OF HAND MILLS AND HEAT ENGINES:

PEAK OIL, CLASS STRUGGLE, AND THE THERMODYNAMICS OF PRODUCTION

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"What people need to hear loud and clear is that we're running out of energy in America."

- George W. Bush, May 2001[1]

"I'd put my money on solar energy...

I hope we don't have to wait until oil and coal run out before we tackle that."

- Thomas Edison, in conversation with Henry Ford and Harvey Firestone, March 1931[2]

INTRODUCTION

In what will unquestionably be one of the decisive turning points in the history of capitalism, the peaking of world oil supplies is approaching. Estimates vary as to whether global production of crude oil has already peaked or whether it will take another ten or twenty years to do so, but it is clear that such a peak will have far-reaching consequences for the whole of humanity and the world's political economy. The term "peak oil" refers to the moment at which humanity reaches its highest point of total global oil production, which roughly coincides with the half-way point in total exploitation of global reserves of oil. Once peak oil production is reached, industrial capitalism, in sharp contrast to the first 200 years of its development, will face a future of ever diminishing oil inputs at ever increasing prices. With global agriculture, transportation, industry and military capabilities heavily dependent on oil, and with no ready alternative as yet available to the fossil fuel energy regime, the implications of peak oil are not merely technical in nature, but profoundly social, as the problem dramatically impacts national and international processes of capital accumulation and class struggle, the nature of inter-imperialist rivalry, and questions of political ecology.

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[1] Quoted in Ronald Bailey, "Energy Independence: The Ever-Receding Mirage", July 21, 2004. http://www.reason.com/rb/rb072104.shtml.

[2] "Quote of the Week," *Post Carbon Institute*, http://www.postcarbon.org/flexinode/list/14.

The edifice of global capitalism has been built upon an underlying energy regime which is about to enter a prolonged process of decline, thus necessitating a fundamental reshaping of social relations – into either a capitalist barbarism marked by bloody "resource wars" and ecological catastrophe, some kind of international socialist order that has broken the bonds of capital and reshaped human economic processes to the flow of available renewable energy resources, or the development of a new and higher stage of capitalism under a different energy regime capable of continued economic expansion and of rehabilitating near exhausted conditions of production. Regardless of which of these paths humanity takes, each represents a fundamental break with the energy regime that underlies today's capitalist mode of production, and this process of transformation is bound to open up new arenas of political struggle and social contestation in every corner of the world.

The first part of this paper is historical and analytic in its focus, looking at the role of energy in the development of human society and seeking to examine the thermodynamics of capitalist production in order to answer the question as to why capitalism has consistently required increasing energy inputs in order to maintain its accumulative processes. I will argue that the great increase in labour productivity, and thus surplus value extraction, which occurred with the introduction of industrial capitalism was due to the development of an energy regime based on fossil fuel stocks which overcame, through technological innovation and social enclosure, an energy regime based on the flow of solar energy. The second part of this paper analyzes the literature and current debates on the timing and consequences of global peak oil production and provides an overview of the debates around peak oil, the consequences of increased competition for fossil fuel reserves, and a look at the possibility of alternative energies making up for declining fossil fuel production. Ultimately, my aim is to develop a historical materialist analysis of energy appropriation that may be of use in assessing the rise of the capitalist system and the consequences and nature of the struggles and social upheavals on the other side of the peak oil depletion curve.

PART 1. CLASS STRUGGLE AND THE THERMODYNAMICS OF PRODUCTION

The term "peak oil" was originally coined in the 1940s and 50s by petroleum geologist M. King Hubbert, who applied his knowledge of individual oilfields to national oil production in the US and in 1956 accurately predicted that US domestic oil production would peak in the early 1970s. Oil extraction in any given field, and in the aggregate, generally follows a typical bell type curve, with the highest quality and easiest to extract oil flowing out from the largest and easiest to find oilfields. Once this "low hanging fruit" has been exhausted, production shifts to oil of lower quality in smaller fields or offshore, and to other non-conventional sources of oil such as tar sands or shale oil, all of which lead to diminishing returns on the energy invested in finding and developing oil. The peaking of world oil production does not mean that the world will suddenly run out of oil, as approximately one half of the world's oil reserves will remain, but it does mean that most of the world's cheap oil will have been extracted and that there will be an accelerating and continuous decline of annual world oil production as costs mount and ever greater capital investments and energy inputs are required to extract the remaining stores of oil.[3] While the precise date of global peak oil production will likely not be known until after it has passed, and while new technologies, economic recessions, or energy conservation can slow the onset of global peak production, a number of important oil-producing regions have already peaked in their conventional oil production. Data from the Geneva-based Petroconsultants group indicates that conventional crude oil production[4] peaked in the United States in 1970, in the former Soviet Union in 1987, in Iran in 1976, in Canada in 1973, in Libya in 1969, and in Venezuela in 1970.[5] The 2005 British Petroleum annual statistical report confirms peaking for over 10 of the world's 49 main oil producing countries, although their statistics for national oil production include crude oil, shale oil, oil sands and natural gas liquids, thus conflating the production of conventional crude oil with various nonconventional substitutes.[6] This leaves the Middle

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[3] Richard Heinberg, *The Party's Over: Oil, War and the Fate of Industrial Societies,* Gabriola Island: New Society Publishers, 2003. pp. 88-91.

[4] Conventional crude oil refers to the "light" or sweet oil that makes up the overwhelming majority of all oil that has been produced to date. Non-conventional oil refers to alternatives to this oil such as the oil produced from tar sands, oil shale, coal bed methane, as well as deep water and polar sources of crude oil.

[5] This information comes from Richard Duncan of the Institute on Energy and Man from a presentation to the Geological Society of America, on November 13, 2000, quoted in Richard Heinberg, *The Party's Over*, p. 103. The Association for the Study of Peak Oil also has a chart with information on world oil production up to 2004 confirming this data at http://www.peakoil.net/uhdsg/world_summary_html.htm.

[6] Oil statistics are notoriously hard to pin down even in regards to such basic issues as total global oil use. For example, OPEC reports world production totals of 93.8 and 99 Mb/d for 2000 and 2004 respectively, while the British Petroleum's *Statistical Review* reports 74.95 and 80.26 Mb/d for the same years. (Colin J. Campbell, *Newsletter No. 57,* ASPO Ireland, September 2005). One of the "largest, most accurate, private

East as the only sizable oil-producing region that has yet to peak, and not surprisingly, the key prize in any struggle to control the world's remaining oil supplies.

The general problem of peak oil comes down to a question of the cost, quality and quantity of the energy inputs required for an industrial economy dependent upon energy for its reproduction. But because the problem of peak oil confronts a specifically capitalist economy rooted in patterns of uneven global development and marked by class rule, the "solutions" to peak oil under a capitalist framework are conditioned by the profit based needs of the world market. Consequently, responses to the energy crisis that make sense from a thermodynamic standpoint (the re-development of local and small-scale agricultural production within cities and suburbs, the introduction of affordable mass transit as opposed to individual vehicle ownership, the elimination of planned obsolescence in consumer goods, and ultimately the development of a "zero growth" economy with a declining world population) are constrained by the economic logic of capitalism which must by definition place profit before the satisfaction of human needs or the well-being of the biosphere. Because of the historical link between increased economic productivity and increased energy use,[7] and the "grow or die" process inherent in capitalist accumulation, the expansion of capitalism is linked to thermodynamically wasteful processes driven by the interests of powerful corporations and states. Initiatives that could reduce energy inputs into the economy by encouraging local production for direct use as opposed to production for exchange on the world market are not only seen as a potential threat to an economic system based on commodifying and profiting from all forms of human activity, but are consistently targeted for takeover by dominant units of capital.[8] The problem of peak oil and energy inputs into economic production is thus not only tied to the material limitations of thermodynamic, geological and biophysical processes, but also to the specific social relations of a given mode of production.

Due to the convertible nature of different forms of energy within the structures of industrial capitalism, I argue that the capitalism has in an overall sense been able to draw a similar kind of "surplus product" from fossil fuel energies as it has from human labour power – and that this energy surplus has been used to not only minimize the contradictions between capital and wage labour in core areas of the world system, but to militarily and economically dominate "peripheral" areas of the globe. Ultimately, the labour process under industrial capitalism makes it possible to equate human and

databases" in the world is that of Petroconsultants in Geneva which has merged with IHS Energy Group and which is the database used by the members of the Association for the Study of Peak Oil. (Sonia Shah, *Crude: the Story of Oil*, New York: Seven Stories, 2004, p. 143).

[7] See Cutler J. Cleveland *et al.* "Energy and the US Economy: a Biophysical Perspective" in *Science* Vol. 225, August 31st, 1984 and Cutler J. Cleveland *et al.* "Aggregation and the Role of Energy and the Economy" in *Ecological Economics* Vol. 32, 2000.

[8] This has been the tendency throughout the history of capitalism as larger units of capital have displaced small-scale producers and replaced subsistence production of use values with the production of capitalist exchange values. This practice is rendered operable through agreements and institutions produced by the World Trade Organization, the IMF and the World Bank as well as various bilateral and multilateral "free trade" agreements.

nonhuman energy inputs within a historically specific set of technological and social relationships. The incredible "productivity" of the capitalist mode of production is due to two interlinked phenomena – the dispossession and domination of alienated and exploited human labor power and its use under "scientifically determined" processes of management *and* the incorporation of this "abstract" human labor power into production processes with ever-increasing quantities of energy capable of mechanical work and of transforming raw materials. Through increased reliance upon fossil fuels to power economic processes and by the continual economic expansion that such fuels allow, capitalism has tried to displace its spatial and temporal crises through low entropy energetic flows into this "industrial technomass."[9]

Conventional oil has long represented a cheap and condensed energy form readily integrated into the economic and military capabilities of the capitalist system. With world oil production peaking, there will be a steadily declining amount of oil energy available to power these accumulative and military processes. Continued expansion could be maintained if capitalism is able to switch to a new energy source compatible with current infrastructure and capable of being used at relatively cheap cost. However, present alternatives are not as efficient, available, or energy-rich as conventional oil, and while the possibilities of the development of new energy forms such as fusion cannot be completely disregarded, they cannot be taken for granted either. The problem of peak oil thus raises several important questions related to energy and capitalist production, and specifically to the production of societal surplus through the fixed capital and machinery powered by fossil fuels upon which industrial capitalism is so dependent. The problem of peak oil can be most effectively addressed when viewed in the historical context of capitalist development and by attempting to understand the historic rise of one of the most profound social and technical revolutions in human history – the substitution of stocks of fossil fuel for the flow of solar energy. In the course of this discussion I hope to outline a tentative analysis of the specific characteristics of industrial capitalism's relationship to energy as it affects accumulative processes, the terrain of contemporary class struggles, and the problem of peak oil, without either ignoring biophysical processes within the economy or succumbing to energy reductionism, two problems which have plagued much of the debate on this question.

[9] I am using the term "technomass" as developed by Al Hornborg who compares it to the biomass produced by living systems. As Hornborg notes: "… both biomass and "technomass" represent positive feedback processes of self-organization, where the system's use of harvested resources is "rewarded" with new resources in a continuing cycle. Both are dissipative structures, requiring inputs higher than outputs and subsisting on the difference. A crucial difference is that biomass is a sustainable process whereas technomass is not." Biomass is sustainable because it draws its energy inputs from solar flow while technomass gets its inputs from finite stocks of fossil fuels. Technomass is produced by human social activity while biomass is produced from nonhuman sources. However, under capitalism the two are in conflict as ultimately technomass "competes with biomass for living space on our planet." (Hornborg, *The Power of the Machine*: *Global Inequalities of Economy, Technology, and Environment,* New York: Altamira Press, 2001, p. 17).

ENERGY AND MODES OF PRODUCTION

Energy is a measure of everything, its presence a determinant of the capabilities of all physical processes and the rate at which they can occur.[10] Energy expresses itself as constant motion, beginning at the atomic and molecular level with vibrations and movements which are manifested in what we feel and measure as heat.[11] Every substance in the universe has a measure of internal energy within its atomic structure, and energy itself comes in many different forms– as light and radiation released from the sun; as chemical energy, created when the bonds between different substances are combined or released; as kinetic energy, the muscle power of various living beings; as heat energy, the difference between bodies at different temperatures; and potential energy, a force displayed by bodies in motion or under the pull of gravity. The most significant characteristic of energy for the purposes of this study is that it is capable of being converted and reconverted between its various forms by geochemical and physical systems including those created by human beings.[12]

According to the first law of thermodynamics, energy can neither be created nor destroyed, but it can be converted between various states, and is dispersed or concentrated by physical and chemical processes. The second law of thermodynamics states that in a closed system receiving no external energy inputs, the level of entropy, or disorder, will tend to constantly increase. Thermodynamic order or low entropy in one place is only made possible by larger disorder or entropy elsewhere. The universe itself is a closed system whose overarching tendency is to dissipate available energy by constantly expanding, with heat energy inexorably moving from hot to cold substances, progressing to an ultimate uniform "heat death" some billions of years from now.[13] The earth and our solar system compose an open system that produces order and life based upon a constant flow of energy in the form of radiation from the sun.[14] Certain physical, chemical and biological processes, such as gravity, photosynthesis and the recycling of carbon and other nutrients in natural cycles, are able to produce transformations and concentrations of low entropy energy-matter which can then be utilized by animals and human beings. While these processes can create new stores of low entropy, they do so by conserving only a

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[10] Howard T. Odum, *Energy Basis for Man and Nature,* New York, McGraw-Hill, 1981, p. 17.
[11] Howard T. Odum, *Energy Basis for Man and Nature* p. 18-19.
[12] For example, light energy created from fusion reactions in the sun reaches the surface of the earth, where its heat causes water to evaporate which then falls as rain on ground above sea level. As it flows into rivers this water gathers potential energy which can be transformed into mechanical work by a human-built waterwheel used to thresh grain to be fed to domesticated animals. These animals can then provide motive power in agriculture and transportation or become food energy for humans.
[13] One of the best contemporary books on the relationship of thermodynamics to the natural and social sciences is *Into the Cool: Energy Flow, Thermodynamic and Life,* Chicago: University of Chicago Press, 2005 by Eric D. Schneider and Dorian Sagan.
[14] All of earth's energy is ultimately derived from solar radiation with the exception of relatively small amounts of geothermal heat rising from the interior of the planet and the effects of the moon on the tides. See David Goodstein*, Out of Gas: the End of the Age of Oil*, New York: W.W. Norton & Co., 2004. pp. 41-57.

small fraction of the energy flow required to produce them, with a much larger share of the energy being dispersed and degraded.[15]

In using these stores of energy, whether in the form of biomass, vegetables and grains, animals raised on these vegetable and grains, or stocks of fossil fuels produced from sunlight millions of years ago, human beings inevitably dissipate their energy through our social metabolism with nature. A substance like coal or oil (created over millions of years by the decay of organic matter energized by the sun and compressed and chemically transformed by gravitational forces), has a high quantity of free energy (a low amount of entropy) that can be transferred from chemical energy into mechanical energy. However, as this coal is transformed into free energy available for our use (via, for example, a heat engine) energy is dispersed into the environment that is never again available to us because it has now been diffused.[16] Therefore, from an economic standpoint it is important to distinguish between quantities of free or low entropy energy and high-entropy energy. For example, fossil fuels have enormous quantities of free (or low entropy) energy which can be easily appropriated, while the vast amounts of solar radiation stored as heat in the world's oceans (while performing an important role in regulating the earth's temperature and atmosphere) cannot be appropriated to do work in economic processes by human beings because they are not concentrated, but rather dispersed across a wide area as high entropy energy. Fossil fuels are unique because the free energy available within them can be converted into work useful to human beings through combustion in "heat engines" – mechanisms that transform the chemical energy of fossil fuels into thermal energy or heat, which in turn can be used to compress gases (water vapor or air) to produce mechanical power or "work". Historically the first machines developed to tap into solar flows of energy were windmills and water wheels used for drainage or milling purposes. But because of the relatively low energy flow and seasonal variation of these sources of energy, their contribution to mechanical work was limited by their location and scale.[17] The integration of fossil fuels and heat machines into the economic process in the course of the industrial revolution was an innovation of world-historic proportions, and one inexorably linked to the rise of capitalism, which due to competitive pressures, sought to raise productivity and discipline workers through the use of fossil fuel powered machines.

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[15] As Rolf Peter Sieferle points out "an annual average solar radiation of c. 4-8 x 10^6 kJ arrives on a square meter of the earth's surface, depending on latitude, clouding etc. About 1-5% can actually be fixed and stored photosynthetically by plants. The vegetative biomass of autotrophic organisms is the energy source for all animal or heterotrophic life. Plant eaters (herbivores) can only use about 10-20% of the energy stored by their food and carnivores 10-20% of the energy in herbivores. That is to say, the available energy and food declines by a factor of 10 on every trophic level, which means that the need for space increases by an order of magnitude." See Rolf Peter Sieferle*, The Subterranean Forest: Energy Systems and the Industrial Revolution*, Cambridge: White Horse Press, 2001.

[16] Nicholas Georgescu-Roegen, *The Entropy Law and the Economic Process*, Cambridge: Harvard University Press, 1971, p. 5.

[17] Jean Gimpel, *The Medieval Machine: the Industrial Revolution of the Middle Ages*, New York: Penguin Books, 1976, p. 7.

In the context of the development of industrial capitalism, vigorous debates occurred within different schools of political economy over the "laws of motion" of this new economic system. Some of the most important contemporary theorists of the rise of capitalism were writers such as Adam Smith, John Stuart Mill and David Ricardo who sought to analyze the value and price of goods and the economic relationships between nations and classes in appropriating surplus product. Karl Marx and Frederick Engels became theorists of capitalist production and the new working-class politics that was called into being by the splitting of society into two antagonistic classes – bourgeois and proletarian. While many of the bourgeois writers on political economy argued for repealing taxes, increasing the range of the free market, and removing feudal customs and controls over production, Marxists sought to explain and change the world from the perspective of the new industrial working-class created in the burgeoning factories of capitalism.

The Marxist emphasis on the centrality of human labour to production relations (and thus to relations of exchange and consumption) was central in undermining the arguments of capitalist ideologues who claimed that all societal surplus was created by the abstinence, moral values, and the entrepreneurship for of the ruling elite who claimed all wealth other than that which they exchanged for worker's wages (at "fair" market prices). But while the importance of human labour in the production process and in the development of human civilization is undeniable, there is another factor bound up with the use of human labour which has almost always been overlooked by contemporary economists, both Marxist and neo-classical: the role of non-human energy inputs to production. At all levels of human production it has been not just labour in general which has secured human development, but human labour directed at unlocking the power of other forms of energy to substitute for and enhance the capabilities of human labour.

In his study of the role of labour in the "transition from ape to man," Engels accorded a primary role in human evolution to the development of socialized labour achieved through manual dexterity and the acquisition of speech, but he pointed out that the energetic underpinnings of this process – the move to a meat-based diet and its connection to two significant modes of exosomatic energy appropriation, the mastery of fire and the domestication of animals and plants – provided the material basis to allow this process to occur.[18] The discovery of fire in particular, and its use in appropriating the energy contained in biomass (dried wood and plant life) to scare off predators, provide warmth and light, cook and preserve food, and hunt large game extended the climatic range in which humans could settle and undoubtedly contributed to the development of human culture. The use of fire and the domestication of animals whose work was appropriated for transportation and agricultural purposes exemplify the fact that from its very beginnings, human social and physical evolution has been based upon increasing exosomatic human energy consumption.

[18] Frederick Engels, *Dialectics of Nature*, New York: International Publishers, 1976, p. 287-288.

Although the Marxist tradition has rightfully been wary of attempts at "energy reductionism" that take away from the primacy of social relations between class forces and that reduce human production to the counting of calories,[19] there are important grounds for an analysis of the energetic basis of different modes of production. Engels envisioned a variety of different stages through which humanity had progressed. While subsequent historical and anthropological work has discovered limitations to some of Engels' conceptions, it remains useful to look at the modes of production of various different types of society (hunter gathering, pastoralist, slave societies, sedentary agriculture, and more recent feudal and industrial capitalist social formations) in regards to their relationship to the appropriation of energy resources. As modes of production, they are themselves dependent upon and have distinct relationships to specific kinds of energy appropriation or underlying "energy regimes."[20]

Indeed, while it is important not to fetishize energy inputs into production, and thus lose track of the social relationships that shape the character of this energy appropriation, it does need to be stressed that changes in energy appropriation may have far-reaching impacts upon a mode of production. For example, Lynn White, a 20th century medievalist scholar, stressed the importance of understanding the energetic underpinnings of the creation of feudalism. He argued that the development of European feudalism was predicated upon new forms of human energy appropriation that enabled the reshaping of social relations. In particular he claimed that the invention of the stirrup in the 8th century dramatically increased the possibility of human appropriation of animal energy for military conflict, thereby unleashing a series of developments culminating in a new mode of production. The heavy cavalry that the stirrup made possible was so militarily successful against foot soldiers that the Carolingian empire of Charlemagne sought to maintain this military force by confiscating church lands and assigning them to vassals on the condition that they provided levies of heavy cavalry in times of war.[21] The increased energy requirements to raise heavy cavalry in a manorial system and the use of the horses themselves in agricultural production led, White argues, to a series of important breakthroughs in food production, as a three-crop field rotation of grains and legumes was developed in order to produce the higher quantities of grain necessary for feeding horses, and the technological breakthrough of the horse drawn heavy plow contributed to increased population, urbanization and production in Europe.[22] The military strength that was concentrated in this new feudal order and its heavy cavalry proved of great significance in the successful Norman invasion of England in 1066. As a result of the Norman victory, the juridical and economic structures of England were reshaped to allow a purer and more dynamic form of feudalism that, as Ellen Wood has argued, eventually provided the basis for the

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[19] See John Bellamy Foster and Paul Burkett, "Ecological Economics and Classical Marxism - The "Podolinsky Business" Reconsidered*." Organization & Environment,* 17 (1): March 2004. pp. 32-60.

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

[21] Lynn White Jr., *Medieval Technology and Social Change,* Oxford: Oxford University Press, 1962, p. 4-5.

[22] Lynn White Jr., *Medieval Technology and Social Change,* p. 75-76.

economic surplus and political/legal arrangements necessary for the breakthrough of agrarian capitalism.[23]

White's arguments need to be put in a larger social context, for is not simply the availability of a new source of energy that propels a society into a new mode of production, but rather a combination of different social factors and relationships between classes that are defined within certain energetic limits. For example, in the 11th century, under the Northern Song dynasty, the Chinese used coal to make iron on a scale unmatched until the European industrial revolution some 700 years later. Private industrialists owned coal fed blast furnaces worked by wage labourers, who produced more than 35,000 tons of pig iron annually, more than Britain was capable of producing in the early 1700s. The focus of this production was to equip the Chinese military for war, and in a single coal-rich area workers produced 35,000 swords, 8000 iron shields, and 10,000 iron spears in a years work.[24] But because coal mining and iron production was directed by a tightly controlled imperial state, and because capitalist processes of commodification of labour and dispossession of peasants were inhibited by political factors, the Chinese did not develop an industrial capitalist society, although they did possess the energetic and technical basis for the development of such a society. Energy inputs, especially those from fossil fuels, can allow the building of larger and more socially complex societies, but the human beings that make history are constrained in the kinds of choices that they can make by a wide variety of social, political and environmental factors. When the English ran out of easily accessible wood in the 14th century to smelt iron, they began shipping iron ore to Ireland to be smelted. Ireland had very little in the way of iron reserves, but its forests could be and were turned into charcoal and used to produce iron for the English. However, if England had not had the massive and easily accessible coal reserves that it did, it is likely that it would never have been home to the world's first industrial revolution nor have achieved its position of global imperial dominance.[25]

Class societies are a relatively new development in human history, emerging some 8000 years ago when for the first time a significant societal surplus was produced (from the technological and energy gains realized in the Neolithic Revolution) and was appropriated by a dominant class which created political structures to facilitate this appropriation. In all precapitalist class societies, the state had the foremost role in extracting surplus from direct producers who for the most part controlled their own means of production. As Ellen Meiksins Wood argues, the development of capitalism differs from other modes of production because of the form of its dispossession of direct producers from their means of subsistence.[26] Instead of economic surplus being appropriated through forms of "extra-economic" coercion, surplus came to be extracted

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[23] See Ellen Wood, *The Origins of Capitalism: A Longer View,* London: Verso, 2002.
[24] Barbara Freese, *Coal: A Human History,* New York: Penguin Books, 2003, p. 206.
[25] Stanley Jevons, *The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-Mines*, Macmillan: 1865. p 245.
[26] See Ellen Meiksins Wood, "The 'Economic' and the 'Political' in Capitalism" in *Democracy against Capitalism: Renewing Historical Materialism,* Cambridge: Cambridge University Press, 2000.

through the commodification of human labor power. Peasants dispossessed from their lands through processes of enclosure were forced to sell the only thing they had left, their power to labor, to capitalists who owned the means of production. Because the labor power as a commodity had the advantage of being able to produce more than its cost of reproduction, Marxists locate the basis of capitalist profit in the surplus value extracted from workers by capitalists over the course of the working day. From this perspective the struggle at the point of social production becomes key as if the capitalist is unable to get workers to do more work than that equivalent to their wage, no surplus value is produced regardless of the specific energy regime. In competing against rival capitalists labor productivity must be raised so as to be able to deal with increased demands from workers and yet still provide a larger amount of surplus value that can go to profits and reinvestments in the production process. Technology and increased inputs of energy are one important way in which productivity can be increased, but it would be a mistake to see technology as a one-sided relationship. Ultimately, as Wood argues, technology and class relations are intricately bound up in specific modes of production:

> A mode of production is not simply a technology but a social organization of productive activity; and a mode of exploitation is a relationship of power. Furthermore, the power relationship that conditions the nature and extent of exploitation is a matter of political organization within and between the contending classes. In the final analysis the relation between appropriators and producers rests on the relative strength of classes, and this is largely determined by the internal organization and the political forces with which each enters into the class struggle.[27]

The development of industrial capitalism required both new energy-intensive forms of production and energy-intensive food stuffs to employ and feed the workers of this new mode of production. This process developed in a deeply interconnected way. The North Atlantic cod fisheries played a central role in providing preserved high-protein foods for both the labouring population displaced from the English countryside and the millions of slaves working on the plantations of the new world who were overwhelmingly engaged in commodity production for Europe rather than producing foodstuffs that could be used for their own subsistence. One of the primary commodities produced by the labour-intensive work of African slaves was sugar – a high-energy food stuff loaded with calories and in high demand by the industrial working-class in Europe. The profits realized from slave labour in the new world provided a store of wealth which helped to finance the invention and production of Watt's steam engine, which was used to drain the mines for increased coal production.[28]

The use of new and improved steam engines led to the de-localization of early factories built near streams and rivers and led to the possibility of their dramatic expansion in scale, the rapid urbanization of English society, and the development of forms of mass transportation such as the railway. The industrial revolution of the 19th

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[27] Ellen Meiksins Wood, "The 'Economic' and the 'Political' in Capitalism"*, p.*

[28] See Eric Williams, *Capitalism and Slavery*, Chapel Hill: University of North Carolina Press, 1994, p. 102-103.

century was powered by coal, which enabled the creation of a "virtuous cycle" of production between the coal, iron, and railway industries.[29] Similarly, the advent of mass production, and the rise of the mass consumer culture that came with it was made possible by the transition from coal to an even more energy-rich oil-based economy by the first quarter of the twentieth century. Why this route of increasing mechanization and industrialization was chosen and has been maintained over the last several hundred years has to do with the inner dynamics of capitalist production, its drive to replace living labor by machinery, and its constant search to expand its own accumulative processes, but capitalist production could of never have expanded across the world and successfully avoided the threat of working-class revolution without the construction of an industrial order that could draw ever-increasing amounts of fossil fuel energies from the bowels of the earth.

The kind of analysis attempted above is inevitably subject to the limitations of space, but the underlying argument is that methods of energy appropriation fundamentally shape the potential development of various modes of production in specific historical eras and that the sources and continued viability of these energy regimes refract upon and affect social relationships. This insight is nothing new, and it is in fact in keeping with Marx's insights regarding the historical development of social classes. As Marx argued:

> Social relations are closely bound up with productive forces. In acquiring new productive forces men change their mode of production; and in changing their mode of production, in changing the way of earning their living, they change all their social relations. The hand-mill gives you society with the feudal lord; the steam-mill society with the industrial capitalist.[30]

Crucially important to Marx's analysis is the placing together of the development of productive forces in all their complexity with social relations that are not "natural" or eternal, but determined by the class relationships of the human beings involved, through the kinds of societies they build and the forms of energy they appropriate in production. The perspective that Marx outlined time and again in his work is one which recognizes the material (and thus energetic) basis of specific forms of social production, but which does so without losing sight of the underlying relations of production between classes in specific historical circumstances.

While Marx was aware of the roles of modes of production and different processes of energy appropriation in determining what kinds of class society were possible, the scientific revolution initiated by the discovery of the laws of thermodynamics occurred late in his life and he did not explicitly develop an analysis of capitalist production as it related to a fossil fuel energy regime. To a certain degree this is understandable because the nature of an energy regime tends only to become noticeable when it enters a transition period or goes into crisis. As long as fossil fuels or another low entropy source of energy is readily available and easily integrated into the capitalist

[29] Barbara Freese, *Coal: A Human History,* p. 66.
[30] Karl Marx, T*he Poverty of Philosophy*, Moscow: Foreign Languages Publishing House, p. 109.

economy the energetic side of production is easily ignored. What the laws of thermodynamics developed in the later years of the 19th-century pointed out however, was that while the total amount of energy in the universe was conserved, the quality of this energy was constantly being degraded by economic production based on stocks of fossil fuels. Lacking a thermodynamic perspective, Marx saw fossil fuels as fundamentally no different from renewable sources of energy such as water[31] while Engels discounted the insights of the second law of thermodynamics altogether seeing it as an "absurd theory" that would be seized upon by clerics and theologists to prove the imminent end of the world.[32] The theorization of the relationship between capitalism and energy resources has been generally neglected by Marxists although it has become a central foundation of the discipline of ecological economics, where the specificity of capitalist forms of exploitation and social organization have unfortunately been left largely unexamined.[33]

After the death of Marx, the laws of thermodynamics arose as a fundamental critique of Newtonian mechanics and led to a profound crisis in materialist thinking. As Kenneth Stokes argues, this led to a bifurcation in materialist thought along the lines proposed by two important thinkers, Ernst Mach and Frederick Engels. Mach argued that materialism could be replaced by a phenomenalistic view of reality that became closely connected with the rise of "phenomenological physics" and the field of "social energetics" while Engels sought to sustain scientific materialist thought by grounding it Hegelian dialectics and positivism.[34] Neither of these attempts to overcome the crises in scientific thought and materialist doctrine was ultimately successful. Engels' dialectical materialism became increasingly reductionist and teleological under the influence of first

[31] Karl Marx, *Capital, Vol. 1*. Moscow: Progress Publishers, 1970, p. 353.

[32] Juan Martinez-Alier, "Marxism, Social Metabolism, and Ecologically Unequal Exchange", a paper presented to the Lund University conference, World Systems Theory and the Environment, 19-22 Sept. 2003, p. 3.

[33] In an exception to this tendency, Marxists John Bellamy Foster and Paul Burkett have done pioneering work in pointing out that Marx himself was an ecological thinker developed his economic thinking based on the "metabolism between man and nature" and who closely followed the work of soil scientist Justus Von Liebig on questions of ecological limits of growth and the metabolism between cities and the countryside. (See John Bellamy Foster, *Marx's Ecology: Materialism and Nature.* New York: Monthly Review Press, 2000. and Paul Burkett and John Bellamy Foster "Ecological Economics and Classical Marxism - The "Podolinsky Business" Reconsidered. *Organization & Environment*, 17 (1): 32-60 March 2004. Marx and Engels corresponded with the Ukrainian socialist and agronomist Sergei Podolinsky over the possibilities of relating energy inputs and human labour to the question of surplus value production and this discussion reveals one of the first divergences between Marxism and the "energy theories of value" proposed by ecological economists. The ecological economist Juan Martinez-Alier has characterized this debate as a missed chance for the development of an ecological Marxism, and the "Podolinsky business" continues to be debated within the ecological and Marxist left. (See Martinez-Alier, "Marxism, Social Metabolism, and Ecologically Unequal Exchange," http://www.humecol.lu.se/-woshglec/papers/martinez-alier.pdf, page 11 and Burkett and Foster, "The Podolinsky Business Reconsidered")

[34] Kenneth M. Stokes, *Man and the Biosphere: Toward a Coevolutionary Political Economy*, Armonk, NY: M.E. Sharpe, 1992, p. 68-69.

German social democracy and then Stalinist Russia, while the doctrine of social energetics became increasingly divorced from any real relationship to class and social struggles.[35]

As Juan Martinez-Alier points out, a series of different economic theorists and historians influenced by the study of the laws of thermodynamics were forerunners of the modern ecological economist tradition and provided theoretical perspectives from which to study the flows of matter and energy as it affected economic processes. William Stanley Jevons, argued that Britain's dominant position in the world economy came from its appropriation of fossil fuels. In a manner virtually identical with the methodology of modern-day peak oil theorists, he pointed out that the British Empire would eventually succumb to rivals (such as Germany and the United States) who had larger and better-quality coal reserves. Patrick Geddes was perhaps the first to examine human history in relationship to the use of energy. The ecologist Alfred Lotka analyzed human and animal evolutionary processes from the standpoint of maximizing energy consumption. Frederick Soddy argued that energy and not money capital was the real basis for all economic growth and Wilhelm Oswald developed an influential doctrine of social energetics seeking to unify science on the basis of thermodynamic laws rather than mechanical ones.[36] The specific problems facing the Marxist movement beginning with the crisis in social democracy during the First World War and the earthshaking experiences of the Bolshevik Revolution and its subsequent degeneration led to a disengagement from debates over energetic and thermodynamic processes in production, and contributed to a present lack of awareness of the existence of earlier Marxist perspectives that could be brought to this debate.

THE THERMODYNAMICS OF CAPITALIST PRODUCTION

Industrial capitalism arose in the context of a transition from an agricultural energy regime based upon solar inputs in which peasant producers created agricultural surplus, to an urbanized fossil fuel energy regime based on the domination of fixed capital over living labour. In the course of developing this new fossil fuel regime, capitalism enclosed the physical territory on which subsistence and small-scale agricultural production was taking place and replaced it with an energy regime based on fossil fuel stocks. By physically enclosing the means of production formerly used by peasants in subsistence agriculture, capitalism divorced them from their means of production and forced them to work within an industrial "technomass" and to create the material preconditions for a new kind of energy regime and a new means of labour exploitation.

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[35] Although limitations of space do not permit an exploration of this topic, the rise of Monism and the debates between Vladimir Lenin and Aleksander Bogdanov are particularly interesting for understanding the historic split between "materialist" and "energetic" theories of history.
[36] Martinez-Alier, *Ecological Economics: Energy, Environment and Society*. Oxford: Basil Blackwell, 1987, p. 8. Also see Kenneth Stokes, *Man and the Biosphere* pp. 66-71.

The capturing and unlocking of fossil fuel energy made it possible for humanity to go beyond the limitations of "biotic energies" dependent upon solar flows of energy. This in turn made possible the development of capitalist globalization by unifying national economies and enabling the projection of economic and military power on a global scale. As Elmar Altvater argued:

> 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."[37]

Altvater suggests that this appropriation of fossil fuel energy made possible for the first time a true "world order" in which "the 'metabolism' of humankind, society and nature reached a global scale."[38] Altvater goes so far as to argue that "without fossil energies neither the process of capitalist production and accumulation nor the modern monetary world market could exist."[39]

An economic system that uses stored-up solar energy in the form of stocks of fossil fuels is capable of dominating modes of production dependent upon solar energy flow. The building of heat engines operating on fossil fuels to power machinery can mass produce high-grade metal ores which, when combined with fossil fuels, formed the basis for industrial production and global military dominance. As the European conquest of the Americas, Asia and Africa proved, biotic energies and organic matter are incapable of successfully resisting the military capabilities deployed by a fossil fuel energy regime. It is the development of a fossil fuel energy regime which accounts for the global spread of European dominance and the ultimate success of projects of conquests and colonization which have shaped the history of capitalism. Nurtured on the one-time gift of millions of years of fossilized sunlight in the form of hydrocarbon reserves under the earth's soil, capitalism used this energetic resource to annihilate the boundaries of time and space and achieve global dominance.

While it is evident that exosomatic energy inputs into productive processes have been crucial in the development of class society through the neolithic and industrial revolutions, energy has been subsumed into the category of "raw materials" by both neoclassical and Marxist economists. Marxists were concerned to place human, and specifically working class, agency at the center of production and thus, like the neo-classical economists, saw non-human energy inputs as merely another "raw material" produced by human labour. Both traditional Marxist and neoclassical economists thus failed to recognize that the secret of capital's success has been its combining of exosomatic energy inputs with a working-class dispossessed of its traditional means of production and relationship to the land. Because energy can be easily converted between

[37] Elmar Altvater, "Global Order and Nature" in *Political Ecology: Global and Local*, p. 20.
[38] Elmar Altvater, "Global Order and Nature" in *Political Ecology: Global and Local*, p. 21.
[39] Elmar Altvater, "Global Order and Nature" in *Political Ecology: Global and Local*, p. 21.

its different forms, different energy inputs can be equated in production processes and become just as "socialized" as abstract human labour itself. Because energy is a force which animates "dead labour" (fixed capital) in combining, transporting, transforming, and/or re-arranging raw materials through a process of mechanical "work" mediated by the production process, its use in industrial capitalism has come to play an equivalent role to human labour power. Consequently, Marxist understandings of the unique contributions of human labour to the production of surplus value need to be reassessed.

My point can be best illustrated heuristically by looking at a simplified production process in the earliest stage of capitalist industrial development. In this example, a capitalist has put together a factory in which he hires labourers to use their muscle power to turn a mechanism which is attached to machinery and fed by raw materials. The application of the labourer's force in turning the mechanism produces a new commodity through the technical mediation of machinery, and the commodity is then sold by the capitalist on the market. In a typical Marxist analysis, the capitalist pays the worker for his labour power as measured in a certain number of hours of work. Within that time, through the input of his work as a motive force (in turning a wheel, wielding a set of tools, monitoring an assembly line, etc.) the worker produces a certain amount of commodities for the capitalist that is always an amount greater in value than what the workers labour time is paid for in wages. The worker's labour power, alienated and directed by the capitalist, is the foundation of a Marxist analysis of capitalism and the Marxist conception of surplus value, whereby it is seen as the only commodity that adds extra value to the production process, because the cost of the labour paid for by the capitalist is less than the value of its contribution to production.

Marx suggested that the labour time purchased and set to work by the capitalist can be divided into two parts, that part which produces a value equivalent to the social cost of sustaining and reproducing the worker (the amount needed for food, clothing, rent, and the raising of a family to ensure a continued supply of new labour power), which is called the "necessary labour" time. The second part of the worker's labour power is known as the "surplus labour" time, in which the worker produces value beyond the amount necessary to ensure his own replacement. The "surplus labour" or "surplus value" which is appropriated by the capitalist is the basis for his profits, and is the engine of continued capitalist growth and development. According to Marx, surplus value can be increased either relatively, through mechanical and technological methods, or absolutely, by making workers work harder or for a greater portion of the day. [40] What for Marx was unique about human labour power was that:

> the value of labour power, and the value which that labour power creates in the labour process, are two entirely different magnitudes; and this difference of the two values was what the capitalist had in view, when he was purchasing the labour power.... what really influenced him was the specific use value which

[40] Karl Marx, *Capital, Vol. 1*., p. 223-224.

> this commodity possesses of being *a source not only of value, but of more value than it has itself.*[41] [Emphasis in original]

The capitalist will go out of business if he is unable to realize a profit or spends more on the subsistence costs of labour power than he realizes in the sale of the completed commodity. No capitalist will employ labour power that does not provide either relative or absolute human labor that can be appropriated. Ultimately, the capability of human labour power to produce a surplus value is determined by the level of the productive forces, the amounts of exosomatic energy inputs that are available *and* the relationship of class forces between employer and worker. Marxists posit the exploitation of surplus value as the source of all value in any mode of production, and consider that both the evils inherent in capitalism and its potential undoing are based upon this relationship of wage labour to capital.

To further explore this question, let us suggest that the motive power of the machinery in our previous example is now derived from animal labour power – by a horse or an ox instead of by a human being. In this case we could distinguish between the amount of necessary labour time required for the animal to provide for its sustenance and reproduction (through the creation of commodities being produced at the other end of this machinery) and the surplus labour performed in excess of this time. Just like human labor power, the amount of exosomatic energy added to the production process is shaped by structures of previous human culture and labour, but it is not qualitatively different than human labour power itself. If we were to connect an internal combustion engine to the same wheel, and power it with oil, a similar argument could be made. That oil would produce a form of labouring power (or mechanical work) as its chemical energy was consumed within the body of the internal combustion engine, providing the power to turn the wheel attached to the machinery. Part of the energy expended in the creation of new commodities would go to ensuring its replacement (measured by the costs of finding, extracting, refining and transporting the oil) while the energy spent beyond that amount would constitute a surplus which would be appropriated and go towards the profit of the capitalist. The amount of energy required to reproduce an energy input is termed the energy return on energy invested (EROEI) and varies for different types of energy according to the technological sophistication of the productive system. This return is in continual flux as it is related to the level of current technological development as well as to the abundance and efficiency of the energy animating the technology used to capture the energy.

I do not suggest that human labour can be banished from the production process or that its product can be assessed outside of historically specific class relationships, but rather that due to the convertible characteristics of energy, various forms of kinetic or chemical energy can be and are made equivalent to human labour power in the processes of industrial capitalist production. As a result of this process of conversion the proportion of human labour power required for given tasks has been steadily reduced by the introduction of exosomatic energy inputs. From an energetic

[41] Karl Marx, *Capital, Vol. 1*., p. 188.

perspective, Marx's statement that only human labour can create more economic value than it costs must be revised, for based on its energy return on energy invested, all forms of low entropy energy used in industrial production can when integrated with machinery produce economic value in excess of its costs. Even at record high prices, oil still costs less than bottled water in the United States, and the energy content of oil is capable of producing a tremendous amount of work when its chemical energy is transformed into mechanical work.[42] Because of the internal dynamics of capitalism as a constantly expanding system chasing after ever-increasing margins of profit, this increased productivity has not meant a comparative reduction of labour times and freeing of humanity from drudgery, as would be the case under a social system not based on commodity production and the realization of profit, but instead has led to a global tendency to bring ever-increasing numbers of workers into production within ever higher ratios of dead to living labour.

Some Marxists would criticize this approach by arguing for the centrality and indeed absolute preeminence of socialized human labour in making both animal power and oil available to the economic process. They would argue that without socialized human labour and a historically specific class-based economic system, a draft animal or a pool of oil has no capability of producing surplus value in and of itself. Thus, the value of an animal or of oil as an economic input is solely derived from the human labour that has made that energy source available as an economic input in the first place (i.e. the labour time that has been necessary to domesticate, breed, feed, and house that animal or the labour time and application of societal knowledge (technology) to discover, extract, refine, and put to use that oil). This argument is indeed valid insofar as without human

[42] A sense of the transformative powers of hydrocarbons in economic production can be gathered from an example provided by Roscoe Bartlett, a Republican congressman who recently made an hour long presentation on Peak oil in the U.S. Congress. In a verbatim congressional transcript Bartlett described the energetic power of oil as follows: "The energy density in oil is just incredible. One 42-gallon barrel of oil, which if you bought it for $50-some and refined it, maybe another $40-some, it would cost you $100 for the refined products of that barrel of oil. But the energy you get from that is the equivalent of 25,000 man-hours of labour. That would be 12 people who did nothing but work for you all year long. Everything they did was for you, and the energy they would expend in that full year is the energy equivalent of one barrel of oil. Now, you may have a little trouble understanding that, but let me give you a little anecdote that may be simpler to understand. A couple of weeks ago we took my brother-in-law and his wife down to West Virginia. And we have a little Prius car, we get 45 miles per gallon, not that time because it was very heavily loaded and we were going up mountains. And the worst mileage we got was 20 miles per gallon in this Prius hybrid electric, hybrid car, carrying this big load up this steep mountain in West Virginia. That was 1 gallon of gasoline. Still cheaper, by the way, than water in the grocery store. But look at the energy in that 1 gallon of gasoline. It took this car, heavily laden, 20 miles up a steep mountain in West Virginia. Now, how long do you think, Madam Speaker, that it would take you or me to pull that car up the mountain? Obviously, we cannot pull it, but we can use a little mechanical advantage and get it up there. It is a winch called a come-along and there is a guardrail and there are trees and you can use a chain, and you could get the car 20 miles up the mountain. Do you think you can do it in 90 days? If you did it in 90 days that would be just about the equivalent. By the way, that would be a tough pull. That is a long distance per day to go 20 miles in 90 days pulling your car up the mountain." (Congressman Roscoe Bartlett, "Our Dependence on Foreign Oil" Speech to the US House of Representatives, April 20, 2005. http://www.bartlett.house.gov/.

labour and the application of social knowledge, oil and domesticated animals are indeed worthless to us. But the *a priori* existence of human beings that produce the conditions of their own existence does not challenge the equivalence of these different forms of labouring power because the labouring power contained in a human being, just like that latent in an animal or hydrocarbon molecule, does not come into the world prepared for a production process. Just as fossil fuels and animals must be conditioned as inputs, all human labour power must itself be produced and subjected to different kinds of labour to raise, feed, educate, discipline and organize this new labour power in an appropriate production process. From this perspective, the uniqueness of human labour as an energy source lies in the fact that it is embodied in a reasoning biological organism, and that of all forms of energy it requires the smallest amount of "dead labour" or technological/cultural level of development to be put to use in fulfilling human needs or in creating economic surpluses in class societies. Even at the level of the use of human labour power, it is clear that this labour power has always been most successfully expended in appropriating exosomatic sources of energy for the further growth and development of productive processes, which is precisely the tendency that gave rise to class society, and which has ensured the global dominance of industrial capitalism.

At a low level of technological expertise, human labor is the easiest form of energy that ruling elites are able to appropriate for advancing their interests. However, the problem of disciplining and controlling a vast labouring force arises as a potentially insoluble problem, especially if all "surplus labouring power" is to be drawn from human beings alone. Because capitalism commodifies all aspects of social production and reproduction, creating misery at the same time as it organizes, disciplines and prepares a social force capable of over throwing it – the working-class – its most successful means of containing working class struggle has been to produce technical relationships to make various energy inputs interchangeable in order to reduce dependence on inputs of human labour power as a proportion of the overall energy inputs animating dead labour. In doing this, individual capitals can better compete with each other by increasing the "productivity" of the input of human labour that remains. This productivity is *related* to the amount of exosomatic energy flowing through the productive process, especially in the primary sectors of the capitalist economy (heavy industry, industrial agriculture and transport, etc.), but it *is not reducible to it,* as productivity can be increased in a variety of non-energetic ways. This process allows capital to free itself from human labour which could be withdrawn from production process or used to overthrow it. A concrete and historical example of this process can be found in capital's own abolition of slave labour, which at a certain stage of historical development proved crucial to its accumulation strategies but later became a fetter to the development of a fully-fledged industrial capitalism, in no small part because of the capabilities of slaves to revolt, as displayed in the Haitian revolution.[43] In order to maintain stability, capitalism has used both the forces of global repression available to a fossil fuel mode of production and the sharing

[43] Eric Williams, *Capitalism and Slavery.*

of a small portion of its surpluses with antagonistic classes located at the center of the technomass it has created.

As the preponderence of machinery, or "dead labour" over living labour continues to increase, capital becomes ever more dependent on non-human labouring energy to power production, while human labour plays an increasingly important role in directing the flow of energy into this technomass. The accumulated labour of all past generations that surrounds us today – the cars, airplanes, trains, factories, office buildings, computers, software programs, etc. – can only be used in conjunction with living human labour if fossil energies are present to animate this congealed mass of dead labour. Marx recognized that the productive forces of machinery and human labour could be equated, noting that:

> the machine proper is therefore a mechanism that, after being set in motion, performs with its tools the same operations that were formerly done by the workmen with similar tools. Whether the motive power is derived from men, or from some other machine, makes no difference in this respect[44]

Since the dawn of capitalist society, a key factor in reducing working-class power at the point of production, and in increasing competition with other capitals, has been the use of machinery to replace living human labour and to intensify the directive capabilities of human labour power. When mediated through an appropriate technology, all forms of human labour, *both* mental and manual, can be made equivalent to various non-living energy inputs such as oil, solar power, or wind power. The technological mediation of an internal combustion engine allows us to compare the energy in a liter of oil required to move a box of metal and plastic on wheels a certain distance in a certain time to the kinetic energy of whatever number of humans or horses would be required to push or pull the same object at an equivalent rate. With the development of computers, the electrical energy that animates and enlivens all the dead labour (both human and non-human) embodied in the computer makes it possible to compare its capacity to calculate with that of an average human being. If a production process at a higher level of capitalist development requires that a "worker" have the mental abilities necessary to win a chess game, then human mental powers socialized in the appropriate way (i.e. that involve the learning of chess) plus the energy required to feed and house that human being can be compared and made equivalent to the non-human energy (e.g. oil) required to power the computer and the technological knowledge and production required to produce computer hardware and software and its chess playing program to perform at the same level.

Machinery and the Social Organization of Production

[44] Karl Marx, *Capital, Vol. 1*., p. 353.

While we have focused thus far on how capitalist machinery has increased the production of surplus value by appropriating the "surplus energy" within fossil fuels, capital has also used machinery as a means of disciplining and organizing the work force that administers and works these machines and which remains the only force capable of overcoming capitalism. As Marx put it in his chapter on machinery in Volume 1 of *Capital*,

> The immense impetus [that machinery] gives the development of productive power, and to economy in the means of production, imposes on the workmen increased expenditure of labour in a given time, heightened tension of labour power, and closer filling-up of the pores of the working day, or condensation of labour to a degree that is attainable only within the limits of the shortened working day. This condensation of a greater mass of labour into a given period thence-forward counts for what it really is, a greater quantity of labour. In addition to a measure of its extension, i.e., duration, labour now acquires a measure of its intensity or of the degree of this condensation or density.[45]

The technological revolution and the growth of machinery not only brought a "constant revolutionizing of the instruments of production... and with them the whole relations of society,"[46] but also gave capitalists further power in disciplining and controlling labour, which they took advantage of by using the more easily-disciplined labour of women and children. The key to the domination of "dead" labour over living was not simply the building of machines and fixed capital, but the availability of a ready source of reliable energy which could be supplied in ever-increasing amounts to keep pace with the continued mechanization and accumulation of capitalist production. As Renfrew Christie puts it:

> Above all, capital needs more energy as it uses more machinery to increase relative surplus value while decreasing working-class power in the process of class struggle. Because capital needs machinery to expand the accumulation of surplus value, and because capital needs machinery to "substitute" or control workers in struggle, capital therefore needs energy. Energy drives capital's machines; it melts the metal to produce them; it transports the workers and materials; it measures and controls production; and it even heats workers' houses with less labour today than hitherto, thus cheapening the cost of labour power. In all, energy powers the ongoing technological revolution whereby capital has been winning the class struggle.[47]

From my argument concerning the equivalency of human labour power and energy from non human sources of energy such as oil, it becomes clear that with high levels of technological mediation, the energy in fossil fuels has become equivalent to human labour in an overwhelming number of productive processes. In replacing human labour with fossil fuel driven machinery, capitalists reduce the potential of labour unrest and exponentially increase the surplus value they can realize. Human labour cannot be fully replaced or driven out of the production process (at least not unless capital creates a

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[45] Karl Marx, *Capital, Vol. 1*., p. 386.
[46] Karl Marx and Frederick Engels, *Manifesto of the Communist Party*, p. 20.
[47] Renfrew Christie, "Why Does Capital Need Energy?" In Petter Nore and Terisa Turner, *Oil and Class Struggle*, London: Zed Press, 1980, p. 16.

life form or system of artificial intelligence capable of working, reasoning and self replicating itself), but fossil fuels have come to stand in for human labour power on a world scale, and capitalist production is now totally dependent on them. Capitalists can increase their profits by reducing the energy required to find and extract oil or by increasing efficiency of energy inputs to production, but ultimately the availability of cheap energy inputs is absolutely central to continued accumulation processes.

Peak oil signifies the beginning of the end of the process of displacing human labour to solve problems of capital accumulation through the means of cheap fossil few oil energy inputs. A significant rise in the prices of energy will make it harder for capitalists to increase the organic composition of capital (the relationship of dead or expended labour stored up in machinery versus the living labour of actual present workers). As Renfrew Christie argues, with decreased energy available "it will be more difficult to raise labour productivity by the use of more machinery; it will be more difficult to control workers, to speed up production processes, to cheapen the cost of labour power, and, in general to increase relative surplus value."[48] The capitalist class will thus have to increasingly turn to the appropriation of absolute surplus value and to methods such as inflation, depression, and unemployment, as well as military adventures and wars to secure energy resources via strategies of primitive accumulation.

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[48] Renfrew Christie, "Why Does Capital Need Energy?" p. 22.

PART 2. THE PEAKING OF WORLD OIL PRODUCTION

OIL DEPENDENCE AND DEPLETION

The evidence that humanity is facing an energy crisis of unprecedented proportions has begun to enter the mainstream of political discourse in the past several years. Oil, the single most important source of energy for the industrial world order, is a product absolutely necessary for the agricultural, industrial, and military processes that are the basis of all advanced economies in the world today. World oil consumption[49] has grown from 10 million barrels a day in 1950 to 85 million barrels per day in 2005, and the United States Energy Information Agency predicts that consumption will continue to climb, reaching 118 million barrels by the year 2025.[50] In the face of rising demand, oil prices have steadily increased since 2000, and recent projections have suggested that the price of oil, which has recently touched a historic high of $70 a barrel,[51] could easily increase to and stay at prices of $100 a barrel in 2006,[52] and rise to $380 a barrel by 2015, as existing oil fields are depleted and demand skyrockets due to the processes of industrialization now underway in India and China.[53] According to Sadad al-Husseini, the former top executive for the Saudi state oil company Aramco, the possibilities of continuing to increase oil production in Saudi Arabia, home of the most productive oil fields in the world, are severely limited:

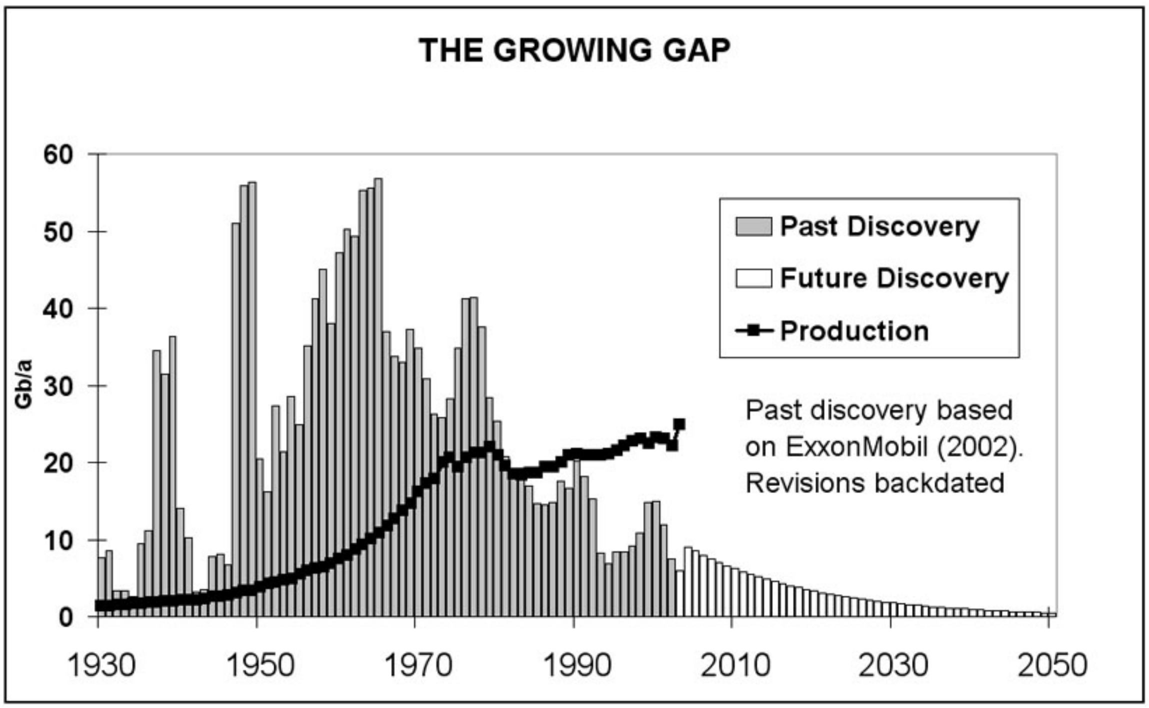
> You look at the globe and ask, 'Where are the big increments?' and there's hardly anything but Saudi Arabia," [Husseini] said. "The kingdom and Ghawar field are not the problem. That misses the whole point. The problem is that you go from 79 million barrels a day in 2002 to 82.5 in 2003 to 84.5 in 2004. You're leaping by two million to three million a year, and if you have to cover declines, that's another four to five million." In other words, if demand and depletion patterns continue, every year the world will need to open enough fields or wells to pump an additional six to eight million barrels a day – at least two million new barrels a day to meet the rising demand and at least four million to compensate for the declining production of existing fields. "That's like a whole new Saudi Arabia every couple of years," Husseini said. "It can't be done indefinitely. It's not sustainable."[54]

The problem of oilfield depletion in Saudi Arabia's "super giant" Ghawar field, the biggest oilfield ever discovered, which individually accounts for roughly 5.5% of daily

[49] This figure includes conventional oil production, tar sand oil, shale oil, and liquid natural gas products.
[50] Michael T. Klare, "The Intensifying Global Struggle for Energy", *TomDispatch*, May 9, 2005.
http://www.tomdispatch.com/index.mhtml?pid=2400
[51] On August 30 of 2005.
[52] Dan Ackman, The Coming Oil Crisis, *Forbes Online*, January 13, 2005,
http://www.forbes.com/2004/10/19/cx_da_1019topnews_print.html.
[53]Adam Porter, "Will Oil Strike $380 a Barrel by 2015?" *AlJazeera.net*, April 21, 2005,
http://english.aljazeera.net/NR/exeres/73CE8286-740C-482B-8150-DA57696BC02F.htm.
[54] Peter Maas, "The Breaking Point: Saudi Arabia, Soaring Demand and the Theory of Peak Oil", the *New York Times Magazine*, August 21, 2005.

world oil production is clear. In order to maintain its flow of oil, over 7 million barrels of seawater are injected into Ghawar every day, resulting in a "water cut" of 55%, meaning that the majority of what is being pumped out of the oilfield is seawater which then has to be separated from the oil.[55] Saudi oil problems can be put in perspective by the fact that world discoveries of oil fields peaked in the 1960s and that very little of the globe remains unexplored by petroleum prospectors. In fact, as Figure 1.0 makes clear, there has been a steady decline in the relationship between the number of barrels of oil discovered and their consumption over the past 30 years.

FIGURE 1.0 THE GROWING GAP BETWEEN OIL DISCOVERY AND CONSUMPTION



Source: Colin Campbell, Uppsala Depletion Group. http://www.peakoil.net/uhdsg/Default.htm

Although oil and other fossil fuels are non-renewable resources, the assumption has always been that these energy reserves will not run out until some time in the future, at which point a new energy regime will be put in place. This assumption is now being challenged from a variety of different perspectives. During the past several years, a number of international experts gathered around Colin Campbell, (a former chief

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55 Paul Roberts, *The End of Oil: On the Edge of a Perilous New World.* Boston: Houghton Mifflin Company, 2004, p. 2. and 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. 77-78.

geologist of Amoco and a Vice President of Fina) have made the argument that the world's oil production will soon reach its peak and begin to steadily decline.[56] One of the most significant additions to Campbell's camp in recent months has been Matthew Simmons, chairman of the world's largest energy investment banking company, Simmons & Co. International, and an energy adviser to George Bush's election campaign in 2000. Simmons is the author of a new book which argues that the large Saudi oil fields which have produced much of the world's "swing production" in the post-World War II era are running perilously close to exhaustion.[57] Some peak oil analysts point to Dick Cheney and other members of the Bush administration as having long been aware of the problems of peak oil;[58] and the topic has also been openly raised on the floor of the U.S. Congress, where Republican Congressman Roscoe Bartlett, Chairman of the Projection Forces Subcommittee of the Armed Services Committee, made a one-hour presentation on the topic on March 14, 2005.[59] The US Department of Energy is also studying the issue, having recently commissioned the respected energy analyst Robert Hirsh to produce a report on the consequences of peak oil and to propose potential amelioration strategies to address the problem.[60] Providing a further basis for the spread of peak oil in the popular consciousness, over a dozen new books have been published in the past two years addressing the question of peak oil, while a Google search for the term now brings up over 5 million hits.[61]

FIGURE 2.0 OIL AND GAS LIQUIDS, 2004 SCENARIO

[56] The web site of the Association for the Study of Peak Oil, founded by Campbell, is available at www.peakoil.net and provides links on its web site to interviews done with members of the group from such media organizations as the *New York Times*, *CNN*, *The Guardian*, the *BBC*, and other major news outlets.

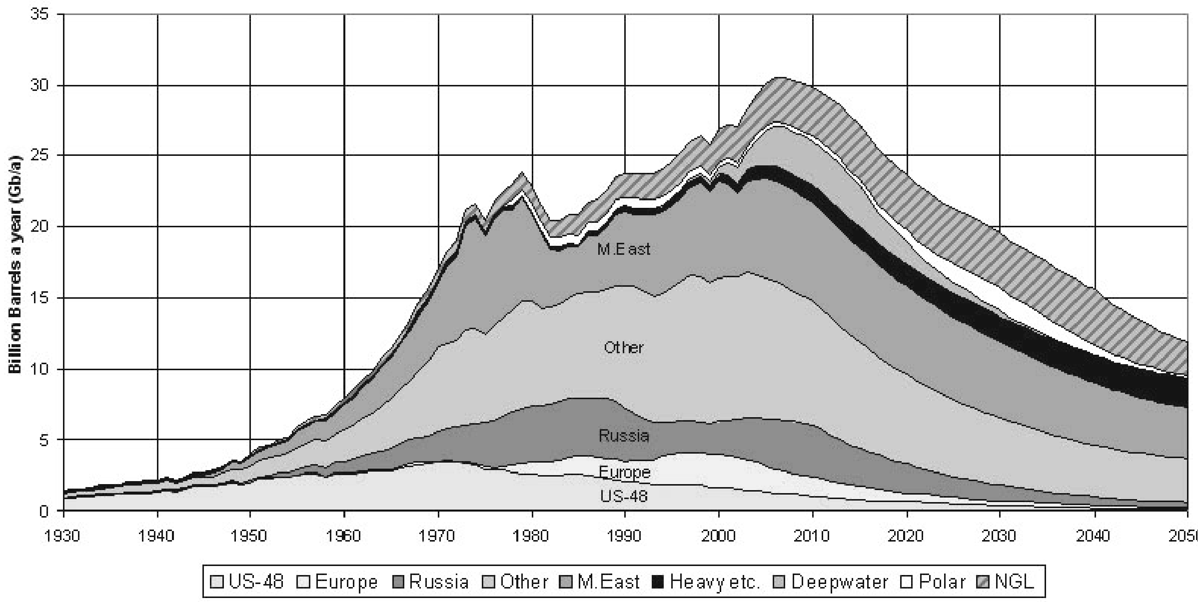
[57] Matthew Simmons, *Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy,* Hoboken, N.J.: John Wiley & Sons, 2005.

[58] See Kjell Aleklett, "Dick Cheney, Peak Oil and the Final Countdown" http://www.peakoil.net//Publications/Cheney_peakOil_FCD.pdf.

[59] Congressman Burkett's presentation to the House of Representatives is available at http://www.energybulletin.net/4733.html. His web site with recent speeches on the topic of peak oil is http://www.bartlett.house.gov.

[60] Richard Heinberg, "Bush Administration Suppresses Peak Oil Study: Where Is the Hirsh Report?", *Counterpunch*, July 30-30 1, 2005. http://www.counterpunch.org/heinberg07302005.html. The Hirsh report is available for download at www.projectcensored.org.

[61] These include such titles as *The Party's Over: Oil War and the Fate of Industrial Societies* and *Power Down: Options and Actions for a Post Carbon World,* by Richard Heinberg; *The End of Oil: on the Edge of a Perilous New World,* by Paul Roberts; *Crossing the Rubicon: the Decline of the American Empire at the End of the Age of Oil*, by Michael C. Ruppert; *It's the Crude, Dude: War, Big Oil and the Fight for the Planet*, by Linda McQuaig; *The Coming Oil Crisis*, by Colin C. Campbell; *Blood and Oil: the Dangers and Consequences of America's Growing Dependency on Imported Oil*, by Michael T. Klare; *Hubbert's Peak: The Impending World Oil Shortage* and *Beyond Oil: The View from Hubbert's Peak*, by Kenneth S. Deffeyes; *The End of Fossil Energy and the Last Chance for Sustainability*, by John G. Howe; *The Collapsing Bubble: Growth and Fossil Energy*, by Lindsey Grant; *Out Of Gas: the End of the Age of Oil*, David Goldstein; *Crude: the Story of Oil*, by Sonia Shah; and *The Future of Oil As a Source of Energy* by Jamal S. Al-Suwaidi, ed.



Source: Colin Campbell, Uppsala Depletion Group. http://www.peakoil.net/uhdsg/Default.htm

FIGURE 3.0 US OIL PRODUCTION 1945 TO 2000

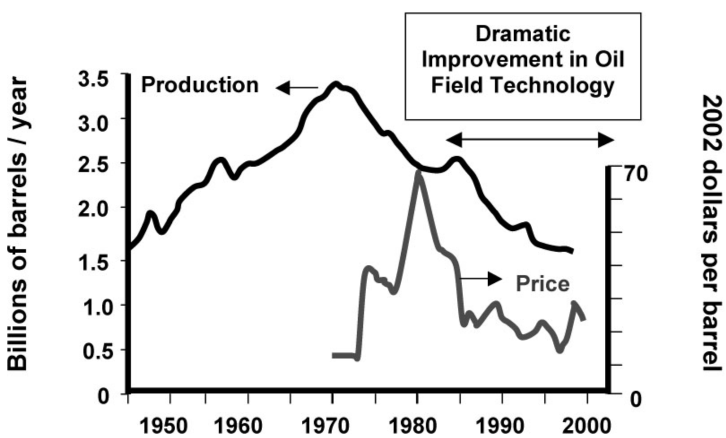


Figure II-3. Lower 48 Oil Production and Oil Prices

Source: Hirsh Report. http://peakoil.com/downfile8

Caption: in many ways the United States offers an excellent case study in the study of peak oil. To date, the United States has been the world's single largest producer of oil but despite the most intensive process of oil exploration across one of the largest and most diverse oil-producing regions in the world, US oil production peaked in 1971 and has been in decline ever since, despite large-scale capital investments and the application of high technology to improve oil recovery methods.

In and of itself the peaking of oil production is not a controversial concept. Practically all petroleum geologists and oil experts agree that global oil extraction will peak, and that the production of oil on local, regional, and international scales follows a Hubbert type curve.[62] The questions of when this peak will occur on a global scale, and of whether or not new discoveries and a mixture of energy conservation and new energy sources can significantly delay this impact, remain the key point of debate. The more "pessimistic" writers on peak oil such as Kenneth Deffeyes argue that world oil production will peak in the fall of 2005, while new data from Campbell and Laherrere suggests that world peak production will happen in 2007. The oil giant Chevron-Texaco launched an advertising campaign in August of 2005 on the theme that the age of easy energy is over and that concerns over peak oil are real, with slogans such as "the world consumes two barrels of oil for every barrel discovered" and "it took us 125 years to use the first trillion barrels of oil. We'll use the next trillion in 30."[63] Even the "optimists" within the US International Energy Agency expect conventional oil production to peak "sometime between 2013 and 2037."[64] Predicting an exact date of peak oil production is made difficult by the routine overestimation of oil reserves by both major oil companies seeking to boost their stock values and by OPEC producing countries whose inflated reserve values allow them to increase their production quotas.[65] Setting aside the question of the accuracy of these projections, even if they are correct in indicating that there continues to be enough oil in "proven" reserves to accommodate another 30-40 years of use at today's demand, this does not take into account the fact that demand is drastically increasing due to the industrialization of the Chinese, Indian, and other Third World economies, with world demand projected to double by the year 2035.[66] The other problem with current assumptions about reserves is that patterns of oilfield depletion always express themselves as a process of steady decline and decreased production, and do not follow the model projected by the International Energy Agency or the US Geological Survey, which envisions reserves running steadily at current rates for 40 years and then suddenly dropping off to nothing.

In the Western Hemisphere the scarcity of oil resources is evident in attempts by Chinese state corporations to buy up oil corporations and to acquire contracts previously destined for the United States in Venezuela and Canada, and by increasing tensions between the government of Hugo Chavez and the US over Venezuela's use of oil resources.[67] As Michael T. Klare puts it, "never has the competitive pursuit of untapped oil and gas reserves been so acute, and never has so much money as well as diplomatic

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[62] Robert L. Hirsh, "Peaking of World Oil Production: Impacts, Mitigation, & Risk Management," February 2005, Report for the US Department of Energy, p. 18-19.

[63] Chevron's advertising campaign is online at http://chevron.com/about/advertising/.

[64] John Vidal, "Analyst Fears Global Oil Crisis in Three Years," *The Guardian*, Tuesday, April 26, 2005, http://www.guardian.co.uk/oil/story/0,11319,1470330,00.html.

[65] See Sonia Shah, *Crude: The Story of Oil*, p. 136-142.

[66] John Vidal, "The End of Oil Is Closer Than You Think", *The Guardian*, Thursday, April 21, 2005, http://www.guardian.co.uk/life/feature/story/0,13026,1464050,00.html.

[67] Geoffrey York, "Energy-Hungry China Frantic for New Supplies", *The Globe and Mail*, Monday, November 29, 2004, p. B4.

and military muscle been deployed in the contest to win control over major foreign stockpiles of energy."[68] Concerns over energy reserves have an obvious military component, as is evidenced by the presence of nearly 250,000 US troops and military contractors in Iraq, home to some of the world's largest untapped reservoirs of crude oil, and by the militaristic and openly imperialist agenda advanced by the Project for the New American Century, many of whose proponents are closely linked to the American oil industry and hold leading positions within the current Bush administration.[69] US armed forces and military bases now completely encircle the natural gas and petroleum producing countries of Southwest Asia, and there are consistent rumblings that the US is planning a military intervention against Iran, home to one of the world's largest reserves of natural gas, a leading oil producer and increasingly an ally and trading partner of China and Russia.[70]

There are also serious ecological aspects to this problem, as increased demand for oil is leading to greater emissions of fossil fuels, while the refusal of the world's worst polluters to sign on to the Kyoto Accord can be interpreted as a recognition that greater "dirty" coal use will be required to make up for falling oil and natural gas production. Exploration for new oil reserves threatens the Arctic National Wildlife Reserve as well as many other ecologically sensitive areas around the world and may even lead to further oil and gas prospecting in Antarctica to shore up sagging supply.[71] Faced with declining oil production, the world is likely to see a widespread recourse to relatively plentiful, but still finite, stocks of coal and biomass to make up for the energy shortfall; their use will dramatically increase greenhouse emissions and intensify the degradation of the natural environment.[72]

The transition to a "post carbon" future is likely to be a difficult one, because no other energy source seems to offer the concentrated and easily usable energy of oil, which currently provides 40% of the world's energy and 90% of its transportation fuels.[73] Oil as a raw material or "feedstock" is central to the world's petrochemical industry as well as to the powering of the industrial agriculture that feeds the majority of the world's population. As Richard Manning has pointed out, "every single calorie we [North Americans] eat is backed by at least a calorie of oil, more like 10. In 1940 the average farm in the United States produced 2.3 cal of food energy for every calorie of fossil energy it used. By 1974 (the last year in which anyone looked closely at this issue), that ratio was

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[68] Michael T. Klare, The Intensifying Global Struggle for Energy, *Tom Dispatch*, May 9, 2005.
[69] Linda McQuaig, *It's the Crude, Dude: War Big Oil, and the Fight for the Planet.* Toronto: Doubleday Canada, 2004, pp. 45-49.
[70] Scott Ritter, "US War with Iran Has Already Begun" June 23, 2005, *AlJazeera.net* http://english.aljazeera.net/NR/exeres/7896BBD4-28AB-48BA-A949-2096A02F864D.htm.
[71] Antarctica Fact Sheet , Department Of Energy Information, Country Analysis Briefs, http://www.eia.doe.gov/emeu/cabs/antarctica.html.
[72] See Paul Roberts, *The End of Oil,* p. 311.
[73] Tony Wesolowsky, "When Oil Peaks..." *Asia Times Online*, January 26, 2005, http://www.atimes.com/atimes/Global_Economy/GA26Dj04.html.

1:1."[74] The situation has only worsened since then, as it is estimated that the food processing industry now requires 10 calories of oil energy for every calorie of food energy produced. Moreover, as Manning points out, North American food production is geared towards providing inputs to this industry and not towards the production of food readily consumable by humans; the result has been a mode of agricultural production that does not produce ready to eat food products:

> America's biggest crop, grain corn, is completely unpalatable. It is raw material for an industry that manufactures food substitutes. Likewise, you can't eat unprocessed wheat. You certainly can't eat hay. You can eat unprocessed soybeans, but mostly we don't. These four crops cover 82% of American cropland. Agriculture in this country is not about food; it's about commodities that require the outlay of still more energy to *become* food… It takes 35 calories of fossil fuel to make a calorie of beef this way; 68 to make 1 calorie of pork.[75]

Our modern methods of "farming with oil" have proven to be far less energy-efficient in terms of the flow-through of energy inputs than pre-industrial modes of farming,[76] and the petrochemical industry which produces the pesticides and fertilizers needed for this energy-intensive agriculture requires increasing flows of fossil fuels which will be seriously compromised when world oil production peaks. One need only consider that 75% of total global agricultural exports are from advanced Western countries dependent on mechanized agriculture fueled by oil to get a sense of the scale of the potential problem.[77] The sharp spike of oil prices in the summer of 2005 has produced serious blackouts in Indonesia and led to the collapse of some East African agricultural systems where rising oil prices have shut down diesel powered irrigation and electrical networks.[78]

The oil industry has been responding to difficulties in finding oil by consolidating itself and merging to an unprecedented degree, something historically rare in an era of high oil prices and soaring profits. In 1998 British Petroleum and Amoco merged; in 1999 BP-Amoco and Arco merged and so did Exxon and Mobil, creating the largest corporation in the world. The year 2000 saw two more of the famed "seven sisters" of oil companies, Texaco and Chevron (which had already swallowed Gulf, another of the "seven sisters") merge into a new entity, Chevron-Texaco. Phillips and Conoco, two large independent oil companies, merged in 2001, and in 2002 Shell acquired Pennzoil-Quaker State. Frontier Oil and Holly merged in 2003, while in 2004 Marathon acquired 40% of Ashland, Westport acquired Kerr-McGee, and analysts suggested that a merger between BP-Amoco and Shell was in the offing. 2005 has seen the buyout of Unocal by Chevron-Texaco, which frustrated the bid of the state-run Chinese oil company CNOOC, while another state-run Chinese oil company, Chinese National Petroleum, recently signed a

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[74] Richard Manning, "The Oil We Eat: Following the Food Chain Back to Iraq", *Harper's Magazine*, February 2004.
[75] Richard Manning, "The Oil We Eat."
[76] See Juan Martinez-Alier, *Ecological Economics.*
[77] Richard Manning, "The Oil We Eat."
[78] Colin J. Campbell, *Newsletter No. 57,* ASPO Ireland, September 2005.

$4.18 billion deal to acquire PetroKazakhstan.[79] While these mergers can also be explained in terms of other market forces they are certainly one way of gaining "new" oil reserves for companies whose exploration efforts have not been paying off in the expected manner.

The possibility of current alternative energies replacing fossil fuels as a primary energy source is most unlikely When environmental costs for the treating and containment of nuclear waste are taken into account, nuclear power does not emerge as a cost-effective alternative to fossil fuels.[80] Public pressure and the difficulty of turning a profit on nuclear power has resulted in no new nuclear power plants being built in the United States since 1973. Moreover, nuclear energy production is dependent upon a finite amount of uranium which also follows a depletion pattern and must be expensively refined. In an article analyzing the possibilities for nuclear power replacing fossil fuels as a source of energy, John Busby, an expert in power generation and a chemical industry specialist, points out that "the world's energy consumption in 2003 was 409 exajoules [an exajoule is a joule x 10^{18}], of which fossil fuels provided 90% as primary energy. Of this total, 60 EJ was in the form of electrical energy, with only 10 EJ provided by nuclear generation." In order to replace fossil fuel production, Busby estimates that 20,000 nuclear power stations would have to be built, requiring a total of 4.6 million tons of uranium per year. Given that current world production of uranium to fuel the world's 441 nuclear power plants totals 36,000 tons of uranium, and that the other 30,000 tons required to meet existing world demand is derived from decommissioning nuclear weapons and reusing mine tailings, the difficulties of developing enough nuclear power plants to meet today's energy needs, much less those of the world twenty years from now, is clear.[81]

Hydro electricity is an important and renewable form of energy, but most existing sites for hydropower already have dams built upon them, and the silting up of these dams will necessitate further large capital investments to keep them running. The so-called "hydrogen economy" is still looking for an energy input, as hydrogen is a carrier of energy, not a source of energy, while solar and wind power have a long way to go before they can pay for their own costs of development and provide more than a fraction of the energy needed for modern energy-intensive economic processes.[82] In its report on coming energy trends Exxon Mobil sums up the problems with renewable energies by noting that "renewable energy presents business and investment challenges, with limited promise of near-term profitable investment, even with government subsidies."[83] Wind and solar energy contribute only 0.2% of total US electricity generation, and even if they grew at the

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[79] Life After the Oil Crash, http://www.lifeaftertheoilcrash.net/SecondPage.html, accessed August 22, 2005.
[80] Richard Heinberg, *The Party's Over,* pp. 132-139.
[81] John Busby, "Why Nuclear Power Is Not the Answer to Global Warming" in Colin Campbell, *ASPO Newsletter*.
[82] Paul Roberts, *The End of Oil*, p. 86-87.
[83] Exxon Mobil, *A Report on Energy Trends, Greenhouse Gas Emissions and Alternative Energy*, February 2004, p. 16.

projected rate of 9% per year they would only contribute about 1% of total expected electricity sales in 2020.[84] Overall, the Exxon report is critical of the potential profitability and widespread application of renewable forms of energy, and argues that even in a best case scenario hydrogen fuel cells, which have been in development since their first use in 1839, are not expected to become commercially viable until after 2020.[85] Natural gas is seen by some as a potential bridging fuel when oil depletion sets in, but like oil it is a finite natural resource, prone to the same peaking dynamic; and unlike oil, massive capital investments are required in order to transform gas into a super-cooled liquid capable of being transported across the globe by supertanker.[86] Moreover, massive quantities of natural gas energy are being diverted for use in the extraction of unconventional oils, as in the case of the tar sands of northern Alberta, which are expected to require the entire natural gas reservoir of the Mackenzie Delta to provide the energy input necessary to refine unconventional oil.[87] Despite rosy forecasts for the future of North American natural gas production in the late 1990s, production has entered a process of dramatic decline rather than growth as expected, and the new power plants built in North America to generate electricity from natural gas are being forced to consider large-scale imports of liquid natural gas.[88]

The drive to a new post-carbon economy is not only hindered by the technical difficulties in finding alternate sources of energy infrastructure (the airplanes, tractor trailers, container ships, heavy construction equipment, and military forces necessary for the maintenance of today's global economy can't be run on wind or solar power), but also by the financial interests of the dominant capitalist elites who resist the development of sustainable, decentralized and community-owned energy infrastructure that would impinge upon the profits of the major oil and energy corporations. The global reach of the oil industry and its connections to the military industrial complex in the United States at the highest levels of government indicate that this sector is looking forward to reaping the skyrocketing profits that will come as oil prices rise–and that even if it could undertake them, it has little interest in supporting the drastic initiatives needed to help wean the world off oil consumption.[89] Instead of attempting to find new forms of energy production that are environmentally sound, locally controlled, sustainable, and which reduce the energetic complexity of capitalist society, these corporations and the nation states that back them are increasingly willing to use military force in attempts to secure control of strategic reserves of fossil fuel energy.

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[84] Exxon Mobil, *A Report on Energy Trends,* p. 16-19.
[85] Exxon Mobil, *A Report on Energy Trends,* p. 16-19.
[86] Paul Roberts, *The End of Oil*, p. 249-250.
[87] Richard Heinberg, *PowerDown: Options and Actions for a Post-Carbon World.* Gabriola Island: New Society Publishers, 2004, p. 121. For an excellent discussion of present problems with natural gas production and transportation in North America, see James Howard Kunstler, *The Long Emergency*, p. 102-110.
[88] Robert L. Hirsh, "Peaking of World Oil Production: Impacts, Mitigation, & Risk Management," p. 33-36.
[89] Linda McQuaig, *It's the Crude, Dude*, pp. 14-16.

A further and perhaps fundamental problem with alternative renewable energy technology is that energy sources such as wind, water, nuclear, and solar power are not capable of reproducing the necessary conditions of their own production. A fossil fuel "energy platform" is central to powering the heavy machinery used to mine and refine the minerals necessary for the production and transportation of the batteries, solar arrays, and raw materials necessary for the construction and maintenance of alternative energies. Coal has historically been used to power the furnaces producing the metal alloys for batteries and is mined with diesel-powered equipment, while oil and natural gas are key feedstocks for the building of plastic products necessary for high-tech products.[90] The vast construction efforts necessary to build a new hydroelectric or nuclear facility and to produce and transport the materials to build them are similarly dependent upon fossil fuels. As James Howard Kunstler puts it, alternative energy systems can be best seen as "accessories" to the fossil fuel regime but not as a replacement to them, as in addition to lacking the many specific advantages of energy, they are ultimately dependent upon fossil fuel production themselves.[91]

Unfortunately, the possibilities of conservation and energy efficiency, mantras pushed by much of the environmentalist movement, may have the paradoxical effect of increasing the rate at which fossil fuel resources are consumed in an economic system based upon continual economic expansion. William Stanley Jevons, a noted British economist writing in the latter half of the 19th-century on the problem of coal depletion, formulated the "Jevons paradox" according to which increased efficiency in the use of a natural resource, contrary to what might be expected, would tend towards its increasing consumption, not its preservation.[92] Jevons made his observation on the basis of the dramatic increase in fuel efficiency achieved over the evolution of the steam engine which, as it became more efficient, reduced the price of coal and thus made the use of steam engines even more profitable, thereby encouraging their further use. Jevons pointed out that throughout the history of steam engines, fuel efficiency continued to increase but that this only served to increase the aggregate use of coal as steam engines proliferated as various capitalist firms acquired them in competition with each other. Jevons' observations are equally applicable to the use of oil in a capitalist economy, as the introduction of more fuel-efficient cars, while decreasing the amount of fuel used by individual vehicles, has only increased the total amount of fuel used as the number of cars on the road has continued to increase.[93] Fuel and energy efficiency can only reduce the total amounts of energy consumed in an economy committed to remaining at a "steady state" or even decreasing in size, an absolute anathema to capitalism.

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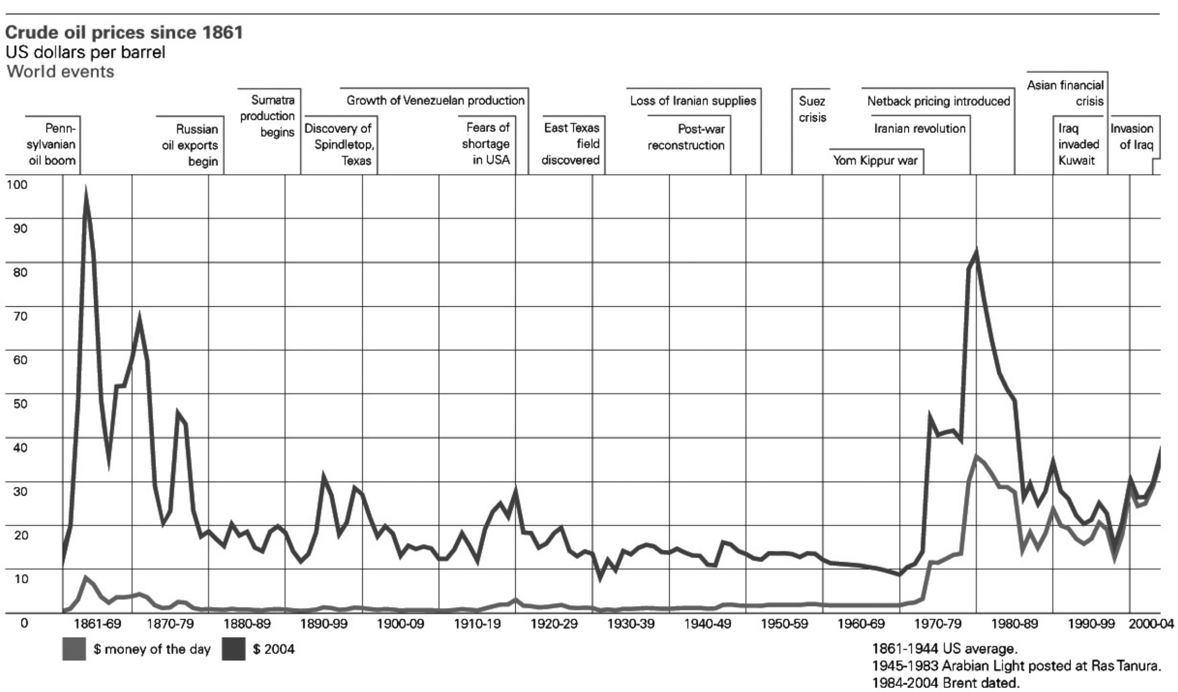
[90] James Howard Kunstler, *The Long Emergency*, p. 127-128.
[91] James Howard Kunstler, *The Long Emergency*, p. 127-128.
[92] See Chapter 7 of Jevons' *The Coal Question*, and Brett Clark and John Bellamy Foster, "William Stanley Jevons and the Coal Question: An Introduction to Jevons's "Of the Economy of Fuel."" *Organization & Environment*, Mar 2001, 14, 1," p. 95.
[93] Brett Clark and John Bellamy Foster, "William Stanley Jevons and the Coal Question", p. 95.

DEBATES IN THE LITERATURE

In recent years a growing literature has developed, popularizing the problem of peak oil and debating its implications. While comparatively few of these debates have entered academic literature in the social sciences, the debates around peak oil can be categorized according to three primary perspectives, and it is likely that most further contributions to the debate will take place along the contours shaped by this literature. Until very recently, the mainstream economists saw no significant problems with fossil fuel depletion. After the oil price crash of 1986, oil prices stayed at historic lows throughout the 1990s (with the exception of a brief oil spike during the 1991 Gulf War), and with the fall of the Soviet Union, energetic prospects seemed good for the infinite expansion of capitalism. Indeed, when measured over the long term, the oil majors and OPEC have been very successful in keeping the price of oil in a constant band between $10 and $30 a barrel which has served to keep oil company profits steady while also foreclosing the possibility of developing profitable alternative energy technologies.

FIGURE 4.0. CRUDE OIL PRICES SINCE 1861



Source: BP Statistical Review, 2005. http://www.bp.com/genericsection.do?categoryId=92&contentId=7005893

Historically, this price range was maintained by the monopolistic practices of the major oil companies (from the 1890s to the 1970s) and then by OPEC, which regulated production and kept prices within this band. Up until the peak of its own production in

1971, the US operated as the global swing producer to make up for production shortfalls and disruptions elsewhere. With US production in decline, the role of global swing producer passed to Saudi Arabia, which since the Second World War has been very closely economically and militarily intertwined with the interests of the US. As oil prices began their upward march in 2000, conventional economists argued that enormous amounts of hydrocarbons remained available for exploitation, a large proportion of which existed as tar sands and oil shale, and that higher oil prices would spur new technological innovation and further exploration for oil and substitutes that would overcome any potential energy crisis.

One of the better known critics of peak oil theorists from this perspective is Michael C. Lynch, a petroleum analyst and consultant who has testified before the United Nations, the U.S. Congress, the International Energy Agency and the World Bank. Lynch and Campbell have long been adversaries in the debate over peak oil, and Lynch's article "The New Pessimism about Petroleum Resources: Debunking the Hubbert Model (and Hubbert Modelers)"[94] was written to explicitly criticize the Hubbert methodology. The main focus of his attack is that Campbell and other Hubbert modelers approach oil production from a geological and not a social perspective. Therefore, according to Lynch, the Hubbert method does not acknowledge the power of market forces to mobilize new technologies to increase the percentage of recoverable oil and increase energy efficiency. As Lynch puts it:

> the primary flaw in Hubbert-type models is a reliance on URR [Ultimately Recoverable Reserves of oil] as a static number rather than a dynamic variable, changing with technology, knowledge, infrastructure and other factors, but primarily growing. Campbell and Laherrere claim to have developed better analytical methods to resolve this problem, but their own estimates [of recoverable oil] have been increasing, and increasingly rapidly.[95]

Lynch points out that Campbell made previous predictions of oil production peaking in the 1980s and 90s, and has consistently had to roll back his predictions. Another bone of contention is with the HLS Petroleum/Petroconsultants database which Campbell and his supporters use for their statistics. While Lynch concedes that this database is probably more reliable than most publicly accessible oil statistics, he points out the difficulty of confirming the statistics quoted by Campbell and others when a look at the database they use costs over $35,000.[96] Taking on a major argument of peak oil theorists, Lynch argues that the historical drop in oil discoveries in the 1960s was a result of political factors, and not scarce oil supplies. He suggest that because of the takeover and nationalization of oil producing regions by national governments in the late 60s and 70s, the incentive to carry out wide-ranging discovery and exploration was removed because OPEC countries already had more oil than they needed to produce and thus had no

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[94] Michael C. Lynch, "The New Pessimism about Petroleum Resources: Debunking the Hubbert Model (and Hubbert Modelers)" http://www.energyseer.com/NewPessimism.pdf.
[95] Michael C. Lynch, "The New Pessimism about Petroleum Resources."
[96] Michael C. Lynch, "The New Pessimism about Petroleum Resources."

interest in looking for more oil which, if brought into production, would further lower already low oil prices.[97]

Campbell answers Lynch by agreeing that regular revisions to depletion models are necessary. Campbell notes that "public reserve and production data are grossly unreliable, and that even the industry databases show widely different estimates. Accordingly, it is necessary to look for trends and relationships, as well as to apply common sense and geological knowledge, to try to come up with realistic assessments."[98] Moreover, Campbell, contrary to Lynch's claims, does account for social impacts on oil production, noting for example that:

> modelling depletion involves not only the calculation of natural depletion rates as imposed by the immutable physics of the reservoirs, but also relies on assessing politico-economic factors, especially in relation to critical Middle East supply. Each country is evaluated individually and then summed to give regional and world totals. It is well said that all numbers are wrong: the challenge being to determine by how much. Much interest devolves on the date of peak, but this really misses the point. It is not an isolated or high peak, merely the indicated maximum on a fairly gentle production curve. Small changes in the estimates and modelling can shift it by a few years one way or the other.[99]

Ultimately, Campbell stresses, it is not the absolute date of the peak that is vital, but rather the recognition that, as evidenced by the example of the United States, oil production does peak, and that despite intensive technological investments over several decades the decline in US oil production has accelerated and appears to be irreversible. The price of oil is certainly shaped by political issues and limitations affecting supply, such as the war in Iraq, strikes or political instability at oil refineries or oil installations, or by climactic problems such as the impact of hurricanes on oil production in the Gulf of Mexico. But fundamentally there are geological limitations to how much oil there is in the world, and even new production possibilities in the Middle East will not stop the reaching of peak oil, even if they can delay its onset on a global level for a given period of time.

In his seminal paper on oil depletion in 1956, M. King Hubbert compared the oil industry to early explorers mapping the world. Ultimately, there is only so much new territory or oil that can be "discovered," and there are a whole set of geological limits determining the conditions under which oil can be produced. While it is certainly difficult to know how much oil remains under the surface of the earth, it is a fact that it is a finite amount which is not meaningfully replaced over the lifetime of the human species. The pattern of overall oil depletion can be generalized from the depletion pattern of individual oil fields and it is by using this methodology that Hubbert concluded that US oil production would peak in the early 1970s. Once a given oil field is brought into production it follows a standard pattern of depletion now known as

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97 Michael C. Lynch, "The New Pessimism about Petroleum Resources."
98 Colin J. Campbell, *Newsletter No. 57,* ASPO Ireland, September 2005.
99 Colin J. Campbell, *Newsletter No. 57.*

"Hubbert's curve". Because the amount of oil in a given field is finite, a bell curve is produced by the fact that production, while starting off slowly following discovery, grows exponentially as more pumping capacity is added. The point of peak production for that field is reached when a pattern of diminishing returns is evidenced, causing rapid decline when extracting the remaining oil which is now no longer pressurized and harder to separate from the geological structures it inhabits.[100]

The fact that many of the leading peak oil advocates came from petroleum geology backgrounds is not surprising when one considers the geological specificity of oil production. The plants and microorganisms that became oil that humans can discover and use had to be deposited in oxygen deprived areas and buried through lengthy processes of sedimentation. Once submerged under the earth's surface and heated, these sediments had to remain within an "oil window" beneath which the oil would be transformed into natural gas or methane, and above which temperatures and pressures would not be suitable to transform it into oil.[101] Once produced, oil deposits must be capped by a layer of impermeable rock such as salt or gypsum to prevent its seepage to the surface. Because of the very specific ways in which oil is produced, and because of their experiences in the hands-on work of oil prospecting, peak oil theorists stress the geological limits of this nonrenewable resource in their writings. Hubbert's point was that there is only a finite amount of oil available in the world to be discovered and used; it is geological processes over eons and not human entrepreneurs that "create" oil. While such a perspective may have limitations if it discounts the role of human social relations to energy production, this, as we have seen, is explicitly not the case for Campbell's work. Some peak oil enthusiasts do adopt neo-Malthusian perspectives and stress that "peak oil is imposed by nature," thus missing the fact that there is nothing "naturally determined" in the development of an industrial capitalist system dependent upon oil, and for this they should be critiqued. But the point remains that human beings exist on a planet with finite reserves of fossil fuels and that our current economic system is overwhelmingly dependent upon the ever-increasing use of these fuels.[102]

Neoclassical economists have traditionally argued that there is in fact no significant problem or shortage of oil supplies and that prices will soon regain their historically normative levels. The neo-classicals' argument relates to the efficiency of the market in resolving issues of supply; thus they suggest that an infinite substitution of

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[100] Kenneth Deffeyes, *Hubbert's Peak:* , p. 40-69.

[101] Shale oil for example is a hydrocarbon known as kerogen which has not yet been adequately heated and transformed by geological processes to become oil. This process can be carried out by human intervention, but it requires significant inputs of energy to heat up and accelerate the natural processes of oil formation making it prohibitively costly to do so.

[102] There did exist a scientific grouping in the former Soviet Union in the 1980s that claimed that oil is in fact produced abiotically within the earth's crust, and not from decaying plant matter. This perspective is not taken seriously by those in the oil industry as existing fields have not been replenished from sources within the Earth's mantle and oil has not been discovered using abiotic oil principles but the argument has been recently resurrected in debates over the possibilities of world oil production peaking. To view a good summary of these debates see http://www.questionsquestions.net/docs04/peakoil1.html.

natural resources based upon market pressures can take place. Historically speaking, much of the international Marxist movement has shared the cornucopian assumptions of the neoclassical economists concerning the never-ending availability of natural resources. In regarding capitalism as a historically progressive economic system which broke down feudal structures of oppression and domination and launched the great scientific and technological revolutions of the 19th and 20th centuries, Marxists by and large considered the contradiction between the enormous wealth created by increasingly social forms of production and increasingly private forms of appropriation as opening up the possibilities of a socialist society. Marx and many Marxists saw the expansion of capitalism throughout the world as a process which created a truly global and international working class that "disciplined, united and organized by the processes of capitalist production"[103] would, once the historical role of capitalism had been completed, overthrow the system and restart production in a just and equitable fashion under the rule of a "free association of producers." While focused on the extremely important conditions of conflicting social classes in making history, the mainstream of Marxist thought has been largely silent on the issue of thermodynamic processes in human production and society.[104] Nonetheless, although the Marxist project has been dealt a number of severe blows over the course of the 20th century, the most trenchant and politically nuanced analyses of international capitalism and the movements of resistance that it has spawned continue to be found within the Marxist tradition. Unfortunately, while the Marxist analysis provides rich insights for understanding imperialism and empire, possibilities for revolutionary social organization, historical analyses of various revolutionary movements, and processes of capitalist accumulation, most Marxists have been surprisingly uncritical of neoclassical dogmas regarding the use of natural resources and energy stocks.[105]

"Retort," a group of San Francisco-based writers in the Marxist tradition,[106] recently released a new book, *Afflicted Powers,* which contains a lengthy discussion on the political economy of oil. In arguing against the perspectives of Colin Campbell and Kenneth Deffeyes (whom they describe as neo-Malthusians), Retort advances a perspective similar to that of Michael C. Lynch, suggesting that new oil resources in West Africa, deepwater fields in Mexico and Brazil, the Canadian tar sands, or new Russian production are capable of prolonging the point of global peak production to any time between 2010 and 2112.[107] Blissfully unaware or uninterested in the fact that serious concerns over depletion of US oil production helped to construct foreign-policy objectives and imperial interests in the 1920s, 1940s, and 1970s, Retort approvingly quotes the MIT economist Morris Adelman to the effect that "oil available to the

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[103] Karl Marx, *Capital Volume 1,* p. 715.

[104] There are of course important exceptions to this tendency as expressed in the work of Joel Kovel, Michael Lowy, John Bellamy Foster, and Paul Burkett.

[105] One important exception to this tendency has been the grouping linked around the journal *Capitalism Nature Socialism*, and the eco-socialist thinking of James O'Connor and Joel Kovel.

[106] Members of Retort situate themselves within council communist and situationist Marxist traditions.

[107] Retort, *Afflicted Powers: Capital and Spectacle in a New Age of War*, New York: Verso, 2005, p. 62.

markets is for all intents and purposes infinite" and thus shouldn't be seen as the defining cause for US military intervention in Iraq.[108]

The debate as to whether or not market indicators and increasing technological sophistication are capable of responding to and resolving problems of ecological devastation and declining energy returns on energy invested has been the subject of a lively debate over the past 30 years in the context of the rise of ecological economics. This school of thought, defined by thinkers such as Nicholas Georgescu-Roegen, Herman Daly and Juan Martinez-Alier provides a theoretical grounding for much of the "pessimistic" literature regarding peak oil (the work of Heinberg, Campbell, and Kunstler) which draws its conclusions from the fact that economic processes – which always involve the flow through of energy and material inputs – are inescapably entropic, as they are fundamentally based upon appropriating low entropy energy and materials (fossil fuels and various minerals) and produce waste in the form of greenhouse gases and pollution once consumed. Because the sources of low entropy energy and materials required for human existence are produced by nonhuman processes (gravitational energies, photosynthesis, and various biogeochemical cycles – involving water, carbon, oxygen, nitrogen, and phosphorus) that are temporally and spatially incompatible with the ever expanding industrial production of capitalism, ecological economists have critiqued both Marxist and neoclassical economic approaches for ignoring the ultimately determinative limitations of thermodynamic laws on human production.

Nicolas Georgescu-Roegen, one of the founders of the modern ecological economics school, insisted that "the economic process is solidly anchored to a material base which is subject to definite constraints."[109] Arguing against the circular diagrams of neoclassical economic thought where ever-increasing amounts of money endlessly circulates between various economic sectors, Georgescu-Roegen proposed that because of entropic degradation, "the economic process has a unidirectional irrevocable evolution" and that both Marxist and neoclassical economists had succumbed to money fetishism by failing to recognize this fact.[110] According to Georgescu-Roegen, the rise of industrial capitalism has been based upon the discovery and use of a one-time "energy bonanza" in the form of fossil fuels which provided a concentrated low-entropy source of energy capable of launching an economic system beyond the limitations of the appropriation of solar flows of energy. Industrial capitalism's increasing reliance upon fossil fuels which made possible the mechanization of agriculture and human labor is thus in the long-term impossible to maintain as finite stocks of fossil fuels can not be indefinitely substituted for the near infinite flow of solar energy. As Georgescu-Roegen put it, "the higher the degree of economic development, the greater must be the depletion [of stocks of low-entropy necessary for this development] … hence the shorter becomes the expected life of the human species"[111] as terrestrial stores of low-entropy minerals and

[108] Retort, *Afflicted Powers*, p. 62.
[109] Nicolas Georgescu-Roegen, *The Entropy Law and the Economic Problem*, p. 45.
[110] Nicolas Georgescu-Roegen, *The Entropy Law and the Economic Problem*, p. 45.
[111] Nicolas Georgescu-Roegen, *The Entropy Law and the Economic Problem*, p. 47.

fuels are consumed. Georgescu-Roegen was ultimately drawn to a kind of neo-Physiocratic political approach which stressed the importance of developing sustainable, localized agricultural production with minimal use of low-entropy physical stocks not reproducible over the lifespan of the human species.[112] As he famously put it:

> Every time we produce a Cadillac, we irrevocably destroy an amount of low entropy that could otherwise be used for producing a plow or a spade [or for that matter a wind turbine or solar panel]. In other words, every time we produce a Cadillac, we do it at the cost of decreasing the number of human lives in the future. Economic development through industrial abundance may be a blessing for us now and for those who will be able to enjoy it in the near future, but it is definitely against the interest of the human species as a whole, if its interest is to have a lifespan as long as it is compatible with its dowry of low entropy.[113]

While most "pessimistic" writers on peak oil do not explicitly cite the work of Georgescu-Roegen, their claims that peak oil will usher in an era of civilizational collapse, population die off, and entry into a new "dark age" or "long emergency" are premised upon the application of thermodynamic principles to the question of peak oil. Neoclassical or Marxist perspectives that ignore thermodynamic questions and the difference between the finite stocks of fossil fuels and the much larger, but harder to harness, solar flow of energy thus inevitably end up creating economic conceptions divorced from the material realities of the physical processes necessary to sustain life and industrial civilization on this planet.

The neoclassical perspective on energy has historically stood as the primary approach taken by business leaders and the oil industry as a whole, an approach which has always emphasized the certainty of continued economic expansion. However, in recent years this consensus has begun to fray, and the critics are not all coming from the margins of society or from radical ecological perspectives. The first priority of President George W. Bush's administration was to investigate the status of the US energy system, and soon after taking office Bush empowered a commission known as the National Energy Policy Development Group to assess the state of energy production and consumption in the US and internationally. The commission, a veritable who's who of the Bush administration,[114] issued a report stressing that "America in the year 2001 faces the most serious energy shortage since the oil embargoes of the 1970s." The report

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112 In this regard Georgescu-Roegen stands in the tradition of the socialist agrominist Sergei Podolinsky.

113 Nicolas Georgescu-Roegen, *The Entropy Law and the Economic Problem*, p. 47.

114 The policy development group included Dick Cheney, the Vice President; Colin Powell, the Secretary of State; Paul O'Neill, the Secretary of the Treasury; Gale Norton, the Secretary of the Interior; Ann Veneman, the Secretary of Agriculture; Donald Evans, the Secretary of Commerce; Norman Mineta, the Secretary of Transportation; Spencer Abraham, the Secretary of energy; Joe Allbaugh, the Director of the Federal Emergency Management Agency; Christine Whitman, the Administrator of the Environmental Protection Agency; Joshua Bolten, Assistant to the President and Deputy Chief of Staff for Policy; Mitchell Daniels, the Director of the Office of Management and Budget; Lawrence Lindsey, the Assistant to the President for Economic Policy; Ruben Barrales, Deputy Assistant to the President and Director of Intergovernmental Affairs; and had as its Executive Director Andrew Lundquist.

argued that this problem is due to growing energy demand, the outdated and rundown energy infrastructure of the country ("not a single major oil refinery has been built in the United States in nearly a generation" and most oil pipelines are in desperate need of repair and upgrading), and the steady depletion of domestic oil production, which produces 39% less oil than it did in 1970, despite enormous capital investments over the past three decades.[115] The George W. Bush government, closely connected to the US oil industry, has been very clear about the serious problems of oil depletion facing the US as a world power, and many commentators see the invasion of Iraq and the privatization of its oil industry under US control as part of a broader US strategy for securing its international supplies of oil.[116]

If the neoclassical approach to peak oil is to deny it as a serious problem, the perspective advocated by Princeton professor emeritus and petroleum geologist Kenneth Deffeyes in his books *Hubbert's Peak: the Impending World Oil Shortage* and *Beyond Oil: the View from Hubbert's Peak,* and by energy investment banker Matthew Simmons in *Twilight in the Desert: the Coming Saudi Oil Shock and the World Economy,* is to note the fundamental challenges faced on the downslope of Hubbert's curve, and to argue that ruling elites must begin immediate planning for a post-carbon world. This plan would include widespread energy conservation, increasing reliance on nuclear power, growing fuel efficiency in transportation and (in some cases) a return to local food production. While Deffeyes and Simmons are in agreement that the fossil fuel age is drawing to a close, they do not foresee the possibilities of mass social upheaval and struggle over control over the economy or state as a likely outcome of this disruption (Deffeyes' analysis is in fact explicitly based upon the assumption that both the American political system and its economy will remain stable).[117] For them, the capitalist system is so completely naturalized as the only economic system imaginable that the only realistic alternative is to hope that world leaders will develop a "Plan B" to overcome the shock of the peaking of conventional oil production. Deffeyes' suggestions of what such public policy might look like include the replacement of vehicles with high-efficiency diesel powered cars and trucks, the development and subsidization of high technology, mining and agricultural sectors within the US to produce high-value products to trade on the world market in exchange for fossil fuels, and the pairing of electrical generation with resource extraction to increase thermodynamic efficiency within the economy.[118] Because all these options are only a means of slowing down fossil fuel depletion, ultimately Deffeyes, like M. King Hubbert, sees nuclear power as the only remotely practical answer to declining reserves of fossil fuels.[119]

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115 Report of the National Energy Policy Development Group, *National Energy Policy: Reliable, Affordable, and Environmentally Sound Energy for America's Future*, US Government Printing Office, May 2001, p. vii-x.
116 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.
117 Kenneth S. Deffeyes, *Beyond Oil: The View from Hubbert's Peak,* New York: Hill and Wang, 2005, p. 187.
118 Kenneth S. Deffeyes, *Beyond Oil*, p. 182-183.
119 Kenneth S. Deffeyes, *Beyond Oil,* p. 182.

Simmons adopts a similar approach, stressing that since the primary use for oil is transportation, such needs must be minimized while increasing fuel efficiency. He further notes that geopolitical problems are likely to arise from competition between the US and China and India over oil resources, and argues that rising oil prices will see a major transfer of wealth from industrialized nations dependent on fossil fuels to OPEC producing countries. Assuming that this wealth will trickle down to the average members of society (and not be returned as financial capital to Western banking institutions, as occurred in the 1973 oil crisis), Simmons suggests that the growth in demand in OPEC nations for OECD goods and services could provide a much-needed boost to world economic production ("a new Marshall plan") which could create a real "middle-class" in the OPEC nations.[120] Ultimately, Simmons suggests that what is needed is a "Plan C", a new energy regime, or as he puts it "a new energy miracle," that will power the society of the future. But because neither hydrogen, solar, or wind power options exist as viable alternatives, Simmons sees these technologies and the conservation methods proposed by people such as Deffeyes as a type of bridge to buy time until the "best scientific minds of the world" can discover and implement a new energy source capable of being used by the world's existing energy infrastructure.[121]

The third approach to the question of peak oil is much more pessimistic in its assumptions regarding the capacities of industrial (capitalist) society to handle the disruption introduced by peak oil. Writers such as Richard Heinberg, Howard Kunstler and a group of writers associated with a neo-Malthusian perspective,[122] predict that the effects of peak oil will include a new great depression and unresolvable financial crisis, culminating in a massive decrease in the human population, thoroughgoing destruction of the environment, and ultimately a return to pre-industrial agriculture and subsistence production. This perspective has in some cases tended towards a kind of energy-reductionist neo-Malthusianism, neglecting the fact that many of the so-called "natural limits" to human growth are predicated on specific capitalist social relations. But they are correct in noting the correlation between world population growth and the increasing use of fossil fuels and increased energy consumption in agricultural production, which means that a serious decline in fossil fuels could indeed lead to a massive population crash.

Perhaps the most alarming observation in Kunstler's book is that the arrival of peak oil production coincides with a series of other potentially catastrophic difficulties facing humanity. Chief among those is the problem of global climate change and rapidly rising sea levels which could seriously impact the majority of the world's population which lives at sea level. According to Kunstler the AIDS pandemic and powerful new diseases such as SARS and influenza are serious threats which, when combined with declining groundwater supplies and increasing erosion of arable land, could cause a

[120] Matthew Simmons, *Twilight in the Desert*, p. 347-350.
[121] Matthew Simmons, *Twilight in the Desert*, p. 352-354.
[122] The web site www.dieoff.org hosts a number of writers from this neo-Malthusian perspective.

serious crisis in human society. Global climate change and international pandemics would:

> coincide with our imminent descent down a slippery slope of oil and gas depletion, so that all the potential discontinuities of that epochal circumstance will be amplified, ramified, reinforced, and torqued by climate change… The disruptions and hardships of decelerating industrialism will destabilize governments and societies to the degree that concerted international action – such as the Kyoto protocols or anything like it – will never be carried out. In the chaotic world of diminishing and contested energy resources, there will simply be a mad scramble to use up whatever fossil fuels people can manage to lay their hands on.[123]

The effects of hurricane Katrina in New Orleans have shown the structural weakness of the richest country in the world in containing natural disasters inflicted by climate change and aggravated by free-market economic policies; they are a portent of the future envisioned by Kunstler. As in the case of hurricane Katrina, climatic changes could hasten oil production decline by disrupting the production of fossil fuels and their refining. By some estimates Katrina displaced 55,000 offshore oil workers in the Gulf of Mexico, stopped the arrival of oil supertankers carrying up to 900,000 barrels of oil a day to the Louisiana Offshore Oil Port, sunk 30 oil rigs, shut down eight refineries, and cut the electricity to the pipelines that transport 3 million barrels of oil a day to consumers in the Midwest and East Coast.[124] In the wake of Katrina the US was forced into making an unprecedented 60 million barrel withdrawal of oil from the stockpiles of the International Energy Agency to make up for the shortfall and prevent oil prices from rising even further. As world oil production becomes more dependent on offshore drilling and unconventional oil production in inhospitable climes, climate change and patterns of extreme weather will likely take an increasing toll on supplies of world oil.

Kunstler proposes that the peaking of world oil production will see an end to the process of globalization inaugurated by the industrial revolution and that there will be a turn towards economic re-localization as industrial production and transportation collapses due to the reduction of energy inputs. Kunstler argues that the large cities, big corporations, powerful governments, and international trading networks that so dominate the world today will undergo a massive process of shrinkage as the energy inputs vital to their continued existence wither away.[125] Ultimately, he suggests that the large urban centers and tracts of suburbia where most North Americans live will be faced with severe food shortages and that the United States itself will devolve into regional confederations during what he terms "the long emergency." Kunstler limits his analysis of the effects of crisis to the United States and outlines the possible breakdowns in national food production, energy infrastructure and transportation systems while also suggesting that racialized class antagonisms will intensify. Ultimately, he argues that those

[123] James Howard Kunstler, *The Long Emergency* p. 148-149.
[124] Tom Whipple, "The Peak Oil Crisis: The Storms of August", Falls Church News-Press, September 8-15, 2005. http://www.fcnp.com/527/peakoil.htm.
[125] James Howard Kunstler, *The Long Emergency* p. 239.

areas retaining the built environment of the pre-oil age will be most likely to maintain civilizational coherence, while other regions may see a return to previous feudal or share cropping modes of production.[126]

Richard Heinberg, who is one of the few writers on peak oil to offer a comprehensive set of responses to the crisis, outlines four different kinds of responses he sees as possible. The first he calls "last one standing": an accelerated process of competition for the world's remaining energy resources which will ultimately culminate in war over an ever-declining resource base. The second option he articulates, one suggested by progressive environmental, antiwar, and anti-globalization movements, is what he calls the "powerdown" option, an approach of cooperation, conservation, and international redistribution of resource usage, the development of alternative energy sources, and a 'humane but systematic' reduction in world population growth and energy use. Thirdly, there is the option of "waiting for a magic elixir": hoping for the best and denying the problem of peak oil. Finally, there is the option that Heinberg sees as immediately feasible, one of "building lifeboats." This option assumes that industrial civilization cannot be saved, and that individual and community efforts should be devoted to "preserving the most worthwhile cultural achievements of the past few centuries" by building self-sufficient communities to weather the coming storm.[127]

The "last one standing" approach is familiar to those aware of the practices of Western imperialism. As George Kennan, the head of a US State Department planning committee, wrote in 1948:

> We have about 50% of the world's wealth but only 6.3% of its population. In this situation, we cannot fail to be the object of envy and resentment. Our real task in the coming period is to devise a pattern of relationships which will permit us to maintain this position of disparity without positive detriment to our national security. To do so, we will have to dispense with all sentimentality and day dreaming; and our attention will have to be concentrated everywhere on our immediate national objectives. We need not deceive ourselves that we can afford today the luxury of altruism and world benefaction.... The day is not far off when we are going to have to deal in straight power concepts.[128]

This approach is also being advanced by the George W. Bush White House in its "war on terrorism," which has had the far-from-coincidental outcome of placing US troops at the centers of world oil and natural gas production. While this tendency can only be expected to increase in the coming years and is likely to aggravate rivalries that, since the end of World War II, have been submerged by global US hegemony, it is important not to discount popular resistance to this program both within and outside of the United States. Already, the US finds itself deeply mired in the Iraqi conflict, giving little sign of its ability to successfully exploit Iraq's oil reserves; moreover, a global antiwar movement emerged on a scale unprecedented in world history to challenge the launching

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[126] See James Howard Kunstler, *The Long Emergency*, Chapter 7.
[127] Richard Heinberg, *PowerDown*, p. 14-15.
[128] George Keenan, Dept of State Policy Planning Study No. 23, 1948, http://www.globalresearch.ca/articles/CRG312A.html.

of the war. The contradictions between what the *New York Times* called these two "superpowers"–world public opinion and the US empire– could intensify with the rise of new anti-imperialist and potentially revolutionary struggles against global capitalism, and may produce a deep-rooted radicalization in US society as the realities of a "war without end" sink in.

Fundamentally, Heinberg's "powerdown" option is the only real alternative that can transform human society into a more ecologically and energetically feasible economic order. Nonetheless, it is an approach that goes completely against the logic of capitalism, which needs to continually expand in order to survive. Perhaps the most relevant example of a "powerdown" approach occurred in Cuba in the early 1990s during the "special period" caused by the collapse of the Soviet Union and the abrupt cessation of oil imports and foreign trade with the Soviet bloc. Average caloric intake dropped from 3000 calories per day in 1989 to 1900 calories per day in 1993 (the equivalent of losing one meal a day, every day).[129] Many observers suggested that the economic crisis that faced Cuba, and that has now largely been overcome, is similar in scale and effect to what would happen worldwide after oil production peaks. The main difference is that Cuba, in addition to enjoying a tropical environment, also has a socialist society with a high degree of popular mobilization, education and technical expertise, as well as a responsive state apparatus willing and able to efficiently mobilize resources and institute rationing where necessary.

Cuba responded to its crisis by introducing large-scale organic and local agriculture, returning to teams of oxen instead of oil-powered tractors on farms, and virtually eliminating pesticides and artificial fertilizers from food production. Although some concessions were made by reintroducing the US currency and private markets in order to generate foreign currency for much-needed imports, the response to the crisis was shaped by the fact that it was coordinated by a state structure not based upon private profit. Richard Heinberg suggests that to achieve such a powerdown solution one would need to come up with mechanisms to reduce economic growth as conventionally measured in terms of GDP, limit per capita resource usages, and equalize wealth between both rich and poor nations and the classes within them, while also stabilizing and reducing human populations. How exactly this could be done under the framework of capitalism and a global imperialist order is unclear, and ultimately Heinberg ends up proposing an essentially individualist and idealist path of personal responsibility, monetary reform and the lobbying of the rich and powerful.[130] Missing from his analysis is the possibility of class and social struggles overcoming capitalism as a system and instituting the necessary redistribution of wealth and economic planning necessary to ease the transition from a capitalist high-energy-based economy to an equitable and democratic socialist society based on the appropriation of renewable energies.

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129 Bill McKibben, "What Will You Be Eating When the Revolution Comes?", *Harper's Magazine*, April 2005.
130 Richard Heinberg, *PowerDown,* p.95-101.

In the approach that he summarizes as "waiting for the magic elixir," Heinberg takes on the possibility that other alternatives to oil may be found that would not necessitate a rupture with the current energy regime or capitalist system. He examines the possibilities of developing tar sands, the oil industry's next best hope, the potential of methyl hydrates and the much vaunted "hydrogen economy," and concludes that even should these alternatives work, the ultimate problem is our economic pattern of growth, which will result in the complete degradation of the environment even if we find alternate sources of energy to replace fossil fuels. The entire world can not enjoy the living standards of North America and Europe; attempts to achieve such a lifestyle will be accompanied by decreases in soil fertility, freshwater and biodiversity, as well as by the problems associated with global warming, which together will precipitate economic crisis. In this regard Heinberg's analysis is quite complementary to the approach of James O'Connor in his work on "the second contradiction of capitalism," which incorporates an analysis of economic crisis created in the social resistance to capital's destruction of its conditions of production.[131] While some Marxists argue that "capitalism can in principle continue to reproduce itself under any natural conditions, however degraded... short of the complete extinction of human life"[132] the degraded conditions of production in a peak oil scenario will add to the immediacy of working-class resistance to capital. Capitalist production, and its ability to overcome spatial and temporal crises, look much different on the rising curve of increasing fossil fuel availability and a relatively pristine natural environment, than they do in an era of declining energy availability and significant ecological destruction.

The final option that Heinberg proposes is that of "building lifeboats" or small enclaves where sustainable and ecologically friendly processes can sustain small portions of society and the best cultural and technical achievements of industrial civilization can be preserved. While this process of building local and immediate alternatives will ultimately be needed in any dramatic transition away from a fossil fuel economy, Heinberg again forecloses the possibilities of generalized and transformative struggle against capitalism and proposes what essentially amounts to escapist solutions for those able to afford them (primarily the white and middle-class inhabitants of North America and Europe). While he stresses the importance of community solidarity as opposed to individual survivalism, building "lifeboats" falls far short of the strategy needed to take back our world from it those driving it to the brink of destruction, and can easily lead to escapist or individualist responses to the crises generated as a result of peak oil.

The situation thus described gives added impetus to those in the global justice and ecological movements who are currently trying to transform the global economic order to consider the wide-ranging implications of peak oil on the world we are trying to change. While it is ultimately impossible to know for certain when peak oil production will occur, the report on peak oil entitled *Peaking of World Oil Production: Impacts, Mitigation*

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131 See James O'Connor's "The Second Contradiction of Capitalism" in *Natural Causes: Essays in Ecological Marxism.* New York: The Guilford Press 1998.
132 Paul Burkett, "The Value Problem in Ecological Economics" p. 160.

and Risk Assessment, commissioned by the National Energy Technology Labouratory of the US Department of Energy, offers one of the best thought-out and most reasonable perspectives within which to frame this debate. The report, principally authored by Robert L. Hirsh, a well-known and respected energy expert,[133] examines the effects of attempts to mitigate the impact of peak oil using three different scenarios, with responses initiated once peaking occurs, 10 years before peaking, and 20 years before peaking. After reviewing the evidence, Hirsh concludes that peak oil is a serious problem that deserves immediate attention. The primary issue at hand is the severe liquid fuel crisis that will occur due to the reliance of the vast bulk of land, water, and air transportation on oil. The most important way to mitigate the problem is through the large-scale production of alternative liquid fuels through the development of nonconventional oil including the Fisher-Tropsch method of liquefying coal. Hirsh argues that drastically increasing oil prices associated with peak oil will significantly reduce US gross domestic product and have significant negative effects on Third World countries more dependent upon oil and less able to cope with high prices.[134] While fuel conservation and increased efficiency will have some effect on short-term reductions of oil consumption, a failure to take immediate action will leave "the world with a significant liquid fuel deficit for more than two decades," while initiating the crash program 10 years before peak production will help with the situation but not completely resolve it. The last of Hirsh's scenarios, whereby the mitigation crash program is initiated 20 years before peak production, does offer the possibility of avoiding a serious liquid fuels shortfall, but it depends on bringing significant non-conventional oil supplies online, the difficulties of which have been discussed above. Ultimately, as the Hirsh report notes, "the world has never confronted a problem like this, and the failure to act on a timely basis could have debilitating impacts on the world economy."[135] Even with the implementation of Hirsh's recommendations, there remains the problem –one his report does not address– as to how we can transfer away from a fossil fuel energy

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[133] Hirsh's official biographical statement notes that "Dr. Robert L. Hirsch is a Senior Energy Program Advisor at SAIC [Science Applications International Corporation]. His past positions include Senior Energy Analyst at RAND; Executive Advisor to the President of Advanced Power Technologies, Inc.; Vice President, Washington Office, Electric Power Research Institute; Vice President and Manager of Research, ARCO Oil and Gas Company; Chief Executive Officer of ARCO Power Technologies, a company that he founded; Manager, Baytown Research and Development Division and General Manager, Exploratory Research, Exxon Research and Engineering Company; Assistant Administrator for Solar, Geothermal, and Advanced Energy Systems (Presidential Appointment), and Director, Division of Magnetic Fusion Energy Research, U.S. Energy Research and Development Administration. During the 1970s, he ran the US fusion energy program, including initiation of the Tokamak fusion test reactor. He has served on numerous advisory committees, including the DOE Energy Research Advisory Board. He has been a member of several National Research Council (NRC) committees, including Fuels To Drive Our Future and the 1979 and recent NRC hydrogen studies. He was chairman of the NRC Committee to Examine the Research Needs of the Advanced Extraction and Process Technology Program (Oil & gas). He is immediate past chairman of the Board on Energy and Environmental Systems and is a National Associate of the National Academies." Source: http://www.d-n-i.net/fcs/hirsch_bio.htm

[134] Robert L. Hirsh, "Peaking of World Oil Production: Impacts, Mitigation, & Risk Management," p. 28-30.

[135] Robert L. Hirsh, "Peaking of World Oil Production" p. 60.

regime. Hirsh's final conclusions are that peak oil production will occur most likely within a decade, and that the problem of peak oil presents a huge challenge that can only be addressed given significant time and massive government intervention. With adequate lead time and resolute planning, the immediate consequences of peak oil could be mitigated through the development of new sources of liquid fuels, but ultimately peak oil remains a "unique challenge" whose consequences will be "abrupt and revolutionary."[136]

CONCLUSION: 15 THESES ON PEAK OIL

From an examination of the literature on the topic of peak oil and the theorizing of the thermodynamics of capitalist production, I advance the following tentative conclusions on the current debate over peak oil.

1.) To date, the debate over peak oil has primarily been conducted in empirical terms, focusing on rates of oil production and consumption, the decline in discoveries of new oil reserves, and debates over the alternatives to energy rich fossil fuels. Because the statistics around remaining reserves of available oil are distorted by inaccuracies introduced by political and financial considerations of the major oil corporations and states who hold this data, determining a date for peak oil production is practically impossible until after the fact. While as some proponents suggest, technological innovations, state-implemented conservation measures, or economic contractions can delay the arrival of peak oil production, the evidence would seem to indicate that no combination of these factors can indefinitely defer the moment of peak oil production in a capitalist economy driven by continued expansion and growth. Furthermore, in the absence of fair and strict international regulation of hydrocarbon production and consumption, individual countries seeking to maximize self-interest are likely to boost their consumption of oil to secure its economic benefits before their rivals do (as in fact the US has done throughout the 20th century). Although the precise date of peaking cannot at this point be determined, there is substantial evidence pointing to a peaking of oil production by the end of this decade.

2.) The peaking of world oil production is a very real threat to industrial civilization and the continued accumulation of capital. Because virtually every process of capitalist accumulation is ultimately reliance upon the ever-increasing availability of high-energy fossil fuels, a long-term contraction in oil supply will wreak havoc with the ability of the capitalist

[136] Robert L. Hirsh, "Peaking of World Oil Production" p. 64-67

system to continue its expansion and overcome the spatial and temporal problems which plague it.

3.) Those who would propose that the problem of peak oil can be overcome by greater investments of technology to recover the relatively large amounts of oil left in the ground from previous drilling have failed to address the sobering fact that all such attempts have consistently failed to stop aggregate oil depletion in the US over the past 30 years, despite extensive use of the most sophisticated technology and rising oil prices. While new technological innovations may slow oil depletion, the claim that they will reverse it cannot be taken seriously until such time as these innovations are shown to actually reverse historical depletion trends.

4.) The suggestion that the problem of peak oil can be overcome by the use of nonconventional heavy oils such as tar sands and oil shale fails to take into account the thermodynamic limitations of such alternatives and the facts that conventional oil represents the highest-energy, easiest-to-recover, and easiest-to-transport fuel ever discovered and that all major transportation systems are based on this fuel. Secondly, even if market prices rise to levels that would make production of oil sands or shale oil profitable, it would still have to make sense from a thermodynamic perspective. If producing a barrel of shale oil requires more than a barrel of oil in energy equivalents, then it is a losing proposition from an energetic perspective regardless of market price. In the Athabasca tar sands two tons of sand must be mined to produce one barrel of oil, and two thirds of the oil in that barrel is required for the energy necessary to produce the other third. And none of this takes into account the amounts of water needed to produce tar sands. One expert has estimated that replacing the current global usage of conventional oil with oil from the tar sands would create a waste pond of oil slurry the size of Lake Ontario.[137] Estimates by leading energy companies take into account these problems, which is why a recent projection from Exxon-Mobil predicts that by the year 2030, tar sands will only be producing 5% of world energy needs, with the rest to be made up, Exxon-Mobil hopes, through increased OPEC production.[138]

5.) Critics of peak oil are fond of quoting the Saudi oil minister and leading figure of OPEC, Sheikh Yamani, who stated that "the Stone Age did not end because of a lack of stones, and the oil age will not end due to a lack of oil." The problem with this argument is the fact that throughout human history the development of new energy regimes has involved a switch from less concentrated sources of energy to more concentrated

[137] Richard Heinberg, *The Party's Over*, p. 112.
[138] ExxonMobil. *A Report on Energy Trends, Greenhouse Gas Emissions and Alternative Energy* February 2004. http://www.exxonmobil.com/corporate/Newsroom/Publications/eTrendsSite/index.asp.

and easier-to-extract sources. Thus, in the 1600s, the English moved from an energy regime based on biomass for personal heating and iron working to one based upon coal, because coal was a more energy-rich material (and more available than declining reserves of biomass). Similarly, the shift from coal to oil was encouraged by the fact that oil is higher in energy content, is more easily transportable, and requires significantly less human labour to produce and transport. A shift from conventional oil to tar sands or shale oil will have none of these advantages and represents a step backwards in the quality of the energy used. It is unclear what will happen to an industrial society habituated to constantly increasing inputs of cheap energy to maintain itself when these inputs and their quality decline. Dramatically increased costs of lower quality energy resources could lead to precisely the kinds of economic crisis, resource wars, and ecological catastrophe that many writers on peak oil anticipate.

6.) The development of a new form of abundant energy to power continued cycles of capitalist accumulation remains a possibility that cannot be discounted. However, at this date there are no convincing alternatives to the fossil fuel energy regime, and even should such a new form of energy production be discovered and immediately developed, there will be a serious disruption to the global economy as virtually all of the world's transportation and energy infrastructure will have to be rebuilt to adapt to this new energy regime.

7.) Shortages in conventional oil production will be reflected in a return to fuels such as coal and biomass that will greatly increase the production of greenhouse gases and further degrade the environment. A switch to nonconventional oil will also further impact the environment due to the enormous quantities of waste produced, and the water required for processing it. Use of more polluting fuels will intensify the greenhouse gas effect and also degrade the overall conditions of capitalist production, thus increasing the possibilities of deep-seated economic crisis and social upheaval.

8.) Most writers on peak oil have made two fundamental mistakes. The first has been a tendency to fetishize oil in such a way as to obscure the social relationships between human beings that make oil such an essential commodity in industrial production. Virtually all writers on peak oil naturalize capitalism as an economic system and fail to understand the relationship of exosomatic energy appropriation to the historic development of capitalism, which has always sought to use machinery as a substitute for and means of controlling human labour and as a tool for developing and consolidating patterns of unequal exchange and imperial domination. The second major mistake made by most Marxist and neoclassical economists has been to ignore the limitations on economic production imposed by thermodynamic laws which restrict the spatial and temporal extension of industrial capitalism. When questions of concrete social relations and entropic processes are included in the analysis of peak oil, industrial capitalism and a fossil fuel energy regime appears as an unsustainable anomaly and not as the future of human progress.

9.) The kinds of "resource wars" envisioned by Michael T. Klare[139] are more likely to develop as inter-imperialist rivalries grow between regional hegemons and the United States empire over access to remaining oil reserves. One of the main ways that capital can remain in limited control in an era of declining oil production is to intensify the functions of the state both by tightly controlling domestic and international oil resources, and by instituting systems of rationing to control labour strife and rising inflation. This will include an increasing role for the state at the local and municipal level where important struggles may break out for control over the implementation of post-peak oil social programs (i.e. local food production, coordination of imports and exports to cities, reorganization of transportation systems, zoning of land, etc.) As the world advances to and beyond peak oil production, the capitalist state will play an increasingly important role as a "collective capitalist" and stabilizer of the economic order, and will lead the way to an increased reliance upon strategies of "primitive accumulation". Because the other side of Hubbert's curve will create highly unstable economic conditions, it is highly likely that the capitalist state will increasingly come to control or nationalize major oil companies to produce oil that would not be developed under normal market conditions, or that would go to foreign competitors.

10.) The publicizing of peak oil production as a concept will have a significant de-legitimizing effect on the capitalist system, as it becomes increasingly clear that a petroleum-based lifestyle is impossible to maintain in the long-term and is only possible to enjoy temporarily by plundering the resources of other nations. In the resource wars of the coming century, the peaking of world oil production will provide an opening for socialists to argue for the development of an ecologically sustainable form of production integrated with historic demands for workers' control of production. It also increases the likelihood of capitalists endorsing totalitarian and fascist forms of state power to ensure control of limited energy supplies and to constrain a restive population.

[139] Michael T. Klare *Resource Wars: The New Landscape of Global Conflict,* New York: Metropolitan, 2002.

11.) Developing a socialism for a world past peak-oil production requires a comprehensive reassessment of typical Marxist perspectives regarding growth and economic expansion. Successful revolutions which inherit a seriously damaged global ecology and ever decreasing energy stocks will require a return to a more labour-intensive economic system based on smaller-scale local production geared to renewable energy and material flows.

12.) The increasing difficulty of producing more oil, and the increasing capital outlays required to access unconventional oil and offshore reserves, indicates a growing vulnerability of capital to the disruption of oil production. Popular struggles now breaking out in Venezuela, Bolivia, Iraq, and Nigeria gain a leverage beyond their actual strength due to the dependence of capitalism upon limited flows of fossil fuels. In an era of increasing production and discovery of oil, popular and nationalist struggles for control of oil wealth were subverted by capital's development of oil fields elsewhere, and by the threat of swing production in the US and Saudi Arabia. Popular struggles over control of hydrocarbon resources are now in a more powerful position than ever before as even relatively small disruptions to oil supply can ratchet up oil prices worldwide and win concessions from major oil companies and imperialist states.

13.) Central to understanding the consequences of peak oil is an analysis of capitalism, the first economic system to be based on a fossil fuel energy regime. Such an analysis needs to address the contradictions created by the system as it alienates human labour, creates antagonistic economic classes, destroys the natural environment, and stratifies nations and regions according to a "thermodynamics of imperialism."[140] The problem with most accounts of peak oil is that instead of recognizing that humanity's relationship to oil is fundamentally based upon our relationships to the organization of production, oil is fetishized as a commodity so that it is oil that becomes the agent in determining what we eat, the clothes we wear, how we move around, etc. Because of the central role that oil has played in animating machinery, a change in oil affects everything, including relationships of production, the metabolism between humans and nature, and patterns of imperialist domination. But those changes are reflected through and implemented under a specific kind of social organization – capitalism – that will only consider outcomes that will maintain its processes of accumulation. Thus the question of peak oil and the resolving of the enormous social disruption it will cause is fundamentally an issue of class struggle that can only be successfully resolved through the development of an economic system in

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[140] Alf Hornborg, *The Power of the Machine,* p. 93-95.

tune with thermodynamic limits and geared to meeting basic human needs and not profit maximization.

14.) Unlike human beings, hydrocarbons can release productive energy around the clock, and an increase in the amount of hydrocarbons available can reduce the price per energy unit of this work. The problem faced by capitalism and any industrial system based on hydrocarbons (even a socialist or communist one) is that the supply of hydrocarbons is finite and prone to depletion. So far, capitalism has been able to rely on the ever-increasing availability of hydrocarbon energy. But when the supplies start to run out and oil prices rise, the effects will be not dissimilar to a comprehensive and simultaneous world-wide increase in the cost of labour because of the global use of oil in all aspects of industrial production to produce mechanical work. Not only that but the costs of variable capital will also increase as the costs of subsistence for labor are tied to the costs of oil and other energy sources. Because cheap energy inputs have been able to reduce the subsistence costs for the world's working class, an increase in energy prices caused by oil production peaking will see a dramatic rise in food, electricity and transportation costs, all of which the capitalist class will try to get the working class to pay for through a significant decrease in real wages. Thus there is the real likelihood that in an era of declining fossil fuel availability the sweeping and instantaneous effects of ongoing increases in oil prices will intensify global class struggles.

15.) The effects of the occasional blackout or disruption to the electrical power grid that animates the complex networks of dead labour so prevalent in late capitalist society indicate the fundamental importance of energy inputs to industrial capitalism. In an era of steadily-declining fossil fuel inputs, as envisioned in a post-peak oil society, the production of surplus value and the overall stability of the capitalist system are at stake. The question will also require a significant rethinking of socialist thought, because previous conceptions of revolutionary change involving the taking over of an increasingly productive and powerful economic system will no longer be valid. What the strategies are that socialists could advance in this situation are beyond the scope of this paper, but they bear close study as the preponderance of evidence indicates that a post-peak world will be the new terrain of political struggle in the coming decades.

APPENDIX A.) REGULAR OIL PRODUCTION OF THE 15 LARGEST OIL-PRODUCING NATIONS IN THE WORLD IN 2004

Country	Present Production (In Billion Barrels/Year)	Present production (in millions of barrels a day)	Total Past Production (In Billion Barrels)	Reported Reserves in Billions of Barrels (from *Oil and Gas Journal*)	Depletion Rate (annual prod. as a % of the amount of oil there remains to produce)	Year of Peak Oil Discovery	Year of Peak Oil Production
Saudi Arabia	3.08	8.43	97	259.4	1.86%	1948	2008
Russia	3.00	8.21	127	60.00	3.5%	1960	1987
US-48	1.54	4.21	172	22.00	5.0%	1930	1971
Iran	1.36	3.73	56	125.8	1.9%	1961	1974
China	1.25	3.41	30	18.25	4%	1959	2003
Mexico	1.23	3.36	31	15.67	4.9%	1977	2003
Norway	1.11	3.03	17	10.45	6.6%	1979	2001
Nigeria	0.77	2.12	23	25.00	2.7%	1967	2006
UK	0.76	2.09	20	4.67	6.7%	1974	1999
Kuwait	0.68	1.85	32	96.5	1%	1938	2015
Venezuela	0.63	1.71	47	77.8	3.5%	1941	1970
Libya	0.50	1.40	23	36.00	1.5%	1961	1970
Iraq	0.47	1.27	28	115.0	0.6%	1928	2017
Canada	0.40	1.10	19	178.88	5.5%	1958	1973
Algeria	0.38	1.05	13	11.31	2.4%	1956	1978
WORLD	**23.2**	**63.66**	**919**	**1263**	**2.4%**	**1964**	**2005**

Caption: This table shows the yearly conventional oil production of the 15 largest oil-producing nations in 2004, the amount of oil they have cumulatively produced, the amount they claim according to the Oil and Gas Journal to have remaining in reserves, the yearly rate of depletion of their oilfields, the year that oil discoveries in that country peaked, and real and projected dates that oil production will peak. It should be noted that the statistics for this table are for conventional crude oil only and do not include the shale oil, oil sands and natural gas liquids that are factored in to the oil production statistics of British Petroleum's Annual Statistical Review or International Energy Agency reports of the United States government. Source: Adapted from figures provided by Colin Campbell of the Uppsala Hydrocarbons Depletion Study Group http://www.peakoil.net/uhdsg/Default.htm.

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