Marx, Machinery and Motive Power: the Thermodynamics of Class Struggle

For Prof. David McNally

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The past several decades have seen a wide-ranging debate over the question of the economic limits of growth, not only in regards to the scarcity of key natural resources, but also in terms of the stresses being put on the integrity of ecosystems integral to the continuation of life as we know it on planet Earth. Many of these concerns are grounded in concepts belonging to the school of "ecological economics" developed in the 1960s and 1970s by such thinkers as Nicolas Georgescu-Roegen and Herman Daly, who articulated a critique, grounded in thermodynamic principles, of both neo-classical economics and mainstream Marxism. Georgescu-Roegen and Daly brought attention to the inevitably entropic nature of industrial production and argued that any industrial economic system based on "drawing down" non-renewable low entropy sources of energy and raw materials would ultimately exhaust the resources it needed or would fall victim to the high entropy pollution and ecological disruption that it produced.[1]

The dependence of industrial capitalism on what Elmar Altvater has termed a "fossil fuel energy regime" is a perfect example of the problems that Nicolas Georgescu-Roegen and Herman Daly outlined, as in addition to the pressing concerns about the consequences of the large amounts of carbon dioxide released into the atmosphere from the combustion of fossil fuels, increasing evidence suggests that on a global level, the extraction of conventional crude oil is reaching peak levels, and that within the next decade, oil production will begin an irreversible decline with grave consequences for the industrial order.[2] With non-Middle Eastern supplies of natural gas facing their own peak

[1] See Herman E. Daly and Alvaro F. Umana, eds. *Energy, Economics, and the Environment: Conflicting Views of an Essential Interrelationship*, Boulder, Colorado: Westview Press, 1981 for a summary of these perspectives.

[2] Over a dozen new books on the topic of peak oil have appeared in the past year alone, and politicians ranging from members of the U.S. Congress to French Prime Minister Dominique Villepin and Venezuelan

and with alternative energies unlikely to meet the shortfall of oil and natural gas, global capitalism may find itself thrown into crisis as a shortages of liquid fuels and high energy prices lead to skyrocketing price increases, disruption of the production and distribution of essential goods and services and the sharpening of class struggles. Because of the ubiquitous use of oil and natural gas in generating electricity and heating, supplying fuel and fertilizer for industrial agriculture and providing energy for transport, high energy prices will immediately be felt as significant cost of living increases for much of the world's population. Moreover, barring the miraculous discovery and widespread application of a new non-carbon based energy system, the increasing cost and declining availability of oil and natural gas will most likely be met with a widespread return to the use of coal and biomass, fuels which release much greater amounts of carbon dioxide and toxic pollutants into the atmosphere and that will accelerate climate change.[3]

President Hugo Chavez have announced that the age of cheap oil is over. The head of the world's largest energy investment bank, Matthew Simmons (an adviser to President George W. Bush), is also in the camp of peak oil pessimists, as are a growing number of petroleum geologists and oil company executives. For one of the clearest arguments concerning peak oil from a thermodynamic and ecological economics perspective see Richard Heinberg, *The Party's Over: Oil, War and the Fate of Industrial Societies*, Gabriola Island: New Society Publishers, 2003. For an assessment of the role of oil scarcity in current geopolitical conflicts see Michael T. Klare, *Blood and Oil: The Dangers and Consequences of America's Growing Dependency on Imported Petroleum*. New York: Henry Holt & Co., 2005.

[3] Due to problems of space and focus, I will not take up a full examination of the question of peak oil in this essay, but instead refer the reader to Part 2 of my work "Of Hand Mills and Heat Engines: Peak Oil, Class Struggle and the Thermodynamics of Production", Master's Major Research Paper, York University, October 2005. The key points that are addressed within that paper and which form the basis of assumptions made in this work are as follows: 1.) There is an increasing global consensus that "the age of cheap oil is over" and that a global peak in world oil production will take place in the next decade. 2.) Peaking of oil production within the United States which has today been the largest cumulative oil producer in world history, occurred in 1971 and despite intensified exploration and the adoption of high technology to maximize distraction levels US oil production has declined by 39% of what it was at its point of peak extraction. The US example provides a template for the overall challenges facing global oil production and indicates that phenomenon of peak oil is not a theoretical possibility that may happen far in the future, but rather a concrete reality which has been affecting the course of world politics for the last 30 years. 3.) World demand for oil which is currently at approximately 85 million barrels of oil per day is projected to increase to 118 million barrels of oil a day by 2020 as developing countries industrialize and come to require increasing amounts of oil as a feedstock for petrochemical industries, an input to agriculture, and a fuel for their civilian and military transport. 4.) World oil discoveries peaked in the 1960s and no major

The environmental problems associated with the use of fossil fuels have been the subject of numerous studies, international conferences and well-meaning declarations, but there nonetheless seems to be little substantive analysis of what the root causes are of our 'addiction to fossil fuels' and of why dominant interests are so unwilling to undertake the transition to a new energy regime. The failure to adequately grapple with this question stems from the fact that two of the most important schools of thought that hold important components of the analytical framework necessary for this undertaking -- ecological economics and Marxism -- miss crucial insights that the other brings to the debate. What is manifestly absent from most ecological economist thought is a critique of capitalism as a historically specific economic system which is not only based on ever-increasing expansion but is also compelled to substitute machinery and raw material for human labor in its quest to achieve higher margins of profit and increased productivity, and to undercut working-class self-organization and power. Moreover, in failing to recognize commodified, alienated and exploited labor as lying at the root of the capitalist system, the ecological movement has not, for the most part, been able to see the intimate connections between a project of preserving ecological diversity and a class project based upon the overthrow of capitalism and its replacement by an alternative economic and political order.

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new oil fields have been discovered in the past four years. Oil production in virtually all non-OPEC oil-producing countries has peaked and is in decline and as Matthew Simmons, author of *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy*, Hoboken, N.J.: John Wiley & Sons, 2005 has pointed out it is extremely unlikely that Middle Eastern OPEC nations will be able to double their oil production in order to meet projected world demand 5.) No ready substitute for conventional oil exists as all alternatives to oil require some form of fossil fuel based energy to build or maintain them. Of central importance to discussing alternative energies is the question of the energy return on energy invested. From this framework conventional oil and other fossil fuels are qualitatively better sources of energy than any alternatives, a explanation for their continued centrality in the world economy, where oil for example accounts provides 90% of all transportation energy in the world and 40% of all other energy generation capacity.

For its part, Marxism as a historical movement has paid little attention to the social, political and ecological contradictions entailed by the inherently entropic nature of industrial production. Ironically, with the notable exception of Marx and Engels, the Marxist movement has by and large failed to bring an adequate ecological analysis to bear on questions of capital accumulation and working-class resistance to capital. In a stage of capitalism when the world is faced with the almost certain specter of massive climate change, mass die-offs of oceanic and terrestrial life, and the rapidly approaching exhaustion of easily accessible fossil fuel energy inputs, the possibility that capitalism will develop the forces of production to a point at which they can be successfully appropriated by the working class seems increasingly remote, especially given the subjective failure of the international working class movement to develop an effective means of expressing its class interests. It seems increasingly likely that by the time capital reaches a state of irreconcilable global crisis, it will have driven the world's ecosystem into crisis and exhausted the world's easily available stocks of low entropy fuels and materials, leaving for those who would attempt to build anti-capitalist alternatives the ruins of a collapsed and no longer functional industrial framework.

In large part the ecological blind spot within modern Marxism stems from the fact that the Soviet Union, the first society founded on Marxist principles, was forced by capitalist encirclement and threats of invasion to rapidly build up a fossil fueled industrial base along the lines pioneered by developing capitalist economies. In the context of the ebb of a wave of international revolution and the consolidation of a tyrannical and bureaucratic regime, many of the progressive environmental and democratic perspectives within Marxism, and specifically within the Russian Marxist tradition were disavowed.

However, in recent years, work by Paul Burkett and John Bellamy Foster has done much to remind us that in many of his most important works, Marx displayed an ecological awareness far in advance of many of his contemporaries (and even of many of his critics today), and that despite the Soviet experience, Marx's Marxism and specifically his conception of the "metabolic" relationship between humans and nature must become a central part of the framework of contemporary environmentalism.[4]

In this paper I will argue that Volume 1 of Marx's *Capital*, and specifically his chapter on Machinery and Large-Scale Industry, provides one of the most important starting points for understanding capitalism's addiction to fossil fuels and its existence as a global economic system responsible for today's ecological crisis. Following Marx's discussion of machinery, in the first part of this essay I suggest that in its transition from an agrarian form to an industrial one, capital came to rely on machinery as an indispensable tool to break workers' resistance, increase the productivity of commodity labor power and to aggressively spread the commodity form across the world. The second part of this essay takes up some of the debates on the thermodynamics of production and considers them in the light of Marx's analysis of capitalism and machinery. I argue that although Marx provides us with a basic framework with which to understand the growth of industrial capitalism, and although he and Engels, contrary to the arguments of some ecological economists, did have a nuanced analysis of thermodynamic principles within economic processes, they did not develop an adequate theorization of the relationship between energy and machinery necessary to fully explore class struggle and inter-imperialist rivalry as it occurs in the later stages of industrial capitalism. Because modern

[4] See *Marx's Ecology: Materialism and Nature.* New York: Monthly Review Press, 2000.

machinery requires a cheap and reliable source of low entropy energy to keep its machines going, and because there are at present no ready alternatives to fossil fuel energy regimes, the capitalist system has been growing ever more dependent on finding and producing fossil fuel resources. During the industrial revolution fossil fuels provided the means to overcome the organic limits of agrarian capitalism, and coal, oil, and natural gas became the lifeblood of the capitalist system – providing energies which, like labor power, must be kept coursing through the system lest fixed capital and processes of accumulation should come to a halt. While Marx's failure to consider this problem can be explained in terms of the fact that he was writing during the birth of the modern industrial age when fossil fuel resources were plentiful and at a time when he considered socialist revolution imminent, his failure to adequately consider energy inputs to the economic process has greatly limited the potentials for developing an ecological Marxism capable of addressing the sharpening of class conflict and inter-imperialist rivalry that is arising with the peaking of world oil production. A Marxist analysis of the role of machinery in the development of capitalism that is enriched by Georgescu-Roegen's and Daly's notions of the inevitably entropic nature of industrial production provides a crucial framework within which to situate the problem of fossil fuel dependence and the likely consequences for the capitalist system and any alternative mode of production that may follow it of the depletion of this resource. Such an approach makes it possible to understand the peaking of world oil production and the beginning of the end of the age of fossil fuels as an epoch making turning point for contemporary class struggles, a position which is central for both understanding and changing the capitalist world order.

PART ONE: MACHINERY & LARGE-SCALE INDUSTRY IN MARX'S *CAPITAL*

> The bourgeoisie, during its rule of scarce 100 years, has created more massive and more colossal productive forces then have all preceding generations together. Subjection of nature's forces to man, machinery, application of chemistry to industry and agriculture, steam navigation, railways, electric telegraphs, clearing of whole continents for cultivation, canalization of rivers, whole populations conjured out of the ground -- what earlier century had even a presentiment that such productive forces slumbered in the lap of social labor?
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> -Karl Marx and Frederick Engels, *The Manifesto of the Communist Party*, 1848. [5]

The "colossal" productive forces of social labor that Marx and Engels referred to in *The Manifesto of the Communist Party* arose not only from changing property relations and the "scientific" exploitation of human labor, but also from the way in which capitalism appropriated stocks of fossil fuel energy and channeled them in an ever increasing flow into the production process. At the root of industrial capitalism and its astonishing conquest and transformation of the world in the past 250 years is the fossil fuel powered machine. From steam powered textile factories, locomotives and steamships, to coal-fired foundries and electrical generating plants to the automobile, jet engine and intercontinental ballistic missile, fossil fueled machinery has transformed capitalism and the world we live in. Fossil fuels -- coal, oil, and natural gas -- are a rich source of stored up solar energy that contain huge amounts of readily accessible energy in a portable and accessible form. And in every year from the first commercial application of the steam engine in 1715 to the present day, the capitalist world economy has

[5] Karl Marx and Frederick Engels "Manifesto of the Communist Party," in Karl Marx and Frederick Engels, *Collected Works*, Vol. 6 (New York: International Publishers, 1976): pp. 477-517.

incorporated an ever-increasing amount of this fossil fuel energy in its economy.[6]

It is conventional to view the rise of capitalism and industrial society teleologically, as an inevitable consequence of scientific rationalism, the declining power of religion, the influence of the Protestant work ethic, or any number of other "inevitable" social and political processes. But this does not explain why an industrial capitalism based on fossil fuels developed in 18th-century England, and not rather in 12-century China, whose manufacturers used rich coal deposits to produce more iron and steel than all of Europe did in 1800, or why when the ancient Greeks invented steam powered machinery they did not apply it to increasing economic production.[7] To understand why the growth of industrial capitalism and the widespread use of fossil fuels to power machinery arose in 18th-century England and nowhere else in the world requires an understanding of the historical specificity of capitalist social relations and the economic laws of motion inherent to capitalism as an economic system.

While early capitalists wrote about the new systems of machinery and industrial discipline they were developing, Karl Marx was the most outstanding theorist of the origin of machinery and its relationship to capitalist production. Marx devoted chapter 15 of *Capital,* his famous critique of capitalist production, to the study of how the introduction of machinery under capitalism changed class dynamics and reorganized production, where he argued that the rise of modern machinery was integral to the consolidation and expansion of capitalist class rule by overcoming working-class resistance, enabling capitalism to overcome rival modes of production, and most

[6] Valclav Smil, *Energy in World History*, Oxford: Westview Press, 1994, pp. 157-222.
[7] Barbara Freese, *Coal: A Human History*. New York: Penguin Books, 2003.

importantly, by providing the basis for the seemingly unending extraction of surplus value from the working class. Marx stressed the importance of understanding machinery within the context of specific modes of production, and defined machinery as:

> a mechanism that, after being set in motion, performs with its tools the same operations as the worker formerly did with similar tools. Whether the motive power is derived from man, or in turn from a machine, makes no difference here. From the moment that the tool proper is taken from man and fitted into a mechanism, a machine takes the place of a mere implement.[8]

Under the capitalist mode of production, the machine is the predominant means by which human labor can be displaced from the production process and the best way to make the labor that remains more productive. In various pre-capitalist modes of production, ruling elites had little interest in displacing human labor from the productive process, as the societal surplus appropriated by ruling elites was taken with the direct application of state backed coercive force and not through technological improvements to the production process. In the feudal societies of Western Europe, strict written and customary laws determined all aspects of economic production, and innovations in the labor process were strictly regulated because it was feared that they could create dangerous social upheavals by displacing workers from the production process.

The extraction of surplus under capitalism is fundamentally different than in precapitalist class societies, where surplus was extracted from the direct producers through the political power of the state, or through what Ellen Meiksins Wood calls the institution of "politically constituted property".[9] Under capitalism, the surplus is extracted through economic means, based on the wage labor/capital relationship and not through the direct coercion of the state (although the state clearly remains present to

[8] Karl Marx, *Capital* Vol. 1., p. 495.
[9] Ellen Meiksins Wood, *The Origin of Capitalism: A Longer View*. London: Verso, 2002.

enforce capitalist property relations and to put down open revolt from the working class). Workers are denied free access to the means of production and must sell the only thing they have -- their power to work -- to capitalists as a commodity in order to survive. Capitalists buy this commodity, what Marx called "labor power", and by setting it to work in the production processes that they control, use it to produce commodities which are then sold on the market. The source of capitalists' profit is the fact that over the workday, the workers' labor power not only produces enough to pay for the costs of their subsistence (the wage that they receive) but also creates what Marx calls a "surplus value", an extra amount of labor which is appropriated by capitalists as profit.[10]

Because every capitalist is in competition with many other capitalists, and seeks ever higher profits to reinvest in production, the key to continued accumulation lies in increasing the productivity of the labor power purchased from the worker. This growth in productivity may take place in what Marx called "absolute" terms -- by lengthening the working day and by intensifying the pace of work -- or in "relative" terms, by changing means and methods of production and thereby increasing the proportion of the worker's labor time that can be appropriated by the capitalist. Marx saw machinery as being fundamental to the increasing of both "absolute" and relative surplus value and argued that in this process, "like every other instrument for increasing the productivity of labor.... the machine is a means for producing surplus value."[11]

While Marx identified a number of ways in which machinery could be used to increase the absolute rate of surplus extraction, machines were most effective in

[10] Karl Marx, *Capital* Vol. 1., pp. 320-339.
[11] Karl Marx, *Capital* Vol. 1., p. 492.

increasing surplus value in relative terms by displacing workers from the production process and increasing the productivity of those workers who remained. Because human beings can only be pushed to a certain level of exhaustion, increasing labor productivity through the substitution of newer and more sophisticated forms of machinery has been at the core of the continued development of capitalism and explains its dynamic growth and expansion. This process, which first began with the direct substitution of machinery for human labor power with the start of the industrial revolution in England in the mid-18th-century, has been continued through later waves of innovation by the use of machinery which replaces "intellectual" labor as well as primarily manual work. Marx outlined three key ways in which machinery was and continues to be central to the growth, expansion, and relative stability of labor-capital relations.

Firstly, the introduction of machinery increases the productivity of the labor power that the capitalist has purchased and set to work, which means that for the same wage and in the same amount of time more goods can be produced per worker, thus leading to greater profits for the capitalist who first introduces this machinery. The increased availability of the cheaper commodities produced with this machinery has the effect of lowering the worker's costs of living and thus the overall cost of labor power on the market. Because the cost of the means of subsistence has decreased, capitalists can drive down wages in relative terms, as workers can buy more commodities for less money. The ultimate effect of this process is that a smaller proportion of the working day is spent by workers in laboring for their own reproduction, and thus a relatively greater

proportion of time is spent working to produce surplus value for the capitalist.[12]

Secondly, the increase of productivity achieved with the introduction of machinery has the result of displacing the workers from their jobs and creating what Marx called a "reserve army of the unemployed," which by acting as a pool of desperate would-be wage labor drives down the cost of wages to the subsistence minimum and provides a cheap labor force for new and emerging branches of industry.[13]

As well as the two macroeconomic processes described above, Marx argued that machinery was essential as a tool that could be used by capitalists to break working-class resistance at the point of production. Because the introduction of machinery reduced the need for muscular strength as a motive force in production, it allowed for the incorporation of women and children into the industrial workforce. Capitalists found that women and young children were more easily disciplined and could be paid much lower wages than their male counterparts. Moreover, capitalists could further reduce their labor costs by employing the whole family at the same total wage they used to pay the male bread earner. With the whole family at work for a lower wage, greater profits were achieved by the capitalist than could have been the case by employing just the male head of the family. The introduction of machinery and the replacement of male workers by women and children "at last breaks the resistance which the male workers had continued to oppose despotism of capital throughout the [earlier] period of manufacture."[14]

In addition to its effects in destroying working-class families and pitting workers

[12] Karl Marx, *Capital* Vol. 1., p. 530.
[13] Karl Marx, *Capital* Vol. 1., p. 532.
[14] Karl Marx, *Capital* Vol. 1., p. 526.

against each other, machinery was also introduced in specific circumstances to break strikes and overcome working class self-organization at the point of production. Conscious of this fact, workers often resisted exploitation by attacking specific types of machinery which were seen as having been introduced for the express purpose of breaking their class power:

> The struggle between the capitalist and the wage-laborer starts with the existence of the capital-relation itself. But only since the introduction of machinery has the worker fought against the instrument of labor itself, capital's material mode of existence. He is in revolt against this particular form of the means of production because it is the material foundation of the capitalist mode of production.[15]

As Marx was aware, there was a long history of resistance by workers to the machinery introduced to make them redundant. He noted that in the 1630s a wind-driven sawmill near London was destroyed by a group of workers who feared the loss of their jobs, while in 1758 the first wool-shearing machine driven by water power was burned down by some of the 100,000 people that it had thrown out of work. Similarly, the Luddite rebellion in the early 1800s was directed at new machines introduced during the industrial revolution.[16] It was not until later, Marx argued, that the English working class learned to change its "attacks from the material instruments of production to the form of society which utilizes those instruments".[17]

Under capitalism, Marx argued, machinery is not just a "superior competitor to the worker" but a "power inimical to him. It is the most powerful weapon for suppressing a strike, those periodic revolts of the working class against the autocracy of capital."[18] Marx looked at the evidence provided by capitalists themselves in their own assessments

[15] Karl Marx, *Capital* Vol. 1., p. 554.
[16] Karl Marx, *Capital* Vol. 1., p. 554
[17] Karl Marx, *Capital* Vol. 1., p. 555.
[18] Karl Marx, *Capital* Vol. 1., p. 562.

of their production methods and argued that "the steam engine was from the very first an antagonist of 'human power', an antagonist that enabled the capitalists to tread underfoot the growing demands of the workers, which threatened to drive the infant factory system into crisis." [19] Indeed, he added, "it would be possible to write a whole history of the inventions made since 1830 for the sole purpose of providing capital with weapons against working-class revolt."[20] Machinery was thus a crucial aspect of the process of primitive accumulation and dispossession as capitalists struggled to overcome and discipline a new industrial workforce against the old habits of communal solidarity and village living.

The point raised by Marx is an interesting one, for it describes a dialectic of struggle between labor and capital in which labor struggles themselves can be seen to be an active part in the technological development of capitalism. Just as state intervention in the form of the factory acts which legislated maximum working hours in the factories ended up benefiting the richest capitalists who were able to invest in new machines to replace over-exploited workers,[21] the resistance of workers at the point of production forced capital to invest in new machines to overcome the increasing organization and class consciousness of workers. As Marx and early capitalists were well aware, the development of capitalism was not a *fait accompli* -- workers and the dispossessed were capable of pushing it into crisis through their struggles.

The introduction of machinery also led to a prolonging of the working day in an effort to realize as much profit as possible. Machines which were not run around the

[19] Karl Marx, *Capital* Vol. 1., p. 563.
[20] Karl Marx, *Capital* Vol. 1., p. 563.
[21] Karl Marx, *Capital* Vol. 1., p. 635.

clock but which remained idle for part of the day were not able to "soak up" as much "living labor" as those in continuous operation, and thus could not realize as large profits. The lengthening of the workday remained the key way in which capitalists could increase surplus value production "absolutely" by gaining a greater portion of the workers' time, and this tendency remains present in both sweatshops and "white collar" office complexes today. As Marx put it:

> If machinery is the most powerful means of raising the productivity of labor, i.e. of shortening the working time needed to produce a commodity, it is also, as a repository of capital, the most powerful means of lengthening the working day beyond all natural limits in those industries first directly seized on by it. It creates, on the one hand, new conditions which permit capital to give free rein to this tendency, and on the other hand, new incentives which whet its insatiable appetite for the labor of others.[22]

The work process was intensified as the introduction of new machines transformed old work rhythms and closed the pores of the working day by making workers function at the speed of the machine. Machinery also deskilled the work process and undermined the power of workers who in earlier modes of production had near complete control of the production process. Artisanal workshops where production processes and trade skills were jealously guarded and passed down through generations were replaced by factories in which every aspect of work was under the surveillance and management of the capitalist. With the introduction of machinery in the new factories there was:

> ...a tendency to equalize and reduce to an identical level every kind of work that has to be done by the minders of the machine. The widescale introduction of machinery has the effect of reducing the cooperative structures between workers that existed in the period of manufacture and divides workers between those who are employed operating the machines and those who merely attend them."[23]

[22] Karl Marx, *Capital* Vol. 1., p. 526.
[23] Karl Marx, *Capital* Vol. 1., p. 545.

Machinery also required that discipline be taught early on to workers, "in order that [they] may learn to adapt [their] own movements to the uniform and unceasing motion of an automaton."[24] However, capitalists were happy to maintain some of the old divisions of labor in order to better exploit workers:

> A lifelong specialty of handling the same tool [under the manufacturing system] now becomes the lifelong specialty of serving the same machine. Machinery is misused in order to transform the worker, from his very childhood, into a part of the specialized machines.[25]

Marx argued that in addition to transforming work processes within established capitalist societies, the introduction of machinery was decisive in opening up the world to the dominance of the capitalist mode of production. Modes of production and specific branches of industry which did not incorporate the use of machinery were easily overcome by industrial capitalism. Drawing a connection between economic warfare and the one-sided military nature of colonial warfare then forcibly expanding the world market, Marx argued that the result of competition between unequal processes of production "is as certain as is the result of an encounter between an army with breach-loading rifles and one with bows and arrows."[26] The widespread use of coal in the British economy led to greatly increased steel and iron output, and the use of these raw materials revolutionized warfare through the standardized production of modern weapons as well as forms of mass transport such as steamships and railways. This warfare was as much economic as military, since

> …the cheapness of the articles produced by machinery and the revolution in the means of transport and communication provide the weapons for the conquest of foreign markets. By ruining handicraft production of finished articles in other countries, machinery

[24] Karl Marx, *Capital* Vol. 1., p. 546.
[25] Karl Marx, *Capital* Vol. 1., p. 547.
[26] Karl Marx, *Capital* Vol. 1., p. 578.

> forcibly converts them into fields for the production of its raw material.... by constantly turning workers into 'supernumeraries', large-scale industry, in all countries where it has taken root, spurs on rapid increases in emigration and the colonization of foreign lands, which are thereby converted into settlements for growing the raw material of the mother country, just as Australia, for example, was converted into a colony for growing wool. [27]

Machine based production under capitalism laid the groundwork for the opening up of the world to capitalism and the penetration of non-capitalist economies, creating imperialist dynamics which continue to divide the world to this day:

> A new and international division of labor springs up, one suited to the requirements of the main industrial countries, and it converts one part of the globe into a chiefly agricultural field of production for supplying the other part, which remains a pre-eminently industrial field.[28]

In order to have this kind of international success, the factory system needed to reach "a definite degree of maturity," which happened when the use of fossil fuels and machinery reached the point that their own production could be transformed:

> However, as soon as the factory system has attained a reasonable space to exist in, and reached a definite degree of maturity, and in particular as soon as the technical basis peculiar to it, machinery, is itself produced by machinery, as soon as coal mining and iron mining, and metallurgical industries, and the means of transport have been revolutionized; in short, as soon as the general conditions of production appropriate for large-scale industry have been established, this mode of production acquires an elasticity, a capacity for sudden extension by leaps and bounds, which comes up against no barriers but those presented by the availability of raw materials and the extent of sales outlets.[29]

The basis for the successes of Western imperialism and the domination of the capitalist mode of production throughout the world is thus, according to Marx, fundamentally related to the expansion of machine production and its generalization through all branches of industry. The invention of fossil fuel powered machinery and its application to capitalist labor processes appears as a savior of the capitalist mode of production and

[27] Karl Marx, *Capital* Vol. 1., p. 579.
[28] Karl Marx, *Capital* Vol. 1., pp. 579-580.
[29] Karl Marx, *Capital* Vol. 1., p. 579.

the guarantor of its local and international domination. Without machinery to increase labor productivity, overcome working-class resistance at the point of production, and project economic and military might across the world, the question could be seriously posed as to how agrarian capitalism could have grown and expanded beyond the ecological limits that constrained it.

While stressing the importance of machine production to the capitalist system, Marx never suggested that it was technology itself that was the driving force of history or that changing class relations could be explained by recourse to technological determinism. As Marx argued, it was not the steam engine itself, but rather the creation of machines that had human labor as a motive force, that explained the development of machinery and the growth of industry under capitalism. Once production existed under a capitalist framework with machines powered by human labor power, the logic of capital meant that there would be significant economic rewards for any capitalist successful in replacing human labor with a cheaper alternative. In some cases that alternative was children's or women’s labor, but ultimately it was far more profitable to completely drive out human labor as a motive force and replace it with fossil fuel driven machinery. This process occurred not because of the inevitable growth of more advanced forms of technology, but rather because capitalist social relations necessitated the constant improvement of labor productivity.

Although various machines had been invented in antiquity they were rarely involved in large-scale economic production, and it was not until the medieval era in Europe that machinery (primarily for the grinding of grain) came into widespread use. Marx pointed out that in those areas of production

> where man has always acted as a simple motive power, as for instance by turning the crank of a mill, by pumping, by moving the arm of the bellows up and down, by pounding with a mortar, etc., there is soon a call for the application of animals, water and wind as motive powers.[30]

But he also stressed the fact that in pre-capitalist social relations technical changes lead to these implements "acquiring the stature of machines, but without creating any revolution in the mode of production".[31]

> The steam engine itself, such as it was at its invention during the manufacturing period at the close of the 17th century, and such as it continued to be down to 1780, did not give rise to any industrial revolution. It was, on the contrary, the invention of machines that made a revolution in the form of steam engines necessary. As soon as man, instead of working on the object of labor with a tool, becomes merely the motive power of the machine, it is purely accidental that the motive power happens to be clothed in the form of human muscles; wind, water or steam could just as well take man's place.[32]

Marx's account thus differs from a technological determinist perspective which sees technology itself as a driving force of history. Marx recognized the machine and, in particular, the steam engine as central to the industrial revolution, but he saw this revolution as having been put into motion by the laws of capitalist accumulation and its drive to increase the productivity of labor power. As Paul Burkett and John Bellamy Foster point out, the transformation of property relations that heralded the rise of agrarian capitalism was key to capital's control of the industrial labor process:

> After all, the ability of the capitalist to separate the tool from the worker and install it in the machine -- and the subsequent application of science to the technical improvement of machinery on the capitalist's profit-making behalf -- presumed that the worker had already been socially separated from control over the means of production.[33]

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[30] Karl Marx, *Capital* Vol. 1., p. 496.
[31] Karl Marx, *Capital* Vol. 1., p. 496.
[32] Karl Marx, *Capital* Vol. 1., p. 496.
[33] Paul Burkett and John Bellamy Foster, "Metabolism, Energy, and Entropy in Marx's Critique of Political Economy: Beyond the Podolinsky Myth", presented at a Marxist Sociology session of the American Sociological Association Meetings, San Francisco, August 14-17, 2004, p 18.

The introduction and application of machinery is fundamentally linked to class struggle, and to extracting surplus value from the working class. Technology is not some neutral force that spontaneously develops of its own accord, but a means by which individual capitals can outcompete their rivals, and a tool by which capital as a whole can collectively maintain its control over the working class. Certain technological innovations may result (as they did in Marx's time) in the disappearance of whole trades and industries, but the global process remains one of drawing ever-increasing numbers of workers into the capital-wage labor relationship as technology and capitalist production advances relentlessly.

From Marx's work in *Capital* it is clear that the introduction of machinery was based upon three interlocking advantages -- its dramatic impact on increasing the productivity of the commodity of labor power, its ability to overcome the self organization of the working class at the point of production, and the possibility of realizing a truly global capitalist system. However, while the internal "laws of motion" of capitalism made the introduction of machinery logical, and indeed necessary for capitalism's continued success, it was the large-scale presence of fossil fuels in England and the technology of the heat engine (which transformed thermal energy into mechanical motion) that allowed capitalism to stay a step ahead of the class conflict at the center of the capital-labor relation. While an agrarian capitalism functioning without fossil fuels originated in 16th-century England, it was an inherently transitory mode of production, and an attempt to develop industrial capitalism without fossil fuels would have faced

stringent ecological and energetic limits.[34] Two interlocking phenomena must therefore be central to any study of the rise of industrial capitalism. The first of these, the logic or 'laws of motion' of the capitalist system which led to the use of machinery in production in order to increase the productivity of labor power and overcome working-class resistance, we have already examined. The second, the importance of a ready supply of low entropy energy which could provide the material basis upon which industrialism and the "real subsumption" of labor could be generalized and maintained on a global level, will be the subject of the second part of this essay.

[34] Pomeranz, Kenneth. The Great Divergence: China, Europe, and the Making of the Modern World Economy. Princeton, NJ: Princeton University Press, 2000, pp-59-61.

PART TWO: FOSSIL FUELS AND CLASS STRUGGLE

In his chapter on machinery Marx examined the advantages and drawbacks of the different kinds of power that could be used to animate machinery and to provide energy for the production process. The first type of energy that Marx surveyed was horse power, which he noted was limited by the physical space required to harness the horses to the machinery and by the grain that the horses needed in order to subsist. Marx next looked at wind power, which had been used for hundreds of years in Europe and Asia as a source of energy, but which faced drawbacks due to its "inconsistent and uncontrollable" nature. Water power was the single most important source of power (and was the largest single input of motive power to English industry until the 1820's),[35] but it too had its limitations since "the flow of water could not be increased at will, it failed at certain seasons of the year, and above all it was essentially local."[36] All of these sources of power, including human labor, were used to drive machinery, but unlike fossil fuels their power as a motive force could not be exponentially increased, and they were all too constrained by their energetic form or by the physical limits to the concentration of their energy to meet the needs of industrial capitalism's hectic growth.[37]

As Marx indicated, it was not only the availability of machinery that contributed to capital's perennial victory in the class struggle, but also the availability of machines which are mobile, function consistently, and whose fuel source can be increased to match the growth of machinery itself. Moreover, the cost of creating these machines and their

[35] G. N. von Tunzelmann, *Steam Power and British Industrialization to 1860*, Clarendon Press Oxford, 1978, p. 4.
[36] Karl Marx, *Capital* Vol. 1., p. 498.
[37] E. A. Wrigley, "The Classical Economists, the Stationary State, and the Industrial Revolution" in *Was the Industrial Revolution Necessary?* edited by Graeme Donald Snooks, London: Routledge, 1994, p. 34.

energy inputs must be less than the old more labor intensive system they replace in order to be profitable in a capitalist economy. Marx was well aware that it was the coal powered steam engine which had unlocked the possibility of the widespread use of machinery beyond the limits imposed by animal, wind and water power:

> Not till the invention of Watt's second and so-called double acting steam engine was a prime mover found which drew its own motive power from the consumption of coal and water, was entirely under man's control, was mobile and a means of locomotion, was urban and not -- like the water wheel -- rural, permitted production to be concentrated in towns instead of -- like the water wheel -- being scattered over the countryside and, finally, was of universal technical application, and little affected in its choice of residence by local circumstances.[38]

The importance of the steam engine cannot be underestimated, as it formed the fundamental basis for the ongoing success of the industrial revolution and made possible the rapid growth of industrial capitalism. While the groundwork for the industrial revolution (a class of laborers divorced from the means of production and compelled to exchange their labor power on the market, and a class of employers freely able to deploy their capital to exploit these workers) was laid during the growth of agrarian capitalism in the English countryside, and while steam power was not responsible for powering the first industrial workshops, fossil fuel powered heat engines provided the vitally important "elasticity" and "capacity for sudden extension by leaps and bounds" needed by industrial capitalism.[39] As Marx noted, Watt's genius lay in his specification of the steam engine not "as an invention for a specific purpose, but as an agent universally applicable in industry," and the steam engine did indeed establish the "general conditions of

[38] Karl Marx, *Capital* Vol. 1., p. 499.
[39] Karl Marx, *Capital* Vol. 1., p. 579.

production appropriate for large-scale industry" in becoming ubiquitous and essential in all key areas of the industrial economy -- mining, transportation, and manufacturing. [40]

Importantly, Marx himself had relatively little to say about the role of fuels in the machines he studied in Volume 1 of *Capital*. He did note that the expansion of capitalism resulted in the use of raw materials and fuels but he reflected little on the consequences of this process from the point of view of energy sources thus utilized. Marx had however discussed the question in more detail some 20 years earlier in a series of notes discussing the rise of capitalism and the level of workers' wages.[41] In this work Marx sought to understand the relationship between the growth of productive capital and its three components --

> 1) the raw material which is worked up;
>
> 2) the machines and materials such as coal, etc., which are necessary to drive the machines; buildings, etc.;
>
> 3) the part of capital intended for the maintenance of the workers.[42]

Marx was interested in the proportions to which these various components would increase as capitalism develops, with special emphasis on the third part, workers' wages. Stating that the "growth of productive capital is linked with its concentration, and with that the fact that it can only be profitable if it is exploited on an ever larger scale," Marx argued that as the productive forces grow, the relative size of the productive capital tied up in raw materials and machinery and fuels would expand, while the "growth of the parts of productive capital transformed into machinery and raw materials is not

[40] Karl Marx, *Capital* Vol. 1., p. 579.
[41] Karl Marx, "Wages," in Karl Marx and Frederick Engels, *Collected Works*, Vol. 6 (New York: International Publishers, 1976): pp. 413-437.
[42] Karl Marx, "Wages" p. 430.

accompanied by a similar [proportional] growth of the part of productive capital intended for wages," because if it were to be profits would shrink and, "the purpose of the use of machinery and the increased division of labour would, of course, be thwarted."[43]

As the proportion of capital allocated to pay wages decreases in relative terms, the amount spent by the capitalist on raw materials and machinery will increase, because "after the capitalist has put a larger capital into machinery, he is compelled to spend a larger capital on the purchase of raw materials and the fuels required to drive the machines." By introducing machinery to increase the productivity of the labor power he has purchased, the capitalist shrinks the size of his work force, (in either relative or absolute terms) and thus his total output on wages, while simultaneously creating a larger "reserve army of labor" of workers desperate to sell their labor. For the capitalist to increase his work force, "production must have been enormously expanded for it to be possible to retain the same number of workers or even increase it, and the proportion of workers to the productive forces has relatively become infinitely more a disproportion."[44] The result, according to Marx is that over-accumulation is accelerated, and that consequently the next economic crisis would be even bigger than the previous one. The dynamic of capital is thus an inherently expansive one which sees overall spending on wages decreased while the production of machinery and its use of raw materials and fuels is constantly accelerated. Marx summarized this tendency as follows:

> It is, therefore, a general law which necessarily arises from the nature of the relation between capital and labour that in the course of the growth of the productive forces the part of productive capital which is transformed into machinery and raw material, i. e., capital as such, increases in

[43] Karl Marx, "Wages" p. 431.
[44] Karl Marx, "Wages" pp. 431-432.

> disproportion to the part which is intended for wages; i. e., in other words, the workers must share among themselves an ever smaller part of the productive capital in relation to its total mass....[45]

This process is integral to the development of capitalism, and it "increases in the same measure in which the productive capital as a whole grows". Even after an economic crisis caused by the over-accumulation of capital, Marx argued that capitalism must again turn to increasing the relative predominance of machinery and raw materials over the wages that it pays to workers. Thus, in order to compensate for its contradiction, capitalism is forced to further realize it, and this happens "in geometrical proportion, and in order afterwards, in a time of crisis, to readjust it, it is enlarged still more."[46]

While laying out a clear argument that the overwhelming tendency of capital was to increase its output of raw materials and machinery, Marx never addressed the question of what would happen if capital could not find sufficiently cheap sources of energy to keep the machinery that powered its exponential growth running. He outlined a logical structure that would suggest that if the costs of the fuels for machinery should dramatically increase, capital would have to forgo its profits, further reduce the proportion of productive capital going to workers in the form of wages, or most ominously, cease to expand in its process of accumulation, but he never explored this question or its relationship to the class struggle. But while it is of course correct that certain sectors of advanced capitalist economies are tending towards less resource intensive forms of production, this is by no means true if the capitalist system is taken as a whole, and such "immaterial" perspectives ignore the inescapably entropic nature of production and consumption. The other argument, often made by neoclassical economists

[45] Karl Marx, "Wages" p. 432.
[46] Karl Marx, "Wages" p. 432.

(and also by many Marxists), is that out of necessity, human society can infinitely substitute alternative sources of energy for the current fossil fuel based industrial order. This is a question that Marx also did not raise, although we shall consider it later in this paper.

Despite having developed a framework completely applicable to a thermodynamic analysis of industrial capitalism 20 years before he wrote *Capital*, Marx did not in either his notebook writings on wages or in Volume 1 of *Capital* discuss the potential limits of the availability of fossil fuels or consider their role in contributing to economic crisis and class struggle. Moreover, in certain passages of Volume 1 of *Capital*, Marx also came close to conflating the distinction between the technical knowledge surrounding the ability to exploit fossil fuels and their continued contribution to production, which unlike this knowledge is not "free". While his meaning in the following passage is not fully explained (and he does expressly distinguish between raw materials and "natural forces" elsewhere in his work),[47] Marx suggests that it is the steam engine that produces steam, and makes no mention of the energy source required to make the steam engine produce its steam, which in a thermodynamic sense is quite different from the knowledge of how to make a heat engine produce mechanical work.

> The productive forces resulting from cooperation in the division of labor cost capital nothing. They are natural forces of social labor. Other natural forces appropriated to productive processes, such as steam, water, etc., also cost nothing. But just as a man requires lungs to breathe with, so he requires something that is the work of human hands in order to consume the forces of nature productively. A water wheel is necessary to exploit the force of water, and the steam engine to exploit the elasticity of steam. Once discovered, the law of the deflection of a magnetic needle in the field of an electric current, or the law of the of iron by electricity, cost absolutely nothing.[48]

[47] Marx, *Capital* Vol 2, p. 360.
[48] Karl Marx, *Capital* Vol. 1., p. 508.

In this passage, Marx missed a clear opportunity to distinguish between the energetic input "flows" of renewable energy sources such as water, and the finite "stocks" of coal that may only make their contribution to the economy once in the lifespan of the human species before being dissipated as high entropy pollution.

Despite the huge economic transformations and the 150 years or so that have passed since Marx examined the various energy sources powering the first industrial revolution, capitalism remains overwhelmingly dependent on fossil fuels for providing energy inputs to the economy. As Valclav Smil points out:

> Global statistics show a sustained exponential growth in fossil-fuel production since the beginning of the 19th century. Coal mining grew a hundredfold, from 10 million to one billion tons, between 1810 and 1910, and it reached nearly 5 billion pounds by 1990. Crude oil extraction rose about 300-fold, from less than 10 million tons in the late 1880s to more than 3 billion tons a century later. During the same period natural gas production rose 1000 fold from less than 2 billion to nearly 2 trillion cubic meters.[49]

In the United States today the breakdown of energy inputs into the economy is as follows -- 40% of total energy supply comes from oil, 24% from natural gas, 23% from coal, 8% from nuclear power, and 5% from all other sources of energy, with oil powering 97% of all cars, trucks, buses, planes, trains, and ships.[50] On a global level, oil powers 90% of all vehicles and provides 40% of all other energy inputs. Notwithstanding international agreements such as the Kyoto protocol (which has been rejected by those nations most dependent on the use of fossil fuels for continued economic growth), there seems to be very little chance of the industrial world cutting back its use of carbon based fuels, not so much because of a failure to recognize the problem of climate change, but

[49] Valclav Smil, *Energy in World History*, p. 185.
[50] Michael T. Klare, Klare, Michael T. *Blood and Oil: The Dangers and Consequences of America's Growing Dependency on Imported Petroleum*, New York: Henry Holt & Co., 2005, p. 7.

because of the paucity of real alternatives to fossil fuels. Nuclear power, despite its promise of energy "too cheap to meter," is prohibitively expensive when long-term externalities and maintenance are figured into the cost equation. Wind power is still subject to the vagaries of nature, while solar panels are only capable of capturing a small fraction of the solar energy they receive. The much vaunted hydrogen economy is ultimately still dependent upon external sources of energy to produce its fuel, and all existing "alternatives" to fossil fuel including sun and wind power are in fact ultimately dependent on fossil fuels for their own production and maintenance. As James Howard Kunstler argues:

> No combination of alternative fuels will ever permit us to operate a substantial fraction of the systems we currently run -- in everything from food production and manufacturing to electric power generation, to skyscraper cities, to the ordinary business of running a household by making multiple car trips per day, to the operation of giant centralized schools with their fleets of yellow buses.... To some degree, all the non-fossil fuel energy sources actually depend on an underlying fossil fuel economy. You can't manufacture metal wind turbines using wind energy technology. You can't make lead acid storage batteries for solar electric systems using any known solar energy systems.[51]

Similarly, the construction of nuclear power plants and hydroelectric projects require enormous inputs of fossil fuel energy. The mining of coal is heavily dependent on the cheap availability of diesel fuel to power mining equipment, and the development of non-conventional oil such as the tar sands of Alberta or Venezuela require enormous energy inputs (up to two thirds of the energy contained in a barrel of tar sand oil must be spent to produce it) to extract and refine the oil.[52] At present, this energy source comes from natural gas, but there are increasing indications that natural gas production in North

[51] James Howard Kunstler, *The Long Emergency: Surviving the End of the Oil Age, Climate Change, and Other Converging Catastrophes of the Twenty-First Century*. New York: Atlantic Monthly Press, 2005, p. 100.
[52] Richard Heinberg, *The Party's Over*, p. 60.

America is peaking as well.[53] Neo-classical economists are quick to point out that unconventional oil such as the Albertan tar sands, which is unprofitable to produce when oil sells for $20 a barrel, becomes profitable and is added to the world's oil reserves when prices increase. However, these economists fail to take into account thermodynamic limitations to the production of nonconventional oil. As it now stands, the easiest to access tar sands require two thirds of a barrel of oil equivalents to produce a barrel of tar sand oil, with the energy source coming from declining reserves of natural gas. The crucial question for tar sand production is not so much market prices of oil, but the thermodynamic efficiency of producing the oil. Production of oil becomes impossible, regardless of the market price for oil, if it costs more than a barrel of oil in energy terms to produce a barrel of oil.[54] While the possibility that capitalism will develop some new non-carbon based alternative source of energy cannot be ruled out, fossil fuel dependency and the reaching of the peak in global oil and natural gas production does represent a serious problem for capitalism, and one which will be played out on the terrain of class struggle, a point to which we will return later.

If he did not adequately address the question of fossil fuel energies in steam engines, Marx did accord a central position to energy considerations in his understanding of labor power, which he treated as a metabolic-energetic process. As Burkett and Foster argue, Marx described labor power as being "above all else, the material of nature transposed into a human organism" -- or, in an alternate translation of the same German phrase, "energy transferred to a human organism by means of nourishing matter."[55]

[53] James Howard Kunstler, *The Long Emergency*, p. 102-110.
[54] Richard Heinberg, *The Party's Over*, p. 62.
[55] Paul Burkett and John Bellamy Foster, "Metabolism, Energy, and Entropy," p. 9.

Burkett and Foster show how, in drawing on the work of the German energy physiologist Ludimar Hermann and the English physical chemist Sir William Robert Grove, Marx analyzed the energy inputs to human labor required to reproduce various types and intensities of human labor according to thermodynamic principles. As a result, Burkett and Foster argue, "Marx's analysis of the value of labor power clearly incorporates the conservation of energy as well as the inevitability of matter-energy dissipation".[56] They explain the fact that Marx did not use the terms "entropy" and "thermodynamics" because "these terms were only then being introduced into physics and thus were not used widely even within the scientific community when Marx wrote *Capital*."[57]

As Bellamy Burkett and Foster point out, Marx kept up-to-date with the latest advances in science and adopted many of the key approaches of the developing field of thermodynamics to what he termed the "metabolic rift" created by the capitalist division between town and country. At the conclusion to his chapter on machinery, Marx stated that:

> Capitalist production collects the population together in great centers, and causes the urban population to achieve an ever-growing preponderance. This has two results. On the one hand it concentrates the historical motive power of society; on the other hand it disturbs the metabolic interaction between man and Earth, i.e. it prevents the return of the soil of its constituent elements consumed by man in the form of food and clothing; hence it hinders the alteration of the final natural condition for the lasting fertility of the soil.[58]

Marx was greatly influenced by the German soil scientist Justus von Liebig and closely followed the debates surrounding the crisis of soil fertility which were raging in European and North American agricultural circles. Linking the exploitation of the working class to the degradation of the natural environment, and drawing on Liebig's

[56] Paul Burkett and John Bellamy Foster, "Metabolism, Energy, and Entropy," p. 9
[57] Paul Burkett and John Bellamy Foster, "Metabolism, Energy, and Entropy," p. 11.
[58] Karl Marx, *Capital* Vol. 1., p. 637.

analysis, Marx concludes his chapter on machinery and large-scale production with a passage of great relevance for today's looming ecological crisis:

> Moreover, all progress of capitalist agriculture is the progress in the art, not only of robbing the worker, but of robbing the soil; all progress in increasing the fertility of the soil for a given time is the progress towards ruining the more long-lasting sources of that fertility.... capitalist production, therefore, only develops the techniques and the degree of combination of the social process of production by simultaneously undermining the original sources of all wealth -- the soil and the worker.[59]

The problems that agrarian capitalism faced through the divide of town and country and the disruption of the return of nutrients to the soil were overcome by industrial capitalism through the use of synthetic fertilizers derived from fossil fuels (half of the nutrients used annually by the world's crops today are supplied by synthetic nitrogen fertilizer produced from natural gas).[60] Burkett and Foster have gone to great lengths to point out the ecological content of Marx's thought in terms of his conception of labor as a metabolic relationship between humans and their environment, his understanding of labor power in energetic terms and his and Engels' attentiveness to contemporary science. They point out that Marx and Engels:

> relied on an open-system metabolic-energetic model which adheres to the main thermodynamic strictures of ecological economics, but which also (unlike ecological economics) roots the economy's violation of solar and other environmental sustainability conditions in the class relations of production.[61]

They go on to add:

> What Marx and Engels generated in their historical-dialectical materialism was a theory of the capitalist labor, production and accumulation process that was not only consistent with the main conclusions of thermodynamics originating in their time, but also extraordinarily open to ecological laws.... in other words, classical Marxism, contrary to widespread myth, has an extraordinary affinity for what has become known as

[59] Karl Marx, *Capital* Vol. 1., p. 638
[60] Valclav Smil, *Energy in World History*, p. 190.
[61] Paul Burkett and John Bellamy Foster, "Metabolism, Energy, and Entropy," p. 1.

"ecological economics…[62]

However, while Marx developed a coherent ecological critique of agrarian capitalism and developed a framework for the development of a thermodynamically sound critique of industrial capitalism, Marx and Engels did not follow through the logical conclusion of their premise and address the role of fossil fuels in production.

In laying an important framework for the recovery of Marx's Marxism as an emancipatory and ecological body of thought, Burkett and Foster 'bend the stick' too far in refusing to accept that Marx's analysis of capitalist growth processes did not address the crucial role that exosomatic energy sources could play in the growth and potential decline of industrial capitalism. Marx did consider various types of motive power in relation to machinery, and he did understand that physical wear and tear would degrade fixed capital and that the expansion of machine production would require larger amounts fuels and raw materials. But Marx did not adequately recognize the fundamental importance of fossil fuels in breaking the limits of the old organic agrarian capitalist economy, or address the issue of the impact of possible fossil fuel depletion on class struggle as global capitalism became ever more dependent on linking living human labor to fossil fuel energy sources. It is perhaps too much to have expected Marx to have been able to foresee this problem, writing as he was at the beginnings of industrial capitalism when fossil fuels were only just being introduced, but the fact that he didn't, greatly weakened the possibility of developing a revolutionary and anti-capitalist ecological politics.

[62] Paul Burkett and John Bellamy Foster, "Metabolism, Energy, and Entropy," p.28.

The work of the Marxist environmentalist Elmar Altvater is a good example of the kind of approach that is necessary to bridge the gap between ecological economics and Marxism. Altvater argues that the transition to a fossil fuel based energy regime was the basis of creating a truly global order, for "without fossil energies neither the process of capitalist production and accumulation nor the modern monetary world market could exist."[63] Altvater goes on to stress the importance of fossil fuels in breaking the old limits of a solar flow based economic system, and notes that:

> As long as 'the societal relationship with nature' was based on biotic energies, on the soil and the fruit it bore, on the speed and range of an ox or horse-drawn cart, on the tonnage, maneuverability and speed of a sailing vessel and on the art of navigation, the material possibility of overcoming these limits of space and time was slight and the capacity of creating a world order remained restricted.[64]

Although the early industrial system that Marx witnessed in England was not solely powered by fossil fuels, and while Marx did not reflect upon the likely outcome of the depletion of fossil fuels, the methodological contribution that he made by outlining the relationship between the use of machinery in production and the class struggle provides a framework to understand why capitalism is so dependent on machinery. But this Marxist analysis needs to be incorporated into an analysis of the entropic limits to industrial growth, and specifically of the consequences in class struggle terms of the declining availability of fossil fuels. Paul Burkett in seeking to develop a Marxist approach to entropy is quite right to criticize ecological economists for not considering how:

> The social (class) relations of production, and historically specific resource-allocation mechanisms, help define these effective limits and determined the extent to which they

[63] Elmar Altvater, "Global Order and Nature" in Keil, Roger *et al.* eds. *Political Ecology: Global and Local.* London: Routledge, 1998, p. 27.
[64] Altvater, "Global Order and Nature" p.20.

> tend to be exceeded. Both authors treat production, knowledge and economic limits as if they develop in a social-relational vacuum.... for example, neither author asks whether a system of production driven by the quantitatively unlimited goal of capital accumulation has a specific tendency to accelerate entropy and overstretch its natural environment and, if so, whether this tendency in any way threatens the reproduction of such a system.[65]

Burkett is right that the greatest flaw of ecological economics is that it naturalizes capitalist production, and while critiquing capitalism's inherently expansive nature, doesn't seek to understand why the logic of capitalism dictates this behavior. Instead of looking to class struggle as a source of revolutionary agency, many ecological economists end up calling for capitalists or the state to regulate the worst excesses of the system. While Burkett is quite right to critique ecological economists for this failing, he makes the significant mistake of discounting the importance of low entropy fuels to maintaining capitalist processes of accumulation. Burkett argues that:

> The entropy law does apply in terms of any given quality of materials and energy available for human production. But it also suggests that, short of human extinction, capitalist reproduction in no way hinges on the maintenance of natural wealth of any given entropy level. In other words, capitalistically-induced crises in the conditions of human development do not necessarily mean crises of capitalist reproduction.[66]

While Burkett's arguments may hold water in an ideal and abstract model of capitalism, they make little sense when applied to the material realities of capitalist production in historical terms. As I have shown in the earlier part of this essay, Marx emphatically argued that the transition to industrial capitalism and the extension of global capitalism did in fact hinge on the availability of large amounts of low entropy fossil fuels paired with machines that could transform this chemical energy into mechanical work. The availability of low entropy sources of energy also has a direct relationship to capitalist reproduction as a whole. Tighter energy markets caused by the declining

[65] Paul Burkett, "Entropy in Ecological Economics: A Marxist Intervention," *Historical Materialism* 13/1 (2005): pp. 130-131.
[66] Paul Burkett, "Entropy in Ecological Economics" p. 118.

availability of low entropy energy sources, as well as a variety of "capitalistically-induced crises" stemming from bad management and the lack of appropriate regulation, have led to power blackouts and brownouts that in disrupting energy supplies to entire urban areas do decisively, if temporarily, halt capitalist reproduction. While situations like the blackout of 2003 in northeastern North America and the rolling brownouts and blackouts that afflicted California in 2001 are by no means everyday occurrences, in an era of declining fossil fuel resources, they could well become routine.

Burkett concludes his article by arguing that:

> For capitalist production, all that matters is that labor-power and material conditions be separately available in forms that can be combined as commodity production by wage labor. Given this precondition, capitalist reproduction does not depend on any particular limit to the entropy level and its matter-energy environment.[67]

What is missing from Burkett's analysis is Marx's understanding of the relationship of machinery to class struggle. Not only do capitalists deploy technological advances to undermine working class self-organization, but increased labor productivity based on stocks of low entropy fuel and the huge wealth generated by it in the imperialist metropoles have substantially increased the standard of living of the working-class, even while capitalists have appropriated the lion's share of this wealth. The "golden era" of capitalist development from 1945 to 1973 was conditioned by many different macroeconomic processes, but one key component in this era of massive economic expansion and decomposition of working-class organization was the huge inflow of cheap energy to Western economies from Texan and Middle Eastern oil fields. While low entropy sources of energy are of course not an independent agent, their existence and control by the capitalist world economy can shape the overall forms of class struggle, as

[67] Paul Burkett, "Entropy in Ecological Economics" p. 143.

cheap energy in the context of expanding production can provide room for capitalists to make concessions in exchange for "class peace" and compliance in reaching increased productivity targets. Similarly, the tendency of productive capital to perpetually bring ever more machinery and raw materials into production can be checked by the availability of fuels needed to power the machinery as well as by the capacity of labor to struggle for higher wages or better working conditions. In this context, variations in the quality of materials and available energy can and do have a direct impact on the demands of labor and the shape of class struggles. Higher entropy fuels such as offshore oil or tar sands require a much greater investment of capital and labor to bring online, and increased costs are passed on to the working class as a whole in the form of higher prices and an increase in the cost of overall means of subsistence. Although Marx failed to draw any conclusions from the possibility of declining low entropy stocks of raw materials, he did deal directly with the point that Burkett raises, and stressed that the quality (or level of entropy) of raw materials available to capital contributes to determining the reproduction and accumulation of capital.

> In so far as they serve as means to absorb labor, as media in and by which labor and surplus-labor are materialized, the exchange-value of buildings, raw materials, etc., is quite immaterial. That which is ultimately essential is on the one hand the quantity of them technically required for their combination with a certain quantity of living labor, and on the other hand their fitness; in other words, not only the machinery, but also the raw and auxiliary materials must be good. The good quality of the raw material determines in part the rate of profit. Good material leaves less waste. A smaller mass of raw materials is then needed for the absorption of the same quantity of labor. The resistance to be overcome by the working machine is also less. This affects in part even the surplus-value and the rate of surplus-value. The laborer consumes more time with bad raw materials than he would with the same quantity of good material. Wages remaining the same, this implies a reduction of the surplus-labor. Furthermore this affects materially the reproduction and accumulation of capital which depend more on the productivity than on the mass of labor employed, as shown in volume I.[68]

[68] Karl Marx, *Capital*, Vol 3 p. 83.

The declining availability of fossil fuels whether from geological or political limitations thus has a direct impact on both class struggles and inter-imperial rivalries for control of the remaining stores of cheap fossil fuel energies. The consequences of rising oil and natural gas prices are most immediately felt by workers and low income people as their costs of subsistence are directly increased. As oil prices rise, the cost of transport to and from work increases, as does the cost of basic food products produced with synthetic fertilizers derived from fossil fuels and formed and transported by oil driven machinery. Oil and natural gas byproducts are used as a feedstock in a wide variety of consumer goods, including synthetic clothing and plastic household goods, and also for a range of industrial applications as well as for power generation. Consistently, where ever there has been a serious interruption of fossil fuel supply or a sharp rise in the costs of fossil fuels, the effects have been felt by the working class and have often resulted in protest and resistance.

In October of 2005, protests spread throughout Indonesia after the government increased the price of cooking fuel by 186% and the cost of gasoline by 88%. Indonesia's fuel subsidies, a victory of earlier working-class struggles, account for more than a third of all central government spending -- more than the budget for health or education -- and are a holdover from Indonesia's years as an oil exporter (Indonesia passed its point of peak oil production in 1977 and is now a net importer of oil.) [69] The impact of higher fuel costs has contributed to political instability in the past, as riots and protests against rising fuel prices in 1998 played a role in the toppling of former dictator Suharto. After the US-led occupation of Iraq, oil rose from a cost of five cents a gallon under Saddam Hussein

[69] "Indonesia clashes over fuel hike", October 1st, 2005, BBC News. http://news.bbc.co.uk/1/hi/world/asia-pacific/4296320.stm.

to $.49 a gallon in December of 2005, a price rise which was met with sustained rioting and protests against the government's policies. In July of 2005 massive fuel riots took place in Yemen, where 22 people were killed,[70] while in March of 2006 riots in Singapore erupted following a protest against rising oil prices led by Malaysian Trade Union Congress.[71]

Perhaps one of the most significant areas of consistent protest has been oil-rich Nigeria, which has regularly seen protests over rising oil prices from oil consumers, oil workers, indigenous peoples and organized labor. In 2003 the Nigeria Labour Congress led workers on a one-week nationwide strike that was successful in forcing the government to reduce fuel prices. In 2004, a four-day general strike took place against fuel price increases, and most recently there have been a series of occupations of oil company installations and the kidnappings of foreign oil workers.

The direct correlation between the costs of subsistence and the affect of increased exploitation were made clear by a Chinese taxi driver quoted in a recent *Washington Post* article chronicling the phenomenon of protests against rising fuel prices:

> Zhang Qihe, 43, a Beijing taxi driver, has seen gas rise from about 91 cents a gallon in 1999 to about $2.30 a gallon now. As a result, he estimates he has to work an extra hour a day to make ends meet. "After a 14-hour workday, I go home exhausted," he complained.[72]

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[70] "Yemen Cuts Fuel Price After Riots", July 27th, 2005, Aljazeera News, http://english.aljazeera.net/NR/exeres/330F9422-C6F9-4C62-8E94-97CD656061AE.htm.
[71] Melissa Goh, "Malaysian police disperse protesters over fuel price hike", March 26th, 2006, Channel NewsAsia. http://www.channelnewsasia.com/stories/southeastasia/view/200017/1/.html.
[72] Paul Blustein and Craig Timberg, "High Oil Prices Met With Anger Worldwide: Both Rich and Poor Countries Make Moves To Appease Citizens", October 3rd, 2005, Washington Post, http://www.washingtonpost.com/wp-dyn/content/article/2005/10/02/AR2005100201315_pf.html.

Neither the effects of oil price increases nor the protests against them are limited to Third World countries. In September of 2000, protests and demonstrations against higher fuel prices rocked Europe. Two thirds of Britain's oil refineries were blockaded by angry truckers, and blockades in France, Belgium, Germany, and Italy forced concessions from governments.[73] Increases to the price of oil are also felt by workers in the US, where it is estimated that every 1 cent increase in the price of gas removes $1 billion dollars out of the pockets of American consumers. While the level of political organization against fuel price increases is much lower in the US than in many other parts of the world, the US working class is being severely affected by fuel price increases, and may move into action should conditions worsen. Both the airline and automotive industries have been devastated by the consequences of high oil prices and there are serious worries that increased consumer spending on gasoline may trigger inflation and a puncturing of the US housing bubble, leading to serious economic hardship.[74]

With the peaking of world oil production capitalism will face a historic turning point. Its new short-term strategies of accumulation will be based upon securing the declining low entropy sources of energy, most of which remain within the Middle East, and striving to boost production to allow for continued economic growth. In the medium term, capitalism, if it is to survive, must shift to some alternative energy source in a manner every bit as transformative and revolutionary as the move from biotic energies to of fossil fuel energy regime was, and end its dependence on fossil fuels. This source of non-carbon based energy must be cheap, nonpolluting, avoid contributing to global

[73] "Fuel protests build across Europe" BBC News, September 10th, 2000. http://news.bbc.co.uk/1/hi/world/europe/919354.stm.
[74] Alexandra Marks, "The Ripple Effect of Prices at the Pump", The Christian Science Monitor, March 26th, 2006. http://www.csmonitor.com/2004/0326/p03s01-usec.html.

climate change, and be capable of integration within existing energy distribution infrastructures. Should capitalism not develop such a source of alternative energy in time, we can expect that the climate change feedback loop will be accelerated as coal and biomass are used to replace declining stores of oil and natural gas. At the same time, international competition for remaining stores of low entropy oil will be accelerated, and dramatic increases to the cost of living will lead to a global intensification of local, national and international class struggles.

As industrial capitalism matures and its machines devour ever increasing amounts of non-renewable fossil fuels, a point of crisis will be reached when capital will no longer be able to externalize its contradictions. What will happen then is anyone's guess, but two points seem particularly relevant for further reflection. Firstly, Rosa Luxemburg's famous posing of the choice between "socialism or barbarism" serves to remind us that the failure of the great revolutionary wave of 1917-1937 was perhaps even more of a historic failure to transform capitalism and the fate of the human species than is commonly recognized. Those committed to the revolutionary overthrow of capitalism would do well to examine the causes and consequences of this defeat and learn from the mistakes of the Marxist movement so as not to repeat it. Secondly, with the depletion of easy to access fossil fuel reserves and the impacts of global climate change, it is becoming increasingly likely that any future communist society will be required to build socialism under conditions of declining labor productivity and under the solar energy constraints left behind by 20th century industrial capitalism. Should this be the case, the implications for Marxist theory and practice are significant, and deserve to be put at the center of a reconstitution of the

revolutionary project, if humanity is to avoid a barbarism far worse than the one that destroyed the revolutionaries of Rosa Luxemburg's generation.

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