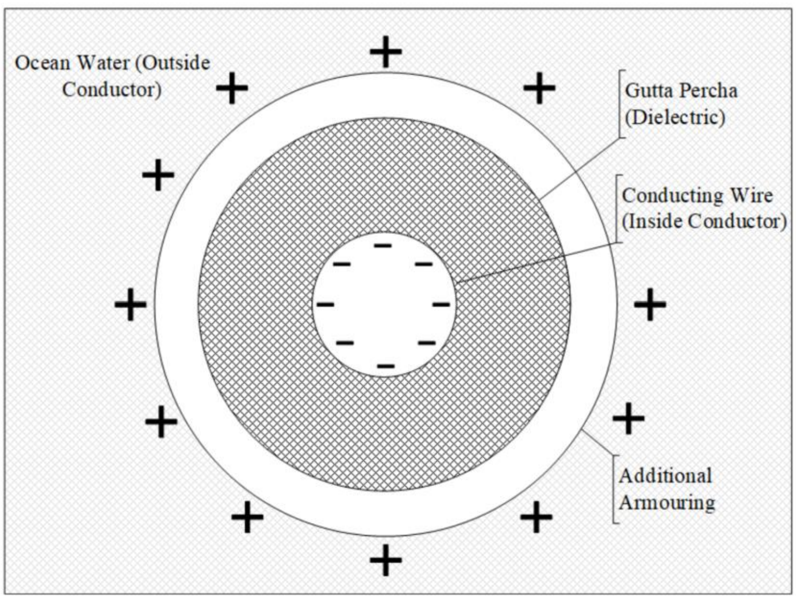

Figure 5. A simplified submarine telegraph cable cross section, as compared to a Leyden jar

An additional finding for Faraday was that the cables he inspected at both the Gutta-Percha Company of London and the Electric Telegraph Company were exceptionally long. A parallel plate capacitor's energy storage is a function of its surface area; so, likewise, the longer a cable becomes, the greater is its capacity to store charge and the more time is required to discharge a signal.[364] Latimer Clark's frustration with induction phenomena inspired this dramatic description of their interference in technological progress:

> There is no phenomenon in electricity that has a more important bearing on the electric telegraph than that of induction, and none which interferes more with the commercial success of telegraphic enterprise. If it were not for this evil presenting itself in the form known as retardation of the current, any telegraph cable, however long, could be worked at almost any speed; and although much may be done to reduce its effects, there is at present no known method for avoiding them altogether.[365]

The morally coded language Clark uses to describe induction aligns the effects of fields with commercial success, on the one hand, and malicious interference on the other. He imagines that if induction's weirdness could simply disappear, cable companies would be able to lengthen their cables to their hearts' content and dispatch clear signals between receiving stations thousands of miles away. Of course, electricity does not simply flow down a wire padded with inert insulation. Instead, the electromagnetic influence polarizes the dielectric, inhibiting an electrical short from the wire to the outside environment.

Since there was nothing to be done about the cables' external media (that is, the ocean water), the solution was to optimize the dielectric material. Gutta percha insulated wires before signal interference, and companies continued to use gutta percha after an 1859 Joint Committee convened to resolve scientific and manufacturing issues in cable

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[364] *The Joint Committee Appointed by the Lords of the Committee of Privy Council for Trade and the Atlantic Telegraph Company to Inquire into the Construction of Submarine Telegraph Cables together with the Minutes of Evidence and Appendix Presented to both Houses of Parliament by Command of Her Majesty,* (London: George Edward Eyer and William Spottiswoode, 1861), 308. In cables, induction varies proportionally to the square root of the conductor's diameter, and inversely to the square root of the dielectric's thickness.

[365] *Joint Committee*, 303. Clark's commentary appears in his contribution to the Joint Committee's appendix section.

telegraphy. However, field theory also changed Britain's economic and imperial attachments to gutta percha. Before 1859, gutta percha was employed in some cable construction, but it was not standardized. After 1861 when the Joint Committee published their findings, other dielectric materials were dismissed in favor of gutta percha, which became the new standard for cable insulation. One reason for this decision was gutta percha's superior performance in salt water. Rubber and gutta percha are stereoisomers, sharing similar chemical compositions, but gutta percha is denser and thus more watertight.[366]

Undoubtedly gutta percha was an excellent insulating material, but perhaps more importantly, it was a material with well-documented properties, shortcomings, and potential. When asked his opinion of gutta percha by the Committee's Chairman, Fleeming Jenkin explained, "I wish to call attention to the fact, that we do begin to know something of the defects of gutta-percha, and how to prevent their evil consequences, whereas probably many years will pass before we shall have gained the same knowledge of india-rubber, which doubtless has not some of the same defects we know of in gutta-percha, but probably has others…".[367] Jenkin hedges gutta percha's "evil consequences" by arguing that, first, science has already demystified many of them, and second, telegraphy cannot spare the time for research and development of an alternative dielectric when gutta percha will suffice. Thomson's work on conduction through long circuits provided equations for optimal wire diameter and insulation thickness, so standardizing

[366] John Tully, *The Devil's Milk: A Social History of Rubber* (New York: Monthly Review Press, 2011), 124.
[367] *Joint Committee*, 148.

gutta percha allowed scientists to eliminate induction disturbances in cables of specific length and thickness.[368]

After Faraday's field theory connected telegraphy's signal issues to the dielectric phenomenon, the question of insulation, and specifically gutta percha, began charting the course of telegraphy projects. Jenkin's suggestion to incorporate gutta percha research in an overall conservative approach to cable manufacturing seemed fiscally and scientifically reasonable. Helen Godfrey argues that risk aversion played an important role in shaping gutta percha market demand for decades.[369] Rather than speculating on alternative dielectrics, scientists and investors directed resources towards optimizing gutta percha's properties and standardizing the material. This conservative attitude paid off in quick and successful construction. By 1866, the first successful transatlantic line set a precedent for a flurry of other projects that followed, and as the nineteenth century ended, Britain's telecommunications network extended to North America, South America, Africa, East Asia, Australia, and India.[370] Gutta percha insulated nearly every mile of submarine telegraph wire, and Britain shipped it out of Singapore at a rate devastating to the gutta percha trees. In 1844, Britain imported roughly 200 pounds of gutta percha, but by 1873 that figure ballooned to 2700 tons.[371]

In a material sense, globalizing telegraphy depended on scientists' and capitalists' understanding induction phenomena, and then standardizing its methods and

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[368] *Joint Committee*, 110.
[369] Godfrey, *Submarine Telegraphy*, 46.
[370] Bruce Hunt, "Insulation for an Empire: Gutta-Percha and the Development of Electrical Measurement in Victorian Britain," in *Semaphores to Short Waves: Proceedings of a Conference on the Technology and Impact of Early Telecommunications*, ed. Frank A. L. James (London: Royal Society of Arts, 1998), 85.
[371] Hunt, "Insulation for an Empire," 92.

infrastructural materials. Thomas Ernest Herbert underscores this point in his 1906 exposition on British telegraphy. "It may be said, without exaggeration," he asserts, "that if gutta percha and its properties had not been known, submarine telegraph lines would perhaps never have been successful."[372] Bruce Hunt takes this line of reasoning one step further to posit that perhaps field theory would not have developed when and how it did without gutta percha. That is, Hunt argues that the scientific community invested in Faraday's induction hypotheses only when there was a material need to apply them.[373] Unarguably gutta percha was a key resource in telegraphic and electrical science, but the conditions for gutta percha's success combined market demand, local and global economic interaction, and translations across value systems and sites of difference. Without such networks, the British never could have accessed this remote and site-specific resource.

Soon after submarine telegraphy's widespread success, it became clear to western powers that gutta percha was a finite resource. By the early twentieth century, roughly 27,000 tons of gutta percha insulated copper telegraph wires, each ton derived from trees capable of yielding only about eleven ounces of sap when fully grown.[374] Cable manufacturers recognized the gutta percha shortage as an imminent crisis, though they foisted the responsibility for their own resource shortage on the collection techniques of Indigenous traders. The next part of this chapter complicates the Victorian archive's

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[372] Thomas Ernest Herbert, *Telegraphy: A Detailed Exposition of the Telegraph System of the British Post Office* (London: Whittaker & Co., 1906), 270.
[373] Hunt, "Insulation for an Empire," 85, and Bruce Hunt, "Michael Faraday, Cable Telegraphy, and the Rise of Field Theory," *History of Technology* 13 (1991), 2.
[374] John Tully, "A Victorian Ecological Disaster: Imperialism, the Telegraph, and Gutta-Percha," *Journal of World History* 20.4 (2009), 575.

monolithic perspectives on sustainability and trade at the periphery. I will echo Godfrey's word of caution that almost all historical materials available to us register some level of European perspective;[375] yet even with these limitations, we can discern the layers of sociocultural translation in the gutta percha trade, and its refusal to assimilate in the tradition of plantation agriculture.

SOURCING THE DIELECTRIC: THE GUTTA PERCHA SUPPLY CHAIN

This section turns to the topographically complex regions where Indigenous collectors sourced gutta percha in the nineteenth century, and where it entered the global economy through trade networks of socially, politically, and geographically interlinked groups. Although gutta percha became one of the most imperative colonial resources of the British periphery by the late nineteenth century, the gutta percha trade did not follow a typical core-periphery relationship. Unlike other agricultural resources, gutta percha resisted domestication: the trees' insular location, their cell structure, and the planets' sheer finitude of mature trees are among factors that debarred their access to non-Natives. Since gutta percha did not grow along the coast, collectors embarked on dangerous and lengthy upriver expeditions in between their regular cycles of swidden agriculture, the technique of burning forest areas to clear land for cultivation. Forest produce collectors made autonomous decisions to cultivate land or venture upriver on foraging expeditions, and they made these choices based on personal need and market demand. Once collectors extracted the gutta percha, they bartered with Chinese traders who transported the

[375] Godfrey, *Submarine Telegraphy*, 117.

produce along rivers to depots where it entered the external economy. The mechanisms of this supply chain shielded the trade from total British intervention because each node in the trading infrastructure preserved particularized skills and knowledge, while also participating in cultural and value exchange across adjacent nodes.

Indigenous expertise was the core of gutta percha trading. The British, and to a large extent the boat traders who bartered for forest produce, lacked the skills necessary to survive forest expeditions. However, even if forest collectors and traders remained relatively autonomous on otherwise British occupied land, Britain's nineteenth-century presence in the Malay Peninsula altered local modes of governance and kinship ties by controlling colonial subjects through their own cultures. This method of distributed policing operated by employing Malay, Indigenous, or Chinese leaders to tax and govern their own peoples at the behest of British Residents. As Godfrey points out, "traditional laws were to be respected except in so far as this interfered with the concept of western ideas of justice or the security of Sarawak,"[376] one of the essential locations of the gutta percha trade. Controlling subjects at a distance and through their own cultures was an effective strategy of subjugation and maintaining what the British considered general law and order; however, when it came down to fulfilling the growing demands of the gutta percha market, Britain could not successfully supplant or significantly alter the trade networks already in place. The fin-de-siècle gutta percha shortage most threatened British consumers because the trees were of little or no spiritual and nutritive value, and because

[376] Godfrey, *Submarine Telegraphy*,145.

traders had other market options.[377] For the telegraph industry, it was a crisis with no easy solution. Britain's conservative approach to submarine cable insulation left them with no recourse to different dielectric materials. Per the Joint Committee's findings, no other material had been standardized, and their options were already limited by the messy induction disturbances to signal transmission. Britain's approach depended on industrial standardization: standardizing the insulation, and then fitting the agricultural practices to that model.

Like their treatment of electromagnetic field theory, the British approached gutta percha as an object to be mapped out and translated into an operational architecture, *i.e.*, settler-capitalist agriculture. Following Tsing's argument on scale, we might also say that the gutta percha shortage threatened the British project more than it threatened Southeast Asian traders because the British attempted to scale gutta percha up to meet the rapid expansion of global telegraphy. Gutta percha trees were incompatible with such unilateral changes in scale. "Scalability is not an ordinary feature of nature,"[378] Tsing reminds us, especially when a system is not self-contained, but rather symbiotic with environmental and location-specific variables. Gutta percha trees are found only in Malaysia, Singapore, Sumatra, and Borneo, which means that the harsh geography of their environment, one factor among many, contributes to their site-specific thriving.

As for the actors in nineteenth-century Southeast Asian supply chains, they did not depend on gutta percha for survival. Indigenous collectors could cultivate seasonal

[377] Helen Godfrey, "Pulled by Wire, Pushed by Desire. Submarine Telegraphy and the *Gutta Percha* Trade of Nineteenth Century Sarawak, an Indigenous Trade in the Global Economy," *Borneo Research Bulletin* 44 (2013), 157.
[378] Tsing, *The Mushroom at the End of the World*, 38.

agriculture, or alternatively embark on expeditions for other forest produce. Similarly, Malay and Chinese traders adapted their goods to availability and market demand. It was the British whose attempts to assimilate gutta percha to a scalable, plantation-style project failed, assuring their continued reliance on Indigenous knowledge and various other trader middlemen. Europeans, including the British, did construct gutta percha plantations and forest reservations. Had these succeeded, British colonizers almost certainly would have exploited Indigenous labor by forcing collectors to work for European, Malay, or Chinese employers.[379] The repeated failure of gutta percha plantations exposed the insufficiency of western science to transplant settler-capitalist agriculture to a space where physics and empire relied on those modes of exploitation to expand. Crucially, it should have exposed the failure of a developing, purportedly universalizing energy concept to assimilate land, bodies, animals, and plants to an energy-capitalism nexus.

Considering that the history and legacy of the telegraph is well-known and celebrated, but gutta percha's role in cable infrastructure and electromagnetic field theory is not, science and technology histories owe the nineteenth century gutta percha trade and its questions of sustainability a deeper dive. Even now, twenty-first century colonial violence in Southeast Asia continues to throw differences between western and nonwestern sustainability narratives into relief. Relatively recent legislation has discredited swidden agriculture as a forest management practice, arguing instead in the

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[379] Godfrey, *Submarine Telegraphy,* 158.

favor of corporate logging.[380] Native populations in Malaysia have also contended with palm oil plantations and large-scale expropriation, including an upheaval of native customary laws and systems of land tenure.[381] Malaysia and its surrounding regions are thus the sites of numerous attempts to seize land, colonize subjects, and control resources. The history of gutta percha in British telegraphy is worth detailing because it diverges from the normative core-periphery power dynamic, while also affirming that Britain's global influence required transformations of salvage accumulation into recognizably capitalist industrial processes.[382]

In this section, I examine the supply chains through which gutta percha entered the nineteenth-century global economy. The process of transforming forest produce into raw material for cable insulation involved many different sites of cultural, spiritual, and economic exchange. The British, who did not value the nuances of these links, were eager to undercut them where they could. The second part of this section therefore covers how the gutta percha trade disempowered the British, and how they policed colonial subjects with their own cultures while simultaneously denigrating Indigenous knowledge. In particular, the British questioned the soundness of traditional gutta percha extraction methods. Following the convention of other relatively recent histories on trade in

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380 Masahiro Ichikawa, "Degradation and Loss of Forest Land and Land-Use Changes in Sarawak, East Malaysia: A Study of Native Land Use by the Iban," *Ecological Research* 22 (2007), 404.

381 Jean-François Bissonnette, "Representations as Practices: Producing a Native Space in Sarawak, Malaysia," *Journal of Cultural Geography* 28 (2011), 348.

382 Anna Tsing argues in *The Mushroom at the End of the World* that "[t]ranslations across sites of difference *are* capitalism: they make it possible for investors to accumulate wealth (62). What we see in the gutta percha trade is an example of just such salvage capital, but we also find patches of resistance where the supply chain does not succeed in equalizing diverse rhythms to meet the demand of capital's scale.

Borneo,[383] I reference Indigenous nations in this section using nomenclature from the Victorian archive, with the exception of the term "Dyak."[384] Many of these groups still dwell in and around the Malay Peninsula.

The Gutta Percha Trade Ecology

By the end of the nineteenth century, gutta percha had been incorporated as telegraph insulation all over the globe: a remarkable explosion for such an isolated and limited resource, and for which an industry did not exist until 1846.[385] Native and Malay populations in Southeast Asia had been using gutta percha for centuries before it piqued the interest of Europeans. In his 1898 "Cantor Lectures on Gutta Percha," Eugene Obach cites the first gutta percha specimen brought back to Europe as that of seventeenth-century curiosity hunters.[386] However, gutta percha never met any significant interest or demand until 1843, when it was introduced to London by two medical professionals, Dr. José D'Almeida and Dr. William Montgomerie.[387] From 1843 to the 1860s, gutta percha transformed from a relatively obscure material into one without which global telegraphy might not have existed.

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383 See Helen Godfrey, *Submarine Telegraphy and the Hunt for Gutta Percha*; F.L. Dunn, *Rain-Forest Collectors and Traders*; Benedict Sandin, *The Living Legends: Borneans Telling Their Tales*.

384 "Dyak" is a term that Europeans used indiscriminately to describe the Indigenous peoples of Southeast Asia during the colonial period.

385 William T. Brannt, *India Rubber, Gutta-Percha, and Balata: Occurrence, Geographical Distribution, and Cultivation of Rubber Plants; Manner of Obtaining and Preparing the Raw Materials, Modes of Working and Utilizing Them, Including Washing, Loss in Washing, Maceration, Mixing, Vulcanizing, Rubber and Gutta-Percha, Compounds, Utilization of Waste, Balata, and Statistics of Commerce* (Philadelphia and London: Henry Carey Baird & Co. and Sampson Low, Marston & Co., Limited, 1900), 226.

386 Obach, "Cantor Lectures on Gutta Percha," 2.

387 Obach, 2-3.

In Obach's lectures, the question of resource sustainability is posed in the terms of how best to extract value from the forest while preventing Indigenous foragers from destroying it. The gutta percha problem is not presented as a failure of the plantation system, nor of the universalizing logic of industrialization, but rather as a failure of indigenous forest expeditions. As Obach explains, "[a]s soon as the valuable properties of gutta percha had been recognised in Europe and a demand had been created for the article, the countries all around Singapore were searched with great avidity for Taban[388] trees, and almost a craze for getah-collecting sprang up amongst the indigenous population. The consequence was that an immense number of trees of great size and age, probably hundreds of thousands, were ruthlessly destroyed during the first four or five years, and whole forests denuded of them, like those on Singapore."[389] Obach's prose suggests that an uptick in market demand drove local Indigenous to a frenzy of tree-felling. In reality the craze was British. Indigenous populations followed market trends as they always did, that is, to supplement their seasonal patterns of subsistence agriculture and to barter for prestige goods. Southeast Asian Indigenous populations had been affected by shifting trade and political conditions since at least 1600,[390] and they worked forest produce expeditions around their own agricultural cycles as well as colonial market demand. Therefore, when the market favored gutta percha they were motivated to supply

[388] *Taban* refers to the name of the gutta percha tree. The Malay population called the tree *Taban* and the gutta percha product *getah taban*.
[389] Obach, "Cantor Lectures on Gutta Percha," 12.
[390] Godfrey, *Submarine Telegraphy*, 135.

it. They also extracted gutta percha in the manner that they always had, that is, by felling mature trees and making incisions in the bark.[391]

Obach's treatment of Indigenous forest produce collecting techniques falls in line with the standard Victorian narrative of the gutta percha trade. In the nineteenth century, naturalists and ethnographers, including Alfred Russel Wallace,[392] described Indigenous groups of the Malay Peninsula as primitive, superstitious head-hunters,[393] removed from civilization. This construction ignored the vital role of these Indigenous in local trade. Chinese and Malay traders depended on Indigenous collectors for the produce they brought to international markets. The Malay population had the most direct contact with the British and were therefore the most direct subjects of the imperial civilizing mission.[394] Indigenous collectors, on the other hand, were left to the forests. The British did not attempt forced assimilation, but rather viewed Native peoples as a threat to the gutta percha resource, despite their expert ecological knowledge and singular ability to navigate the local terrain.

In fact, the success of gutta percha trading in the nineteenth century depended on the sophisticated interactions and cooperation of Indigenous collectors with other key actors in what I consider a vital extension of telegraphy's infrastructure. Here, I want to enlarge the scope of the gutta percha supply chain. F.L. Dunn's model of forest produce

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[391] Godfrey, *Submarine Telegraphy*, 3.
[392] Alfred Russel Wallace, *The Malay Archipelago: The Land of the Orang-utan, and the Bird of Paradise, A Narrative of Travel, with Studies of Man and Nature*, 2 vols., 2nd ed., 1865 (London: Macmillan and Co., 1869). HathiTrust.
[393] Many Native groups did incorporate the heads of their enemies into daily rituals and spiritual life. These practices were sophisticated and political, though Victorian ethnographic accounts tend to describe them as evidence of Indigenous primitivism.
[394] Rusaslina Idrus, "The Discourse of Protection and the Orang Asli in Malaysia," *Kajian Malaysia* 29, no.1 (2011), 57-58.

supply chains identifies four major nodes in the Malayan rain forest subsistence economy. Across these nodes certain values and knowledges are exchanged, while others remain localized.[395] Godfrey has reworked Dunn's model for the nineteenth-century gutta percha supply chain, classifying four groups essential to trade: collectors, secondary traders, tertiary traders, and shipper/carrying traders. Godfrey amplifies and extends Dunn's claim that locals formed an "ecological-economic" system with their environment.[396]

This is the peripheral infrastructure that secured the global outreach of telegraphic energy fields: the collection and trading architecture that regulated the acquisition of British gutta percha, without which, as we know, there would have been no global telegraphy. In what follows I will work through a cursory analysis of the supply chain so as to lay bare the particularities and the transcultural interconnections that effectively protected gutta percha trading from outsiders. I center Borneo's Indigenous collectors, but I would be remiss not to identify other actors in the gutta percha trade, such as the Chinese and Malayan traders who functioned as vital middlemen in bazaars and other points of cultural contact.

The convergence of gutta percha trading was the British-occupied principality of Sarawak, the larger of the two states on the island of Borneo. Sarawak housed the British-owned Borneo Company Limited (BCL), whose direct involvement in submarine

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[395] F.L. Dunn, *Rain-forest Collectors and Traders: A Study of Resource Utilization in Modern and Ancient Malaya*, Monographs of the Malaysian Branch, No. 5 (Kuala Lumpur: Royal Asiatic Society, 1975), 99-103.
[396] Godfrey, *Submarine Telegraphy*, 158-59.

telegraphy promoted gutta percha trade in this region.[397] Because of Sarawak's adjacency to the entrepôts Singapore and Kuching, the supply chain linked into world trade networks. Moving gutta percha from the forest interior to an entrepôt required three distinct mechanisms: Indigenous expertise, trading bazaars, and the development of credit networks for barter goods.[398] As we will see, the concerted operation of these mechanisms debarred British colonizers from converting the process of gutta percha extraction to the standard plantation model.

The Iban, Kayan, Punan, Kelabit, Murut, and Kenyan were all active gutta percha collectors, forming the first node in the chain.[399] Collectors had intimate topographical and ecological knowledge, developed over generations of dwelling and subsisting in the harshest regions of Borneo. They maintained proximity to the forests and eventually bartered with secondary traders who traveled along river highways. The key role of collectors was to survive dangerous, months-long expeditions in the forest, where only they cached the location of gutta percha trees and extracted their sap.[400]

As a complement to their extensive knowledge of the natural environment, collectors applied their spiritual beliefs to the art of forest navigation and agricultural cycles. Animal augury guided most aspects of daily living and was influenced by a general belief in *antu* or *toh*,[401] the spirits with which humans share the material world. European explorers and scientists who accompanied collectors on gutta percha

[397] Godfrey, *Submarine Telegraphy*, 63.
[398] Godfrey, 190.
[399] Godfrey, 138.
[400] Godfrey, 161.
[401] Charles Hose, William McDougall, and Alfred Cort Haddon, *The Pagan Tribes of Borneo: A Description of Their Physical, Moral and Intellectual Condition, with Some Discussion of Their Ethnic Relations*, vol. 2 (London: Macmillan and Co., 1912), 19-20. Google Books.

expeditions recorded demonstrations of their spiritual practices. Alfred Haddon, for example, produced an ethnographic study of Sarawak from his 1888 travels in the region. He reported a "cult of omen animals… of such importance in the daily life of most of the tribes of Borneo,"[402] and cataloged several scenarios where bird augury guides decision-making. In one example, Charles Hose, the Resident of the Baram District, expresses frustration during a forest expedition when the appearance of a *pelandok* (greater mouse deer) obstructs their progress:

> On the second day of one of Hose's journeys through the jungle, the chief who was with him saw a *pelandok* rush across the path. Hose being behind did not observe it, but he saw all his party sitting on a log, and the chief informed Hose that he could not proceed that day as his 'legs were tied up.' This was most inconvenient, as Hose was in a hurry; but the men would not go on. Hose freely took upon himself all the responsibility, and said he would go first and would explain to the *pelandok* that he was the person in fault. The chief would not agree even to this, and did not budge, but said he would follow the next day. Hose went on with some of the men as far as he could, and then camped. Next day the chief caught Hose up at noon and appeared very much surprised that no harm had befallen him. Hose chaffed him about his legs, and was 'pleased to see that they had become untied'![403]

Hose does not want to delay the expedition for a *pelandok* and infantilizes the chief by offering to negotiate with the animal, and again by teasing him when the chief is surprised that Hose had managed to avert the harm augured by the *pelandok*. Besides accounting for Hose's impatience, Haddon describes the slowness of augury in gutta percha expeditions, explaining that the *beragai* (scarlet-rumped trogon) was a requisite signal to start a journey, followed by sighting a *nendak* (white-rumped shama), followed by a three-day's waiting period, and finally catching a glimpse of another *beragai* on the

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[402] Alfred C. Haddon, *Head-Hunters Black, White and Brown* (London: Methuen & Co., 1901), 381. HathiTrust.
[403] Haddon, 386.

right.[404] This singular combination foretold a healthy journey for all and plenty of gutta percha, and was therefore worth the wait. It was considered additionally requisite to consult the hawk before expeditions of any kind. Addressed as *Bali Flaki* by Kenyahs and *Laki Neho* by Kayans, the hawk was a formal guide, and expeditions could not proceed without first securing the proper favorable omens.[405]

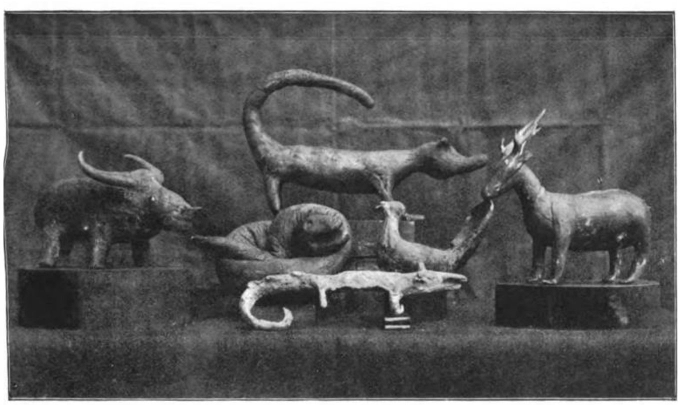
In contrast to the uniformity and interchangeability of plantation agriculture, animal augury ensured careful and individualized attention to each gutta percha expedition. Whereas Europeans blamed Indigenous collectors for their "wasteful" tree felling, foragers' expeditions refused the mappable, wholesale extraction of labor that colonial industry demanded from their bodies and natural resources. Moreover, Indigenous agriculture and foraging were accurate because they required experts to interpret and synthesize evidence from the environment. Iban scholar Benedict Sandin confirms that there is little guesswork involved in animal augury. Regarding birds in particular, message interpretation is a methodological practice involving what he describes as "four major sets of variables":

1. The place at which the call is heard, the conditions under which it is heard and the direction of the call relative to the hearer;
2. The nature of the call itself and its possible occurrence in a sequence with the calls of other augural birds;
3. The direction from which an augural bird flies across a person's path, the individual's purpose of travel and the place at which the bird crosses his path relative to his place of departure or destination;
4. The condition of the person who hears a call or sees the flight of a bird, his status and age, or that of the person to whom the omen bears reference.[406]

[404] Haddon, *Head-Hunters*, 390.
[405] Hose et al., *The Pagan Tribes of Borneo*, 51-55.
[406] Benedict Sandin, *Iban Adat and Augury* (Penang: Penerbit Universiti Sains Malaysia, 1980), 109-110.

Based on Sandin's variables, we can see that the Iban used repeated observations about their environment to construct a rubric for social and natural encounters.

Like the Iban, the Punan and the Kenyah practiced bird augury on gutta percha expeditions; and, though they named birds differently, they respected similar omens. For example, according to Kenyah protocol on travel, "If the *Esit* [spiderhunter] flew from the right to the left side, it was an unlucky sign because it symbolized the failure of the venture, so it was necessary for the traveler to return home for he could not obtain anything he was looking for."[407] Likewise, Kayan augury advises, "if it [the spiderhunter] flies from the right to the left side of the road, it is a bad omen and must be respected with an offering of an egg by the worshipper."[408] Their shared spiritual literacy and experience in the forest allowed different Native peoples to trade knowledge of where gutta percha could be found and how to avoid danger.



OBJECTS MOULDED IN GUTTA PERCHA BY NATIVES.

Figure 6. The transcript of the 1897 Cantor Lectures on Gutta Percha provides a photograph of gutta percha animal figurines crafted by Native peoples. These pieces appeared in the Kew Museum.

[407] Benedict Sandin, *The Living Legends: Borneans Telling Their Tales* (Cawangan Sarawak: Dewan Bahasa Dan Pustaka Malaysia, 1978), 35.
[408] Sandin, 55.

Even after an expedition's completion, animals remained key signifiers in the gutta percha trade. Animal effigies made of gutta percha were often found in produce shipments (see fig. 6). Photographs of such statues appear in the transcript of Obach's Cantor Lectures, as they, along with curated displays of Native tools, informed a British public of the purportedly primitive origins of telegraph insulation.[409] In 1865, Frederick Boyle reported that gutta percha "is usually twisted into fantastic shapes, and in every cargo one mass is found presenting a rude resemblance to an alligator… doubtless intended as a sort of charm or propitiation to the spirits of the jungle. I shall have a future opportunity of speaking of the Dyak belief in 'antus' or wood-devils."[410] Native groups such as the Kayans and the Ibans revered the crocodile as a relative,[411] which explains the preference for "alligator" effigies.

However, British observers who dismissed the effigies as primitive craftwork overlooked their nuances. In addition to signifying the kinship relationship between crocodiles and humans, these figurines may also have been markers by which Chinese traders identified the collectors they bartered with.[412] These *secondary traders*, in Dunn's model, translated Indigenous cosmologies into logistical value in a system of credit and barter where creditors and debtors needed to identify each other, maintain relationships, and operate on trust. In a high-risk system like this, the resignification of gutta percha figurines may have aided traders in credit and barter transactions.

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[409] Obach, "Cantor Lectures on Gutta Percha," 24.
[410] Frederick Boyle, *Adventures Among the Dyaks of Borneo* (London: Hurst and Blackett, 1865), 123-24. Google Books.
[411] Hose et al., *The Pagan Tribes of Borneo*, 76-89.
[412] Godfrey, *Submarine Telegraphy*, 174.

The secondary traders, or boat traders, traveled upriver to Native longhouse dwellings or bazaars in key port locations. There, they bartered for forest produce which collectors traded for a variety of items provided on credit.[413] This was a pivotal node in the gutta percha supply chain because secondary traders ventured into sites of cultural exchange that middlemen with more direct connections to Singapore and Kuching did not face. Although the Malay population participated in secondary trading, Chinese entrepreneurship carried most of Borneo's successful commerce, a fact noted by the British Consular Report for the year 1871.[414] "One reason for the success of Chinese traders," Godfrey explains, "was their practice of establishing 'social bonds' with the local population, including intermarriage, offering gifts, learning the local language, or forgiving small debts."[415] These boat traders were motivated by successful commerce, rather than goodwill,[416] yet by adapting to local customs and suturing cultural rifts, Chinese traders acquired the knowledge required to negotiate and maintain critical credit relationships and bring gutta percha to its next link: *the tertiary traders*. The tertiary traders transported gutta percha to entrepôt locations like Singapore and Kuching, thus forming the node where gutta percha was translated to the value of the international economy. Along with the *shipper/carrying* traders, the tertiary traders undergirded much of the overall effectiveness of gutta percha trading because they took more risks along the

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[413] Godfrey, *Submarine Telegraphy*, 202-03.
[414] *Reports from Her Majesty's Consuls on the Manufactures, Commerce, &c., of Their Consular Districts* (London: Harrison and Sons, 1873), 8. HathiTrust.
[415] Godfrey, 180.
[416] Godfrey, 180.

region's primary river infrastructure, transporting freight to remote areas where there was limited competition for their product.[417]

Brom this breakdown, we see that the essential components of gutta percha trading were Indigenous ecological knowledge, sites of cultural exchange like bazaars in strategic port locations, and the development of a credit and barter system.[418] We can consider all these components an extension of telegraphic infrastructure. A line of credit underpinned the trade, linking Indigenous collectors by association to the Kuching traders who added gutta percha to the external economy. One of the reasons such a risky system succeeded was because it was rooted in mutual aid and communication, rather than exploitation, standardization, and scalability. Traders may not have been motivated by amity, yet there was an overall willingness to exchange cultural knowledge, ideas, and information, even if areas of expertise remained specific to groups or locations.

As I have emphasized, the core of that specialized expertise was Indigenous knowledge. This is a fact noted in myriad British accounts, yet not infrequently paired with a sense of urgency and concern for the imminent extinction of mature gutta percha trees. The Consular Report for 1869 indicates that trees were becoming much more difficult to find, increasing the demand for Native assistance in the forest. In the same breath, this report blames Indigenous collectors for the scarcity. "[O]wing to the reckless way in which trees are felled and the gutta extracted," the Consul proclaims, "they have almost entirely disappeared from the neighbourhood of the rivers, and collectors have

[417] Godfrey, *Submarine Telegraphy*, 186-88.
[418] Godfrey explains the details of this architecture at length in *Submarine Telegraphy and the Hunt for Gutta Percha*, see Chapter 6.

now to penetrate much further into the forests in search of the trees than was formerly the case."[419] The British problematize their own position as gutta percha cultivators, and then pivot to impugn Indigenous methodology. This is what we will look at next: the illusion of British influence over forest resources and trade, and the steps they attempted to assert control.

Distributed Control and Failed Attempts to Domesticate Gutta Percha

By the end of the century, British officials were referring to their resource shortage as the "Gutta Percha Crisis." They attempted to rehabilitate the tree population by planting them in the forest, cultivating them on plantations, and tapping (as opposed to felling) trees. However, none of these trials succeeded.[420] Obviously the future of telegraphy projects was at stake, but the demand for gutta percha created by the telegraphy industry also complicated the interests of the Borneo Company Limited (BCL), the leading British firm in Southeast Asia. Founded in 1856, the Borneo Company Limited profited from trade and business in and around the Malay Peninsula. The BCL was given monopoly rights to many of Borneo's natural resources, but forest produce operated without monopoly restrictions. Therefore, the BCL competed for gutta percha with the traditional barter and credit economy.[421] With monopoly rights and royalty payments the British were able to control Borneo's mineral resources to a considerable degree, but gutta percha remained dependent on Indigenous collection and

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[419] *Commercial Reports Received at the Foreign Office from Her Majesty's Consuls, in 1869-70* (London: Harrison and Sons, 1871), 8. HathiTrust.
[420] Godfrey, *Submarine Telegraphy*, 86.
[421] Godfrey, 110-11.

the traditional supply chain. The British attempted to regulate the supply and movement of gutta percha by mapping out the forests and cultivating tree growth. Their unilateral approach was unsuccessful; gutta percha did not assimilate to domestication.

British subjects in Southeast Asia thus had two challenges at hand: dealing with the gutta percha shortage and competing with the traditional supply chain. Concerning the former, the nineteenth-century archive is riddled with historical accounts of western authorities accusing Indigenous collectors of thinning the gutta percha forests. Most held Native tools and spiritual beliefs accountable, suggesting that trees should be cultivated under supervision and subsequently tapped. In his 1900 book on insulation materials, William Brannt bemoans, "the fact remains that even in the most favorable case the yield of a tree is small, and that with the irrational manner in which the juice is collected, the trees still in existence will become more and more decimated…"[422] Obach similarly lectured that "the present method of obtaining gutta percha from the latex in the bark of the trunk, after felling the tree, is no doubt a very crude and wasteful one, and consequently, any feasible suggestion to remedy this state of affairs deserves our most serious consideration."[423] Echoes of Indigenous inadequacy abound. Even recently, John Tully's history of the rubber industry admits that "methods of extraction were primitive and wasteful," though he ultimately criticizes Europeans for blaming "Malay woodsmen" because Europeans solicited the collectors' help in the first place.[424] In Tully's account, plantation ventures were mostly failures to launch, rather than ecological impracticalities.

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[422] Brannt, *India Rubber, Gutta-Percha, and Balata*, 233.
[423] Obach, "Cantor Lectures on Gutta Percha," 44.
[424] Tully, *The Devil's Milk*, 128.

On the contrary, there are numerous possibilities for the failure of gutta percha cultivation projects. Foremost among these, the vascular tissue of gutta percha plants makes tapping trees for sap difficult if not prohibitive. The latex vessels do not interconnect, so there is no possibility of "bleeding" the tree.[425] Another approach attempted to outplace Chinese secondary and tertiary traders by coaxing latex out of less valuable parts of the tree. Around 1890, Frenchman Eugène Sérullas developed a method to extract latex from the leaves and twigs of gutta percha plants by mechanically chopping them and treating them with acid.[426] This was modestly successful, but it failed to turn a profit. The process required European factories to be geographically nearer to the leaves and twigs they treated.[427] William Thomson, who at this point devoted his intellectual and pecuniary resources to studying gutta percha and its commercial applications, invested in Sérullas's process. With his financial backing, the Gutta Percha Corporation was formed in 1897 to apply Sérullas's patent to a Straits Settlements manufacturing operation. Despite the opportune location of its factory, the company failed. The final product was of poor quality, and the cost of production and shipping sank profits.[428]

Ultimately, because the British did not have isolated seed for gutta percha trees, they focused their efforts on forest management. This included dividing the forests into tracts or blocks, identifying the most valuable species, and either marking them for protection or transplanting them. Singularly focused, the British ignored the surrounding

[425] Godfrey, *Submarine Telegraphy*, 3.
[426] Tully, 129.
[427] J.S. Gamble, "Gutta Percha Trees of the Malay Peninsula," *Bulletin of Miscellaneous Information (Royal Botanic Gardens, Kew)* 1907, no.4 (1907): 118, http://www.jstor.com/stable/4111825.
[428] Godfrey, 82-83.

ecosystem, and other trees and wildlife interfering with the cultivation of marked trees were razed.[429] It was only in 1915 that Britain's cable company, Telcon, established a plantation. Telcon sought to completely displace Indigenous labor and "unsustainable" tree-felling, yet the company could not find a way to viably tap the gutta percha trees.[430] The plantation was never a large-scale success. Gutta percha trading peaked in 1903, and telegraph construction waned soon thereafter because of World War I trade interruptions and the development of wireless telegraphy. After the war, synthetic insulation materials supplanted gutta percha and the "crisis" was inconsequential.[431]

Why were Europeans so unyielding to traditional ecological knowledge, instead insisting on monocropping, processing, and domestication, even when attempts proved unlucrative or outright impossible? Following Daniel Headrick's argument on telegraphy and empire, I would reason that the artifice of British control in the Malay Peninsula was both affirmed and exacerbated by the 1857 uprising in India against the British East India Company. The rebellion prompted a frenzy of telegraphy projects to link the subcontinent to London,[432] a development that both increased demand for gutta percha and heightened anxiety over imperial control. In Sarawak, a complementary rebellion occurred in 1857, inciting retaliatory subjugation by the resident British Administration.[433]

But policing the growth and movement of gutta percha exceeded mere suppression of colonial subjects. The tactics deployed to control the gutta percha trade

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429 Gamble, "Gutta Percha Trees of the Malay Peninsula," 118-121.
430 Godfrey, *Submarine Telegraphy*, 91-92.
431 Godfrey, 150-53.
432 Daniel R. Headrick, *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850-1940* (Oxford: Oxford University Press, 1988), 99.
433 *Reports from Her Majesty's Consuls on the Manufactures, Commerce, &c., of Their Consular Districts* (London: Harrison and Sons, 1878), 279. HathiTrust.

reveal a desire to bring the people, plants, and ecosystems of Southeast Asia under a universalizing, mappable rubric. According to A.M. Burn-Murdoch, the British Conservator of Forests, "The systematic exploitation of the gutta percha areas will only be possible in reserved forests, tracts being taken in hand annually."[434] The desire to make things knowable and thus governable, assimilable to a rubric already in place, is a cornerstone of western science, industry, and capitalism. As the nineteenth century moved forward, energy science increasingly supported, and drew support from, the notion that all ideas, bodies, and lifeways could be linked together and flattened into lean extractive processes. Faraday's field theory, after all, needed to be translated, assimilated to the language of mathematics to prove its legitimacy. Universalism, interchangeability, and profitability belong especially to the credo of energy physics, whose scientists and supporters increasingly argued that all matter fit under energy's definition as the ability to do work. Because the mechanisms of the gutta percha trade, including the plant itself, resisted the plantation system model and its formulas of extraction, the gutta percha trade also resisted the ongoing development of an energy-capitalism nexus. Thus, gutta percha and its trade structures were frustrating anomalies.

Institutional science and capitalism are both mechanisms of translation and control. As Tsing reminds us, global capitalist structures are successful because they coordinate industrial manufacturing with salvage accumulation.[435] The British struggled to fit the non-capitalist gutta percha apparatus into its traditional exploitive infrastructure. Until synthetic insulation unseated gutta percha, Native collectors and the intermediary

[434] Gamble, "Gutta Percha Trees of the Malay Peninsula," 120.
[435] Tsing, *The Mushroom at the End of the World*, 23-24.

traders of the supply chain remained essential actors in the procurement and movement of the only standardized latex of the telegraph industry. We therefore should examine how the British employed tactics of distributed and indirect influence to control populations and trade in Southeast Asia. One strategy was to claim minimal interference in local cultures while also employing local Malay, Chinese, and Indigenous leaders to police their own peoples as an arm of the British administration. Gastón Gordillo's analysis of twenty-first century infrastructural control in South America argues that agents of large corporations that are violently disrupting local ecosystems attempt to "gain the trust of potential clients by adapting to their practices and cultural rhythms and by contributing to local institutions through donations and the organization of social events."[436] In the Victorian era, a lineage of "white rajahs" in Sarawak likewise tried to establish an influential rapport with locals.

The Borneo Company Limited paid royalties to the so-called white rajahs of Sarawak in return for access to resources.[437] James Brooke became the first rajah of Sarawak when he endeavored to extend British influence into Southeast Asia during a period of only marginal support for such an enterprise.[438] After James Brooke, his nephew Charles assumed responsibility for the region. Between 1841 and 1946, the Brooke family controlled Sarawak under a regime predicated on purportedly minimal

[436] Gastón Gordillo, "The Metropolis: The Infrastructure of the Anthropocene," in *Infrastructure, Environment, and Life in the Anthropocene*, ed. Kregg Hetherington (Durham and London: Duke University Press, 2019), 85.
[437] Godfrey, *Submarine Telegraphy*, 110-11.
[438] Robert Pringle, *Rajahs and Rebels: The Ibans of Sarawak under Brooke Rule, 1841-1941* (Kota Samarahan: Universiti Malaysia Sarawak, 2010), 2.

interference, though English presence deeply altered Indigenous social structures.[439] The Brookes fragmented their administration into divisions, each controlled by a local Resident who employed Malay, Chinese, or Indigenous political leaders to police regional populations and collect taxes.[440] Thus, despite the relatively sparse British staffing, Brooke administrators were able to control colonial subjects through their own cultures, to a degree.

Before Brooke rule, for example, Iban society was uncentralized, with political power distributed among longhouse communities. Individual families lived in longhouses resembling communal apartments and respected traditional Iban *adat*, a complex set of social rules maintained through kinship.[441] In 1842, James Brooke officially recognized Malay written law and claimed to have recognized *adat*, except in cases of punishment. The Brookes expanded the judicial roles of Indigenous leaders and used a perversion of *adat* to govern subjects where they felt it appropriate, usually to British advantage.[442] Although Brooke rule reworked Iban social structures, British manipulation of Indigenous culture as a tactic of distributed control nevertheless gestures back to a reliance on Indigenous knowledge. Bluntly subjugating a Native population that vastly outnumbered its British counterpart might have been impossible, or it might have incited revolution. In another scenario, Indigenous collectors might have refused to collect gutta

[439] Ramy Bulan, "Native Customary Land: The Trust as a Device for Land Development in Sarawak," in *State, Communities and Forests in Contemporary Borneo*, ed. Fadzilah Majid Cooke (Canberra: ANU Press, 2006), 45.
[440] Godfrey, *Submarine Telegraphy*, 144-45.
[441] Clifford Sather, Introduction to *Iban Adat and Augury*, by Benedict Sandin (Penang: Penerbit Universiti Sains Malaysia, 1980), xiv-xv.
[442] Sather, xvi.

percha despite market demand. The Brooke Administration could disrupt lifeways, but they could not declare absolute sovereignty over Indigenous peoples.

Because Chinese intermediary traders also functioned as key actors in the credit economy, British Residents tried to manipulate credit relationships by lending cash to traders who presented letters of credit from connections in Kushing. The Brooke Administration thus attempted to function as a bank. Traders who borrowed from the Brookes would owe allegiance to British lenders instead of other traders in the supply chain. Ultimately, however, shortage of cash made this strategy too difficult to supersede traditional credit and barter relationships.[443] There were too many nuances and intercultural transactions in trader relationships that flew under the British radar.

The gutta percha animal figurines, at once spiritual and logistical, remind us of how a worldview inaccessible to colonizers ended up literally around the wire. Godfrey describes a typical journey for a little gutta percha animal making its way to the Woolwich cable factories in London: "There, thrown in with other gutta supplies, the small figure was chopped, boiled and massaged, ending up as a tiny section, unseen in the West India and Panama cable linking the American continents with Britain and beyond. By that time, the figurine had been carried, sold, traded, shipped, commodified, and finally transformed beyond recognition – and tested under a manufacturing regime developed by leading edge scientific and manufacturing practice at the time."[444] The transformations described here at once gesture to the cultural and infrastructural

[443] Godfrey, *Submarine Telegraphy*, 198.
[444] Godfrey, 277.

complexity involved in acquiring the figurine, and the violence exacted in its resignification as standardized cable insulation.

We often learn that the Victorians added telegraphy to their imperial arsenal; as the telegraph girdled the globe, so did British control. Scholarship has also made much of telegraphy as a tool of information flow and sympathetic connection. Yet much of this empire of commerce and information distribution depended on the "invisible" British empire,[445] which did not operate through direct flows from periphery to center, but rather relied on the modalities of salvage accumulation *around* the infrastructure of cables, themselves. The infrastructure of telegraphy therefore includes the many supply chain nuances that remained unnavigable to British settlers. I have studied the gutta percha trade as a link in the development of energy physics. However, the illusion of total British control goes beyond the gutta percha trade, as Carl Trocki argues in his study of Victorian opium supply chains.[446] The viability of invisible infrastructure obtains for many nineteenth century colonial materials.

Therefore, as we approach the literature section of this chapter, I want to emphasize that unorthodox scientific thinking and knowledge impervious to colonial mapping and control appear in fin-de-siècle literature as threats to British integrity and identity. We observed how Faraday's unconventional approach to field theory, which was at first dismissed, was later hammered into an institutionally acceptable form. Field theory, in turn, depended on Indigenous knowledge and salvage accumulation.

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[445] Godfrey, *Submarine Telegraphy*, 24-25.
[446] Carl A. Trocki, "In Compassion to Mankind," in *Opium, Empire, and the Global Political Economy: A Study of the Asian Opium Trade, 1750-1950* (Milton Park and New York: Routledge, 1999), 58-88.

Institutional support for field theory caught on only after it verified and standardized a colonial material for telegraph cable insulation. Procuring gutta percha then required the expertise of Indigenous collectors and intermediary traders. Though British Residents tried to control their subjects by manipulating local Native, Malay, and Chinese leaders, they ultimately learned that gutta percha trees and trade were governed by their own diverse, unscalable structures. Such failed attempts at laterally distributed control presage the counter-colonial threats in late-Victorian gothic texts like *Dracula* and *The Beetle*.

***Dracula* and *The Beetle*: Confronting Inscrutable Forces and Ambient Energies**

Bram Stoker's *Dracula* and Richard Marsh's *The Beetle* do not self-consciously reproduce the cultural concerns of the gutta percha trade and its relation to field theory, yet they are noteworthy representatives of Britain's reflexive critical turn in the late Victorian period. In both novels, a rival power invades London and threatens England's supremacy by attacking its most elemental institutions. In the last two decades of the nineteenth century, Britain reached the zenith of its imperial dominance in the "scramble for Africa," but not without encountering growing competition from other western powers like the United States and Germany. Additionally, with its increased reliance on fossil fuels, Britain needed more land and labor on the periphery to supply raw materials for industry.[447] As we saw with their occupation of the Straits Settlements and the Malay Peninsula, the British employed what John Darwin calls "informal empire," or

[447] Daggett, *The Birth of Energy*, 137-38.

“pragmatic acceptance of limited power.”[448] Rather than explicit sovereign control and blunt subjugation of peoples, informal empire indirectly influenced colonial subjects by enforcing various government styles that disrupted local sociopolitical life. While informal empire enacted violent cultural and economic transformations, it was also a tactical choice deployed as “the maximum influence that Victorian governments *could* exert… rather than the most they wanted to.”[449] Therefore, Britain’s empire was massive but unstable. The widespread popularity of *Dracula* and *The Beetle* evidence the resonance of imperial identity crisis with a late Victorian readership.

Both novels stand out within the late Victorian gothic revival not just for their commercial success, but also because they have remarkably similar plotlines yet take different approaches to marshal gothic tropes and energy logic against knowledge and bodies that appear unknowable, unmeasurable, or unassimilable. On the one hand, *Dracula* is the story of an imperial invasion by an eastern European, non-white threat. The Count is like the ouroboros of vampire capitalism, consuming human bodies and producing new vampires until no human bodies remain. Count Dracula is horrifying to British sensibility because he is brilliant at controlling the infrastructures of influence. He can do what they have failed to do on the fringes of their own empire. He translates value across technological, economic, and cultural differences. He enrolls animals, English women, and psychologically disabled persons to do his bidding at a distance. He is a master of translating salvage accumulation into the industry of producing new vampires.

[448] John Darwin, “Imperialism and the Victorians: The Dynamics of Territorial Expansion,” *The English Historical Review* 111, no.447 (June 1997): 617-619. https://www.jstor.org/stable/576347.
[449] Darwin, 617.

Physically, he is an ambient, atmospheric force, controlling weather and bodies in a region of space, like Faraday's invisible field lines. In this case, Dracula does not merely set up a "flow" of occult influence between his subjects to control them; if Dracula's powers are at all electromagnetic, he commands the entire field.

On the other hand, the monstrous invader in *The Beetle* threatens Englishness because they[450] elude categorization, not because they are a logistical mastermind. Marsh's novel narrates the vengeance crusade of a gender-nonspecific, age-nonspecific, race-nonspecific individual against a British politician and future statesman. The Beetle character is at once nothing and everything: they are an unstable pastiche of physical characteristics indigenous to regions Britain occupies. The Beetle confronts the stability of British institutions and identity because most characters in the novel do not know how to position themselves in relation to the Beetle. The text allegorizes the possibilities of other ways of being and knowing, particularly concerning energy, by building a grotesque and unclassifiable threat. Though they try, the British cannot map the Beetle onto any stable framework, and they therefore attempt to destroy the Beetle with destructive concentrations of energy and technological force. Because the novel unfolds with the British empire as center, it forecloses any possibilities of understanding their adversary, or of exploring how the Beetle's forces of influence operate, instead using western perspectives to suggest that the Beetle fits nowhere and must be exterminated.

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[450] Although most scholarship uses the pronoun "it" to refer to the Beetle character, I will use them/them pronouns to avoid further dehumanizing the minoritized groups this character represents. However, in doing so I do not mean to assign the Beetle any particular gender identity.

Despite these preferences for western progress, the novel's most potent revelation is its strong suggestion that Sydney Atherton, *The Beetle*'s prominent man of science, is more terrifying, murderous, and destructive than the Beetle. Atherton designs a fictional weapon of mass destruction in Marsh's novel nearly half a century before nuclear warfare arrived in the twentieth century. In Sydney's case, he decides to market it to governments as a "preserver of the peace,"[451] selling to the highest bidder. The Beetle character may confront Englishness with the apparently unknowable, uncategorizable, and the grotesque; but the electromagnetic qualities associated with Atherton are far more heinous because they bring energy infrastructures into the realm of the instantly genocidal.

Compared with *Dracula*, Marsh's novel is structurally similar. They are both epistolary novels where western characters record, transcribe, and piece together key details of a terrifying episode they shared. Count Dracula and the Beetle are both shape shifters. They both control the actions of animals and can deprive humans of free will by placing them under a mesmeric thrall. Both villains physically and psychically violate their British victims in some form, and women seem most vulnerable to attack. Finally, both novels end in a race of logistics, though the British characters in *The Beetle* lead a disorganized and frantic chase, in contrast to *Dracula*'s obsessive collating of information. The foreigner retreats and the western crew marshal a mixture of new and old technologies to track down the monster. Both novels explore a confrontation of bodies and knowledges that are inscrutable to westerners. Despite these structural

[451] Richard Marsh, *The Beetle* (1897; Peterborough: Broadview, 2004), 102. Citations refer to the Broadview edition.

similarities, the upshot of energy infrastructures in each novel varies depending on how the text approaches nonwestern knowledge. I would argue that *Dracula* investigates the crisis of western epistemology and empire by turning the capital-energy nexus into a monster who can extract value across many infrastructural strata, *i.e.*, the entire "field." *The Beetle*, on the other hand, suggests that the western scientific industrial complex cannot map or categorize everything, but *can* systematize and control just about anything; it all comes down to targeting energy science for cultural and biological extermination, rather than forced assimilation.

Because the plot of *The Beetle* is generally less familiar than that of *Dracula*, I will briefly summarize it. A rising statesman whose real name is not disclosed but who is called "Paul Lessingham" is attacked by a foreigner who can control subjects with their mind and shape-shift into a beetle. We learn that, twenty years previously, Paul Lessingham spent time in Cairo, where he followed the sound of a girl's singing into a café in the native quarter. When she beckoned to him, "[w]hat seemed an invitation was virtually a command."[452] Lessingham found himself trapped in the den of an Isis-worshipping cult, where what appeared to be human-beetle hybrids sexually violated him, engaged in "orgies of nameless horrors,"[453] and offered British women as human sacrifices. Lessingham managed to escape and make his way back to London, where – now, twenty years later – he finds himself again pursued by the Beetle.

Exactly why the Beetle invades London is uncertain. They articulate a desire to torture Paul Lessingham and capture his fiancée Marjorie Lindon. The Beetle cuts off her

[452] Marsh, *The Beetle*, 240.
[453] Marsh, 243.

hair, dresses her in men's clothing, and attempts to smuggle her out of the country. However, the text never deconstructs the Beetle's obsession with Paul Lessingham; we do not know whether the revenge is motivated by Lessingham's escape, or by his unwelcome tourism in Cairo. What *is* clear is that Sydney Atherton, a prominent English scientist who is in love with Marjorie, also despises Lessingham; and the text makes much of Atherton's being an occidental foil for the Beetle. After the Beetle fails to mesmerize Atherton, they try to form an alliance with him, citing shared hatred of Lessingham as common ground. Rather than align with the Beetle, however, Atherton threatens them. He has developed a weapon of mass destruction: "legalised murder – on the biggest scale it ever has been planned."[454] Although he plans to sell this weapon, he can use small doses to instantly murder anything or anyone he pleases.

Cowed by Atherton's display of power, the Beetle decides not to attack Lessingham directly but rather to defile and kidnap Marjorie. They remove all markers of her class rank and femininity, cutting off her hair and dressing her in working-class, men's clothing. In this debasing disguise, a mesmerized Marjorie follows the Beetle around London, arriving finally at the train station. The British crew (*i.e.,* Atherton, Lessingham, an unemployed former clerk named Robert Holt, and a private investigator named Augustus Champnell) track the Beetle down by telegraph wire and arrive by train just in time to witness a train accident that seriously injures Marjorie and apparently kills the Beetle. The Beetle's death is implied yet remains inconclusive because only the charred remnants of an unidentifiable creature survive the wreckage. The novel ends with

[454] Marsh, *The Beetle*, 102.

Champnell's summary of the years following this event: while Marjorie eventually recovers and marries Lessingham, "[w]ere his real name divulged she would be recognised as the popular and universally reverenced wife of one of the greatest statemen the age has seen."[455] As for Atherton, we are told that he continues his scientific investigations and that he is married to a woman whose "wealth has made him one of the richest men in England,"[456] a detail suggesting Sydney now has the personal funds to bankroll any project he designs.

In this chapter's final section, I want to consider how electromagnetic field theory and a conception of the "invisible" colonial networks that sustained British power converge in the late Victorian literary imagination to render visible an extended telegraphic infrastructure. *Dracula* and *The Beetle* both center telegraphy as a western technology of control, positioning occult fields variously against and within telegraphy's electromagnetic science. I argue that these novels contribute to a cultural assimilation of a dominant energy concept. They reinforce the industrial values that underpinned early energy science, despite that nonwestern and otherwise unorthodox knowledges resisted a singular framework for energy. The texts respectively acknowledge other lifeworlds and energy infrastructures yet foreclose their viability by exterminating and vilifying the Count and the Beetle.

Although I have focused this chapter on the gutta percha trade, the gesture of looking "around" the telegraph wire is also a method of seeking out the multilayered, distributed infrastructures that buttressed the British empire and its sciences. As such, we

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[455] Marsh, *The Beetle*, 319.
[456] Marsh, 321.

might likewise examine any number of "keystone" colonial resources, or "pivotal agent[s] of change"[457] that determined the contours of trading relationships. For example, opium, too, functioned as a keystone factor; yet opium remains more visible to us than gutta percha, which disappeared into near obscurity with the advent of synthetic insulation materials. To readers of *Dracula* and *The Beetle*, however, gutta percha would have been universally recognized as an important colonial resource, particularly for its use in telegraphy. I argue that this makes it a crucial variable in any political and literary history of energy science.

Dracula and *The Beetle*, which do not directly reference gutta percha, are nonetheless attuned to ways in which literature and language work as dehumanizing agents alongside the institutional authority of science, and the increasing authority of scientific energy. These novels apply the license of culture, science, and arrangement of information to contribute to a public consciousness of what energy is and what it should do. Because Indigenous ecological knowledge at the center of gutta percha trading reinforced the successful operation of Faraday's field theory, and because electromagnetic science works as both a threat to and advantage of western power in these novels, my analysis concentrates on the confrontation of western sensibilities with potentially different frameworks for field energy – as the field beyond western energy science, an institution functioning as an arm of humanistic universalism.

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[457] Trocki, "In Compassion to Mankind," 58.

Along those lines, Sylvia Wynter's "The Ceremony Must be Found: After Humanism" proposes an "overall rewriting of knowledge"[458] to unsettle the "hegemony of the groups who spearheaded the Industrial Revolution" and the "transumption of humanism's 'natural Man'" that followed. Wynter, writing almost a century after Stoker and Marsh, describes the performative function of dominant literatures to prescribe a collective way of being and knowing that relegates the liminal – "[w]hatever the group… whatever the category – the Orient, Africa, the tropics" – to a "Chaos" of the unrepresentable.[459] Recently, Zakiyyah Iman Jackson has taken up Wynter's claims that nineteenth century literature reified the definition of culture and thus "the ongoing displacement of local knowledge (or culture-specific orders) by a hegemonically (re)produced but no less epistemically violent Western scientific conception of the cosmos."[460] Jackson analyzes postcolonial and/or speculative literatures as theoretical modes to redraw the boundaries of "Culture," thus opening up opportunities for new worlding to flourish. By contrast, *Dracula* and *The Beetle* give us a touchstone for the nineteenth-century speculative gothic material that imagines those possibilities into Chaos, the unrepresentable, or a counter-imperial threat.

In *Dracula*, the Count's "mistiness," or his command over his body's dimensions and composition, is an index of his field-like influence. He does not organize direct flows of power to his advantage, but rather mobilizes multiple strata of energy in his field of control. For example, he becomes the wolf, but also uses wolves as extensions of his

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[458] Silvia Wynter, "The Ceremony Must be Found: After Humanism," *boundary 2* 12/13, no. 3/1 (1984): 43. http://www.jstor.com/stable/302808.
[459] Wynter," 37-42.
[460] Zakiyyah Iman Jackson, *Becoming Human: Matter and Meaning in an Antiblack World* (New York: NYU Press, 2020), 86.

center. The Count literally orders and re-orders his material body, appearing variably as a wolf, a bat, fog, or a pillar of dust. Otherwise autonomous animals serve as "allies… at his command,"[461] working for him from a distance. Even when he appears as one shape, his form is unstable, and one cannot trust it. When Dracula commandeers the *Demeter*, its crew struggle to describe the threat on board. The ship's captain paraphrases his seaman's sketch of an encounter with the Count. The seaman cannot confirm whether he saw a man or a shape, and he fumbles to describe his experience in language. Instead, he calls Dracula "It," as nothing in his prior experience resembles the vampire: "I saw It, like a man, tall and thin, and ghastly pale… I crept behind It, and gave It my knife; but the knife went through It, empty as the air."[462] Indeed, Dracula is *on* the ship, but he is also ambient: he conjures a violent storm, and he appears simultaneously as man and mist. It is not accurate to describe Dracula in concrete, Newtonian language. He is more like Faraday's "centres of force," occupying an active region of space.

Like energy, Dracula seems to be nothing and everything at once. He is dynamic and transforming. And, like field energy, he is an area of active space more than a discrete individual commanding a flow of power. He is disturbing because he appears to violate a number of inviolable Laws of Nature, including the newly codified thermodynamics. Moreover, like electromagnetic field theory, he also appears to defy an established onto-epistemological order. He diffuses into a subtle mist and yet reorganizes his matter against an entropy gradient to form his solid body at will. We experientially

[461] Bram Stoker, *Dracula* (1897; New York: Dover Publications, 2000), 42. Citations refer to the Dover edition.
[462] Stoker, 73.

understand that bodies do not do this. And yet, echoing the seaman's description, Dracula makes himself perhaps *emptier* than air, as he can slip through soldered metals.[463] Barri Gold argues that such "entropic individuals" in nineteenth century literature should be seen not as defying thermodynamic law but rather as concentrating enormous amounts of energy for their own administration by creating a complementary disorder in the larger, surrounding system.[464] If we build Gold's reading into the notion of Dracula as a threat to the British empire, then Dracula is exploiting energy-rich resources on a massive scale to the detriment of Britain (and of humanity), and he is doing it very well.

In fact, as a grotesque competitor in the scramble for empire, the vampire can accomplish what Britain cannot. Where Britain and the western energy program failed to extract salvage from human and nonhuman life that resisted assimilation or domestication, Dracula moves across many dimensions of energy to extract labor from a complex infrastructure of humans, animals, weather, and other vampires. Renfield, the institutional patient who invites Dracula inside John Seward's residence, gives us a glimpse of the psychic and physical layers of the vampire's infiltration. He describes,

> I laughed at him, for I wanted to see what he could do. Then the dogs howled, away beyond the dark trees in His house. He beckoned me to the window. I got up and looked out, and He raised his hands, and seemed to call out without using any words. A dark mass spread over the grass, coming on like the shape of a flame of fire; and then He moved the mist to the right and left, and I could see that there were thousands of rats with their eyes blazing red – like His, only smaller. He held up his hand, and they all stopped… The rats were all gone, but He slid into the room through the sash, though it was only open an inch wide – just as the Moon herself has often come in through the tiniest crack and has stood before me in all her size and splendour.[465]

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[463] Stoker, *Dracula*, 205.
[464] Gold, *ThermoPoetics*, 227.
[465] Stoker, 239-240.

If Dracula's industry is vampire production, here we witness the "invisible" supply chain transactions he orchestrates before reaching the factory, Mina Harker's bedroom. With their blazing red eyes, the thousands of rats are a spatial extension of the Count, like active field lines sensed at a distance by howling neighborhood dogs. He uses these animals to goad Renfield into inviting him in, after which he can access Mina. Only then does Dracula set up a "telegraphic" connection between his mind and hers.

Scholarship on *Dracula* frequently analogizes blood and electricity as vital "fluids." We might think of Mina's blood connection with Dracula as a figurative telegraph through which consciousness flows, though her ability to communicate with him is limited by the technical restrictions of the apparatus. She can be hypnotized only during certain hours, for instance. Likewise, Dracula can use her body for his own intelligence only when she is not using his. But, if we consider a broader, more field-like approach, his manipulation of Mina is not direct. The conditions for their communication are created by the Count's manipulation of resources into tools of control. We have seen that he gains access to Mina's bedroom by extracting information and labor from Renfield.[466] Dracula also drains the blood of four men through the vessel of Lucy Westenra, supplying energy to order and reorder his body's matter, to grow younger, and to further influence minds. He enlists rats, moths, flies, and wolves to labor for him. If there is a wire between Mina and the Count, they battle for control of the field more than they do the flow of electromagnetic influence.

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[466] Stoker, *Dracula*, 239.

The competition between Dracula and Stoker's western characters brings us to the question of perspective: do the vampire hunters know what or who they are hunting, and can readers trust the narrative? The simplest answer is no, although the novel takes its epistolary archive seriously and makes much of the power in classifying one's enemy to exterminate him. *Dracula* is full of facts on the vampire, but these facts confront the limits of western knowledge. The Count casts no reflection, as if the looking glass throws him into the realm of the unrepresentable, the domain of "Chaos." As we have discussed, Dracula's ability to manipulate his own matter, animal bodies, the weather, and his position relative to time confound western apperception. The text further describes him as other animals he does not literally become, *i.e.*, a lizard and a leech.[467] He exists anachronistically or perhaps even outside of time, hoarding centuries-old specie in his centuries-old castle,[468] and mysteriously "grow[ing] young."[469] To the western outsiders constructing the narrative that becomes the text, his powers are inscrutable but enumerable, and therefore Dracula can be killed.

If the mechanism of Dracula's powers is inscrutable, the *rules* are not. Despite Dracula's supernatural command of energies, hard limitations do restrict his powers. He cannot, for example, shape-shift in the daytime, or enter a household without an invitation.[470] The immutable limits of vampire being allow the western hunters to track Dracula down and destroy him. Stoker's novel is constructed entirely from transcribed notes and epistles, phonograph recordings, and various other print matter, all ordered

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[467] Tim Youngs, "The Bat and the Beetle," *Beastly Journeys: Travel and Transformation at the fin de siècle* (Liverpool: Liverpool University Press, 2013), 74.
[468] Stoker, *Dracula*, 40.
[469] Stoker, 148.
[470] Stoker, 205-06.

chronologically. The western characters conclude that ordering this narrative will serve as a weapon against the Count as they mount their logistical plan to cut him off mid-retreat to Transylvania. Even if they cannot compete with Dracula as master of his energies and of those in his field of influence, they can nevertheless "stamp him out" by writing him into the bounded constructions they understand. Van Helsing galvanizes the team by reminding them, "He can do all these things, yet he is not free… we can confine him to his coffin and destroy him, if we obey what we know."[471] The power for the western crew thus becomes controlling the authority of knowledge, and extending that authority to energy and its infrastructures. In this way, train and ship schedules complement the vampire's ontological restrictions, allowing the hunters to follow, record, and home in on Dracula's movements. The Count has no authentic voice in this novel, although Mina's mind connection with him arguably brings us closer to his perspective.

Like *Dracula*, *The Beetle* is an epistolary novel. However, while the former repeatedly asserts its narrative authenticity and weaponizes its own narrative against Dracula, *The Beetle* remains more skeptical of narrative reliability. The novel is broken into four books, each narrated by a different character whose account is questionable for some reason or another. The characters' descriptions of the Beetle vary, though all witnesses agree that the Beetle's identity, itself, is unstable. They appear feminine to one character, masculine to another, and shifting between genders to yet another. The Beetle is sometimes so aged that their face is "an amazing mass of wrinkles,"[472] and sometimes

[471] Stoker, *Dracula*, 206.
[472] Marsh, *The Beetle*, 53.

in "the prime of life."[473] From Lessingham's backstory, we learn that the Beetle is associated with an ancient Egyptian cult who worship the scarab beetle and the goddess Isis. Although the novel's British characters refer to them by varied racialized monikers including the "Arab party," and "Mr. Arab,"[474] their racial identity is never confirmed. Augustus Champnell admits after the Beetle's death that they were "probably no more an Arab than [he] was."[475] Therefore, we have four unreliable narrative accounts of an encounter with a foreign individual, and the most consistent information we glean is that this person's characteristics are excessive and unstable, and that they command mystical electromagnetic fields to influence their British adversaries.

We first hear from Robert Holt, a homeless and unemployed former clerk who is starving to the point of deliriousness when he encounters the Beetle. As soon as he exclaims, "For a loaf of bread what wouldn't I do?" he miraculously stumbles upon the Beetle's house and breaks in through an open window.[476] As if anticipating skepticism, Holt hedges, "I realised, and, so to speak, mentally photographed all the little details of the house in front of which I was standing with what almost amounted to a gleam of preternatural perception. An instant before, the world swam before my eyes. I saw nothing. Now I saw everything, with a clearness which, as it were, was shocking."[477] The text does not expect readers to accept the testimony of a starving man on good faith, even if he insists that his memories are reliable. Indeed, we learn that all the characters filter and reproduce each other's narratives to a degree.

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[473] Marsh, *The Beetle*, 141.
[474] Marsh, 273-75.
[475] Marsh, 298.
[476] Marsh, 46.
[477] Marsh, 47.

The question of narrative authenticity is most explicit in Champnell's concluding chapter, which outright disputes the reliability of Holt's and Marjorie's testimonies. He writes, "[i]t should be mentioned that the portion of this strange history which purports to be The Surprising Narration of Robert Holt was compiled from the statements which Holt made to Atherton, and to Miss Lindon…".[478] Apparently, in his disheveled and starved state, Holt discusses the Beetle with Marjorie and Atherton, who later entrust Champnell with the narrative. Similarly, Champnell invites us to regard Marjorie's written account with some caution. Marjorie contributes her portion after surviving the train accident that kills the Beetle. Champnell suggests that Marjorie's writing is more therapeutic than accurate; that "while mentally, she still hovered between the darkness, and the light, her one relaxation was writing."[479] All characters indeed establish themselves as potentially unreliable narrators, though Champnell's reiteration of this fact reminds us that the most arresting and grotesque details of the novel are also suspect. Coming from the novel's private investigator, *The Beetle*'s metonymic stand-in for objective inquiry and analysis, this invitation to scrutinize the narrative deals a hard blow to "ultimate truth," one of Britain's institutional virtues.

In the novel's first book, Holt reveals his traumatic episode with a foreigner who lures him into a house, then violates him sexually and psychically. Upon entering the Beetle's house Holt senses the presence of evil,[480] though he does not acknowledge another person in the residence until he finds someone lying in bed. He struggles to

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[478] Marsh, *The Beetle*, 321.
[479] Marsh, 321.
[480] Marsh, 49.

describe the Beetle, as they fit no discernable category. Holt's hodgepodge sketch of the Beetle unfurls over several paragraphs, in sentences that both describe and diagnose the individual. "I could not at once decide if it was a man or a woman," Holt begins. "Indeed at first I doubted if it was anything human. But afterwards, I knew it to be a man, - for this reason, if for no other, that it was impossible such a creature could be feminine."[481] Groping for a gender assignment, the best Holt can do is assume the Beetle is male because they are "supernaturally ugly."[482]

By deciding, albeit arbitrarily, that his interlocutor is male, Holt prefigures his later mesmeric and sexual encounters with the Beetle as homosexual. However, the Beetle's penetrative acts, themselves, are remarkable iatrical. Inside the Beetle's house, Holt loses autonomy of his body, though not of his mind. He is forced to lie prone for hours while the Beetle systematically inspects his body with their eyes, fingers, and lips. "It stooped, then knelt," Holt describes. "My only covering was unceremoniously thrown off me, so that I lay there in my nakedness. Fingers prodded me then and there, as if I had been some beast ready for the butcher's stall… Fingers were pressed into my cheeks, they were thrust into my mouth, they touched my staring eyes, shut my eyelids, then opened them again, and – horror of horrors! – the blubber lips were pressed to mine – the soul of something evil entered into me in the guise of a kiss."[483] Besides the obvious and recurring theme of "unmanning" English subjects, the Beetle's perverse yet detached inspection of Holt mocks the ethnographer's choreography of inspecting exotic

481 Marsh, *The Beetle*, 53.
482 Marsh, 53.
483 Marsh, 57.

specimens and fitting them within species and racial hierarchies. The Beetle's probing of Holt's orifices, the clinical gaze turned on the male, western subject's naked body, shocks Holt for its reversal of the natural order: of race, gender, and species. The Beetle's sterile kiss ultimately produces a diagnosis. The Beetle pronounces Holt to be "as good as dead!"[484] and leaves the house.

Later in the novel, the Beetle applies this same clinical kiss to a minor character, bringing him back from the brink of death. This victim had accidentally exposed himself to Sydney Atherton's weapon prototype. As such, the Beetle's "kiss" appears to be a therapeutic as well as diagnostic tool. Holt, though, can barely stomach his role as emasculated, exotic curio. He turns his own clinical gaze on the Beetle, enumerating their apparent "deformities" and applying the implicit authority of biology, physiognomy, and other then-contemporary taxonomical heuristics to deprive the Beetle of Humanistic attributes. So far as we know, Holt has no expertise in any sciences, yet he takes stock of the Beetle as one would a specimen:

> The cranium, and, indeed, the whole skull, was so small as to be disagreeably suggestive of something animal. The nose, on the other hand, was abnormally large; so extravagant were its dimensions and so peculiar its shape, it resembled the beak of some bird of prey… The mouth, with its blubber lips, came immediately underneath the nose, and chin, to all intents and purposes, there was none. This deformity – for the absence of chin amounted to that – it was which gave to the face the appearance of something not human, - that, and the eyes. For so marked a feature of the man were his eyes, that, ere long, it seemed to me that he was nothing but eyes.[485]

That the Beetle's features are both too large and too small suggests that they are not just bug-like, but also a poorly assimilated blend of stereotypical racial characteristics. Holt's

[484] Marsh, *The Beetle*, 57.
[485] Marsh, 53.

catalog of the Beetle's physical characteristics gestures to a Victorian preoccupation with miscegenation and racial hierarchies, and of science's role in qualifying them.

Indeed, the issue of racial classification in *The Beetle* resembles the taxonomy "problem" ethnographers and anthropologists encountered when studying the diverse populations of Southeast Asia. In *The Pagan Tribes of Borneo*, Charles Hose and his ethnographic companions take stock of the physical characteristics of Borneans and conclude that Hindu-Javanese, Arab, Chinese, and Indigenous intermixing over many generations has produced a racially and culturally blended population. They posit, "[i]t is not improbable that at one time Borneo was inhabited by people of the negrito race… individuals may be occasionally met with whose hair and facial characteristics strongly suggest an infusion of negrito or negroid blood."[486] Hose refers to headshots taken of Native subjects as visual evidence of their patchwork ethnicity. In a related manner, the English characters in Marsh's novel never characterize the Beetle as a complete subject but rather itemize their features to synecdochally link each to some peripheral part of the British empire.

When Sydney Atherton first meets the Beetle, he likewise performs a clinical examination of their physical characteristics; however, the text quickly builds structural parallels between Atherton and the Beetle that are absent with Holt. Again, there is a moment of puzzling over taxonomy. Atherton observes that the Beetle "was oriental to the finger-tips," "was hardly an Arab," "was distinctly not Mussulmanic… whatever his race might be" and that there "seemed to suggest that, in his veins there ran more than a

[486] Hose et al., *The Pagan Tribes of Borneo*, 26-29.

streak of negro blood."[487] Because the novel is organized so that Atherton's testimony immediately follows Holt's, Atherton's visual inspection of the mysterious foreigner feels initially like a repetition of Holt's failure to assign them specific race, gender, and age classifications. However, Atherton ironically aligns himself with the Beetle by competing for control of energy as power. Atherton is the only English character that the Beetle fails to mesmerize, and the features that index Atherton's ability to manipulate electromagnetic forces suggest physical homologies between Atherton's body and the Beetle's, that is, the apex of English masculinity and its perceived inverse.

For example, Atherton and the Beetle share notably "penetrating" eyes. Though Atherton assesses the Beetle's eyes as possessing "the mesmeric quality… which are oftener found, thank goodness, in the east than in the west,"[488] Marjorie describes *Atherton's* eyes in similar terms. When she observes his charm over the wealthy Dora Grayling, Marjorie remarks that he has "the most extraordinary eyes." She wonders, "I fancy that those eyes of his have as much to do with Dora's state as anything. I have heard it said that, if he chose to exercise it, he might become a danger to society. I believe he has hypnotised Dora."[489] In this light, Atherton's derisive note that mesmeric creatures are such "for whom it is always just as well to keep a seasoned rope handy"[490] might be ironically self-descriptive.

Sydney Atherton also shares the Beetle's manipulation of animals to demonstrate a mastery of energy. However, while the Beetle venerates and becomes the scarab, and

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[487] Marsh, *The Beetle*, 140.
[488] Marsh, 105.
[489] Marsh, 194.
[490] Marsh, 105.

employs animals in their surroundings as a general extension of the Beetle's influence, Atherton's animals are captured and killed to further and demonstrate his scientific research. The Beetle initially finds Atherton in his laboratory, where he has just murdered a cat with his genocide weapon prototype. Prior to the Beetle's arrival, Sydney kidnaps a cat outside of Paul Lessingham's house and announces to a friend that he will demonstrate "on a small scale, the action of the force which, on a large scale, [he] propose[s] to employ on behalf of [his] native land."[491] Placing the cat in a glass box, Atherton gleefully murders it, violating what Anna Maria Jones estimates is at least three articles of the Cruelty to Animals Act, a law designed specifically to prevent scientific experimentation on animals.[492]

The Beetle, by contrast, does not murder animals but instrumentalizes them, like Dracula, within a spatial field of power. When the British crew interrogate the Beetle's landlord to discern their whereabouts, she complains about her recent cat problem: "I didn't use to notice hardly a cat in the neighborhood till that there Arab party came, -there isn't much to attract them; but since he came there's been regiments. Sometimes at night there's been troops about the place, screeching like mad…".[493] Where Sydney's cat is a small casualty of what he imagines will become a war-transforming weapon, the Beetle's cats are troops. They emerge from far-flung London neighborhoods to form regiments working at the Beetle's command, which suggests a distributed and field-like application of power. Moreover, the Beetle's cats are viewed as obstructing the British

[491] Marsh, *The Beetle*, 135.
[492] Anna Maria Jones, "Conservation of Energy, Individual Agency, and Gothic Terror in Richard Marsh's *The Beetle*, Or, What's Scarier than an Ancient, Evil Shape-Shifting Bug?", *Victorian Literature and Culture* 39 (2010): 78, doi:10.1017/1060150310000276.
[493] Marsh, 275.

characters' progress. Rather than understanding these animals as an extension of the Beetle's field of influence, their landlord and the British crew denigrate the animal behavior because, to them, it is a nuisance and a waste of their time as they search for Marjorie. By contrast, when Atherton brags of his energetic powers and potential influence over other species and nations, it is undistributed, unnuanced, and reinforces Britain's imperial agenda. Atherton's energy bolus is one-dimensional: neither field nor flow, it simply destroys and consumes.

This brings us to what I consider Marsh's fundamental departure from *Dracula*'s upshot of energy infrastructure. *The Beetle* does not extend the invisible colonial infrastructures of telegraphy and electromagnetic communication so much as it quashes their potential by linking Atherton and the Beetle with their respective electromagnetic qualities, and then suggesting that the Beetle's supernatural field-like influence, though mysterious and unclassifiable, is no match for Atherton's ultimately genocidal control of energy. If the Beetle is a threat to England and a master of forces that Atherton does not understand, Atherton can, with his own understanding of energy and science, wipe the Beetle and their culture out altogether. When Lessingham asks Atherton what his latest project is, he answers, "Death." Taken aback, Lessingham asks how long humans will presumably continue their arms race. Sydney implicitly references the second law of thermodynamics: "Until the sun grows cold," after which "[t]here'll be no defence, -nothing to defend."[494] In her reading of *The Beetle*, Anna Maria Jones argues that, though Atherton invokes the terror of entropy in our world's inevitable heat death, the unknown

[494] Marsh, *The Beetle*, 109.

exchanges of energy in the interim, in the waiting for that heat death, are far scarier. In other words, "[t]he end of all things, while horrifying, is predictable – a calculable outcome"; but "the movements of those delicate human machines and their effects on fellow creatures and the world – are terrifyingly incalculable."[495] The Beetle is, for Atherton, a threat for which no western rubric exists. But, dealing with such dimensions of energy external to western knowledge is, for Atherton, more terrifying than having the power to exterminate them if necessary.

Atherton comes close to admitting this in so many words. As he's ruminating on his infatuation with Marjorie, his rivalry with Lessingham, and this new foreign threat in London, he ponders, "these things were as microbes which, acting on a system already predisposed for their reception, produced a high fever; I was in a fever, - of unrest. Brain in a whirl! – Marjorie, Paul, Isis, beetle, mesmerism, in delirious jumble… When I get warm I grow heated, and when I am heated there is likely to be a variety show of a gaudy kind."[496] Indeed there is: he soon thereafter uses his prototype to murder the cat for spectacle. But there are two sciences at work in Atherton's language. He combines the analogy of microbial agency in his own system with heat produced from thermodynamic energy transfer to describe his body's fevered state. Some foreign, external agents are not serving his core, have disturbed his homeostasis, throwing him into the delirious jumble of fever. Secondly, there seems to be a thermodynamic distinction between his being "warm" and "heated." The former is perhaps induced by fever and the latter by psychic

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[495] Jones, "Conservation of Energy, Individual Agency, and Gothic Terror in Richard Marsh's *The Beetle*," 72.
[496] Marsh, *The Beetle*, 135.

distress. It is evidently the heated state that drives him to murder, which is unsurprising since he identifies the Beetle's psychic powers as the seat of their ability to prey on the weak.[497] Atherton and the Beetle are like two poles of one electromagnetic phenomenon, and the suggestion lingers that Atherton emerges as the bigger threat to humanity.

That Atherton views energy as an extermination tool reflects the novel's outcome: a train accident crushes the Beetle to death in a wild collision that restores Lessingham's masculinity, preserves Marjorie more or less intact, and eviscerates their tormentor. It is an energetic *deus ex machina* that hurls the full force of train and telegraph at the Beetle. As the Englishmen pursue the Beetle's train, Lessingham recenters his manhood. The wild locomotive transfers masculine energy to his body with every jerk and rattle. Champnell observes Lessingham's transformation and reflects, "one thing was absolutely certain, that if we did come to smash while going at that speed we should come to as everlasting smash as the heart of man could by any possibility desire. It is possible that the knowledge that this was so warmed the blood in Lessingham's veins… it seemed to me that he was getting a firmer hold of the strength which had all but escaped him, and that with every job and jolt he was becoming more and more of a man."[498] It is not just the likelihood of death, but the prospect of an energetic, sublimating death, that restores Lessingham. His perceived proximity to such a death removes the terror of possibilities in the interim, or the unpredictable energetic exchanges that anticipate the end.

But it is not Lessingham who comes to smash, it is the Beetle. Like Atherton's fantasy of world domination by threat of annihilation, the train eviscerates the foreign

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[497] Marsh, *The Beetle*, 105.
[498] Marsh, 315.

invader almost instantly, in one fell swoop. Such a destructive, chaotic resolution depends not on the functioning of logistical infrastructures, as in *Dracula*, but from their failure. The British characters persevere in this battle only because the train breaks down, not because telegraphy and rail travel are superior logistical weapons. From the flaming wreckage, the men extricate Marjorie and stoke her fading "spark of life," fanning it "again into flame."[499] Marjorie is now a source of British energy to be rekindled and rehabilitated, while the Beetle remains uncategorizable, yet now inert, Chaos. Champnell explains that scientists are trying to identify the burnt organic remains they recovered from the train wreck, but have as yet come to no consensus. Some argue that the remains are "possibly of some creature of the cat species. Yet others affirm that it is not blood at all, but merely paint." And yet others posit it might be "the excretion of some variety of lizard."[500] No matter the taxonomical outcome, the Beetle is now energetically dismantled, their remnants left to the assignment and control of British scientists.

Because the Beetle is a synecdochal composite of exaggerated racial characteristics indigenous to Britain's occupied territory, I would argue that the onus of controlling a distributed, informal empire collapses into the upshot of violent biological and cultural erasure. *The Beetle* employs the technologies of capitalist reproduction and translatability, but unlike *Dracula*, the figures of imperial science hurl destructive, chaotic energy at what they perceive as a foreign threat whose field-like characteristics evade categorization. Atherton's genocidal weapon and the train wreck that destroys the Beetle throws the legitimacy of western logistical infrastructures into question. If the

[499] Marsh, *The Beetle*, 319.
[500] Marsh, 319.

British cannot kill the Beetle by assembling information to wield against them, they can certainly use science and technology to flatly wipe the Beetle out. By contrast, *Dracula*'s narrative insists on its reliability and the meticulous collection of information to map, contain, and eliminate the Count.

At the end of *Dracula* and *The Beetle*, each foreign threat is ultimately destroyed; yet *Dracula*'s approach is one of systematic management while *The Beetle* employs energy to exterminate a field-like threat, rather than trying to map and assimilate it. In *Dracula*, the capital-energy nexus extolled by western powers turns itself on Britain. The vampire is a master of translating non-vampiric resources into the industry of vampire production. As such, Dracula mocks Britain's failure to work the field of its periphery and translate salvage to capital where human and nonhuman life resisted energy's union of work and capital. In *The Beetle,* the foreign invader is ultimately less threatening than the British scientist. The British cannot classify, systematize, or order their imperial subjects (as *Dracula* suggests is necessary), but they can dispense massive and concentrated energies to wipe out any obstructions or threats to the imperial agenda.

CONCLUSION

The mechanism of telegraphic energy transmission persists in the public imagination as a kind of flow, despite Oliver Heaviside's prediction that we would soon get "out of the wire into the dielectric." We have seen that one reason for this might be that western science has a history of rejecting unconventional thinking, or alternatively hammering it into an institutionalized framework. Faraday's electromagnetic field theory rebuffed longstanding Newtonian ideals like action at a distance and mathematical blackboxing of phenomena without recourse to physical explanation. Because emerging telecommunications infrastructures needed Faraday's insights, electromagnetic field theory dominated many late-century energy concerns, yet only after his original papers had been adulterated and spun back into the language of flow by Thomson and Maxwell.

Faraday's field theory indicates that the energy in telegraphy cables exists in the space around the wire. This drastically changed Britain's approach to cable construction, which, after 1861, required gutta percha for insulation. Because gutta percha grew only in the interior of Southeast Asian forests, the British found themselves increasingly reliant on Malayan supply chains and Indigenous ecological knowledge. When the trees grew scarce, the British blamed Natives for the "crisis," though it was clear that Europeans were the most desperate party. By the end of the century, Britain was scrambling for a solution, but could not successfully domesticate gutta percha as they could other plantation crops.

Meanwhile, the fin de siècle gothic revival reflected Britain's attitude towards energy's role in the global circulation of information, commodities, and bodies. The western energy concept enforces, overall, a universalizing Humanism, scientific structure, and extractive logic. Yet during the period of new imperialism, the gutta percha trade demonstrated pockets of resistance to that dogma, revealing possibilities of using energy contrary to exploitation and accumulation. *Dracula* has been read through a multitude of late Victorian anxieties, to which I would add a counter-imperial threat who has mastered capitalist-energy resistant worlds and translated them as salvage accumulation into a world-dominating industry. For this, Dracula manages the field, rather than the flow, of energy. The western characters in *Dracula* systematize energy and logistics against him; that is, because his powers are limited and knowable, he can be killed. On the other hand, *The Beetle* deals with a similar foreign threat by using energy to exterminate the unknown, unclassifiable, Chaotic subject. This is arguably a more sinister outcome, and one which suggests that Britain is more frightening than any foreign invader.

With this in mind, we turn next to the politics of entropy and the North British agenda to secure their worldview within the very structure of energy. By structuring energy at the level of its most elemental units, Scottish scientists could claim homogeneity and interchangeability across the cosmos, and thus enforce their industrial-minded work ethic and extractive ethos as natural law. These physicists did not receive unanimous support from the scientific community, however. They were challenged by other competing interpretations of energy transfer, conservation, and dissipation. Thus, the concept of entropy did not emerge as an uncontested scientific fact, but rather as a controversy and battleground for the popularization of the second law of thermodynamics.

Chapter 4:

Structuring Ether: Vortices, Demons, and the Telos of Entropy

In 1865 the German physicist Rudolf Clausius coined the word, *entropy*, with the axiom: "*1. The energy of the universe is constant. 2. The entropy of the universe tends to a maximum.*"[501] This economic phrasing of the thermodynamics laws combines the conservation of energy principle with a new quantity, entropy, representing a system's unavailability to perform mechanical work. Clausius explained that he had "intentionally formed the word *entropy* so as to be as similar as possible to the word *energy*; for the two magnitudes denoted by these words are so nearly allied in their physical meanings, that a certain similarity in designation appears to be desirable."[502] Indeed, the second half of the nineteenth century seems to abound with the entanglement of energy and entropy. Sooty cities were a physical reminder that the dense fossil energy of coal, once burned, would never reappear as concentrated fuel. Theories of urban and imperial degeneration suggested that Britain's national energy might decay, and that a rival imperial power, or a developing race, might supersede British dominion. Most literally, however, scientists prognosticated the entropic heat death of the universe. Degeneration was written into the laws of physics, and it had acquired its own word.

Entropy's association with heat death is well known, but thermodynamicists had been making tragic predictions about the dissipation of the cosmos since at least the

[501] Clausius, *The Mechanical Theory of Heat*, 365.
[502] Clausius, 357.

1850s, the decade before Clausius threw *entropy* into the lexicon of energy science. William Thomson led the interpretation of the second law as inevitable cosmic dissipation, a campaign he launched in the early 1850s and popularized into the 1860s with lectures calculating the age of the sun, and with articles published in Christian magazines that used the new science of energy to explain the end of the world. This North British interpretation was not universally accepted by physicists. Clausius, for instance, took a radically different approach to the second law. He characterized it in his initial writings only as the impossibility that heat will spontaneously move from a colder body to a hotter one without the addition of energy from an outside source. Intellectuals outside of physics, too, accepted the second law of thermodynamics but remained skeptical of the heat death hypothesis. Frederick Engels famously rejected the idea of cosmic dissipation because he considered it a misleading and religious interpretation of the second law.[503]

This chapter examines the politics of entropy, or, more precisely, the debates concerning the second law of thermodynamics and its consequences on the scale of deep time. Because the science in this chapter tells the story of competing interpretations of dissipation, and of the political stakes of legitimizing those interpretations, I approach the question of "structuring" energy a bit differently here. The preceding three chapters examine the political and linguistic co-production of energy science in conjunction with emerging infrastructural changes. This final chapter is more literal about theorizing the

[503] John Bellamy Foster and Paul Burkett, "Classical Marxism and the Second Law of Thermodynamics: Marx/Engels, the Heat Death of the Universe Hypothesis, and the Origins of Ecological Economics," *Organization & Environment* 21.1 (2008), 7.

structure of energy: I study the intense interest of British physicists towards the end of the nineteenth century to find the "true" structure of the ether, what Victorian scientists believed was the medium of transmission for energetic forms like heat, light, and electromagnetism. By developing what they called a vortex model of the ether, Scottish physicists believed they could dismantle the materialism of their secular adversaries and secure the second law of thermodynamics from any negentropic interpretations. In other words, by finding the structure of ether, William Thomson and his colleagues could legitimize the heat death hypothesis and its theological overtones without recourse to biblical literalism.

The stakes of structuring energy from the bottom up were high for North British physicists because, across Britain and continental Europe more broadly, groups with varied industrial, theological, and intellectual agendas competed to control the production of scientific truth. By producing a distinctly Scottish Presbyterian scaffold for energy, from the ether to the fuel sector, these scientists hoped to fuse their worldview with the daily infrastructures of modern British life. Traditional Scottish education continued to prepare many of its students of science for ministry careers,[504] so Thomson, Maxwell, Tait, and their colleagues were not eager to secularize curricula. Additionally, as chapters one and two explain, the Scottish scientists wedded their Presbyterian ethics to both political economy and industrial progress. They invested in the cosmic dissipation hypothesis because it reconciled evidence for a changing, developing universe with belief in a divine Creator. As Cara Daggett puts it, what became known as entropy negotiated a

[504] Smith, *The Science of Energy*, 183.

“middle way” between biblical literalism and evolutionary materialism.[505] It made room for the Presbyterian ethics of productivity and economy, because humans could never undo energetic dissipation. Only God could restore energy to its more concentrated, work-available forms. Therefore, humans had a responsibility to economize energy with the least possible waste and the greatest possible work output.

The period from the 1850s to the 1880s was particularly crucial for situating deep, cosmic time scales into the debates on the dissipation law. In 1859, Charles Darwin published *On the Origin of Species*, which remained ambivalent about the existence of a Creative Deity but suggested there was no guiding telos for the development of earth and its creatures. In 1864, nine high-profile scientists formed the “X-Club,” a group whose work defended what they termed “scientific naturalism,” or the belief that the entire universe was subject to scientific investigation. The X-Club opposed the religious dogma and industrial approach of the Scottish physicists. They believed theology and engineering had no place in science.[506] And, because they believed in a particle-based universe that science could ultimately place under its inspection, their materialistic determinism threatened the totality of the heat death hypothesis. If the most elemental units of energy and matter were discrete particles, they reasoned, then each event would be determined by its antecedent; and by knowing the states of all particles one might theoretically reverse the arrow of time, for linear time was an illusion. In 1874, X-Club member John Tyndall used the conservation of energy law as a defense of materialism in

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[505] Daggett, *The Birth of Energy*, 73.
[506] Ruth Barton, “’An Influential Set of Chaps’: The X-Club and Royal Society Politics 1864-85,” *The British Journal for the History of Science* 23.1 (1990), 58. https://www.jstor.org/stable/4026802.

his infamous “Belfast Address” at the British Association for the Advancement of Science. Tyndall employed the first law of thermodynamics to argue that conservation binds nature to a deterministic universe,[507] an argument that the Scottish group countered by giving energy a variety of figurative and mathematical forms beyond the pale of human determination, running the gamut from Maxwell’s demon[508] to the vortex structure of the ether.

In general, British scientists loved to model energy: as allegory, as analogy, as mathematics, and as ethical roadmap. Energy is a powerful concept because it is at once universalizing and protean. It connects all matter, forces, and branches of science; but it has no power to do so without animation. We need to give energy linguistic and material form before it acquires any kind of meaning at all. For the Scottish scientists, energy needed to place clear limits on determinism. Energy could not, even in theory, violate the second law of thermodynamics because doing so would cheapen the ethical imperative to produce as much work with as little waste as possible. Moreover, by asserting that the universe slid towards inviolable dissipation, Scottish scientists could provide scientific evidence for ongoing western assumptions about labor and waste. Work ethic was now a moral and scientific heuristic used to map and exploit the bodies of workers, and to extract as much value from the earth as possible. If the universe was on a natural course towards dissipation, then industrious nations were morally obligated to extract resources from fruitful regions that left energy in the ground, allowing it to decay. Letting this

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[507] John Tyndall, *Address Delivered before the British Association Assembled at Belfast* (London: Longmans, Green and Co., 1874), 45.

[508] Maxwell’s demon was a thought experiment introduced by James Clerk Maxwell and used to qualify the statistical limitations of the second law of thermodynamics. The details of Maxwell’s demon are described later in this chapter.

potential work go to waste violated Presbyterian ethics, particularly because, once dissipated, that energy was irrecoverable. The secularists, however, believed that industrial-minded Scottish physicists had shaped too much of energy doctrine. In particular, John Tyndall relied on his German education and acquaintance with leading German physicists[509] to challenge the dominant interpretation of the dissipation law.

As such, there was a tug of war for control of energy science during the latter half of the nineteenth century, a political battle which Crosbie Smith describes as the X-Club materialists' attempt to dissolve the North Britishers' monopoly on the new laws of thermodynamics.[510] In the end, though, the North British group staged a lasting intervention. Even after we think we have scrubbed the traces of *Natural Theology*[511] from our science curricula, and even after we have banished the ether from institutional physics, vestiges of nineteenth-century Scottish energy doctrine linger in our pro-industrial assumptions about how to exploit and manage fuel reserves. Energy, in this interpretation, was not meant to be freely available to everyone. It was not designed by God to be distributed in unfettered quantities. Natural stores of energy were a Divine gift, designed to be carefully managed by the most industrious humans, and before the energy naturally and irreversibly decays. "The future prosperity of nations," Daggett argues, "could be directly connected to the quality of their energy and their energy-driven machines through geopolitical judgment that hinged upon energetic accounts."[512] All nations, in this sense, were not created equal. Likewise, a successful, enterprising,

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[509] Smith, *The Science of Energy*, 178.
[510] Smith, 171-72.
[511] William Paley's influential book *Natural Theology* (1802) argued that evidence for a Creator could be found in natural artefacts, whose analogous structures indicated the work of a divine Engineer.
[512] Daggett, *The Birth of Energy*, 77.

energetic nation did not find a way *out* of the entropy law; it maximized its productivity within the limitations God placed on the material world. Energy science seemed to defend Britain's imperial project by supporting its endless expansion and exploitation of labor from regions that were, it appeared, letting their natural resources decay. Moreover, because the North British interpretation insisted that entropy was cosmic law, the physical waste produced by extractive capitalism and industrializing nations was seen as an inevitability of the natural world. It was the responsibility of humans to maximize production through economic energy transfers; but this meant, as Allen MacDuffie explains, that the entropy concept was "used to paint a picture of energy waste as natural, universal, and inevitable."[513] Energy, then, was about mindfully directing transfers to benefit some nations and peoples at the expense of others, and certainly at the expense of the natural world overall.

The vortex model of the ether was a tactic used to marshal evidence against a materialist deconstruction of the dissipation law, and to garner widespread support in the larger scientific community for the North British energy agenda. In the first section of this chapter, I follow the history of these competing interpretations of entropy between the 1850s and the end of the century, and I investigate the rise of the vortex theory of ether and matter. The vortex theory combined ether and matter into one continuum, foreclosing the possibility of determinism based on precise knowledge of particle position and momentum. This theory influenced a wave of attempts to model the structure of the ether. It waxed in popularity from the 1870s to late 1890s, when a

[513] MacDuffie, *Victorian Literature, Energy, and the Ecological Imagination*, 14.

younger generation of energy scientists refreshed and extended the work of the aging North Britishers.

The second section of the chapter proposes a new reading of Edward Bulwer-Lytton's novel, *The Coming Race*, based on the North British agenda to align the "true" structure of the ether with their conservative interpretation of the entropy law. *The Coming Race* was an instant bestseller on its publication in 1871.[514] It describes an advanced civilization of humans who dwell deep beneath the earth's surface. When a young American man accidentally encounters this ancient race during his exploration of a mine, he learns that their cyborg-like mastery over an apparently limitless energy source has removed any reliance their ancestors once had on the sun. Scholars usually acknowledge that the novel folds energy science and evolution into a utopian satire that validates Britain's imperial program and simultaneously issues a warning that a superior race might quietly develop in the background. Bulwer-Lytton had confirmed such interpretations in letters to his editor.[515] But, because the novel was published during a volatile period in the history of energy science, the extent to which Bulwer-Lytton's imagined race can control the entropic conditions of energy invoke political questions about the nature of the universe and the limitations of materialism.

The Vril-ya, as individuals of this race call themselves, have developed a nerve in their wrists that allows them to control "vril," the ether-like unification of all energies. Although most critics of the novel treat vril generally, as an etheric fluid or as

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[514] Sarah C. Alexander, *Victorian Literature and the Physics of the Imponderable* (Pittsburgh: University of Pittsburgh Press, 2016), 86.
[515] Edward Bulwer-Lytton, *Appendix A to The Coming Race* (1871; Peterborough: Broadview, 2008), 169-171. Citations refer to the Broadview edition.

electromagnetism, Sarah Alexander interprets vril as a negentropic energy source. Alexander affixes the negative entropy of vril to the fantasy of leaning into the extractive violence of capitalism without its dissipative consequences. She locates *The Coming Race* within the surge of transatlantic literary utopias between 1870 and 1900, and she argues that the Vril-ya's society retains all the elements of a capitalist economic system without the entropy of capitalism. In other words, the Vril-ya live without war and poverty because, the novel opines, capitalism "only creates inequality because energy is entropic."[516] Societies advanced enough to conquer entropy also apparently enjoy capitalism without its symptoms of decay.

Following Alexander's argument, this chapter proposes that vril is necessarily negentropic because it increases, rather than decreases, the work availability of a system. Vril is never extracted from an energy reserve. Rather, it is freely available to all creatures with the requisite physiological apparatus (*i.e.*, a nerve in the wrist) for directing it against entropic drift. I maintain, however, that the North British, theological argument on the nature and limitations of the entropy law would have considered the Vril-ya's control of energy dissipation as a gross violation of the second law of thermodynamics. Moreover, they never would have *wanted* the possibility of pulling energy out of the ether at will. Directing vril is not the same as industrial capitalism's productive management and selective distribution of God's gift of finite energy stores. Far from a utopic fantasy of unfettered fuel availability, *The Coming Race* is a satire of scientific naturalism's overextension of particle physics. Like Maxwell's demon, an

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[516] Alexander, *Victorian Literature and the Physics of the Imponderable*, 88.

allegory designed to foreclose the possibility of energetic loopholes, the Vril-ya can tap into negentropic properties of vril because they are demonic, hardly-human beings. I therefore extend the usual interpretation of Bulwer-Lytton's satire into a critique of the negentropic fantasy, or a fantasy that scientific knowledge of the universe and its particles will lead to a mastery over the cosmic dissipation of energy.

A Foundation for an Irreversible Universe

The vortex model of ether proposed that matter was not material at all. All things we perceive as material were supposedly different vibratory manifestations of an all-pervading ethereal fluid.[517] According to vortex theory, ether and matter were continuous, and there was no such thing as empty space or individuated particles. Vortex theory was originally proposed by William Thomson in 1867, but it was popular among Cambridge-trained mathematicians and physicists through the end of the century.[518] This section situates the vortex theory within a broader claim made by Thomson and his colleagues that the material universe was necessarily progressive, or, in other words, that previous material states could not be restored without a violation of the second law of thermodynamics. In Thomson's words, restoration was impossible without "a creative act or an act possessing similar power."[519]

Vortices addressed the question of "creative power," or agency from without, by removing any individuated structure from the most elemental units of energy and matter.

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[517] Helge Kragh, "The Vortex Atom: A Victorian Theory of Everything," *Centarus* 44 (2002), 32-33.
[518] Kragh, 33-34.
[519] In Smith and Wise, *Energy and Empire*, 498. Quoted from William Thomson, Preliminary draft for the 'Dynamical theory of heat', PA 128, ULC, pp. 5-6.

Vortex mechanics proposed that atoms are stable rings of vortex motion, like tiny tornados that form ringed or knotted shapes. Even potential energy was reduced to the kinetic energy, or the motion, of vortices.[520] In an infinite continuum of matter and ether, every vortex of energy is dependent on an infinity of other, interconnected vortices. Therefore, only an infinite mind could particularize the universe's energy to the point of determinism.[521] The vortices, themselves, could be generated or destroyed only by "an act of creative power"; and they, Thomson maintained, were "the only true atoms."[522]

By the time Thomson banished the Lucretian atom[523] in 1867, he and his colleagues had already been constructing a vision of a progressive, irreversible universe since the 1850s. This earlier context for the vortex theory helps locate the politics of structuring an ether-matter continuum within the broader controversy of entropy politics. Chapter two of this dissertation explains Thomson's initial rendering of the dissipation law in an 1852 paper, and the specific language he attached to the second law of thermodynamics. In the same paper, "On the Dynamical Theory of Heat," Thomson responded to Rudolph Clausius's 1850 findings that heat in a closed system will not move from a colder body to a warmer one without the addition of external energy. Thomson summarized Clausius's axiom in his own paper: "*It is impossible for a self-acting machine, unaided by any external agency, to convey heat from one body to*

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520 Bruce Hunt, *The Maxwellians* (Ithaca and London: Cornell University Press, 1991), 97.
521 Smith and Wise, *Energy and Empire: A Biographical Study of Lord Kelvin*, 430.
522 William Thomson, "On Vortex Atoms," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 34:277 (1867), 15. https://www.doi.org/10.1080/14786446708639836.
523 The Roman philosopher Lucretius defended the Epicurean atomic theory, which argued that matter consists of basic indivisible elements, or atoms.

another at a higher temperature."[524] Although Thomson claimed to be paraphrasing Clausius, this axiom appears nowhere in Clausius's 1850 work. Moreover, Clausius's scientific style, as Smith puts it, "differed so radically from the North British engineering perspectives"[525] that interpretations of the second law of thermodynamics fractured along British and German fault lines.

Although Clausius coined "entropy," it was Thomson who was interested in popularizing a new concept and extending its consequences on a cosmic level.[526] Clausius discussed dissipation in terms of heat "striving"[527] to move only from warmer to colder bodies. The axiom that Thomson alluded to, updated in Clausius's 1865 publication, was: "*Heat cannot itself pass from a colder to a warmer body*".[528] This places limitations on work availability, but Clausius dispensed with any personal responsibility for the cosmic dissipation hypothesis, and credited Thomson specifically for that extension of the second law.[529]

In his "Dynamical Theory" and elsewhere, Thomson's language evokes the idea that the material universe has been designed by a divine Engineer who bestowed both material gifts and limitations on living creatures. Jessica Riskin calls this scientific tradition "theological mechanism,"[530] and traces it to Protestant Reformers' split with

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524 William Thomson, "On the Dynamical Theory of Heat, with numerical results deduced from Mr. Joule's equivalent of a Thermal Unit, and M. Regnault's Observations on Steam," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 4 (1852), 14.
525 Smith, *The Science of Energy*, 166.
526 Smith, *The Science of Energy*, 168.
527 Clausius, *The Mechanical Theory of Heat*, 270.
528 Clausius, 270.
529 Clausius, 364.
530 Jessica Riskin, *The Restless Clock: A History of the Centuries-Long Argument over What Makes Living Things Tick* (Chicago and London: University of Chicago Press, 2016), 4.

Catholic doctrine and its icons, sacraments, and rituals that combined matter and spirit.[531] Paley's 1802 *Natural Theology* belongs to this tradition, and indeed Thomson spent the end of his 1871 Presidential Address for the British Association for the Advancement of Science lamenting the decline of Paley's influence in particular, and of teleology in general.[532] When Thomson says, "it is impossible for any *self-acting machine, unaided by any external agency*" to transfer heat from a colder to a warmer body, he is drawing on the language of theological mechanism. Self-acting machines, including living beings, are systems subject to thermodynamic law. By applying a source of outside energy to a system, we can increase its work availability. The aid of "external agency" is the only way to overcome dissipation. On a cosmic scale, only the external agency of the divine Creator can restore the dissipation of the universe.

Riskin argues that "agency," itself, is a key term in the debate between active and passive matter. In the argument for theological mechanism, agency comes from without; or, God designed the world, so matter has no self-organizing properties. But, according to history's competing notion of how matter operates, there is also a long trend of believing in vital forces and the self-structuring characteristics of matter.[533] When Clausius argues that heat "incessantly strives to pass from warmer to colder bodies,"[534] his language resembles this latter tradition, much more so than it does Thomson's vision of

[531] Riskin, *The Restless Clock*, 22-23.
[532] At the end of Thomson's speech, he pitted *Natural Theology* against natural selection: "I feel profoundly convinced that the argument of design has been greatly too much lost sight of in recent zoological speculations. Reaction against the frivolities of teleology, such as are to be found, not rarely, in the notes of the learned Commentators on Paley's 'Natural Theology,' has I believe had a temporary effect in turning attention from the solid and irrefragable argument so well put forward in that excellent old book." William Thomson, "Presidential Address," *British Association for the Advancement of Science* (Taylor & Francis, 1871), 28. https://archive.org/details/b30571042/mode/2up.
[533] Riskin, *The Restless Clock*, 3.
[534] Clausius, *The Mechanical Theory of Heat*, 270.

teleological dissipation. Though Thomson and his North British colleagues believed in free will, especially the free will to direct the transformation of earth's natural energy stores, they never meant for matter, itself, to possess creative or self-organizing properties. Indeed, Smith argues that the dissipation law evidenced a clear cosmological beginning and end "to undermine all those creeds which espoused a self-regulating, self-sustaining and eternal material world."[535] Thus, when Thomson argued in 1867 that ether vortices were permanent fixtures that could be created or destroyed only by an act of "creative power," he was also arguing that the most basic unit of energy was set in motion by a divine Engineer at the birth of the universe.

All of Thomson's work on the second law of thermodynamics committed to unambiguous, inviolable dissipation. From 1852 through the 1860s, he drew on a Scottish view of mind-matter dualism that upheld the power of will to control inert matter through design, though not to annul the laws of nature.[536] As I argue in chapter two, Thomson built this progressive worldview into the language he contributed to the thermodynamics canon. He also maneuvered energy science into place as evidence for that view in the material world. In a series of publications, Thomson centered the sun as the ultimate source of all energetic transformations on earth, organic and inorganic. He argued, first, that from the sun we can trace every form of energy on our planet, and second, that the sun's heat is dissipating.

In 1852 and 1854, Thomson's lectures and publications on dissipation constructed a hierarchy of energy stores whose mechanical effect relied on the sun. In his "On the

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[535] Smith, *The Science of Energy*, 240.
[536] Smith and Wise, *Energy and Empire*, 612-13.

Mechanical Action of Radiant Heat or Light," he listed a variety of energy forms interconnected by the first law of thermodynamics, and then argued that the origin of most, if not all, energetic transformation was solar:

> *Heat radiated from the sun* (sunlight being included in this term) *is the principal source of mechanical effect available to man.* From it is derived the whole mechanical effect obtained by means of animals working, water-wheels worked by rivers, steam-engines, and galvanic engines, and part at least of the mechanical effect obtained by means of windmills and the sails of ships not driven by the trade-winds. … The mechanical effect so largely used in the sailing of ships by the trade-winds is derived partly, perhaps principally, from the earth's motion of rotation, and partly from solar heat.[537]

By underscoring humans' reliance on solar energy, Thomson set up a Great Chain of Being through which energetic transformations descended. As one of God's natural energy stores, the sun's heat ultimately produced the mechanical effect of the structures that support life and commerce. Yet each successive transformation removed solar energy further from the divine, dissipating the sun's heat into increasingly unavailable forms.

Thomson's 1854 "On the Mechanical Energies of the Solar System" similarly addressed the sun as "the source of energy from which all the mechanical actions of organic life, and nearly every motion of inorganic nature at its surface, are derived".[538] Here Thomson extended his argument, explicitly asserting that the sun is "losing heat." The sun's heat, "thus emitted, is dissipated always more and more widely through endless space, and never has been, probably never can be, restored to the sun, without acts as

[537] William Thomson, "On the Mechanical Action of Radiant Heat or Light: On the Power of Animated Creatures over Matter: On the Sources Available to Man for the Production of Mechanical Effect," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 4.25 (1852), 260. https://doi.org/10.1080/14786445208647119.
[538] William Thomson, "On the Mechanical Energies of the Solar System," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 8.54 (1854), 409. https://doi.org/10.1080/14786445408651955.

much beyond the scope of human intelligence as a creation or annihilation of energy or of matter itself, would be."[539] In this classic Thomsonian statement on dissipation, the second law of thermodynamics is, *for humans*, unambiguous and all-pervading, down to the heat death of the sun. But for a creature whose intelligence exceeds that of humans, we might imagine an act of energetic creation or annihilation.

Finally, in 1857, Thomson formally proposed the cosmic dissipation hypothesis, or the idea that the sun will eventually lose too much heat to continue to support life on earth. Thomson drew three conclusions from his calculations of the dissipation law:

> 1. There is at present in the material world a universal tendency to the dissipation of mechanical energy.
> 2. Any *restoration* of mechanical energy, without more than an equivalent of dissipation, is impossible in inanimate material processes, and is probably never effected by means of organised matter, either endowed with vegetable life, or subjected to the will of an animated creature.
> 3. Within a finite period of time past the earth must have been, and within a finite period of time to come the earth must again be, unfit for the habitation of man as at present constituted, unless operations have been, or are to be performed, which are impossible under the laws to which the known operations going on at present in the material world are subject.[540]

In this iteration, energetic dissipation and its consequences are packaged together as thermodynamic law and cosmic inevitability. There was a time before humans, there will be a time after humans, and the second law of thermodynamics can approximate such a timeline.

There was a twofold purpose to centering the sun in these dissipation publications. First, applying the second law of thermodynamics to the sun's heat loss

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539 Thomson, 410.
540 William Thomson, "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy," *Proceedings of the Royal Society of Edinburgh* 3 (1857), 141-42. https://doi.org/10.1017/S0370164600027541.

could, in theory, date the earth. Thomson used this as a weapon against geologists[541] and biblical literalists, alike. After 1859, he charged Darwin's natural selection with the same apparent inaccuracies. His famous lecture, "On the Age of the Sun's Heat," incorrectly assumed that the earth must be between twenty and one hundred (or so) million years old.[542] But Thomson also used his dissipation of the sun calculations to argue that there was a definitive difference between dead matter and living creatures. Based on his thermodynamic dating system, Thomson argued that it was impossible for life to have "taken place by any fortuitous concourse of atoms,"; and it was rather an act of "'creating and directing Power'" that distinguished living creatures with the power of agency.[543]

The North British physicists popularized the heat death hypothesis and its evidence for creative Power at all levels of scientific expertise. In his 1871 Presidential Address to the British Association for the Advancement of Science, Thomson addressed his colleagues with unwavering support for "intelligent and benevolent design," whose evidence teaches us "that all living beings depend on one ever-acting Creator and Ruler."[544] On the other end of the spectrum, Maxwell's *Theory of Heat,* a work intended for the casual student of science, instructed that "there is no generation or destruction" of molecules within individual organisms, themselves. Therefore, "evolution is quite inapplicable to the case of molecules" because they can be neither created nor destroyed

[541] The North British energy physicists specifically targeted Charles Lyell's uniformitarianism, which argued that the geological forces shaping vast changes on earth were constant, uniform, and directionless.
[542] William Thomson, "On the Age of the Sun's Heat," *Macmillan's Magazine* 5 (1862), 392.
[543] Smith and Wise, *Energy and Empire*, 612.
[544] William Thomson, "Presidential Address," *British Association for the Advancement of Science* (Taylor & Francis, 1871), 28. https://archive.org/details/b30571042/mode/2up.

without external Power.[545] Thomson and his colleague Peter Guthrie Tait likewise targeted non-experts with an article in *Good Words* magazine, a prominent Presbyterian periodical. They explained that this article meant to straighten out the history and concept of energy for any curious reader, especially well-meaning but misinformed Christians.[546] Here, the authors aimed to dispel the competing energy doctrine of John Tyndall and his colleagues, who were trying to uncouple the science of energy from North British cosmology.[547]

Like many of Thomson's *Royal Society* publications, the end of Thomson and Tait's *Good Words* article folded dissipation law calculations into theological narrative. They prophesied, "we must conclude that when all the chemical and gravitation energies of the universe have taken their final kinetic form, the result will be an arrangement of matter possessing no realizable potential energy, but uniformly hot – an undistinguishable mixture of all that is now definite and separate – chaos and darkness as *'in the beginning'*".[548] Writing for a Presbyterian audience, Thomson and Tait explicitly connected their definition of energy to the darkness of Genesis and the chaos of divine Creation and Destruction. "[U]nless fresh energy is communicated," they instructed, dissipation is a "sober scientific certainty," a "fixed law" of nature.[549]

The entropy question concerned, therefore, not just how old the earth must be, but also how life began and how it must end. Tyndall, who had witnessed the growing

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545 James Clerk Maxwell, *Theory of Heat* (1871; Mineola: Dover Publications, 2001), 330. Citations refer to the Dover edition.
546 William Thomson and Peter Guthrie Tait, "Energy," *Good Words* (Alexander Strahan and Co., 1862), 601. https://hdl.handle.net/2027/njp.32101076425162.
547 Smith, *The Science of Energy*, 184.
548 Thomson and Tait, 606.
549 Thomson and Tait, 606-607.

influence of the North British cohort with concern, was among the scientific naturalists who embraced natural selection in the decade following Darwin's publication of *On the Origin of Species*.[550] Tyndall decided to conceptually unite the first law of thermodynamics and evolution, a strategy that would untether the conservation law from dissipation and Thomson's heat death hypothesis. Key to Tyndall's strategy was using theories like natural selection and the conservation of energy as evidence that nothing in nature is beyond the dominion of scientific investigation. In his "Belfast Address," Tyndall boasted,

> In our day grand generalizations have been reached. The theory of the origin of species is but one of them. Another, of still wider grasp and more radical significance, is the doctrine of the Conservation of Energy, the ultimate philosophical issues of which are as yet but dimly seen – that doctrine which 'binds nature fast in fate' to an extent not hitherto recognized, exacting from every antecedent its equivalent consequent, from every consequent its equivalent antecedent, and bringing vital as well as physical phenomena under the dominion of that law of causal connexion which, so far as the human understanding has yet pierced, asserts itself everywhere in nature.[551]

By suggesting that the law of conservation adhered to a materialistic determinism, "exacting from every antecedent its equivalent consequent, from every consequent its equivalent antecedent," Tyndall essentially jettisoned the North British irreversible universe. If the law of causality was a fact of nature, anything from evolution to entropy could, in theory, be scrutinized by science.

Human understanding could "pierce," as Tyndall put it, just about anything in nature if we have enough conditional information. In the struggle to control the

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[550] Smith, *The Science of Energy*, 171.
[551] John Tyndall, *Address Delivered before the British Association Assembled at Belfast* (London: Longmans, Green and Co., 1874), 45.

cosmology of entropy, atomic structure was a critical concern here. Tyndall and the scientific naturalists relied on the continental, particularly the German, classical worldview of particle interactions. However, vortex theory competed with this view by suggesting that discrete particles did not exist. If the vortex theorists could validate their structure for the ether, they could also claim that the "true" structure of energy (*i.e.*, the vortices) could be created or destroyed only by "an act of creative power."[552]

Smith and Wise argue that the promise of vortex theory enhanced the power Scottish energy scientists already held over physics and the growing field of thermodynamics. "If vortices were indestructible," they explain, "they had the additional advantage that only God could create them… And while the modern Lucretians could only explain properties of matter by attributing them to a variety of mysterious forces inhering in atoms, the economical Creator of vortices worked simply with primitive inertia in the universal fluid."[553] Those modern Lucretians, in other words, were pulling for a self-organizing power within matter, itself, which might support the hypothesis that life on earth existed without a divine telos. Vortex theory threatened scientific naturalism from evolution to entropy because it was, as Robert Silliman explains, "the lowest common denominator of all natural forces."[554] The theory gestured to the idea, in compelling mathematical terms, that a divine Engineer created an infinite variety of motions in the ether, and these differences in motion accounted for distinctive kinds of

[552] Thomson, "On Vortex Atoms," 15.
[553] Smith and Wise, *Energy and Empire,* 419.
[554] Robert H. Silliman, "William Thomson: Smoke Rings and Nineteenth-Century Atomism," *Isis* 54.4 (1963), 464. https://jstor.org/stable/228151.

matter and their properties. It was simple, universalizing, and impossible to conclusively prove or disprove.

The vortex theory burgeoned in January 1867, when Thomson watched one of Tait's Edinburgh demonstrations on smoke rings. Tait produced smoke rings from two boxes situated at varying angles to each other, the direction of which determined how the smoke rings would behave. Two rings that approached each other from opposite directions, for example, expanded increasingly slowly. On the other hand, rings directed towards each other at oblique angles reverberated violently in opposite directions.[555] Tait's demonstration convinced Thomson to review Hermann von Helmholtz's paper, *Wirbelbewegung*, which was a study on vortex motion.[556] The work of a German physicist[557] ironically influenced Thomson's vortex theory of atoms, though there is no evidence that Helmholtz was ever convinced by Thomson's proposed structure for ether and matter.

Tait's smoke rings and Helmholtz's paper inspired Thomson to conceptualize the ether and matter as a universal continuum of various kinds of motion. After 1867, he published the theory and popularized the vortices, motivating other scientists to join the trend. Unlike older atomic theories, the vortices were interdependent and could not be reduced to the laws of classical mechanics. The concept seemed almost too convenient, yet powerful mathematical evidence supported Thomson's claims. For instance, vortex

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[555] William Thomson, "Elasticity Viewed as Possibly a Mode of Motion" in *Popular Lectures and Addresses*, 3 vols (London and New York: Macmillan and Co: 1889), 145.
[556] Silliman, "William Thomson: Smoke Rings and Nineteenth-Century Atomism," 464.
[557] Despite that German and British physicists differed in technique, Helmholtz and the Scottish cohort were amicable colleagues. Helmholtz never did agree with their dissipation law agenda, however.

rings could account for the thermodynamic properties of gases.[558] They could explain different varieties of matter by finding endless possibilities of vortex knots and ring patterns.[559] Mathematically, the vortex theory seemed to fall into place with the demands of extant physics. But, since there was no way to directly look at ether vortices, or to experimentally validate the theory, its advocates relied on mathematical support and what Alexander calls "symbolic – even fictive" acts of speculation.[560]

Indeed, vortex theory rose to an astounding level of success perhaps because, for a long time, it could be neither proven nor disproven. There was no recourse to rigid matter one could theoretically observe. Tyndall recognized the power of imaginative modeling and attempted a similar technique in his counterarguments for classical Lucretian atomic structure. In his *Use and Limit of the Imagination in Science*, he invited readers to extend their imaginations into the domain of the ether and apply the analogy of sound waves to determine what the most elemental unit of energy might look like:

> Many chemists of the present day refuse to speak of atoms and molecules as real things. Their caution leads them to stop short of the clear, sharp, mechanically intelligible atomic theory enunciated by Dalton, or any form of that theory, and to make the doctrine of multiple proportions their intellectual bourne… Like you and me they one and all believe in an ether and its light producing waves. Let us consider what this belief involves. Bring your imaginations once more into play and figure a series of sound-waves passing through air. Follow them up to their origin, and what do you there find? A definite, tangible, vibrating body. It may be the vocal chords of a human being, it may be an organ-pipe, or it may be a stretched string. Follow in the same manner the train of ether waves to their source; remembering at the same time that your ether is matter, dense, elastic, and capable of motions subject to and determined by mechanical laws. What then do you expect to find as the source of a series of ether waves? Ask your imagination

558 Silliman, "William Thomson: Smoke Rings and Nineteenth-Century Atomism," 470.
559 Silliman, 470.
560 Alexander, *Victorian Literature and the Physics of the Imponderable*, 145.

> if it will accept a vibrating multiple proportion – a numerical ration in a state of oscillation? I do not think it will.[561]

Though he does not explicitly say so, Tyndall's target in this passage is the vortex theory of atoms. "Vibrating multiple proportions" and "numerical states of oscillation" refer to the elusive ether vortices. Here, Tyndall turns the North Britishers' strategy against them, asking his readers to analogize transverse ether waves with longitudinal sound waves. Something hard, real, and material creates a sound vibration. It follows logically, he reasons, that luminiferous waves must also originate from real, material atoms.

It was not unusual for early energy science to resemble a marketplace of competing theories, beliefs, and interpretations. Because the object under scrutiny could not be seen directly, theories required support from both mathematics and experimentation. But theories also relied on the momentum they carried in the greater scientific community, and, as we have seen, momentum was not uninfluenced by analogical arguments, thought experimentation, and rhetorical gymnastics. William James scrutinized this trend in his 1896 essay, "The Will to Believe." James argued that contemporary science rarely based its conclusions on evidence, and instead substituted faith for truth. "Our faith is faith in some one else's faith," he chastised, and criticized individual members of the X-Club and North British group alike for their selective interest in theories that serve only their respective beliefs.[562]

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[561] John Tyndall, *Use and Limit of the Imagination in Science* (London: Longmans, Green, and Co, 1870), 21.

[562] William James, "The Will to Believe" in *The Will to Believe and Other Essays in Popular Philosophy* (New York, London, and Bombay: Longmans, Green, and Co., 1907), 7-10.

James wanted to expose institutional science for its reliance on "wish and will and sentimental preference,"[563] but he also understood how powerfully those motivations furthered the careers of individual scientists and fields of study, in general. When Maxwell casually proposed his sorting demon thought experiment, Thomson jumped at the opportunity to employ the demon at the intersection of desire and the limits of human experience. Bruce Clarke argues that the demon was an allegorical text, that allegory is "the rhetorical form most *like* mathematics in the symbolic equations that build conceptual models. Allegorical texts present a discursive algebra of reified images and emblems, a structural geometry of networked spaces."[564] The vortex theory relied almost exclusively on mathematical modeling as justification for entropy's cosmic totality. But with the addition of Maxwell's demon, the North Britishers had an allegorical extension of their argument for the limitations of particle dynamics. The demon mediated between the abstract mathematical domain of vortices and the cosmological significance of entropy.

The demon emerged quietly, first as a private remark Maxwell sent to Tait in a letter. Maxwell casually explained to Tait, who was preparing materials for his upcoming treatise on the recent history of thermodynamics, that a convenient way to conceptualize the second law was to imagine our inability to control or particularize molecular motion. If we were to "pick a hole" in the second law, as Maxwell put it, then we might imagine "a finite being who knows the paths and velocities of all the molecules by simple

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[563] James, "The Will to Believe," 8.
[564] Clarke, *Energy Forms*, 95.

inspection," and who can sort them by performing no work at all. But humans cannot do this, he concluded, "not being clever enough."[565]

Maxwell later published a more thorough explanation of the thought experiment in his *Theory of Heat*. As a parable, he wanted readers to understand the limitations of the second law. The demon, specifically, tested its limits because natural law proscribes humans from loopholes. Maxwell asked readers to "conceive a being whose faculties are so sharpened that he can follow every molecule in its course, such a being, whose attributes are still as essentially finite as our own, would be able to do what is at present impossible to us."[566] The demon was preternaturally sensitive and agile, but not divine. He simply observed what humans could not, and then directed molecules accordingly.

Next, Maxwell described the experimental conditions. The demon was a gatekeeper for gas molecules in a vessel with two chambers. He vetted molecular speed: hot molecules moved quickly, cold molecules were sluggish. Maxwell explained:

> Now let us suppose that such a vessel is divided into two portions, A and B, by a division in which there is a small hole, and that a being, who can see the individual molecules, opens and closes this hole, so as to allow only the swifter molecules to pass from A to B, and only the slower ones to pass from B to A. He will thus, without expenditure of work, raise the temperature of B and lower the temperature of A, in contradiction to the second law of thermodynamics.[567]

This was how the demon circumvented the second law. Without adding work to the system, the demon used his sharpened senses to gather information about how much energy each molecule carried. Then, he simply opened the door as needed.

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[565] In Smith, *The Science of Energy*, 249-251. Quoted from Maxwell to Tait, 11 December 1867, ULC.
[566] Maxwell, *Theory of Heat*, 328.
[567] Maxwell, 328-29.

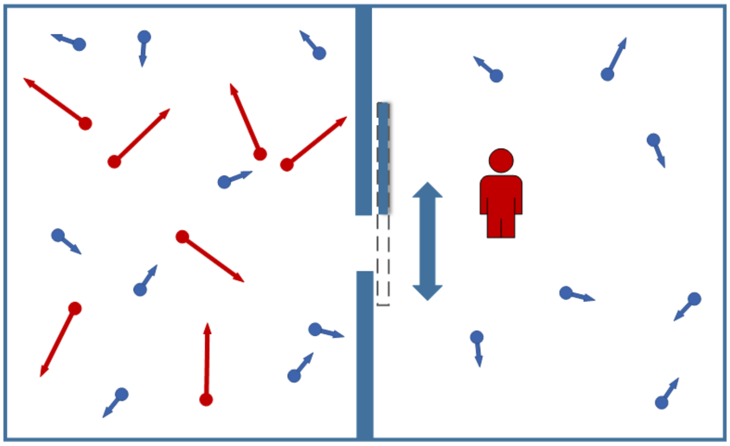

Figure 7. Illustration of thought experiment known as "Maxwell's demon"

The problem was, of course, that humans would never be able to perceive molecules at the level of microstates. One could only ever scrutinize particles on what Maxwell argued was a statistical level, or a level of averages. He explained, "we do not perceive the individual molecules, we are compelled to adopt what I have described as the statistical method of calculation, and to abandon the strict dynamical method".[568] This was meant as a blow to the naturalists' determinism, which relied on particle dynamics. Maxwell took his analysis further. He speculated, "It would be interesting to enquire how far those ideas about the nature and methods of science which have been derived from examples of scientific investigation in which the dynamical method is followed are applicable to our actual knowledge of concrete things, which, as we have seen, is of an essentially statistical nature, because no one has yet discovered any practical method of tracing the path of a molecule, or of identifying it at different times."[569] This statement challenged scientific naturalism's boldness about using the conservation law to "pierce"

[568] Maxwell, *Theory of Heat*, 329.
[569] Maxwell, 329.

all of nature's secrets, as Tyndall boasted, because as it turned out, humans were completely incapable of gathering information about individual molecules, and equally incapable of designing tools to direct their movements.

The demon was Maxwell's brainchild, but it was Thomson who popularized it. In fact, Thomson christened the experiment the "sorting demon of Maxwell,"[570] while Maxwell only called it a "neat-fingered being," or demoted it to the role of a valve.[571] Under Thomson's charge, the demon acquired extraordinary powers. He could change the chemical composition of materials, he could store up energy at will and apply it elsewhere, and he could do all this merely because of his "extreme smallness and agility."[572] Thomson's version of the demon possessed free will and intelligence. With his superior, neat-fingered powers, he was capable of observing and directing energy transformations without creating or destroying any energy. Thomson even conjured up an army of demons who could, with tiny cricket bats, stave off dissipation.[573] But because real systems did not have tiny demons with cricket bats, and because, more importantly, humans were incapable of articulating energy at the level of differentiated particles, reality safeguarded the second law from such loopholes.

Because the laws of physics remained intact despite Maxwell's demon's negentropic skills, Thomson set up a distinction between what he called "abstract" and "physical" dynamics. In a presentation to the Royal Society of Edinburgh, he explained that, under abstract dynamics, reversibility was possible because particles were discrete

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[570] William Thomson, "The Sorting Demon of Maxwell" in *Popular Lectures and Addresses,* 3 vols (London and New York: Macmillan and Co: 1889), 137.
[571] Smith, *The Science of Energy*, 251-52.
[572] Thomson, 137-140.
[573] Smith, 252.

and therefore articulable. The demon belonged to such a world. In physical dynamics, however, systems were non-conservative and reversibility always gave way to diffusion.[574] Thomson's strategy involved caricaturizing the demon and spinning him off into his own alternate reality to demonstrate the conditions of violating the dissipation law.

The reality of our world, Thomson argued, was that particle dynamics was just a placeholder, not a deterministic tool. He believed that a vortex ether continuum was the key to understanding the second law of thermodynamics, and that humans had constructed the concept of individuated particles because their minds could not approach the vastness of an undifferentiated ether-matter plenum.[575] Man's limitations within the world of physical dynamics restricted him to a reliance on the sun for all material and commercial bounty, and to a reality where that sun would eventually no longer support life on earth.

These distinctions at the most elemental level of energy's structure are important because belief in an irreversible cosmos reinforced the Scottish commitment to economy and energy management. If all energy stores on the planet were a divine gift that would eventually dissipate, then engineering, science, and industry were bound up in a moral obligation to actualize that gift without squandering it. And, as Daggett points out, even though the Scottish Presbyterian grip on energy science loosened over time, the specter of "geopolitical judgment" still lingers in our assessment of energy control and national

[574] Smith and Wise, *Energy and Empire*, 626.
[575] Smith and Wise, 627.

prosperity.[576] The critical infrastructures of energy extraction and distribution were built with the desire to govern, direct, and control finite reserves. Nations who did this efficiently prospered. They benefited from gifts of energy that would have eventually dissipated, or gone to waste, without the aid of engineering and imperial flows of resources. By building this ethos into the very structure of ether and the matter embedded in it, early thermodynamicists controlled the narrative for a much broader array of conditions that grew out of the North British interpretation of entropy.

Despite the Scottish enthusiasm for national prosperity, the North British energy scientists never longed for a negentropic mechanical contrivance, or an unlimited energy source. In the entropy debates, they insisted upon two key points: our planet's reliance on the sun, and the inevitability of that sun's dissipation. There was no way out of this, only a correct path through. Maxwell's demon mediated between a misapprehended sense of energetic mastery projected by Tyndall, and the inviolable cosmic dissipation of Thomson's "physical" dynamics. The demon could articulate matter and manipulate energy against the second law of thermodynamics, but as an allegory the demon's purpose was to underscore the constraints of human material and spiritual power.

The subterranean humans of Bulwer-Lytton's *The Coming Race* possess demon-like attributes down to their "neat-fingered" manipulation of vril, the etheric union of all energies. By channeling their will through a nerve in their wrist and thumb, the Vril-ya can sort energy into myriad negentropic structures, despite vril's vortex-like smearing of all energetic forms. And, crucially, they live without any reliance on the sun's energy.

[576] Daggett, *The Birth of Energy*, 77.

The Coming Race, I argue, deserves a new reading in the context of the entropy debates and the associated struggle for controlling a grand narrative of energy. While the novel does not directly reference Maxwell's demon or the heat death of the universe, it is nevertheless awash with the language of energy and evolution. Because energy and evolution were intertwined when the novel was published, and because Thomson enthusiastically employed the sun's dissipation as a tactic to disprove natural selection and uniformitarianism, I argue that Bulwer-Lytton's dispensing with the sun altogether magnifies the novel's satire of scientific naturalism. If the sun is not going to burn out, or if the sun's decay does not hinder unlimited energy consumption, then there is no longer a time crunch to use the earth's energy stores wisely before they naturally dissipate. And, if energy is unlimited, there is no longer need for an imperial push to funnel those energy transfers towards benefiting and expanding an empire at the expense of peripheral regions. The next section, therefore, extends the North British critique of a negentropic fantasy into a reading of Bulwer-Lytton's popular novel.

THE WORLD WITHOUT A SUN: *THE COMING RACE* AND ENTROPY POLITICS

Edward Bulwer-Lytton, who believed that all art should have an ethical agenda,[577] loaded *The Coming Race* with polarizing scientific and social content. The novel is a conservative satire that criticizes women's professional and sexual autonomy, lampoons American imperialism, and instructs against polluting superior Aryan races with

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[577] Edward Bulwer-Lytton, *Caxtoniana: A Series of Essays on Life, Literature, and Manners*, vol. 1 (Leipzig: Bernhard Tauchnitz, 1864), 163.

miscegenation.[578] Besides its satire, *The Coming Race* is best known for its apocalyptic dimension: that natural selection has produced a superior subset of Aryans beneath the very earth of expanding and competing western empires. Alexander has also recently suggested that Bulwer-Lytton's novel is a literary utopia that describes a society uninhibited by the second law of thermodynamics. Because energy and capital were conceptually interlaced, the Vril-ya represent the desire to liberate capitalism from its own decay.[579]

The fantasy of liberating capitalism from entropy, Alexander argues, is based on increasingly speculative qualifications of value in both physics and economics. As physicists moved away from the hardness – the realness – of atoms, economists shifted their focus to analogously symbolic ideas like credit and consumer desire.[580] As many have pointed out, and as we have discussed in previous chapters, energy and capital were not interchangeable. Nevertheless, energy science did echo trends in political economy: insistence on the fundamental transposability of all things, especially labor and commodities, and increasingly symbolic rules for the structuring and circulation of value. Because capital and energy were conceptually interwoven, the thermodynamics laws seemed to describe capitalism's degenerative consequences as much as they described the dissipation of industrial machinery. So, Alexander reasons, a capitalist society that does

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[578] Bulwer-Lytton was notorious for his pro-imperialist attitude and misogynistic treatment of his wife. He served as Secretary of State for the Colonies (1858-59), used his wife's property to run for Parliament, and then disinherited her. The unnamed narrator in *The Coming Race* is an American man, a detail which allows Bulwer-Lytton to satirize American imperialism and Yankee optimism at no joking expense to the British empire. He supported the expansion of Britain in Canada and Australia. See Marie Mulvey Roberts, "Notoriety and Madness: Edward Bulwer-Lytton Paying the Price of Greatness," *Critical Survey* 13.2 (2001), 118-119.
[579] Alexander, *Victorian Literature and the Physics of the Imponderable*, 83-85.
[580] Alexander, 139-146.

not rely on finite resources, as we see with the Vril-ya, describes capitalism as nineteenth-century political economists believed it should operate. The Vril-ya live without social inequalities, yet they still function under capitalism. It stood to reason for capitalists that if they could figure out how to eliminate the waste of labor, or the entropy of the system, then capitalism would be flawless.

Figuring out which elements of labor were most "wasteful" was a task that combined the universalism of energy conversion with western hierarchies of race and gender. Anson Rabinbach has located fatigue as a key intersection of the limits of workers' bodies and machine productivity. Because scientists demonstrated that energy was converted into mechanical work in human bodies and industrial machines alike, fatigue became an analyzable element of waste to be rooted out.[581] Here, energy laws provided scientific evidence for movements to police workers' bodies and time management so they could produce as much as possible during work hours. Fatigue prevention was less a matter of workers' rights and was designed, as in the case of machinery, to extract more labor in the long run. Rabinbach explains that too much rest was viewed as equally damaging to the worker as too little rest; and invisible, gendered, and domestic labor were rarely considered. Workers perceived as having excessive leisure time were associated with crime and drink; and, even more so, ethnographers attempted to prove that colonial workers were naturally disposed to sloth and vice.[582]

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[581] Rabinbach, *The Human Motor*, 19-25.
[582] Rabinbach, 30-31.

Though colonial workers were charged with laziness, imperialists also claimed that they were capable of producing much *more* work than domestic laborers.[583] By using the apparently universal metric of fatigue, scientists measured the energetic capabilities of English workers and workers native to warmer climates, and concluded that non-European races were inured to hot climates that conditioned their bodies to produce more work. In short, European races were not more energetic; but because they were naturally more industrious, they worked and produced more.[584] These assumptions gave colonial administrators an "energetic racism"[585] that systematized the people and natural world that they governed by presuming that colonial laborers were naturally capable of producing much more work than their British counterparts. If the land and the people were apparently sluggish but fruitful, and energy science could prove it, then imperial managers assumed they could force productivity out of Britain's colonies.

The Coming Race combines such assumptions about racialized bodies and their capacity for endless work with Victorian Britain's valorization of ancient Egyptians and premodern Aryans. The Vril-ya are an offshoot of the Aryan race, yet they physically resemble ancient Egyptians and, on occasion, Indigenous Americans.[586] Patrick Brantlinger points out that Victorian authors credited the ancient Egyptians for spectacular feats of arts and science, whereas modern Egyptians were "degenerate version[s] of the ancient one."[587] Therefore, the Vril-ya's industrial, architectural, and

[583] Rabinbach, *The Human Motor*, 30.
[584] Rabinbach, 30.
[585] Daggett, *The Birth of Energy*, 135.
[586] Edward Bulwer-Lytton, *The Coming Race* (1871; Peterborough: Broadview, 2008), 39.
[587] Patrick Brantlinger, *Taming Cannibals: Race and the Victorians* (Ithaca and London: Cornell University Press, 2011), 181.

scientific achievements seem to be explained by their Aryan roots, or ancient Egyptian likeness. At the same time, the Vril-ya are a naturally energetic people. They have mastered energy and can labor endlessly, without fatigue, and at no expense to their resources. In this way they seem to operate as energetically abundant, racialized bodies who have mastered their own forces, and who are a threat to western empires.

Along those lines, liberating capitalism entirely from its own decay could mean actualizing the potential of land and bodies that would have worked for themselves, rather than for Britain, were they permitted to industrialize. So, while I generally agree with Alexander's reading of the Vril-ya's liberating capitalism from its own decay, I argue that maintaining a narrative of overall, cosmic dissipation was necessary to uphold limitations on energy distribution and transfer. Controlling the British empire depended on policing the work of its laborers, and the narrative of wasteful but energetic colonial workers was central to that control. The way the Vril-ya manipulate energy resembles what Thomson referred to as "abstract" dynamics, or dynamics beyond the bounds of reality. Therefore, the negentropic imagery in *The Coming Race* that elevates capitalism can also be interpreted as an overextension of conservative forces, or what Thomson would have called "abstract" dynamics. The Vril-ya do not violate natural law, but because they have developed mechanical and physiological contrivances to direct energy against entropic drift, they belong to a reality outside the limitations of human physics. Thus, adding to Alexander's interpretation of vril as a negentropic energy source, I argue that followers of North British energy doctrine almost certainly would have considered this novel a satire of the negentropic fantasy.

The Coming Race plays on a number of key issues in the entropy debates, most notably the systematic and hierarchical progression of energy transformations. Foremost, the Vril-ya have no need for a sun. Thomson repeatedly argued that the sun was a central energy store from which earth derived all other forms of fuel and work. The Vril-ya do not harvest or extract energy from any reserve. Instead, they channel energy from the ether by activating a nerve that runs through their wrists and fingers, and also by particularizing the kind and amount of energy they need with a mechanical staff. Their society has no interest in imperial expansion because they can essentially conjure energy at will, and there is therefore no need to enlarge their territory for resource or labor extraction. When the American narrator boasts of Monroe era westward expansion, British readers are invited to laugh alongside the Vril-ya, who belittle the narrator for his country's misguided beliefs about spreading democracy across the globe.[588] But Bulwer-Lytton unequivocally supported British imperialism and its industrial projects. The Vril-ya, therefore, do not represent Britain's energy desires, but rather bear out the unappealing consequences of trivializing the entropy law. In Bulwer-Lytton's satire, energy does not acquire the North British ethical imperative to direct finite resources economically, or otherwise in the best interest of the nation.

The Vril-ya also venerate the first law of thermodynamics, or the conservation law. In their society, all systems of philosophical and scientific thought converge on the principle of unity, "the simplicity of a single first cause or principle."[589] Such a philosophy dons Tyndall's bias towards universal conservation and its associated

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[588] Bulwer-Lytton, *The Coming Race*, 53.
[589] Bulwer-Lytton, 61.

determinism. The Vril-ya can master energy because, as Tyndall argued, conservation brings "vital as well as physical phenomena under the dominion of that law of causal connexion which, so far as the human understanding has yet pierced, asserts itself everywhere in nature."[590] Tyndall also linked the conservation law with evolution as a way of attenuating the influence of the dissipation law. The Vril-ya control energy via the synthesis of their curated physiological traits and the conservation of energy routed through ether, or what they call vril. And, underneath the earth, dissipation is nowhere to be found.

The Vril-ya shatter the unnamed narrator's belief systems when he falls through a chasm in a mine and finds humans beneath the earth. It is significant that a mine, specifically, is the narrator's gateway to a new world of energetic bounty, with its own logic of energy.[591] Indeed, as he takes stock of his foreign surroundings, some of the first peculiarities he notes are fountains of what he calls "naphtha," for lack of a better word.[592] The fountains are architectural accents, an aesthetic choice which strikes the narrator as equally beautiful and thriftless. He also witnesses the Vril-ya's jewel-encrusted machinery with a mix of horror and awe. Fossil fuels, precious gems, and metals are not valued for their scarcity or commercial utility in this world.[593]

The narrator's observations about how energy is used and where it comes from repeatedly send him reeling. Such observations, and the resulting synthesis between Victorian knowledge systems and those of the Vril-ya, form the backbone of the novel.

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[590] Tyndall, *Address Delivered before the British Association Assembled at Belfast*, 45.
[591] Alexander, *Victorian Literature and the Physics of the Imponderable*, 87-88.
[592] Bulwer-Lytton, *The Coming Race*, 37, 84, 131, 147.
[593] Bulwer-Lytton, 110.

Jennifer Judge characterizes *The Coming Race* as a Menippean satire, or a "highly 'intellectualized'" journey the narrator takes to ultimately unsettle his own systems of knowledge.[594] The Vril-ya test his beliefs with probing questions about his own society, but his systems of knowledge fracture also because he applies upper-world assumptions to his new surroundings. Because he never learns the name of the naphtha-like fluid, the narrator continues to imagine that these fountains are fathomless wellsprings of energy, or at least the spectacle of such a thing. And, if they existed in his own world, they would be poorly managed transfers for energy stores as fuel naturally makes its way down a dissipative gradient.

Even more astounding than the naphtha fountains, the underworld is verdant and teeming with life. "The world without a sun," the narrator describes, "[is] bright and warm as an Italian landscape at noon."[595] In lieu of a sky, a terraformed "cavernous roof" withdraws into the rock until it becomes imperceptible, forming an artificial atmospheric haze. Taking in the buildings, the flora, the synthetic brightness, and the hollowed-out ravines, the narrator concludes that whatever race he has stumbled upon evidently "constructed [their world] by art."[596] All these observations fly in the face of dominant nineteenth-century energy logic. The sun-centered hierarchy of progressive and irreversible energy transformations breaks down in the presence of entire ecosystems that pull their energy from an unseen source. Thomson described the sun as "the source of energy from which all the mechanical actions of organic life, and nearly every motion of

[594] Jennifer Judge, "The 'Seamy Side' of Human Perfectibility: Satire on Habit in Edward Bulwer-Lytton's 'The Coming Race,'" *Journal of Narrative Theory* 39.2 (2009), 139. https://jstor.org/stable/41427202.
[595] Bulwer-Lytton, *The Coming Race*, 38.
[596] Bulwer-Lytton, 38.

inorganic nature at its surface, are derived";[597] yet the sun provides no energy for this race. They have forged all the requirements not just of life, but of civilization, without any solar assistance.

When the narrator looks upon the countenance of the first individual he meets, he questions whether he is indeed beholding a fellow human. Recounting the experience, he explains that the form was human, "[b]ut the face! it was that which inspired my awe and terror. It was the face of man, but yet of a type of man distinct from our known extant races." The face of this being reminds the narrator "of symbolical images of Genius or Demon that are seen on Etruscan vases or limned on the walls of Eastern sepulchres – images that borrow the outlines of man, and are yet of another race."[598] The choice word, "race,"[599] is significant to the novel's suggestion that natural selection is always at work on humankind, making discriminating adjustments to human populations beyond our ability to register those changes. And, indeed, the Vril-ya are the *coming* race because they intend to one day supplant the inferior Anglo Saxons of the upper world.[600] However, because the narrator also recalls that the face reminded him of the symbolic, demonic countenance one finds on an Etruscan vase or in Eastern sepulchres, he is also evoking the Orientalized, Victorian fascination with ancient Egyptians.[601] The Victorians interpreted Egyptian feats of science and engineering as signs of a superior, distant race;

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[597] Thomson, "On the Mechanical Energies of the Solar System," 409.
[598] Bulwer-Lytton, *The Coming Race*, 39.
[599] It is noteworthy that the Vril-ya are not a different species. The novel claims that the narrator can produce offspring with Vril-ya women. Therefore, "race" carries the overtones particular to late-nineteenth century literature that suggested another race might infiltrate Britain and pollute its whiteness.
[600] Bulwer-Lytton, 88.
[601] This literary trend waxed towards the end of the century, as we have seen in Chapter 3.

and the narrator here transfigures the Vril-ya into idealized, serene yet terrifying, ancient Egyptian bodies.

The physical features of the Vril-ya remind the narrator of Etruscan or ancient Egyptian figures, but the Vril-ya also carry an aura that seems harder to place. To the narrator, they are an uncanny combination of serenity and destruction. When he first meets his guides, he feels that they merely "borrow" human form, yet they harbor "forces inimical to man." They possess equally "the faces of sculpted gods"[602] and the figures of demons. But they are demonic because they are endowed with exceptional skills and destructive forces.[603] The narrator's descriptions are fitting, considering how his new hosts can rend rock, eviscerate lesser beings, and command light with a flick of their wrists.

Directing vril actually requires a combination of learned skills and genetic assets. One of his hosts, Zee, presents her hand as evidence of morphological differences between her thumb and wrist, and those of his own hand. He recounts that her thumb "was much larger, and at once longer and more massive, than is found with our species above ground." Additionally, there is "a visible nerve, perceptible under the skin, which starts from the wrist skirting the ball of the thumb, and branching, fork-like, at the roots of the fore and middle fingers."[604] Zee explains that, without such structures, the narrator will never achieve mastery of vril, even if he attempts to use vril-powered devices, like mechanical wings or a vril staff.

[602] Bulwer-Lytton, *The Coming Race*, 40-42.
[603] "Demon" refers to a "malevolent supernatural being," and an "exceptionally fast, strong, energetic, or skilful person." "demon, n. (and adj.)". OED Online. March 2021. Oxford University Press. https://www.oed.com/view/Entry/49788?redirectedFrom=demon (accessed April 9, 2021).
[604] Bulwer-Lytton, 93.

The vril staff is a mechanical device used to modify, amplify, and direct energy. To the narrator it is a useless machine, or possibly even a danger, as "the full exercise of vril power can only be acquired by constitutional temperament – *i.e.*, by hereditarily transmitted organisation."[605] To the Vril-ya, however, the staff is like an appendage. An expert vril-user exercises the wrist and hand nerve while articulating "stops, keys, or springs" inside the staff. One process heals the body while another channels enough energy to destroy enemies or hollow out caverns.[606] This combination of inborn, "neat-fingered" skill and mechanical contrivance is the kind of interlinked exemption from the dissipation law that the North British scientists argued humans could never achieve. In Maxwell's *Encyclopedia Britannica* entry for "Available Energy," for example, he explained that "[The] notion of dissipated energy could not occur to a being who could not turn any of the energies of nature to his own account, or to one who could trace the motion of every molecule and seize it at the right moment." Unlike Maxwell's demon, the Vril-ya do not scrutinize the path of every individual molecule, but Zee explains to the narrator that they do have expert knowledge of the most elemental unity of all energetic forms. They therefore do not need to acknowledge the dissipation of energy since it is, in Maxwell's terminology, "energy which we cannot lay hold of and direct at pleasure."[607]

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[605] Bulwer-Lytton, *The Coming Race*, 91.
[606] Bulwer-Lytton, 91.
[607] In Smith, *The Science of Energy*, 240. Quoted from James Clerk Maxwell, *The Scientific Papers of James Clerk Maxwell*. 2 vols. Ed. W.D. Niven. Cambridge: Cambridge University Press. Repr. New York: Dover, 1965, pp. 646.

Because the various keys and stops in the vril staff give the Vril-ya selective power over storing and transferring energy, the nerve and staff modality also resembles Thomson's description of Maxwell's demon. Thomson claimed the demon could

> store up limited quantities of energy, and reproduce them at will… Let him take in a small store of energy by resisting the mutual approach of two compound molecules, letting them press as it were on his two hands, and store up energy as in a bent spring; then let him apply the two hands between the oxygen and the double hydrogen constituents of a compound molecule of vapour of water, and tear them asunder. He may repeat this process until a considerable proportion of the whole number of compound molecules in a given quantity of vapour of water, given in a fixed closed vessel, are separated into oxygen and hydrogen […].[608]

By selectively resisting, arranging, and articulating with his hands, the demon could split water without adding work to a system. As Maxwell explained in his *Encyclopedia* entry, dissipation is meaningless in the context of such skills because the hierarchy of progressive, irreversible energy transfers breaks down. The demonic Vril-ya thus have no regard for a sun, let alone a sun with an expiration date.

Several other North British energy assumptions collapse in the wake of the Vril-ya's negentropic, sunless world. First, Thomson worked his solar dissipation calculations against naturalists' assertion that it was growing harder to distinguish a difference between living creatures and inert matter. Based on the vortex theory and the teleology of dissipation, he argued, life never could have originated from matter, itself. In *The Coming Race*, Zee troubles this distinction, chastising the narrator for his mind-matter dualism. "But when you talk of matter as something in itself inert and motionless," she rebukes, "your parents or tutors surely cannot have left you so ignorant as not to know that no

[608] Thomson, "The Sorting Demon of Maxwell," 138-140.

form of matter is motionless and inert".[609] The vortex theory safeguarded matter from notions of internal material agency because the creation and destruction of vortices required agency from without. Moreover, any deterministic knowledge of matter on an elemental level required what Thomson called an "infinite mind." But Zee insists that she can assess and manipulate matter and energy, regardless of how inert it appears. Gesturing towards a heap of metal, she explains, "It is animated for the time being by the soul thus infused into it, so that one may almost say that it lives and reasons."[610]

By such power, the Vril-ya also create and compel automata. Riskin explains that automata are key figures in the Protestant Reformation's conversion of how people viewed the distinction between matter and spirit. Protestant reformers removed the Catholic church's automata because they seemed "inspirited," both mechanical and divine.[611] Scottish Presbyterian energy scientists, whose traditions stem from the Protestant split, used the vortex theory to structure energy from the ground up and thus validate their belief in mind-matter dualism. The Vril-ya's automata arouse a similar sense of suspicion in the narrator, who claims that "they actually seem gifted with reason." He has trouble distinguishing humans and automata as he watches from a distance, and the experience unsettles him.[612] Moreover, because he cannot command vril, the narrator has no control over automata. When he is trapped in his room with automata guarding the doorways, they possess more agency over his mobility in the

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[609] Bulwer-Lytton, *The Coming Race*, 93-94.
[610] Bulwer-Lytton, 94.
[611] Riskin, *The Restless Clock*, 22-23.
[612] Bulwer-Lytton, 111.

subterranean world than he does, though they are not, strictly speaking, alive.[613] Because all of the Vril-ya's transportation infrastructures depend on non-living, but "inspirited," matter, the narrator is forced to consider whether the distinction between living, reasoning creatures and inert objects holds in such a world.

The Vril-ya dismantle a second North British assumption, that all life will terminate with the heat death of the sun. Because the Vril-ya rely on neither the sun nor on an irreversible cosmos, they stand to inherit the earth not only via natural selection but also because they can easily terraform barren, sunless regions. Indeed, the narrator's hosts forbid him from disclosing the details of his origins in order to prevent their people from surfacing and exterminating all the lesser races of the earth.[614] Whether the narrator should be destroyed by vril remains an open question. He eventually returns to his own civilization only through the sympathy and negentropic powers of Zee, who rends open the mine's chasm with her vril staff. The narrator records his experiences to warn his fellow men of the inevitable doom of the coming race, the subterranean humans with "powers surpassing our most disciplined modes of force."[615] Thus, the apocalyptic threat of the Vril-ya surfacing supplants any foretold dissipation of the sun. On the earth, and under it, the Vril-ya and their mastery of the conservation law overpower the threat of dissipation. If the upperworld accepted the inevitability of a heat death apocalypse, they now need to assimilate a new narrative.

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[613] Bulwer-Lytton, *The Coming Race*, 160.
[614] Bulwer-Lytton, 53.
[615] Bulwer-Lytton, 168.

For all their demonic cleverness and negentropic powers, Bulwer-Lytton's Vril-ya do not represent the ideal society. The lopsided energy doctrine of the underworld adds to a collection of ironic cultural inversions, including women's physical power and intellectual autonomy over men, and the Vril-ya's veneration of a giant frog[616] as their original common ancestor. Bulwer-Lytton's pro-imperial attitude also motivated him to divest the Vril-ya of ambition. He told his editor that "the realization of these ideas would produce a society which we should find extremely dull, and in which the current equality would prohibit all greatness."[617] The resulting society is not a utopia in earnest, but rather a satire. Therefore, we should consider the representation of energy in this novel as equally tongue-in-cheek. This is unsurprising; in fact, critics have characterized *The Coming Race* as specifically sympathetic to the North British energy agenda.[618]

The Coming Race was published in the midst of a tug-of-war between North British scientists and X-Club naturalists for control of the dominant energy narrative. Bulwer-Lytton's novel is unapologetically conservative in its ironic treatment of contemporary debates, and it likewise remains sympathetic to the conservative energy doctrine of Thomson, Maxwell, Tait, and their colleagues. Though the text does not explicitly reference entropy politics, as it does phrenology, evolution, mesmerism, and other controversial sciences, the Vril-ya's negentropic control of dissipation would have

[616] The Vril-ya treasure their evolutionary origins, which trace back to a giant frog great-grandfather, "at once a sage and a hero." Bulwer Lytton, 96. Because the giant frog is hermaphroditic, scholars have suggested that the Vril-ya's pedigree explains the displacement of sexual characteristics that the narrator finds so disturbing, such as the diminutive stature and strength of Vril-ya men relative to Vril-ya women. Justin Prystash, "Feminism and Speculative Fiction in the Fin de Siècle," *Science Fiction Studies* 41.2 (July 2014), 344.

[617] Bulwer-Lytton, *Appendix A to The Coming Race*, 171.

[618] Clarke, *Energy Forms*, 48.

been considered an example of Thomson's "abstract" dynamics. The Vril-ya combine their unique physiology and their knowledge of conservation principles to particularize and control energy. This resembles Tyndall's interlinking of evolution and the first law of thermodynamics as an attempt to discredit evidence for irreversible cosmic dissipation. *The Coming Race* is therefore a satire of the fantasy of finding negentropic loopholes in the second law of thermodynamics.

CONCLUSION

Even before Clausius coined "entropy" in 1865, the public had long been introduced to the cosmic heat death hypothesis. William Thomson and his Scottish colleagues began popularizing their calculations for solar dissipation in the 1850s, and they doubled down on those efforts after Darwin published *On the Origin of Species* in 1859. Although the North British thermodynamicists generally maintained control of the dominant energy narrative, their interpretation of the second law was not universally adopted by scientists. In particular, German physicists and members of the secular X-Club resisted the theological overtones of the cosmic heat death hypothesis. Between the 1850s and the end of the century, they competed with the North British cohort to control the direction of energy science both in the public imagination and in the larger scientific community. Smith has shown that controlling the scientific prestige economy was a motivating factor, especially among Scottish universities whose players were eager to make room for their interests on the international stage.[619] But, more broadly, the

[619] Smith, *The Science of Energy*, 3.

specifically industrial North British concerns inspired an interpretation of the dissipation law that supported resource extraction as an extension of Presbyterian ethics.

This chapter has situated the entropy debates within related competing interpretations of deep time, like evolution, and has examined the stakes of producing a universalizing scaffold of energy's narrative, starting with the very structure of ether and matter. Structuring energy from the bottom up was a tactic deployed by North British scientists to secure their worldview and dismantle the opposing scientific naturalism of their adversaries, who wanted to break up Scottish dominance over the relatively new field of thermodynamics.

The secular response to North British energy control was launched by John Tyndall, who used the first law of thermodynamics to support natural selection and cast doubt on a dissipative, irreversible cosmos. Tyndall's logic combined particle determinism and conservative dynamics to dispel scientific evidence for a divine Engineer, and to suggest the possibility that life could have arisen out of matter's intrinsic organizational properties. In response, the North British cohort dispatched a series of speculative but effective tactics, including the vortex theory and Maxwell's demon. The vortex theory smeared ether and matter into a universal continuum of vibrations, making particle determinism and conservative dynamics impossible for all but an "infinite mind." Similarly, Thomson's interpretation of Maxwell's demon was designed to foreclose the possibility of conservation-based loopholes in the second law of thermodynamics. The demon belonged to a world of "abstract" dynamics. Humans, however, lived in a reality of "physical" dynamics.

Edward Bulwer-Lytton's *The Coming Race* satirizes this question of the nature and limitations of the second law by empowering the Vril-ya with demon-like negentropic skills. The Vril-ya apply the conservation and unity of energy to direct vril with, to use Maxwell's term, their "neat-fingered" combination of wrist and mechanical staff. By doing so, they terraform a barren, sunless, subterranean wasteland into a booming civilization. Because the Vril-ya do not draw energy from the sun, its expiration date means nothing to them. For this race, there is no time crunch to use fuel stores wisely before they decay, and to direct energy transfers for the benefit of industrious nations. The Vril-ya resemble Maxwell's demon, but they also reflect the energetic racism directed at colonial laborers who were cast as abundantly energetic, and thus capable of greater work yields. Dissipation is not part of Vril-ya reality, and therefore the ultimate threat to humans on earth is not the heat death of the sun, but rather the eventual surfacing of this coming race and their extermination of all human life above ground. Because *The Coming Race* maintains a conservative slant and presents an apparently terrifying society of lopsided nineteenth-century conventions, the energy politics in this novel are equally ironized.

We no longer study the ether or the vortex theory, but the consequences of entropy politics linger in our attitudes about how fuel should be managed and directed. Controlling the dissipation narrative from the ether to energy's critical infrastructures was crucial for the Scottish cohort because they cherished a pro-industrial hierarchy of energy's flow, from the sun down to all the industrial structures that transformed fossil fuels into mechanical work. Energy was not meant to be distributed in unlimited amounts. Instead, successful nations made the most of God's gift of natural energy stores by designing productive machines, expanding their control of resources and labor, and vetting the access of energy to prevent unnecessary waste. This pro-industrial logic has impacted our attitude towards energy infrastructures because it inscribed an ethics of energy management into the laws of thermodynamics. If the universe operated based on unequivocally irreversible and hierarchical energy transformations, the North Britishers reasoned, there was an ethical imperative to produce as much as we can with as little waste as possible. As such, we have applied this gospel to human and nonhuman bodies, the earth, and an economic commitment to endless growth. The coda of this dissertation expands some of these ideas, exploring how nineteenth century energy science can interrogate the social and critical infrastructures of energy in the twenty-first century.

Coda: A Legacy of Victorian Energy

> **Chris Wallace:** Do you believe that – that human pollution, gas, greenhouse gas emissions contributes to the global warming of this planet?
> **Donald Trump:** I think a lot of things do, but I think to an extent, yes. I think to an extent, yes. […]
> **Wallace:** But sir, if you believe in the science of climate change, why have you rolled back the Obama Clean Power Plan, which limited carbon emissions in power plants? Why have you relaxed –
> **Trump:** Because it was driving energy prices through the sky.
> - Transcript of first presidential debate between Joe Biden and Donald Trump, September 29, 2020[620]

Although many party conservatives outright deny anthropogenic climate change, brushing off scientific evidence as political fluff that left-wing legislators use to push their bills through congress, Donald Trump took a different stand during his first presidential debate against Joe Biden. When debate moderator Chris Wallace asked whether Trump believed that human action contributed to the warming of our planet, he admitted that, at least to an extent, he did. Trump didn't deny the science of climate change, he simply granted that he would rather take the climate crisis as it was than sacrifice economic growth to an energy transition. He rolled back the Obama era programs because, as he perceived it, they were "driving energy prices through the sky."

The fossil fuel giants and their investors have worked hard to manufacture public doubt in climate science for decades now.[621] Trump's approach, however, is far more

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[620] "Read the full transcript from the first presidential debate between Joe Biden and Donald Trump," USA Today, last modified October 4, 2020, usatoday.com/story/news/politics/elections/2020/09/30/presidential-debate-read-full-transcript-first-debate/3587462001/.

[621] For more on how a cohort of scientists manufactured a narrative of climate change denial, see Naomi Oreskes' and Erik M. Conway's excellent book, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*.

Victorian: if the earth is on its way out, then we have a duty to extract as much as possible in the meantime. Of course, Trump's rhetoric lacks the heavy-handed theological determinism of the North British scientists, but the logic remains more or less intact. It would be wasteful to invest in an entirely new energy regime, with new infrastructures and economies, when fossil fuels remain a fairly cheap source of energy, and when we already have the infrastructures in place to use them. An energy transition would be wasteful, especially if climate change is already in motion. This certainly resembles Victorian energy logic: we have inevitable cosmic decay, a moral and economic responsibility to manage the earth's energy stores, and – of course – a yoking of energy and capital. The problem is that, now, the death of the universe has come for us as climate change, we do know how to mitigate or even reverse its consequences, but the energy narrative we have followed consistently fails to redress the patterns of social and environmental violence reinforced by our infrastructures.

In this dissertation, I have covered the emergence of energy as a scientific concept during key points of infrastructural development in the Victorian period. We have seen that literatures, science, and infrastructures modeled how we envision energy and its distribution, and that generated an energy regime where infrastructures enforce hierarchies of inequality, fossil fuel extraction, and the pursuit of boundless economic expansion. Here, I conclude with a couple of examples that extend this argument into the twenty-first century, where we face radical planetary changes and lingering structural inequalities that late capitalist energy policies are unequipped to handle. As with Trump's argument, it seems that common objections to drastic energy and economic transitions center the *cost* of sustainable energy production, the question of how unsettling our existing production of fossil fuel energy would disrupt the economy, displace jobs, and hurt us all. What is unvoiced here is that the narratives of endless extraction and economic growth depend on systems that treat humans and the natural world as potential energy, as profit, and that rely on centuries of settler colonial expropriation. The Victorian concept of energy cemented these structures by providing a scientific basis for enforcing them. If people, land, and other natural resources could be reduced to interchangeable and standardizable units of labor, then the entire imperial project of globalizing capitalism seemed scientifically supported. This framework has demonstrated that productivity and efficiency objectives do not intend to reduce consumption, but rather motivate further accumulation with less waste. In what follows I gloss two contemporary examples:[622] agribusiness supply chains and environmental remediation in primarily Black neighborhoods in the United States.

Energy science has built acts of translation into its infrastructures. As we have seen, scalability can sometimes mask the violence of settler capitalist agriculture. In chapter three, we learned that the process of codifying electromagnetic field theory involved hammering Faraday's heterodox ideas into conventional scientific form. Standardizing materials based on field theory's developments in telegraphy then led to Britain's reliance on translations of value from Malayan supply chains and Indigenous ecological knowledge. In this example, the British could not bypass the architectures that resisted

[622] The examples I gloss in this coda are brief and merely scratch the surface of how Victorian energy logic lingers by interpellating the earth and its life into work-available, potential energy apparatuses. My intent here is to suture the gap between the nineteenth century and just a few of the infrastructures we rely on today.

globalizing capitalism's capture of human and other-than-human resources because the gutta percha trade failed settler agriculture. However, this is not always the case. Today, global capitalism continues to rely on what Tsing calls the "seams" or "unruly edges" of supply chains to capture and translate value.[623]

We can find imperial machines of translation and capture at work in the infrastructures of agribusiness, where giant corporations raze forests and evict Indigenous peoples from their land to feed supply chains that carry genetically modified crops all over the world. In his study of industrial agriculture in Argentina, Gastón Gordillo theorizes these logistical infrastructures as an extension of the "metropolis," an assemblage connecting urban centers to "zones of imperial extraction," or parts of the earth with rich energy resources.[624] Soybeans, for instance, are grown in South America and then shuttled all over the world, not primarily to feed humans, but to fulfill the demands of factory farming. As Gordillo points out, industrial agriculture is a source of global warming because it causes deforestation, it relies on pesticides that disrupt ecosystems, and it supports industrial farming, which produces more greenhouse gases.[625]

These infrastructures are Victorian because they reduce humans, other-than-human life, and the planet to profit centers based on energy output. Plant life becomes a single, standardized seed one can manage with pesticides and genetic engineering. The model scales easily to maximize profits, so small towns and forests quickly become agribusiness fields and logistical centers. These shifts interrupt the life and agricultural

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[623] Anna Tsing, "Unruly Edges: Mushrooms as Companion Species," *Environmental Humanities* 1 (2012): 151-52. www.environmentalhumanities.org.
[624] Gordillo, "The Metropolis," 83.
[625] Gordillo, 71.

patterns of, in this case, residents and campesinos of Las Lajitas.[626] Much of the deforestation, expropriation, and ecosystem violence of agribusiness supply chains occur in the global South, from which energy-rich resources are funneled to urban spaces and more affluent nations. Thomsonian values linger in these zones of imperial extraction. This is where huge corporations and logistical companies direct what Thomson would have considered the mindful transformations of energy that increase national wealth and prevent resources from dissipating away on their own, if left untouched. Of course, this broadens the wealth gap and leaves a wake of unequal planetary destruction across the globe, where industrializing countries are expected to shoulder the brunt of climate devastation, even as they contribute the least to climbing greenhouse gas emissions.

In this case, if industrial agriculture shifted to net zero emissions operations, the systems of violence that assist global wealth transfers and geographical damage would remain intact. This is not a matter of replacing the bare bones of our infrastructures with clean energy sources. We must dig deeper to root out, as Rob Nixon calls it, the "slow violence"[627] of our energy philosophy, and the attritional damage of the socio-material infrastructures set in place based on that philosophy. When large corporations attempt environmental remediation without considering how efforts to undo damage might also injure what a community values about memory and geography, then they commit acts of cultural erasure. This is why we cannot write off infrastructure as mere material, as only

[626] Gordillo explains that, after the soybean boom around 2003, Agribusiness devastated the village of Las Lajitas, its social and ecological geography, and its rural workers who farmed and raised cattle. "The Metropolis," 67-68.
[627] Nixon, *Slow Violence and the Environmentalism of the Poor*, 2-3.

pipes, bridges, roads, and waterways. Infrastructure, like place, carries with it an aesthetic and cultural value.

Infrastructures continue to intersect with and reproduce racist hierarchies and socioeconomic inequalities, even as restitution efforts have attempted to undo environmental damage. The predominantly Black communities in Anniston, Alabama, for example, are still dealing with the consequences of long-term polychlorinated biphenyls (PCBs) pollution from the Monsanto industrial chemical factory that dumped PCBs in or near their neighborhoods. The factory operated between 1935 and 1997, exposing West Anniston residents to decades of dangerous pollutants during and after Jim Crow era segregation, which restricted Black populations from settling in safer neighborhoods.[628] This combination of racist legislation and categorizing of Black neighborhoods as waste zones guaranteed that marginalized populations would shoulder the heaviest toxic loads.

Here, we see Black bodies produced alongside PCBs and designated dump sites in the "waste" category of Monsanto's day-to-day operations. In chapter two, we observed how the Victorians insisted that the metabolic health of the social organism depends on growth, and that waste is a necessary byproduct of growth. As long as the organism has access to resources for accumulation and expansion, it should not worry about producing waste; it just needs to find a secure "away" place to store that waste. The residents of West Anniston functioned as the "away" place for the growing Monsanto organism in the twentieth century. In the twenty-first century, Monsanto began destroying its old properties in Anniston, buying neighborhoods, displacing communities, and remunerating

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[628] Melanie Barron, "Remediating a Sense of Place: Memory and Environmental Justice in Anniston, Alabama." *Southeastern Geographer* 57, no. 1 (2017), 63.

its damages with individual payouts to residents. But Anniston's sense of community remained damaged. As Melanie Barron points out, "[s]cientific environmental remediation is not designed to reconcile this memory with the present state of the city; it has a very specific mandate to achieve acceptable levels of pollution risk for the soil, water, and air."[629] Nothing is done about the cultural erasure, a violence that continues to reproduce structural racism even as the environmental conditions improve.

Scientific environmental remediation and other infrastructures of damage control are not equipped to restore the holistic health of vulnerable communities because they continue a tradition of machinic flattening, of reducing the environment and its humans to energy, and of reducing energy to capital. Energy, we know, is *not* capital; yet Victorian energy logic tells us that all material forms are energy, and they are mutually fungible with capital. This logic assumes that the illness, environmental degradation, and structural racism of West Anniston neighborhoods can be reconciled with capital alone. Monsanto can fix the physical infrastructures, pay individuals, and assume that all debts are settled. But the injuries of a landscape, as George Eliot reminds us, run deep in the memory of a place. As such, environmental justice must include acts of memory work and storytelling, and acts of racially responsive community repair.[630]

This is why infrastructures are never simply "roads, bridges, ports, airports,"[631] to return to Shelley Moore Capito's misguided point from the Introduction of this dissertation. To call these forms the "traditional definition" of infrastructure underscores

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[629] Barron, "Remediating a Sense of Place," 64.
[630] Barron, 64.
[631] Sam Mintz, "republicans prepping."

the persistence of an energy concept we can trace back to the nineteenth century, when the emergence of thermodynamics built Presbyterian conservatism and industrial capitalism into the laws of physics. Although what energy has meant to us has indeed shifted over time, the vestiges of the Victorian energy concept remain lodged in our infrastructures, both physical and social. Now more than ever, radical change is needed to shift our infrastructures and energy forms into a new regime. I believe that this change is possible, but only if we understand the limitations of our current energy philosophies. We must understand that the energy concept is not timeless and unchangeable, but historically rooted and politically motivated.

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