CHILDREN OF THE SUN: THE ROLE OF INTELLECT IN THE RHETORIC OF BRITISH ENERGY PHYSICS

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I grieved to think how brief the dream of the human intellect had been. It had committed suicide. It had set itself steadfastly towards comfort and ease, balanced society with security and permanency as its watchword, it had attained its hopes- to come to this at last. Once, life and property must have reached almost absolute safety. The rich had been assured of his wealth and comfort, the toiler assured of his life and work. No doubt in that perfect world there had been no unemployed problem, no social question left unsolved. And a great quiet had followed.

-The Time Traveler

H.G Wells, The Time Machine
1895

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Introduction

In the final Chapter of H.G Well's *The Time Machine*, a time traveler finds himself transported to "futurity" and, quite by accident, becomes the lone human witness to the death of the Sun and the dissipation of its, by then, dull heat. At the mercy of his machine, he is carried further until all that remains on Earth's horizon is the husk of a dead star set against a "remote and awful twilight.". Observing the barren landscape that had been the birthplace of humanity, he laments to the reader that he " cannot convey the sense of abominable desolation that hung over the world."[1]

When I first read this passage I was struck by Well's fatalistic vision for what awaited the the Sun and the planet it had provided for. The Late-Victorian preoccupation with "Heat Death," inspired a kind of morbid fascination in me and eventually brought my attention to the history of Classical Thermodynamics, a pair of theories that seemed to contradict each other. The first law maintained that Energy was indestructible and infinitely transformable, whereas the second law seemed to be a portent for the sort of future imagined by Wells. That these theories had arrived in tandem, as a coherent system, and at more or less the same time, seemed utterly outlandish.

My research into the cultural history of British Energy Physics revealed a narrative far removed from the one I had expected, and for that matter, also turned out to be just one of a number of systems that emerged in the mid-19th century. While some reference to those theories that emerged in continental Europe cannot be avoided, the focus of this paper will be to explore the strain of Classical Thermodynamics that grew out of the unique religious and industrial contexts of Scotland during the first half of the 19th century. This system was the product of an

[1] H.G Wells, *The Time Machine* (New York: Barnes & Noble Classics, 2003), 73-77

informal network of scientists and engineers whom Crosbie Smith has dubbed the “North British Group.”[2] These physicists and engineers codified a set of preexisting beliefs founded upon a revised Natural Theology with Presbyterian leanings, and the convictions of industrialists who had begun to see the steam-engine as an industrial-come-social power completely subordinate to the intellect of man.

The Sun was finally employed as a potent rhetorical device for purveyors of science attempting to popularize Thermodynamics just past the mid-century mark. This project was undertaken at a time when the line between ‘professional’ and ‘amateur’ scientist had yet to be drawn. A communications revolution, enabled by new steam-powered printing technologies, and an upsurge in the publication of “popular” science periodicals, contributed to a climate that was already ripe for contest and controversy. The narrative championed by the North British Group in defense of its particular brand of Thermodynamics mobilized the analogy of an anthropomorphized, spendthrift Sun, re-framing a near infinite cosmic time-line into a human-scale story with teleology and moral implications. If the runaway success of the steam-engine in the 1830’s and 40’s had hinted at the potential for achieving the “dream of cosmic intellect”, the codification of those laws into a universal system validated those hopes, promising an auspicious future for humanity.

Before delving into the social and industrial context of British Energy Physics, I will provide a brief introduction to Classical Thermodynamics and the development of the steam-engine. Part I of this thesis will explore the role of a Presbyterian interpretations of Nature and the adoption of steam-engines as the industrial power of choice by the 1840s. Part II will

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[2] Crosbie Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain (Chicago: University of Chicago Press,1998), 3.*

endeavor to explain how these beliefs were codified into laws and thereby given the authority of empirical science. The final chapters will discuss its popularization and the implications of that process, specifically its rhetorical transformation into a parable for man's intellectual dominion over the Sun.

A Brief Introduction to Classical Thermodynamics

As its Latinate roots suggest, the science of Thermodynamics is concerned with the movement of heat as a form of energy. The first law, commonly referred to as the Conservation of Energy, states that Energy, like matter, can be transformed but never destroyed. According to the second law, while energy cannot be destroyed, it will inevitably be diffused throughout the universe and result in a unified temperature throughout. In simpler terms, Energy can be transformed but never entirely destroyed, however, some energy can be changed into forms that are useless to man.

While this description of the laws is technically accurate, the terms used and the consequences implied already reflect just one particular narrative among many others presented by Physicists and Historians since the laws of Thermodynamic were first articulated in the 19^{th} century. The history of Thermodynamics is notoriously difficult to pin down. Depending on whether you use the term 'Force' or 'Energy,' or look for its transformation in the human body or the cosmos at large, each option will lead you to a distinct understanding in a particular historical context. Because the explanation offered above uses the term "Energy" it can be identified as the intellectual property of physicists in North Britain at mid-century as opposed to the conservation of "Force" articulated by Herman Von Helmholtz in Prussia. The differences between the two were not however simply semantic. Physicists working in the northern region of Britain did so within a particular framework of religious and industrial priorities while Helmholtz was concerned more with the physiological implications of the transformation of "Force."

Before elaborating more on how these independent iterations of Thermodynamics came to be at odds with each other, it is first necessary to point out similar points of departure. There were two widely held theories concerning forces in the natural world that predate the science of Energy and that are particularly relevant to this paper. The first was a contribution by Enlightenment thinkers who largely viewed the world as being made up of forces acting at a distance. In keeping with Classical Mechanics, these forces were not limited to any type of directionality. Newton's laws of motion were imagined in hypothetical, ideal frameworks in which objects moved with uniform motion along a straight line, making direction more or less irrelevant. In effect, lack of directionality came to mean that actions were reversible with all of Nature operating to maintain an equilibrium. The second theory concerned an understanding of "heat" greatly removed from the modern sense of the term. Physicists had yet to adopt the notion of heat as particles of matter moving in relation to one another, subscribing instead to the idea of heat as a substance in its own right. Known as "caloric," this substance behaved with the characteristic of a fluid and its volume in any given object or body determined its temperature. It was as ubiquitous in the natural world as it was, somewhat conveniently, unobservable to the human eye.

It was within this theoretical tradition that Sadi Carnot would contribute to and in some ways even anticipate the Conservation of Energy. Of the many narratives that represent the history of Classical Thermodynamics, almost all give a fair amount of credit to Carnot for prompting a shift towards thinking of energy in a theoretical rather than purely practical frame work, contemplating the characteristics of an ideal engine as opposed to focusing on individual machines in the real world.

In *Reflections on the Motive Power of Fire,* published in 1824, Carnot examined the limits of the steam engine and how much "work" could be obtained from an ideal engine. He concluded that the motive power of steam was generated by the movement of caloric from a body at a high temperature to one at a lower temperature. Considering the dominant source of motive power in industry at the time was not the steam-engine but rather the water wheel it is understandable that Carnot would draw a parallel between steam engines and water mills. Another important implication of this theory was the suggestion of a set temperature scale in which heat could fall but not retrace its path anymore than water could work its way back up stream. This would be a precursor to the scale, and namesake, of Lord Kelvin, also known as, William Thomson. Though caloric still had a prominent part to play in his theory, Carnot's argument for a unidirectional flow challenged assumptions typically made accordance with Classical Mechanics. More importantly, Carnot had offered a compelling theory for explaining the theory behind functioning of steam-engines.

The science of thermodynamics was in many ways a theoretical answer to practical engineering questions that had followed the steam-engine through nearly a century of tinkering and innovation. In 1698, Thomas Savery patented the "Miners Friend," a steam engine used to pump water out of mines which was followed in 1712 by the better known Newcomen Engine. Subsequently James Watt would patent a condenser that increased the steam-engines efficiency significantly. Of even greater importance was his next creation, an engine capable of rotary motion. Up to this point the steam-engine could only provide for lateral movement, for instance, carrying water from the pit of a mine to the surface. An engine capable of rotary motion could turn a wheel and as such resulted in the creation of "automated looms" and "power-looms" which would play a pivotal role in an increasingly important textile industry in Britain. Despite these many innovations, a formal theory was not clearly articulated until the middle of the 19th century. Carnot made an important contribution in this regard but from there the narratives diverge.

The eminent Thomas Kuhn asserted in his 1959 paper that the "History of science offers no more striking instance of the phenomenon known as simultaneous discovery," than the hypothesis of the Conservation of Energy."[3] He argued that within the span of just a few years, from 1842 to 1847, four scattered European scientists working mostly in ignorance of each other, publicly announced the same hypothesis.[4] Kuhn, however, does caution against taking the phrase "simultaneous discovery" *prima facie*, explaining that despite their similarities "Until close to the end of the period of discovery, few of their papers [had] more than fragmentary resemblances…"[5] The more nuanced interpretation, he suggests, is that all of the necessary elements and components that would be synthesized as the hypothesis of the Conservation of Energy rapidly emerged at the same time. With all due deference to Thomas Kuhn, presenting the science of energy as an inevitable discovery, like low hanging fruit waiting to be picked off the proverbial tree of Science, does injustice to a much more complex and interesting story.

While it is true that William Thomson began defining a program for a science of Energy at mid-century, as Rudolf Clausius was defining the similar law miles away in Prussia, Crosbie Smith argues that "…the logical and linguistic similarities should not be allowed to mask the striking conceptual differences between Clausius" and what Smith refers to as his "North British

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[3] Thomas S. Kuhn, "Energy Conservation as an Example of Simultaneous Discovery," in *Critical Problems in the History of Science,* ed. Marshall Clagett (Madison, Wisconsin: The University of Wisconsin Press, 1959), 322.
[4] Ibid.
[5] Ibid

contemporaries."[6] Energy Physics was ultimately a British construct operating within a framework of industry and the religious concerns of Presbyterian physicists. Before elaborating on the how rival claims to the Conservation of Energy impacted the history of British Energy Physics and its scientific authority, time must be devoted to exploring this unique partnership between faith and industry.

[6] Crosbie Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain (Chicago: University of Chicago Press,1998), 169.*

Part I: Faith and Industry

Scottish Presbyterianism

Were you to visit England at the turn of the 19th century and ask a Natural Philosopher for his take on the state of Nature, his response would more than likely reflect the beliefs of William Paley, the Anglican Archdeacon of Carlisle. This predominantly liberal and Anglican view, known as Natural Theology, functioned as a common intellectual context throughout the first decades of the century.[7] As such, it bares mentioning in any discussion related to the influence of religion in the development British Energy Physics.

Nature, as it was envisioned in Paley's *Natural Theology,* could be interpreted in two fundamental ways. Foremost, Nature was seen as the beautiful and complex design of a benevolent God who could be best understood through the study of his creation. Contrary to what many modern readers may assume about a history of antagonism between science and religion, the study of the mechanical operations of nature was, at the time, not only condoned but even encouraged.

> *The works of nature want only to be contemplated. When contemplated, they have everything in them which can astonish by their greatness; for, of the vast scale of operation through which our discoveries carry us, at one end we see an intelligent Power…one mind has planned, or at least has prescribed a general plan for all these productions. One Being has been concerned in all.*[8]

Additionally, natural creation was considered to be in a state of perennial equilibrium and, as such, in agreement with the tenets of Classical Mechanics. Harmony and happiness in the natural order were considered a testament to the goodness of the Almighty.

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7 Robert Young, *Darwin's metaphor: nature's place in Victorian Culture (Cambridge University Press, 1985), 127.*
8 William Paley, *Natural Theology,* ed. Charles Bell, Vol. 2 (London: Charles Knight, 1836) 174-175.

In his introduction to *Natural Theology,* Paley describes a hypothetical scenario in which a passerby discovers a large stone along a path without coming to any remarkable conclusions. The traveler dismisses the object without any special regard or interest. Paley proposes that, if in the place of a stone, the traveler had encountered a watch he would have assumed a creative agent to be responsible for its existence. From this point he develops his argument for Intelligent Design.

Just a few decades later, while the argument for intelligent design put forward in *Natural Theology* retained its preeminence, a novel interpretation of Nature would begin to challenge the assumption of equilibrium. In the 1836 edition of *Natural Theology*, a foot note contributed by editor Charles Bell offers a correction to Paley's static representation of nature and what assumptions might be made by the typical observer.

> *A considerable change has taken place of late years in the knowledge attained even by common readers, and there are few who would be without reflection "How the stone came to be there." The changes which the earth's surface has undergone, and the preparation for its present condition, have become a subject of high interest; and there is hardly any one who now would, for an instant, believe that the stone was formed where it lay.*[9]

This reflects the development of a number of contemporary theories calling for a more dynamic interpretation of Nature, among them Uniformitarianism[10] and the Nebular Hypothesis[11]. These theories challenged traditional notions of balance, leaving Paley's traveler to confront evidence

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[9] William Paley, *Natural Theology,* ed. Charles Bell, Vol. 1 (London: Charles Knight, 1836), 1.
[10] Theory that phenomena observed in present day rock formations were the key to understanding an earth formed through processes that were ongoing. Put forward first by James Hutton and developed by Charles Lyell and William Whewell, all Scottish Natural Philosophers.
[11] Theory positing the formation of the solar system over time from a primitive solar atmosphere. Suggested first by Kant and developed and elaborated upon by Pierre Laplace.

put forward by geologists that, in the natural world, "nothing is as it was, nothing as it will be".[12] The dominant paradigm that would develop thereafter would be one of *progress*. While these theories and a few others, such as the theory of evolution, upset a certain status quo and became points of contention in the Victorian Era, there was still room for a unidirectional vision of Nature even among its critics.

Just one year after William Whewell introduced the term "Scientist," Thomas Chalmers published his contribution to the *Bridgewater Treatises* with the intent of updating Paley's Natural Theology to incorporate the concept of decay and linear time. Traditionally, Christian Cosmology held that the heavens would one day "vanish away like smoke" while the earth would wear out and "wax old like a garment."[13] It was this belief that would be reintroduced into the scientific understanding of time. Apart from emphasizing a unidirectional progression in Nature, this iteration would add a degree of urgency and imminent finality. The influence of this perspective can be seen clearly enough in the works of William Thomson elucidating the diffusion of Energy when he states, "it may be demonstrated that work is lost to man irrecoverably…Although no destruction of energy can take place in the material world without an act of power possessed only by the supreme ruler, yet transformations take place."[14] Again, it is critical to note that while there is a transformation of energy, no true destruction is possible. Only from the reference point of man is there an irrecoverable loss.

Even as Chalmers revised the work of Paley, he did so without disregarding Natural Theology as a means for attaining an elementary understanding of the divine. Despite Paley's Anglican loyalties, his Natural Theology proved convenient for its ability to serve as what

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[12] "The Indestructability of Force," *Macmillan's magazine,* August 1862, 337.
[13] Isa. 51: 6 KJ
[14] Crosbie Smith, *The Science of Energy: A Cultural History of Energy Physics in Victorian Britain (Chicago: University of Chicago Press,1998), 110.*

Robert Young calls a "common intellectual context."[15] Chalmers was accordingly able to build off of the intellectual foundations of Paley while neatly incorporating an emphasis on a biblical time frame, the Calvinist notion of fallen man, and the need for individual redemption.[16]

This resonated with the concept of the Presbyterian notion 'divine gifts,' a view that extended beyond Grace to the endowment of Reason and even to Natural Resources. In Chalmers' estimation, as human beings operating with the benefit of freewill, individuals could choose whether or not to invest these gifts or sit idly by as someone else did in their stead; to do so would mean giving up one's chance at redemption. Any wealth that accumulated as a result could then be invested for the benefit of humanity -through commerce, industry, family, the church, and finally the poor (in that order) according to natural law.[17]It was the obligation of any good Presbyterian to make use of "divinely filled storehouses"[18] not despite but rather because they were subject to limitation. In a world given to decay, efficiency and economic management were paramount.

This proves particularly relevant to the context in which Chalmers put forth his revision of Paley's Natural Theology. Paley had written from within the centralized power of the Anglican Church and the intellectual sphere of Cambridge and Oxford, located far from the turbulent and rapidly industrializing North of Britain.[19] At the time of the publication of the Bridgewater Treatises, the Scottish Kirk was experiencing a mounting tension between proponents for a new "Free Kirk" and the "Old Moderate" Presbyterians.[20] The later still closely

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[15] Robert Young, *Darwin's metaphor: nature's place in Victorian Culture (Cambridge University Press, 1985), 127.*
[16] Crosbie Smith, 16.
[17] Ibid. 22
[18] Ibid.
[19] Ibid, 15.
[20] Chalmers himself would lead the "free kirk" when it parted ways with the Scottish Kirk in the Disruption of 1843.

identified with Enlightenment philosophy and the unrevised version of Paley's Natural Theology. Compounding the issue was an alliance between the old moderates and the intellectual elite.

The beginning of the 19th century saw a series of economic and political crises with the revival of Chartist movements, the Factory Acts, and the repeal of the Corn laws. This occurred in the wake of famine conditions plaguing the first years of the century with the failure of the potato crop, a devastating event even with aid sent from the south of Britain. Industrial centers experienced the growing pains of a rapidly increasing population and a proliferation of slums in the 1830's and 1840's, contributing to a sense of unease. For that matter, the intellectual core of Scotland, the Glasgow and Edinburgh Universities, were surrounded by some of the worst housing conditions in Europe.[21]

This fueled debates over patronage and privileges afforded to the "old moderates." In response to sectarian movements in the Church and fears of the potential in Scotland for an outbreak of revolutionary movements not unlike those threatening on the continent, a group of "New Moderates" lobbied for a reform movement that wouldn't require a departure from the Scottish Kirk. Natural Theology was again turned to as a force for finding common ground, not only between Anglican and Presbyterian interpretations of Nature, but also as a force for uniting the aims of the academic establishment with the demands of industry. The product was a strong commitment to Natural Theology and Natural Philosophy, with a liberally interpreted scripture supporting harmony between the two.[22]

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[21] T. C. Smout, *A century of the Scottish people, 1830-1950* (London: Collins, 1986), 23.
[22] Crosbie Smith, 27.

The Industry of Steam

In his 1827 Treatise on the steam-engine, John Faray attempted to give a detailed account of the history and mechanical operations of various steam-engines in Britain, arguing that "the history of the origin and progress of so important and useful an invention, [could not] fail to be an object of interest to every intelligent inquirer."[23] He offered particular praise while detailing the workings of Watt's rotative steam-engine, citing its invention as the catalyst for a rapid increase in manufacturing towns in the thirty years leading up to the publication of his treatise.[24] It would appear however that in this instance, Faray was putting the cart in front of the horse power. At the time of its publication, the viability of steam and coal as a motive power of industry was still being debated.

Traditional accounts of Britain's Industrial Revolution set its beginning near the inception of the proto-factory system established by Richard Arkwright at Cromford in 1772 with steam-engines arriving shortly thereafter, often depicted as a precocious and potent technology destined for exponential growth. Economic historian Nicholas Craft has observed, however, that the initial growth was much more gradual, with total growth in real output of commodities remaining below two percent until the 1820's. The only sector of industry to see substantial growth from 1770 to 1811 was Cotton, with the real output in the 1780's approaching an average growth of 12.76 percent per year, considerably more than iron or coal.[25]

The importance of the textile industry to both the Victorian Economy and the history of the steam-engine cannot be overstated. Much attention has been given to the role of steam in revolutionizing transportation technology, with steam ships and the spread of the rail road, and

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[23] John Farey, *A treatise on the steam engine: historical, practical, and descriptive,* 1st ed., vol. 1 (Longman, Rees, Orme, Brown and Green, 1827), Preface, Open Library.
[24] Ibid, 406.
[25] Nicholas Craft, *British Economic Growth during the Industrial Revolution* (Oxford, 1985), 47.

yet, the first industry to be transformed dramatically by the emergent factory system, and ultimately the steam-engine, was the textile industry. As far as it's importance to the Victorian Economy, it was the dominant industrial branch from 1820 to 1840. Not only did it accounted for the employment of 14 percent of the population of Great Britain by 1851, textiles also supplied 72 percent of the total value of British exports in 1830.[26]

The spectacular growth in the textile industry in the first two decades of the century was overwhelmingly facilitated by water-power as opposed to steam-engines, even as Faray was writing his treatise praising their technological superiority. Despite his claims that the growth of manufacturing towns in Britain was a direct result of the supremacy of the steam engine, 70 percent of mills at the end of the 18th century and beginning of the 19th were water-powered mills.[27] In fact, the primary source of power during the first phase of the Industrial Revolution was water.[28]

Britain proved to be well situated to take advantage of water power, with its consistent rate of annual rain fall and wealth of perennial streams. Though rivers in regions west of Europe, such as those in India and China, could make similar claims, rivers in Britain spared mill owners the negative affects of silt build up.[29] Rivers on the European Continent also came from high alpine sources that contributed to uneven flows and occasional flooding, both cardinal sins in the mind of a mill-owner. For these reasons, Terje Tvedt has noted in his study of global water systems and their historical context in industry that Britain was uniquely suited to take advantage

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[26] François Crouzet, *The Victorian Economy,* trans. Anthony Forster (New York: Columbia University Press, 1982), 190.
[27] Andreas Malm, *Fossil capital: the rise of steam power and the roots of global warming* (London: Verso, 2016), 79.
[28] Terje Tvedt, "Why England and not China and India? Water systems and the history of the Industrial Revolution," *Journal of Global History*, 2010, 29-50.
[29] Ibid.

of this form of industrial power. The lay out of the industrializing North of Britain was accordingly mapped out upon water courses and an increasingly intricate system of canals developed to facilitate industry.[30]

Water mill technology, despite having been prevalent in Britain for centuries was by no means stagnant. A number of improvements had been made in the second half of the 18th century and first decade of the 19th, many of which could be attributed to the work of Robert Thom. Thom designed a device known as the 'self-acting hydraulic apparatus" which served a similar function to the governor developed by Watt. For his contribution he was rewarded the Large Silver Medal from the Royal Society of Arts in 1821. The hydraulic apparatus automatically regulated the amount of water entering the mill without human intervention, ensuring that the input of power into water-powered looms remained constant and at ideal levels despite any irregularities in rivers. He was also the architect behind an impressive business venture on the River Irwell in 1831 that entailed the construction of a large collective reservoir. The project could support up to 300 water-powered mills, connected by a series of channels descending from a reservoir courtesy of a re-engineered landscape. He aimed to replicate a similar scheme put in place at Greenock known as Shaw's Water Works which had been lauded as a great success in hydraulic engineering.

And so, just before the moment of transition to steam-power in the 1830's, water-power was both reliable and scalable. Thom's venture on the Irwell river never came to fruition, not for any fault in his design, but because the project entailed the sharing of water, a resource which had been deemed *publici juris,* in other words, a natural right just like air or sunlight.[31] The

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[30] R. M. Hartwell, "Economic Change in England and Europe, 1780-1830," ed. C. W. Crawley, in *The New Cambridge Modern History* (Cambridge University Press, 1965), 31-59, March 2008.
[31] Thomas Tomlins, *The Law-Dictionary, Explaining the Rise, Progress, and Present State of the British Law,* 4th ed., vol.2 (London, 1835), s.v. "Water, and Water-Courses."

problem then was less to do with the industrial capabilities of water power, and more to do with its indivisibility under capitalist entrepreneurs.

Apart from the many advantages of utilizing water as a power source, many industrialists had also chosen water-power simply for its affordability over coal. Where water was a renewable and typically dependable resource, mill owners wishing to utilize steam powered machines in their factories had to invest large amounts of capital to compensate for the transportation and labor costs of acquiring coal. Attempting a cost analysis of various forms of prime movers for the New Encyclopedia in 1807, John Robison noted this disadvantage of steam.

> *Water is the most common power, and indeed the best, as being the most constant and equable…Mills may also be moved by the force of steam, as were the Albion-mills at London; but the expense of fuel must undoubtedly prevent this mode of constructing mills from ever becoming general.*[32]

Based on these and other findings, Andreas Malm has put forward the compelling argument that the transition from water power to steam power occurred in the 1830's, much later than previous estimates placing the shift in the late 18th century. He claims that the transition took place in spite of water being "abundant, cheaper, and at least as powerful, even and efficient,"[33] motivated instead by an entrenched sentiment of paranoia in the midst of social, political, and financial crises.

As a result of the veritable success of the cotton industry, investors had contributed more and more to a growing number of mills, soon outpacing the demand for product. The ironic bi-product of the success of a water powered cotton and textile industry was the bursting of an economic bubble in 1825 later termed the "First Structural Crisis of Industrial Capitalism".

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[32] John Robison, *Encyclopedia Perenthesis, The New Encyclopedia; Or, Universal Dictionary of Arts and Sciences,* vol.13 (London, 1807), 154.

[33] Andreas Malm, 93.

Exacerbating the impact of this event was a severe drought that occurred the following year. A moderate degree of recovery was managed in subsequent years until once again the market experienced the effects of the railroad bubble collapsing in 1836. The final blow would come in 1841 with one of the most devastating depressions of the 19th century.[34] These financial crises occurred in tandem with various social movements in response to the repeal of the Combination Laws, the Reform Crisis, and the emergence of Chartism. The chartist general strike in 1842 would bring Britain to the brink of revolution as its citizens watched similar events unfolding on the Continent.

The textile industry proved particularly vulnerable in this environment of stunted recovery and paranoia. As the majority of mills were dispersed across the countryside, spread along ideal river and stream-side plots, it had traditionally fallen to mill owners to provide incentives that would draw in laborers from nearby towns and farther afield. To accommodate an imported labor force, factory towns were constructed that provided housing and many other resources to workers, even elementary education for their children. To accomplish this, a considerable amount of capital was required, leaving the capitalist mill owner at the mercy of his workers especially as the number of mills continued to mushroom and contribute to competition for labor. Again the challenge proved to be a paucity of social leverage rather than an inadequate industrial technology.

In this respect, John Faray's claim that steam power was responsible for the growth of manufacturing towns in England and Scotland in the three decades leading up to the publication of his treatise was misleading but not without some foundation[35]. The majority of the mill

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[34] Ibid, 61.
[35] John Farey, *A treatise on the steam engine: historical, practical, and descriptive,* 1st ed., vol. 1 (Longman, Rees, Orme, Brown and Green, 1827), 406, Open Library.

industry was located in a more rural landscape along the path of disparate streams and rivers, however, the growth of industrial centers such as Glasgow and Manchester was centered around steam-powered mills. The main attraction of factories located in growing industrial cities was the advantage of a more abundant and therefor disposable workforce. By turning to coal and steam power, capitalists were moving the factory to the most convenient source of labor rather than relocating labor to the factory. Workers who did not meet the demands of the factory, or those who accepted the call to join the Chartist movement, could simply be fired and replaced without affecting the bottom line of mill owners.

The adoption of the steam-engine as the motive power of choice for the textile industry provided for a sense of security during a time of social, political, and economic upheaval. Coal was divisible and transportable, allowing for a relocation of mills to populated urban centers. The high cost of coal, while initially a mark against it, was found preferable to investing capital into factory towns vulnerable to vandalism in a climate of unrest and labor movements. Capitalists attained an autonomy that would not have been possible under a communal reservoir project and also escaped the mantle of caring for workers and workers' families in factory towns. Steam-power had proven its value above all as a form of social power adapted for use by any enterprising individual with capital to invest.

A Supernatural Motive Power

When one considers the initial reluctance of mill-owners to embrace steam-power and accept the high cost of coal, it is remarkable to observe the about-face that occurred in the next twenty years. Businessmen, Engineers, and amateur enthusiasts published treatises on the steam-engine and coal both, speaking with reverence about its complimentary technologies and the commerce they enabled. By mid-century, steam-power, and coal by extension, was being credited for the prosperity of the British Empire. It was praised for its remarkable capacity to annihilate both space and time, ostensibly spreading Civilization and Progress to the far reaches of the globe.

> *Without coal, no longer would our favored country be the great factory for supplying the necessities of the great family of mankind. Deprive us of our coal, and no longer should we, by our commerce, convey the conjoined benefits of knowledge and civilization to the remote regions of the globe… Without coal our steam-power would be annihilated, and with that, our prosperity as a nation, and possibly our supremacy.*[36]

In addition to textile mills, steam-engines powered the machinery involved in the fabrication of more steam-engine parts as they became increasingly standardized and mass-produced. In *The Philosophy of Manufactureres*, Andrew Ure expressed wonder at this dynamic, remarking that steam-engines seemed to "furnish the means not only of their support but of their multiplication," demonstrating the engine's ability to perpetuate its own growth.

Steam was celebrated for its versatility and even more so for its lack of agency. Other prime movers, namely wind and water-power, were described as having a degree of autonomy

[36] John Leifchild, *Our coal and our coal-pits; the people in them, and the scenes around them. By a traveler underground.* (London: Longman, Brown, Green, Longsmans, and Roberts, 1862), 12.

dictated by an anthropomorphized environment.[37] Extracting power from these natural sources entailed a battle of wits between human ingenuity and a fickle Nature. Steam on the other hand, was elevated to the realm of the supernatural.

Not only had steam demonstrated that it could afford a form of social control in the realm of labor relations, the resource itself was seen as infinitely malleable and subordinate to the intellect of engineers and industrialists, one of whom stated succinctly, "the power of steam is just what we choose to make it."[38] Andreas Malm has argued that steam was thus presented as "ontologically subservient," to man and as such, "valued for having no ways of its own, no external laws, no residual existence outside that brought forth by its owners."[39] After all, rather than simply wrestling the power of elements from Nature, humans had managed to turn an inert substance (coal) into dynamic power.

Adding to the mystique of the steam-engine, was its novelty as a form of industrial power, at least relative to the history of wind and water-powered machines. It was acknowledged that steam-engines had been preceded by designs for "pneumatic machines" as far back as ancient Egypt, however, the improvement of the steam-engine by Watt was celebrated as a triumph of the age, "wholly modern," having "never once…entered the minds of the ancient poets or sages."[40] A new, theoretical understanding of how heat could be transformed into motion, outlined by the laws of thermodynamics, added legitimacy to this perspective and contributed to the conviction that further innovations would be possible with ever greater payoffs in efficiency. Watt's steam engines, with their vastly improved efficiency and a potential for

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[37] Andreas Malm, *Fossil capital: the rise of steam power and the roots of global warming* (London: Verso, 2016).
[38] Nassau Senior, lecture, Oxford University, 1848, in *Senior Papers* (Aberystwyth: National library of Wales, 1848).
[39] Andreas Malm, 215.
[40] "The Discovery of the steam-engine," *Sharpe's London magazine,* May 29, 1847, 77.

rotative power, were in a category of their own, demoting the Miner's Friend to the status of a quaint precursor.

Summary

The steam-engine rose to prominence in the 1830's within the context of a singular dynamic between religious and industrial contexts, seeming to provide a convenient escape from a mounting number of challenges. As the economy experienced cycles of booms and bust, industrialists turned away from water and its well established advantages for another fuel that afforded more leverage in a climate of labor movements and unrest. Sectarian movements in the Scottish Kirk, divided by disagreements over exclusive privileges and modern scientific theories, reconciled with an updated, albeit Presbyterian, interpretation of Natural Theology. As the resources of Nature were reimagined as a form of divine investment in the elect, the aims of the Kirk and and a rapidly growing urban textile industry came into alignment. In the span of ten tumultuous years, the steam-engine transformed from a sub-par alternative to being the heir apparent and answer to all that ailed the society. Having proved its worth, all that remained was for British physicists to provide a coherent theory and explain the workings of an ideal steam-engine.

Part II: Codifying Beliefs

Developing A Theory

In an address to Section B of the British Association for the Advancement of Science in 1843, James Prescott Joule contested the caloric model of heat, wherein it was argued that heat was transferred from one body to another. Joule supported an alternative theory that this dynamic actually involved transformation taking place between the force expended and the mechanical actions produced. His explorations of the voltaic battery and heat generated through chemical processes inspired an inquiry into whether or not these forces were not only similar in nature but in actuality manifestations of the same type of transformation. He posited that if one were to "consider heat not as a substance, but as a state of vibration, there appears to be no reason why it should not be induced by an action of a simply mechanical character"[41] or in other words, there could be a mechanical equivalent to heat.

Joule did not arrive at this theory in isolation, having benefitted from the earlier works of Count Rumford, Humphrey Davy, Joseph Fourier, and others[42]. As mentioned earlier, Thomas Kuhn noted a similar calculation put forward by German Physicist Julius Mayer, however Joule laid claim to having "established" this equivalence by experiment.[43] It is useful in this instance to consider Crosbie Smith's suggestion that there was a certain significance to Joule's chosen terminology in his paper title. Smith argues that the term 'value' could easily be understood the economic sense of the word and not simply denoting a numerical quantity. This demonstrates

[41] James Prescott Joule, "On the calorific effects of magneto-electricity, and on the mechanical value of heat," *Philosophical Magazine,* July 1843.
[42] James Prescott Joule, "On the Mechanical Equivalent of Heat," *Philosophical Transactions,* January 1, 1850, 61-63, Royal Society Publishing.
[43] James Prescott Joule to William Thomson, March 17, 1851.

again that the theories arrived at by Joule and his contemporaries were not the result of careful abstraction, but were instead symptomatic of a unique industrial context in North Britain.[44]

> *He was therefore engaged in constructing a new theory of heat, not as an abstract and speculative set of doctrines, but as a means of understanding the principles which governed the operation and economy of electrical and heat engines of all kinds.*[45]

And so, regardless of who could can rightly claim the primacy of the theory of equivalence, the true innovation had been the calculation of a 'mechanical value of heat,' which quantified the amount of mechanical power lost or gained with a transformation of heat. Moreover, Joules version of the theory applied specifically to the use of steam-engines in Britain.

Remarkable as this contribution was, there were some contradictions that had yet to be addressed. Whether or not the transformation of heat to mechanical power was reversible had been left ambiguous. Carnot's theory had assumed a transference of heat from an object with a higher temperature to a lower temperature but made no definite claims as to whether or not the flow could not be reversed. Two other figures on the continent, Rudolph Clausius and Emile Clapeyron, had come to the contrary conclusion that there was no mutual convertibility between heat and mechanical power. It was this contradiction that was contemplated by William Thomson and Macquorn Rankine in the 1850's. Their answering system of laws forms what is now known as British Energy Physics, or, Classical Thermodynamics.

Though it has already been used liberally in this paper without the benefit of clarification, the history of the term "Energy" has its own part to play in our understanding of Victorian Thermodynamics. Thomson deployed the term in his 1849 paper 'An account of Carnot's theory

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[44] The peak of the German Industrial Revolution is typically set much later in the last quarter of the 19th century

[45] Crosbie Smith, 66.

of the motive power of heat' in a foot note. Though its first manifestation in scientific terminology had practically been an after-though, a short time later “Energy” would come to encompass not only heat but also light, electricity, mechanical effect, and magnetism.[46] Joule had set a precedent by equating the mechanical force generated through chemical processes and the force generated by steam-engines. From this point is was possible for Thomson to claim that energy was undergoing transformations rather than being destroyed and to expand the meaning and implications of “Energy” to encompass other forces that had traditionally been thought of as independent. For British physicists, and Thomson in particular, “Energy” became the protean force supplied by God to fuel the machinery of the Universe. The 1850's, saw the formation of laws that codified beliefs already articulated by the Chalmers, the 'New Moderates,' and steam-engine enthusiasts twenty years earlier. The story does not, however, end with the development of a coherent theory that could simply be announced in Britain and then exported abroad. British Energy Physics had its own transformation to undergo in the public sphere.

[46] Barri J. Gold, *Thermo-poetics* (Cambridge, Mass: MIT Press, 2010), 71.

Popularizing Thermodynamics

Historians of Victorian Science have recently begun to move away from the "diffusionist model" of science, rejecting the idea that an exclusive group, or scientific elite, was responsible first, for producing scientific theories that could stand on their own merits, and secondly, for transmitting that understanding to a passive audience of amateur scientists.[47] This strategy would be counter-productive when trying to understand the ways scientific knowledge was negotiated in the Victorian Era, especially in the case of British Energy Physics. The laws of thermodynamics were given their basic outline in the 1840's and 50's but as they were introduced into the popular sphere, their practical and moral implications were reinforced and expanded.

Raymond Williams has argued that, during the first half of the 19th century, the idea of "popular science" had yet to take on the implications of "simplification" that is now embodied in the phrase. In fact, common interpretations of "Popular Science" in the Victorian era tended to align with a more traditional and political sense of the word "Popular." To qualify as "Popular Science," a treatise or periodical need simply be "accessible," not only the prerogative of the intellectual elite but "belonging to the people." [48]

In a somewhat ironic turn, this dynamic, that so complicated the lives of those trying to promote their brand of thermodynamic theory, was in small part the result of more steam-engine technologies. "Fourdinier Machines," developed in the first decades of the century, used steam-power to produce paper, dramatically cutting the cost of its productions. Meanwhile, publishers

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[47] Sally Shuttleworth and Geoffrey Cantor, "Introduction," in *Science Serialized: Representation of the Sciences in Nineteenth-Century Periodicals* (Cambridge, Mass: The MIT Press, 2004), 3.
[48] Raymond Williams, *Keywords: A Vocabulary of Culture and Society* (London, 1984), 237.

were beginning to turn to steam-printing machines as a way to cheaply produce newspaper and penny periodicals. Both developments contributed to a "Communications Revolution" by mid-century and helped to bring about a mass-reading public that embraced working-class audiences[49]. Rates of illiteracy and literacy were more or less equal in 1830 but over the course of sixty years the rate of illiteracy would plummet to just one-percent.

Popularizers of British Energy Physics were caught up in a wave of annual scientific publications that had quadrupled since the turn of the century and found themselves confronted with an expanding audience that was more and more invested in the realm scientific knowlege.[50] More importantly, science historian Bernard Lightman argues, "the new medium of the mass publication press radically altered the possibilities of debate and parameters of disciplinary authority."[51] The line dividing professional and amateur science had yet to be truly defined, and as publishers became arbiters of scientific authority, Thomson and his colleagues were left with no alternative but to appeal to an audience that, much like the readers of this thesis, needed to be persuaded that the science of Energy was not only interesting but relevant outside the world of scientific institutions like the B.A.A.S and Royal Society.

It was in this context that the controversy over the rival claims of Joule and Mayer came to the fore and helped to popularize the laws of thermodynamics. Joule had already come to the defense of his mechanical equivalent in 1850, however, the subject only became a matter of popular interest in the 1860's when a feud broke out between John Tyndall and Peter Guthrie Tait. What appeared on the surface to be a battle between naturalistic and theistic science, was at

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[49] Bernard Lightman, "Historians, Popularizers, and the Victorian Scene," in *Victorian Popularizers of Science: Designing Nature for New Audiences* (University of Chicago Press, 2007), 30-31.
[50] Ibid, 32.
[51] Ibid, 13.

its heart a contest over who could claim authority over physical truth and moral authority by default.

In 1862, Tyndall published ‘On Force’, a title which may well have functioned as a statement of intent. Though his rhetoric matched that of Thomson, his use of the term Force[52] eluded to the work of Hermann Von Helmholtz of Prussia whose system existed in a much different context. “Force” or *Kraft* and Thomson’s “Energy” were not synonymous, and Helmholtz developed his theory in a medical rather than industrial context. The primary advantage for Tyndall in referencing the work of Helmholtz and his precursor, Mayer, was the opportunity it provided to suggest a rival program to North British Energy Physics and thereby challenge their monopoly on physical truth. Tyndall’s peers, including Huxley and other members of the X-Club, constituted a community of scientists in London who had not been eligible or wealthy enough to enter the intellectual institutions of Oxbridge and as a result were denied the sort of authority typically reserved for religious academic institutions .[53]

Tyndall’s strategy involved the construction of an alternative history and narrative of thermodynamics. Not only did he employ rival terminology, he also advanced the rhetoric of naturalistic science in opposition to theistic science. Whole books have been written exploring the nature of this debate, however, Mathew Stanley has made the useful observation that they not only championed the same methodologies but were also usually united in purpose.[54] This would appear to support Smith’s conclusion that, “at a time when the role of the ‘professional scientists’ was still being defined in Britain, these controversies served to show, not a simple conflict

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[52] “Force” was the English translation of the German term “Kraft” and should not be confused with “force” as it is understood in the discussion of Classical Mechanics.
[53] Crosbie Smith, 171.
[54] Mathew Stanley, *Huxley’s Church and Maxwell’s Demon* (University of Chicago Press, 2015), Introduction.

between ‘amateur’ and ‘professional’, but an intense battle to secure and shape scientific authority.[55]

As far as Tyndall’s rival narrative is concerned, the crucial take away is that its materialistic rhetoric presented Man as playing a far less pivotal role the in the universe of energy transformations. This was consistent with the dominant trend within other fields of science at the time that were “widening temporal vistas and decentering humanity’s place in the cosmos.”[56] Tyndall capitalized on the physiological implications of Helmholtz’s approach as a means for marketing his program and making it compelling for popular audiences. The Conservation of ‘Force’ and its ability the navigate across the border that had traditionally divided the organic and the inorganic provided a practical connection between the individual human body and the forces of the Universe.[57] Even though there were more fundamental points of agreement between the group in metropolitan London and those writing from Scotland, it still was still incumbent upon Tait to promote a narrative that was competitive enough to uphold the authority of the North British Group. In lieu of a physiological connection between the reader and the forces of Nature, Tait returned to the Biblical Cosmology that had so heavily influenced the development of British Energy Physics.

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[55] Crosbie Smith, 191
[56] Gillian Beer, *Darwin’s Plots: Evolutionary Narrative in Darwin, George Eliot, and Nineteenth-Century Fiction 3rd ed.* (Cambridge University Press, 2009), 160-163.
[57] Towards the end of the century, this would prompt questions of whether or not the mind could be affected through transformations in the material world, giving rise to discussions of mental “fatigue,” or, “Neurasthenia.” Anson Rabinbach, *The Human Motor: Energy, Fatigue, and the Origins of Modernity* Berkeley, CA: University of California Press, 1990).

Children of the Sun

Popular science periodicals attempting to explain the laws of thermodynamics, in particular those written by Tait and his colleagues Stewart, Thomson, and Lockyer, often resorted to using the same rhetorical device, employing the sun as a recognizable and powerful symbol. By the time the Tyndall-Tait controversy had begun to excite popular interest, it had already been well established that the wealth and density of Energy contained in coal could be traced back to the solar heat. The Sun provided for an abundance of plant life on earth that over time compacted and transformed itself into a lucrative carboniferous layer in the earths crust. Vegetation served as food for beasts of burden, and the Water Cycle, powered by the sun, produced winds and rivers that in turn powered mills. A study conducted by Balfour Stewart even found correlations between famine and the periodicity of solar flares. All the goings-on of earth led back to same luminescent motive power, the engine at the heart a great cosmic machine.

> *The fuel that lights and warms our dwellings, and the steam-power that transports us from them to distant lands, and furnishes our mechanicians with a miracle-working means for the achievement of their curious arts; result from the light and heat diffused through the universe by its 'all animating pulsating heart.' In very truth are we the "children of the sun."*[58]

As the Sun was employed to educate audiences about the Conservation of Energy, it was by necessity included in conversations regarding the Second Law, the diffusion or dissipation of heat. Thomson had originally cast the second law in theological and cosmological terms, focusing on more abstract terms such as "thermal agency" and "perfect heat engines." It was only later that his concept of universal heat death would come to be examined specifically

[58] J. Carpenter, "What we owe the Sun," *Once A Week,* October 13, 1866

through the lens of the Sun. This can be observed in a publication from 1862 wherein he attempted to calculate the age of the sun based on the rate at which it was radiating heat; he remarked that sun must have been created as "an active source of heat at some time of not immeasurable antiquity, *by an over-ruling decree*."[59]

This rhetorical reliance on the Sun, and its finite life-span, both drew from and reinforced the traditions that had shaped British Energy Physics, still operating within the mutually affirming frameworks of Presbyterian Faith and Scottish Industrial priorities. The imagery of solar death reflected the linear progression of time according to the newly revised Natural Theology, and meanwhile, helped to popularize thermodynamics by refashioning an infinite cosmological scale into " a human-scale narrative."[60] The sun was constantly anthropomorphized, spoken of as a "He" who was indiscriminately wasting his available store of energy, "*shedding that heat around with the most appalling extravagance.*[61] Allen Macduffie has argued that casting the sun as a profligate spender provided a compelling argument for selling audiences on the value of the laws of Thermodynamics, and in the same fell swoop, fashioned a kind of "moral cosmology."[62] The role of compensating for solar waste had fallen to humanity and with it the responsibility of safeguarding the advancement of civilization.

> *We have been content very much to remain spectators of the contest, apparently forgetful that we are at all concerned in the issue. But the conflict is not one which admits of on-lookers,-it is a universal conflict in which we must all take our share.*[63]

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[59] William Thomson, "On the age of the Sun's Heat," *Macmillan's Magazine,* March 1862. Emphasis added.
[60] Allen Macduffie, "The heat death of the sun at the dawn of the Anthropocene," in *Victorian Literature, Energy, and the Ecological Imagination* (Cambridge, UK: Cambridge University Press, 2014), 70.
[61] Robert S. Ball, "How long can the Earth sustain life?," *The Fortnightly Review,* June 11, 1892.
[62] Allen Macduffie, 72.
[63] Balfour Stewart, *The Conservation of Energy* (London: Henry S. King, 1873), 154.

Echoing the Presbyterian idea of "Gift Economy" that was emphasized in Chalmer's revision of Paley, the narrative submitted by Tait and his peers to challenge the materialistic model of Tyndall, was one in which humanity was the custodian and master of a finite sum of energy. The almighty had endowed the Universe with "divine storehouses of Energy" that powered the mechanical operations of the Universe. Not only was creation the product of intelligent design, machine-like in its operation, and subject to a system of universal laws, it had been designed with the intelligence and dominion of humanity in mind.

> *This wondrous mechanism by which the power of the sun is transmitted to our globe, and conveniently stored up for man's use, is to us a far more striking illustration of Divine Intelligence.*[64]

This notion was not revolutionary in and of itself, after all, claims that Man held an elevated status and dominion over the creatures of Earth date back to the Old Testament. What was truly novel, was the degree to which this dominion was believed to extend, reinforced by a new understanding of universal laws that gave man influence over the very forces of the universe.

> *The sun, then, is the great worker, and the slave of man. He works every spinning-jenny in our manufacturing towns, forges every shaft, propels every ship, turns every water-wheel, and moves the limbs of every man and animal. Man, with the power of intellect, merely stands over him with the rod of dominion, and directs his giant strength to suitable tasks.*[65]

Even as Thomson explained that all Energy would eventually be transformed to the extent that it was no longer accessible to man, in the same breath he reinforced the idea that God retained the capacity to reintroduce this protean force. He therefore left room for ambiguity, claiming "no conclusions of dynamical science regarding the future condition of the earth, can be held to give

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[64] Norman Macleod, ed,. "God's Glory in the Heavens," *Good Words,* December 1860.
[65] Norman Macleod, ed,. "God's Glory in the Heavens," *Good Words,* December 1860.

dispiriting views as to the destiny of the race of intelligent beings by which it is at present inhabited."[66] In effect, through his invention of the steam-engine, it was believed that Man had conquered over Nature and that he was morally obligated to manage its stores of Energy Economically.

> *The sun, then, is the great worker, and the slave of man. He works every spinning-jenny in our manufacturing towns, forges every shaft, propels every ship, turns every water-wheel, and moves the limbs of every man and animal. Man, with the power of intellect, merely stands over him with the rod of dominion, and directs his giant strength to suitable tasks.*[67]

[66] William Thomson, "On the age of the Sun's Heat," *Macmillan's Magazine,* March 1862.
[67] Norman Macleod, ed,. "God's Glory in the Heavens," *Good Words,* December 1860.

Conclusion

The optimism displayed in this narrative of Classical Thermodynamics is far removed from the fatalism of H.G Well's time traveler. Having explored the origins of that optimism and faith in the intellectual capacity of humanity, it is easier to understand what the time traveler must have meant by the "the dream of the human intellect." A Presbyterian view of Natural Economy that depicted humanity's role as a custodian and manager for the forces of the Universe, combined with a reverence for the near supernatural capabilities of coal and steam-power, certainly seemed to suggest that no "unemployed problem" or "social question" would be left unanswered. As those beliefs and convictions were codified into the laws of thermodynamics, they were afforded a universal character and benefitted from the authority of empirical science. The popularizers of British Energy Physics that employed the analogy of a spendthrift sun then provided the final step in creating a scientific parable of Man's dominion over the steam-engine and its luminous counterpart in the cosmos.

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