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TECHNOLOGY AND/IN CAPITALISM – THE GENESIS AND RELEVANCE OF THE RELATIONSHIP FOR THE PRESENT ECOLOGICALLY UNSUSTAINABLE ORDER**

Abstract. *The article critically analyses the crucial relationship between capitalism and technology(ies) in its historical and foundational dimension and its unprecedented natural-environment-altering dimension. It is argued that existing research in political science and political theory and progressive and emancipatory critiques of the unsustainable, exploitative nature of contemporary capitalism lack a critical interrogation of this relationship, which it attributes to a naïve, simplistic and problematic understanding of technology(ies) as neutral instrument(s). Building on materialist and neo-Luddite critiques, a comprehensive analytical framework is developed and applied to critically examine the genesis and nature of the relationship in its various dimensions and contexts, including the birth of the factory system, modern transportation, and modern ICTs. The analysed technological systems are demonstrated to be inherently capitalistic and environmentally unsustainable and their radical transformation should be at the centre of sustainable visions of a future socio-economic order.*
Keywords: *technology, capitalism, industrialisation, materialist critique, neo-Luddism, ecological crisis.*

INTRODUCTION

Those who must rely for their very existence upon artificial systems they do not understand or control are not at liberty to change those systems in any way whatsoever.
Langdon Winner in Autonomous Technology (1978, 327)

Although written in the late 1970s, Winner's quote is especially relevant for our present situation. We are faced with a polycrisis of the contemporary capitalist global order, ranging from the environmental and climate crises, rising inequality, perpetual socially devastating economic crises to socio-political destabilisations and the intensification of geopolitical crises. At least since the 1980s, the need to imagine and enact an alternative order has not only been confined to radical thinkers and emancipatory movements and far-right neo-fascist groups. An intensive search in global policy circles, institutions, and elites has been underway for alternative visions for a future more sustainable socio-economic order. The most progressive mainstream visions (see Brundtland 1987) imagined a more sustainable democratic and inclusive order that would move us away from the present global, extractive and unsustainable fossil-fuel based capitalist system. However, neither these mainstream visions nor the most emancipatory and reactionary visions of the future understand how capitalism in its consolidated industrial form has radically and fundamentally changed our societies and their relationship with the wider natural world. To fundamentally change the existing capitalist order, we must first understand how it overdetermines and structures our social reality, our relationship with ourselves and the natural world generally, and how it has transformed the conditions of our living, production and reproduction, thinking and acting, societies, bodies and minds.

These various visions and existing policy proposal and policies are interesting in that they curiously lack a comprehensive critical investigation of the central technological systems on which our globalised capitalist order fundamentally relies. This is strange given that technology and specific technologies are imagined as central in various visions and policies and politics and technology does figure in these visions of the future which strive to transform our system away from relying on fossil-fuels and the technologies that run and depend on them. However, most of the understandings of technology in these visions are severely lacking and entrapped in a techno-utopian, techno-deterministic and techno-solutionist ideological framework, one in which existing and potential future technologies are primarily imagined as *wonder instruments* (from tech for electrifying mobility, 'renewable' energy tech, (digital) technologies of automation including A.I., to carbon capturing technologies) for solving unsustainable aspects of the capitalist order that in itself is not considered foundationally problematic (Morozov 2022). This is also mirrored in mainstream and a large share of critical political science and political theory that are either uninterested in comprehensively critically engaging with technological systems and central technologies of the capitalist social form and do not consider it a relevant phenomenon to be researched/theorised or their understanding and focus is problematic in its assumptions, scope, general understanding of technological systems, and extreme recency bias where the present technological system is imagined as a revolutionary departure from the past logics and imperatives of capitalism (e.g., Varoufakis 2024; Zuboff 2020).

Existing visions of the future order and mainstream and critical analyses of the current order rest on a problematic notion of technologies in relation to capitalism. They are imagined as neutral instruments and tools that can be utilised for different ends, developed in an almost transcendent process of historical technological development that is inevitable, unguided and objective, and leads to the increased efficiency, comfort and ultimately sustainability (of capitalism?) due to the possibilities of the total technological substitution of older unsustainable technologies and technological tackling of past and present negative effects of older technologies. The latter eco-modernist perspective of the ultimate social benefit arising from (novel) technology which includes the fantasy that economic material growth can gradually be decoupled from extensive unsustainable natural resource use and environmental and climate devastation[1] may be found in visions subscribing to varying political ideologies on the whole political spectrum. This includes Marxist and other socialist visions which view technological development as neutral and technologies as neutral productive forces that can be unproblematically harnessed to establish a radically different system. Many emancipatory visions (e.g., Bastani 2019; Phillips and Rozworski 2019) of the future are entrapped in capitalist understandings of technology(ies) that obfuscate their nature, characteristics, functions, effects, non-neutrality, interest-based design, and limit their potential to be used in radically different ways for emancipatory goals.

This issue is reflected in the dominant critiques of the present 'digital capitalism' (e.g., Varoufakis 2024; Zuboff 2020) that do not problematise capitalism and its relationship with technology(ies) but paint a picture of the system today as a complete novelty in a "back to the future" techno-feudalist imagining of our present thoroughly capitalist context (Morozov 2022). They suffer from seeing the contemporary evolution of capitalism as a revolution and implicitly promote a 'better' sustainable capitalism that is, as we intend to show, quite impossible given the centrality of the specific technologies developed and employed according to capitalist imperatives and logics. In due course, these critiques prevent the development of more adequate practices to resist, collectively struggle against, and develop a future emancipatory non-capitalist, sustainable, eco-socialist vision and also the development of technology(ies) and its relationship with emancipatory power relations, institutions, and structures.

A critical examination of the fundamental relationship between capitalism and technology(ies) in its historical and foundational dimension is thus essential for any kind of comprehensive vision of a sustainable socio-political order. In this article, we first develop a comprehensive analytical framework to historically analyse this relationship. This is followed by an initial reflection on the singular nature of the capitalist system concerning its planetary and local effects on the human and natural world. The central part of the analysis then focuses on

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[1]   For a devastating empirically grounded critique of this fantasy, see Wiedmann et al. (2015), The Material Footprint of Nations.

selected crucial technological innovations and their relationship with capitalism that today are still centrally relevant for the techno-social capitalist organisation of our lives. In this context, we address the factory system and machines of automation, the fossil-fuel powered modern transportation and logistics technologies and system, and the modern electric-powered ICTs while demonstrating their relevance for the contemporary, dominant computer-digital capitalist order.

A MATERIALIST-NEO-LUDDITE ANALYTICAL FRAMEWORK

A critical perspective calls for an analytical framework to be developed that is able to address the complex relationship between capitalist power and technology(ies) for radically transforming societies and their relationship with the natural world. The analytical framework must hence be able to simultaneously analyse capitalist power or power in capitalism and analyse the development and nature of capitalist technologies and technologies in capitalism. Our analytical framework draws from Søren Mau's (2022) interpretation and reconstruction of Marx's materialistic conceptualisation of the three central dimensions of power in a capitalist system, namely the ideological, repressive and economic dimensions of power. This framework offers a more comprehensive view on how power functions in the capitalist system, inherently tied to its reproduction as a specific class system operating in line with the law of value (the logic of profit). What is vital here is that this framework should be understood in the context of the reproduction of the global capitalist system characterised by certain geopolitical hierarchies tied to particular asymmetrical power relations on not only the state level, but the global level too.

The three central dimensions of capitalist power can be further elaborated as follows. The ideological dimension encompasses epistemological frameworks (discourses) for perceiving, imagining, thinking about, and responding to the socio-political reality that they in turn co-create. These frameworks include specific values and presuppositions or *Truths* concerning our place in society and the world, relationships among individuals, and groups. They also include rationalisations and legitimisations of multiple and multidimensional inequalities, hierarchical relationships, and structures, thereby co-enabling the reproduction of the capitalist system. The primary, albeit not exclusive target of this dimension of power are the minds of individuals and groups. The repressive dimension embraces state and corporate policies, institutions, techniques and practices that are chiefly based on the repression, domination and disciplining of individuals and groups and/or the threat of repression if certain norms, rules and behaviours are not followed properly. The chief but not sole target of this dimension are the bodies of individuals and of individuals qua members of specific groups. The economic dimension refers to policies, techniques, practices, machinery/technologies that are directly pertinent to production processes, namely, the capitalist accumulation. The core target of this dimension is not the individual directly but the conditions of human life itself and has its "roots in the ability to re-organise the material conditions of social reproduction... the

processes and activities involved in securing the continuing existence of a given society" (Mau 2022, 12). This framework will be enhanced with Foucault's (1976) central insight into the functioning of modern power especially as concerns the creative aspects of power relations that not only target individuals as bodies and minds but co-create and work through them and their actions, the highly adaptable nature of modern power relations and their asymmetries, and the always already present individual and collective resistance to the existing asymmetrical power relations and their expansion and/or ossification via novel techniques and specifically novel technology(ies).

Our analytical framework also draws on (neo)-Luddite critical reflections of technology(ies) in capitalism that focus on the particular development, implementation, functioning and effects of central technologies on power relations in capitalist class societies (see Costello 2024; Marx 2022; Merchant 2023; Mueller 2021; Sadowski 2018; Tarnoff 2023). Technology in relation to capitalist class relations is never neutral. It inherently asserts specific political aspects. Its development and implementation entail a set of choices made by capitalists holding privileged positions of power vis-à-vis workers and other common citizens. The development and implementation of technologies should not be thought of as inevitable, as part of a transhistorical process of natural, objective technological development that cannot be stopped or redirected. The implementation of novel technologies in a capitalist social formation principally leads to the intensification of asymmetrical power relations that disproportionally favour capitalists. This is almost always associated with higher levels of worker exploitation as their autonomy is reduced, specific tasks are automated, workers are becoming deskilled, while productivity is raised for the sole purpose of cutting labour costs and boosting profits irrespective of the workers' well-being and the quality of the services and goods, not to mention pollution and environmental destruction. Heightened levels of surveillance and control always accompany the implementation of novel technologies; namely, a process always fraught with resistance from the people negatively affected by these technologies. This resistance and alternative ways of developing and implementing technology(ies) that would open this process up to democratic interventions and deliberation and decision-making is either silenced or obfuscated and/or directly attacked for being irrational and impossible. Finally, the capitalist state with its legal system (e.g., IP laws), its repressive apparatus, political system, and the education system together with corporate/mainstream media play a considerable role in these processes. First, by disseminating, popularising, rationalising and legitimising the techno-deterministic and techno-optimistic ideology of the capitalist classes and silencing oppositional views. Second, by actively supporting the development and implementation of novel technologies. This includes the government-supported disruption and destruction of existing legal obstacles or customary limits that prevent the development and implementation of certain technologies and the use of state violence to crush collective resistance against specific technologies if

it appears on the national and global level. The neo-Luddite epistemology allows us to transcend the hegemonic understanding of technology(ies) that imagine technology(ies) as neutral instruments, tools, spaces, platforms, services to be unproblematically utilised for emancipatory ends. This type of thinking fails to critically examine technology(ies) itself and crucial differences between the development, nature and implementation of specific technologies.

Here Marx's (1847) insight that only under a certain condition does a machine become capital should be qualified. Some technologies were (or are not) developed foundationally to align with the capitalist mode of production and it is their particular implementation that transforms them into capitalist technologies. In Marxist terms, these technologies are part of the formal subsumption of pre/non-capitalist technologies and the labour process they enable in the sense that these technologies basically remain unchanged except that they become part of the capitalist accumulation process and ownership relations. These technologies could theoretically be utilised in non-capitalist social forms. Yet other technologies are also developed whose characteristics and implementation occur in a way that makes them part of the real subsumption in capitalism whereby these technologies could only be developed and implemented and possess characteristics inherently linked to the capitalist labour process. They exist by virtue of the nature of the capitalist system, are developed for its quantitative and qualitative expansion, and establish and reify certain relations of power. This means they cannot simply be integrated into a non-capitalist social order and can never be unproblematically applied for emancipatory ends, including sustainability.

While the neo-Luddite perspective provides an initial critical view regarding technologies and their situatedness in capitalism, the three-dimensional framework for understanding power in a capitalist system enables us to be attentive to specific foundational elements and the characteristics of the relationship as well as to comprehensively address them. It permits a focus on the nature of relationships concerning specific dimensions of power in capitalism, and their function and role in broader capitalist social relations, coupled with their genesis, reproduction and transformation on the local and global levels. Following Marx's and Foucault's lucid insights into the immanently dynamic and transformative nature of the modern capitalist order allows us to be attentive to the continuities and changes in the capitalism–technology relationship. We primarily focus on technology(ies) in relation to the economic dimension of capitalist power, leaving the consideration of the other two dimensions to future research.

THE ECONOMIC DIMENSION OF CAPITALIST POWER, ITS RADICALLY TRANSFORMATIVE NATURE, AND RELATION TO TECHNOLOGY

The relationship between the economic dimension of capitalist power and technology(ies) is at once obvious yet also complex, constitutive, contradictory, ambivalent and obfuscated. This is inextricably linked with the prevalent

misunderstanding that a delimited economic sphere of society exists in which production takes place (where the capitalist mode of production is located) that is fundamentally distinct from the spheres of society, politics and the natural environment (see Baker 2006). Nevertheless, when referring to the economic dimension of capitalist power, we must bear in mind that this dimension targets and affects the general conditions of human life itself. For capitalism to become a historically singular social formation, the capitalist mode of production driven by the capitalist imperative and logic of the continuous ever-growing accumulation of profits had to expand to gain the ability to re-organise the processes and activities needed for social reproduction. It namely had to become crucial for the survival of society with this being achieved by radically altering the material conditions of social reproduction. Yet unlike previous social forms, capitalism has radically transformed the general conditions of human life by establishing its imperatives and logic in (almost) every aspect of it (from birth to shelter, food, energy, education, work, health, transport, infrastructure, culture, identity and love). It has also unprecedentedly and singularly transformed and is ever more intensively transforming the conditions of biological life itself on planet Earth (Malm 2016; Mau 2022; Patel and Moore 2017; Wood 2017).

Capitalism is based on a permanent drive towards accumulation while the market is established as the paramount set of social institutions, practices and relations that allocates resources and directs and fosters accumulation processes. Capitalism is hence a historically singular market society in which everything is organised around the production of commodities, the provision of services and consumption, and driven by the imperative of expanding the accumulation of surplus value and, ultimately, profits. It is predicated on the historically specific class division, the particular class struggle between capitalists as the owners of the means of production and workers as those who only own their labour power. Capitalists and corporations are driven and disciplined by this local and global market competition and the need to expand and intensify their accrual of surplus value. The combined expansion of their accumulation is the aggregate economic growth that is the overriding objective of all capitalist nation states. The expansion of accumulation is based on expanding capitalist formal subsumption of various previously not yet commodified, not yet subsumed aspects of human everyday lives (ensuring that our needs and desires can only be realised in the market) and by intensifying the exploitation of workers either by lengthening the working time, intensifying the work, or implementing capitalist technological innovations to maximise workers' output and thereby optimise production. Given that the workers (formally free or in un-free labour relations) are the only source of surplus value, accumulating it has always required a sufficient pool of (relatively cheap) labour power, of people turned into wage labourers or wage labourers in the waiting. It called for the creation of conditions such that most people were dispossessed of their means of production, and to survive needed to work for capitalists, for wages. But after having turned people into docile,

effective and efficient workers in a capitalist setting in which the owners receive most of the (surplus) value) of their workers, transformation of labour had to include the development of a specific organisation of the labour process, of certain techniques and technologies to assure discipline, control, efficiency and limit the autonomy of workers who were continuously resisting their exploitation and struggling for improved wages and working conditions and/or resisting colonial dispossession, occupation and subjugation (Malm 2016; Mau 2022; Patel and Moore 2017; Wood 2017).

Along with the further exploitation of workers, this expansion of accumulation has always required (requires) the conversion of ever-growing amounts of natural resources into means of production and commodities for sale and consumption. In capitalism, people and nature must be treated as a set of resources to be exploited (Wainwright & Mann, 2018). Capitalism is inherently an ecologically devastating, hyper-extractive, exploitative and alienating social form. Even though various human social forms in history have substantially transformed and undermined their immediate environments that precipitated their decline and destruction, capitalism is unique qualitatively and quantitatively. Especially since the development of its industrial form in the early 19th century its effects have been radically transformative with respect to its capabilities for penetrating the everyday lives of people and societies, transforming human bodies, and naturalising specific frameworks of thinking and acting. Its effects have been also radically transformative concerning their scope as it truly became planetary in the sense of affecting and radically altering the lived environments of not simply humans but all living beings in a detrimental, permanent and irreversible way. Capitalism has radically reorganised the relationship between humans and the rest of nature and its global impact, which means we can refer to our age as the Capitalocene (cf. Moore), namely the era when human capitalist societies began to radically alter the planet's ecology through their unprecedented resource extraction, pollution and interventions in the planetary ecology (e.g., monocultural farming). The extent of this radical transformative force of capitalism is clearly shown by the fact that since 2020 human-made mass began to surpass all global living biomass (Elhacham et al. 2020).

Crucially, these processes have precipitated global warming and several continuous ecological crises (e.g., loss of biodiversity, deforestation). Whole continuous ecological crises are a necessary consequence of capitalism, the latter also harbours fundamental contradictions (Saito 2017). Capitalism is constantly eroding its own material conditions, which it purports to tackle by continuous experimentation and socio-technical innovation that further expands and entrenches its imperatives and logics with every successive variation of its global social form, in turn further exacerbating the fundamental issues. It is constantly expanding and further transforming socioecological relations by constantly increasing the production of commodities that circulate in ever-expanding series of exchanges (Patel and Moore 2017; Saito 2017). The unparalleled

intensification of ecological crises in contemporary capitalism implies that there might be absolute limits to the current capitalist (socioecological) metabolism in the sense of a specific capitalist material exchange between human being and the environment, noting the latter relationship is one of mutual determination and transformation (Sacher 2022).

The capitalist separation of humans and nature was always ideological as we were never separated and everything humans have ever produced is always already coproduced with nature and in a wider web of life (Kurnik 2024). Up until the recent ecological crises, capitalism was able to continuously revolution-ise and reinvent itself by establishing novel frontiers, displacing crucial issues and reorienting and reorganising itself to expand its productive capacities. It has thrived by putting nature to work as cheaply as possible and offloading the costs of this cheapness onto populations and environments designated, normal-ised and naturalised as objects of its activities, as legitimate *collateral damage*. As Patel and Moore (2018) observe, "the whole system thrives when powerful states and capitalists can reorganize global nature, invest as little as they can, and receive as much food, work, energy, and raw materials with as little disrup-tion as possible".

Despite its planetary effects, capitalism is a socioecological system that pro-duces and reproduces and operates via radical differentiations, hierarchies and stratifications where the positive and negative effects of the capitalist mode of production are unequally distributed within certain societies locally and glob-ally according to the worthiness of specific populations established through the imperial-capitalist relations. Its socioecological impacts are therefore diverse within and among various geopolitical areas where the poorest, the most exploited and dispossessed communities were (are) burdened by the most ser-ious negative effects. On the other hand, up until recently the capitalist classes were not only enjoying the immense wealth produced by the capitalist social form but also the non-degraded environment in which they lived their healthy, segregated, secured and opulent lives. Nonetheless, the intensification of the cli-mate crisis and wider ecological crisis has substantially reduced the possibility of retaining this radically distinct living condition indefinitely (Dunlap 2024).

However, capitalism would not reach its planetary effects or be able to estab-lish its socioecological reorganisation as hegemonic without capitalist techno-logical innovations. It was the particular nature, characteristics, functions and effects of these technologies that have enabled a global society and the eco-logy-altering effects that have radically reorganised society and the environ-ment, which ultimately have begun to erode the environmental conditions that support human life. The creation and implementation of these technologies were predicated on a series of choices made by capitalists geared toward the goal of expanding accumulation and securing its stable continuation by increasing the control over workers. The unimaginable extent of material production, pollution and devastation could never be achieved without the global expansion of the

factory system and utilisation of fossil fuels to provide this system with required the energy. Still, neither the factory system nor the use of fossil fuels for capitalist energy production, logistics and transportation was an unavoidable, historically necessary innovation, but was instead a set of specific choices and inherently problematic paths taken in line with the capitalist imperative.

THE FACTORY SYSTEM AND THE GENESIS OF INDUSTRIAL CAPITALISM

The genesis of the factory system was based on the destruction of the earlier system of small family-owned shops employing their own machinery and performing specific vital processes in the production of various textiles (the first proper industry). The worker-artisans who worked in these shops were highly skilled and had undergone years of apprenticeship to be able to operate and improve the machinery being used in particular processes. They produced high-quality goods in predictable quantities for capitalists who bought their services and held complete autonomy over their working hours, the production process and could count on a predictable income that guaranteed them a comfortable life (Merchant 2023; Mueller 2021).

The destruction of this production system and this system of technological development was the central element of the radical transformation of society, of the real subsumption of labour under capitalism via its technological reorganisation of production. It was predicated on certain structural conditions, geopolitical developments, the ruthless activities of the first industrial capitalists, the (non)intervention of the British state, and ideological work by intellectuals and the media (Merchant 2023; Mueller 2021; Thompson 1980). The Napoleonic wars and continental blockade triggered an economic crisis that established the conditions of possibility for radical change (Hobsbawm 1986). The most ruthless capitalists who could draw substantial loans created following brutal local and colonial primary accumulation started to build massive factories where, contrary to the existing laws, mass-automation machines were utilised systematically and the most destitute, powerless, docile, presumably non-skilled workers such as children (mainly orphans from the Napoleonic wars provided by state-operated workhouses) and women were employed and could be paid extremely low wages for extremely long working hours doing extremely mind-numbing albeit heavy tasks tied to extremely dangerous machines to which they had to adapt or be maimed and killed by them. These factories allowed industrial capitalists to illegally maximise and unprecedentedly increase the production of cheap but inferior goods and unprecedentedly increase worker exploitation (radically cutting labour costs), thereby gaining a competitive edge that brought an end to the family shops and forced other less ruthless capitalists to follow in their path or be crushed (Merchant 2023).

The above-mentioned developments enabled industrial capitalists to gain enormous wealth while destroying the livelihoods and environments of whole

communities and expanding and entrenching the division of work by dismantling the autonomy of workers. The factory system was predicated on the implementation of the systemic and systematic surveillance of workers and control of the minutiae of workers' activity in various steps in the production process. This included a strict shifts-based regime of production and the need for a continuous further division/segmentation of the process of commodity production into smaller and smaller steps that called for ever less individual skills of workers who had to adapt their bodies and minds to the machine, not the other way round (Costello 2024; Harris 2023; Merchant 2023; Whittaker 2023).

The process was controlled by the capitalist management and overseers with workers being subjugated not only to machines but also to the whims of those that designed and implemented them. The automation of capitalist production was labour-saving in a very specific way in the sense of further intensifying the power held by capitalists over workers. The mass-automation technologies were explicitly anti-democratic, hierarchical and authoritarian, and an instrument of the rationalisation and consolidation of capitalist asymmetrical power relations. They put an end to all ideas of ordinary workers and people having the right to participate in the development and implementation of technologies (Harris 2023; Merchant 2023; Mueller 2021).

The industrial capitalists and their supporters in the government and intelligentsia started to legitimise this process via the notions of the inevitability of technological progress that would ultimately lead to prosperity, less work, and greater comfort but above all to the continuing dominance and expansion of the power of the British Empire. The requirement for the (strict) division of labour for sake of prosperity was also legitimised. This was inextricably linked to the notion of the need for automation and the systematic control and surveillance of the working processes and the workers, which were linked to the heroising of industrial capitalists and derogatory ideas concerning workers. Here the still widespread idea of the maverick entrepreneur who through hard individual work reached the top of the division of labour that is solely responsible for the progress of societies, wealth creation, as well as providing jobs and opportunities became hegemonic. It was in this context that industrial capitalists and their allies popularised the image of the inherently lazy worker, one who is child-like, undisciplined, ungrateful and cheating, which still can be found today. These images and necessity of the division of labour implied that capitalists, the "overseer", the "producer", should be in charge and automation began to be imagined as a central element of enacting and controlling, while also including the never realised fantasy of human work becoming obsolete (Mayor 2018).

Ever since the dawn of the industrial revolution capitalists had two fantasies; first, of abolishing the need for workers – the ultimate cost reduction; and, second, of a fully automated profit machine. It was (is) used to discipline and control workers as an instrument for frightening workers regarding their future 'inevitable' unemployment and thereby rationalising the worsening of their

working conditions and compensation. In addition, it was (is) utilised to disguise the fact of the inescapable need for human labour for any kind of automation to work properly in the long run. The fantasy of full automation formed part of a broader perception of the need for the factory system where the drive to automate as much of the production process as technologically and financially viable was a central part of it (Merchant 2023; Sadowski 2018; Taylor 2018).

Understanding of these processes was widespread among the English textile workers in family shops who were the first to experience the industrial revolution and the first to rebel against it in the form of the Luddite movement, the earliest movement against the specific kind of mass automation technology tied to the factory system. The Luddites knew that industrialisation would destroy communities and livelihoods, but the capitalist elites, the state and the political and intellectual elites rationalised and legitimised this process of concentrating power and wealth as inevitable and beneficial for society in the long term because it would facilitate unimaginable material progress from which everyone was to benefit. The Luddites and other more reformist groups presented policies to immediately address the extreme negative effects of industrialisation on workers and communities. They proposed minimum wages, the redistribution of extreme profits among the citizens, and demanded the prohibition of child labour, taxes on automation machinery, the more democratic implementation of machines and their participatory development that would not be subjected to the imperative of profit maximisation but the one of the greatest social benefit (Merchant 2023; Winner 1977).

Their proposals were not heeded, leaving an armed rebellion as the only remaining possibility to stop this form of industrialisation. Despite initial success, this uprising was crushed by the combined power of industrial capitalists, the British state with its military (the largest military occupation on British soil) and legal system (punishing/executing Luddites) and the media with its techno-utopian, optimistic and naïve visions of technology along with derogatory and irrationalising representations of people's resistance to the factory system. Its effects on the communities were destructive not just for the local worker-artisan communities but for the majority of society and held negative reverberations in other contexts of the British Empire rapidly reaching across the globe (Merchant 2023).

Industrialisation via the factory system controlled by industrial capitalists and supported by the modern capitalist imperial nation state was established as a paradigmatic form of development. It was the backbone of the establishment of Britain's global hegemony over the world capitalist system and all other imperial powers had to follow to economically and militarily compete with the British Empire. The factory system proved immensely destructive for communities and environments. It was built on a massive expansion of production (and consumption) that required not only a massive disciplined and docile labour force for its factories but also a massive amount of input resources, of primary commodities

like cotton produced in the European American colonies and the USA on slave plantations, the proto factories of the developing capitalism (Patel and Moore 2017). British industrialisation called for and precipitated the intensification and expansion of production on slave plantations, causing them to become even more brutal for the enslaved population with respect to their workload, surveillance, disciplining and control. The factory and plantation owners learned specific techniques from each other to extract as much value as possible from their workers and slaves, assure their discipline and docility, and prevent their resistance including the use of forms that would later be rearticulated as scientific management (Whittaker 2023). The genesis of the factory system consolidated and intensified not only the local but also global divisions of labour and the unequal exchange of commodities that still define the global capitalist system (Hickel et al. 2022).

The expansion of the factory system also led to an unprecedented rise in mining activities for extracting metal ores crucial for machine-building and extracting fossil fuels. The latter were key to providing the energy required to run the ever-expanding set of machines in the novel massive factories. The fact that fossil fuels became the primary source of energy for the factories, that the mass automation machines were powered by the steam engine and later the internal combustion engine, was again not an inevitable, neutral selection but the choice of industrial capitalists. They chose fossil fuels not so much to maximise profits in the short term as to consolidate and intensify their power and capabilities to discipline workers and limit the autonomy of the working classes. From an economic standpoint, until the mid-19th century hydro power was a relevant alternative to fossil fuels. The choice of British industrialists for fossil fuels had more to do with the issue of extending control, power and domination and ultimately prevailing in the class struggle with workers. Contrary to water, that capitalists could not control and which enabled the workers a certain amount of autonomy, fossil fuels enabled a greater level of control, a radical reduction in worker autonomy via machines powered by fossil fuels. Fossil fuels enabled new possibilities of intervention and control in metropolises and colonial contexts (Malm 2016).

Along with that, fossil fuels as fossil capital became a central foundation for accumulation, for the generation of profits and expansion of production. Not only machines for producing commodities, but also transporting people, logistics and the transport of commodities to the market and resources to factories, and later the generation of electricity powering the second industrial revolution and even later computerisation-digitalisation, became and remain dependent on fossil fuels. Despite various substantial changes in capitalist accumulation regimes, fossil fuels continue to be the cornerstone of contemporary capitalism. Notwithstanding alternative 'renewable' power sources, fossil fuels and their environmental devastation remain central for mining the required mineral, production, transport, functioning and maintenance of technologies utilised in

solar/wind/hydro power generation (Dunlap 2024). Fossil fuels have also become even more entrenched through various commodities such as plastic and ammonia which are a direct result of the chemical and physical transformation of specific fossil fuels like oil without which the existing levels of the accumulation of capital could neither be retained nor expanded (Paterson 2021).

The latter point is even more pronounced in the case of the capitalist factory system whose centrality for successive regimes of capitalist accumulation is undisputable, which is inextricably connected with the fact that it is the central assemblage of the capitalist production process. It is at the heart of the specific techno-socio-politico-economic system that has defined the capitalist social form throughout its dynamic history and as such it is central for the addressed capitalist social ecology that is now faced with its potential absolute ecological limits. The factory system was the inauguration of a certain form of social organisation whose unstated core goal was to establish and exert control over the whole of society at every point of human existence, to fortify and further extend the domination and alienation of communities and individuals with the aim of maximising production and thereby the exploitation of workers and other non-capitalist parts of the population so as to continuously expand the accumulation of capital. It radically transformed not simply the production process (addressed above) but every other aspect of human communal lives since the factory production process conditioned and relied on the reorganisation of societies, their structures, institutions, ideologies and relations among people and relations to other societies. It fundamentally transformed human minds and bodies and massively altered the urban, rural and natural environments that were reorganised to provide the factories with resources and people, food, energy, shelter and with transportation and logistical capabilities.

THE REORGANISATION OF TRANSPORT AND OTHER SUBSYSTEMS AND THE GENESIS OF INDUSTRIAL CAPITALISM

The factory system required not only the unprecedented expansion of extraction and production of primary commodities in mines and farms/plantations enabled by the introduction of novel technologies but also a specific infrastructure, a fast, reliable and expansive transport system first able to transport these materials to the factories. Second, this system was required to distribute commodities to local and global markets and ultimately consumers. It was also needed to establish reliable, fast and continuous communication and information exchange. Although waterways and the expansion of road systems played a central role, the railroad system and its steam-powered locomotives running on fossil fuels were critical for radically reorganising the human–environment interaction. The building of railroads radically changed natural landscapes together with rural communities and urban centres as they all were adapted to suit the requirements and whims of the railroad system mostly built by emerging railroad tycoons with financial support from the state and its legal and repressive

power. Like the factories themselves, the railroads enabled capitalists to extract enormous wealth through exploitation of the most marginalised workers and to expand the control and surveillance of both capitalists and the state over rural and urban populations in metropolises and in the colonies. Similarly as for the factories, the constructing of railroads was rationalised and legitimised via the techno-utopian, techno-optimistic ideology of inevitable progress supposedly benefiting the whole of society by connecting people and remote places. Along with the consolidation of the factory system, it established the paradigm of the implementation of capitalist technologies where concerns with their negative effects on communities and the environment were silenced, repressed and ridiculed. Moreover, it established the paradigm of capitalist transport systems where the natural and urban/rural environments were destroyed and rebuilt and reorganised with the primary purpose of expanding and securing capitalist accumulation. Forests were cleared, swamps drained, hills destroyed, rivers altered, bridges built, and parts of villages and towns raised without heeding the interests of the local mainly marginalised and colonised communities (Hobsbawm 1986; Post 2011).

Another essential part of the capitalist transport-logistic paradigm was the co-establishment, reification and naturalisation of capitalist hierarchies and stratifications that privileged, and discriminated against certain parts of the population. It was crucial in the processes of class, racist, and sexist domination in the metropolises and the colonies. Where the railroads were built the effects they had on specific (parts of the) population were never neutral, homogenous and equal, but always already informed by social control, regulation, disciplining and ultimately stability for the purposes of continuous capitalist accumulation. How the railroads operated was also overdetermined by class, racist and sexist domination as wealth, gender and race were used to segregate people into particular railroad cars with levels of comfort tied to the perceived social worth of certain populations (Harris 2023). Similar imperatives and logic informed the reorganisation and expansion of ports that became critical hubs for the distribution and circulation of commodities and production as well (Khalili 2021).

The later development of the highway system and the system of motorised individual mobility through cars and goods transport relying on trucks running on internal-combustion engines that use petroleum (oil) has followed but also expanded on the capitalist transportation paradigm and further deepened the capitalist techno-social reorganisation of society and its environments while also massively expanding capitalist accumulation. Even more than the railroad system, the highways and roads adapted and built to suit car/trucks have radically changed human environments. Our cities and villages were transformed to accommodate cars and trucks by turning them into mazes of roads and patches of parking spaces connecting spaces of production, consumption and reproduction. They became inherently hostile to pedestrians as human lives were reorganised according to this individualising transport technology that itself

became one of the central (and for ordinary people) most expensive although necessary commodities to live in our car-centred cities. The consolidation of this system was again not inevitable, but a succession of choices made by capitalists, by corporations with the support and power of politicians and state institutions, including its repressive apparatus (courts, police, military) that silenced opposition and either destroyed or curtailed the development of alternative modes and technologies of transportation (P. Marx 2022). This thereby established a system of additional intensive pollution that, along with the factory system, became primarily responsible for ultimately potentially reaching the planet's absolute natural limits.

Public transport and electric vehicles were not a later techno-social innovation but appeared simultaneously with the individualised internal-combustion, motor-based technologies. However, their development was radically obstructed by the predominant interests of capitalists tied to the power of the state. The radical transformation of the human lived environment enacted a gradual yet thorough indoctrination of people that naturalised this reorganisation of life and made it an almost unquestionable element of modern life to the degree that even emancipatory movements hardly questioned it in its totality (Ladd 2011).

The consolidation of the industrial system triggered and called for a radical transformation of basically all societal contexts, functions and relationships on the local and global levels to adapt, expand or re-create them to feed the machines of the innumerous factories, to address their evolving needs concerning the steady flow of not only resources, fuel and power but also workers and food to make them productive. From agriculture and the distribution of food and consumable goods to healthcare and education, all of these systems and contexts were radically transformed to suit the imperatives and logic of industrial capitalism and its factory system. In all these different contexts, novel capitalist technologies were implemented to improve the efficiency and output (e.g., agriculture via the motorisation of machinery and monocultural specialisation) and to either educate and discipline future workers (e.g., the creation of a system of standardised education that disciplined, segmented pupils and equipped them with reading-mathematical comprehension) or to tackle the ever-expanding negative societal and environmental effects and preserve the health or address the illnesses (caused by industrialisation) of the working population and its healthy reproduction (e.g., the healthcare system, sewage systems, public parks). In all of these contexts, the existing socio-politico-economic hierarchies and stratifications organising populations into worthy/unworthy, productive/non-productive groups were consolidated. Their differential effects on the well-being of individuals were based on their prior categorisation in specific hierarchically organised groups that in these various spaces was further normalised. With the development of industrial capitalism, these systems and the professionals employed to work in them became ever more crucial for the smooth operation of the production system and inextricably connected with the developing scientific

disciplines, expert knowledge, and novel technologies. They also became more and more subsumed by capitalism in the way their services and products became commodities themselves (Hobsbawm 1986; 1987).

Still, the emerging factory system of industrial capitalism also required the expansion and development of systems to address its voracious need to expand the accumulation, which called for new markets. This called for a novel information and communication infrastructure utilising and furthering the development of novel ICTs that would be vital for the radical reorganisation of space and time in industrial capitalism. These novel ICTs would prove to be instrumental in continuously re-establishing social cohesion, thereby ensuring predictability and the specific form of social stability capitalist accumulation requires to keep expanding.

ICTS, COMPUTATIONAL THINKING, AND THE CONSOLIDATION OF INDUSTRIAL CAPITALISM

ICTs and systems facilitated an unparallelled rise in speed of the production and circulation of goods as well as the realisation of profits. Yet they were also crucial for the standardisation, stability and regularity needed to consolidate industrial capitalism. With the widespread adoption of the telegraph, the first wire-based electrical system of communication and information exchange, the almost-instant exchange of information and communication became possible and was soon indispensable for the further expansion and consolidation of industrial capitalism after the mid-19th century. The telegraph required the standardisation of (the measurement of) time critical for the factory system to be able to operate. The latter required the synchronisation of societies (of labour) according to a single regime of time, a standardised (pure and uniform) time. The revolutionary nature of the mechanical clock's integration into the production processes should not be overlooked since it became one of the central technologies of control and organisation in the industrial society (Thompson 1967).

The adoption of the telegraph saw an exponential increase in the quantity of information and unprecedentedly intensified communication that compressed time and space. Together with the transportation/logistics networks, it bound industrial capitalism together (Costello 2024). Industrial capitalists were thus able to gather essential information pertinent to specific markets, and they could more efficiently plan their production and respond to certain issues, events, process, from natural disasters through to revolts and upheavals. They could exert greater control over the production process and their workers along the expanding production and distribution chains and introduce different pricing for their commodities adapted to suit the characteristics of specific markets. These novel ICTs had a transformative effect on older ICTs such as newspapers by providing them with the means to gather previously unattainable instant information on happenings in far removed places (Harris 2023; Mau 2022).

These technologies were also vital for securing the stability, continuity and predictability of the capitalist accumulation as they enabled fresh capabilities of surveillance of various socio-political contexts and populations. They were indispensable for economic power yet also for the operations of ideological and coercive power primarily but not exclusively enacted by the imperial-capitalist state apparatuses crucial for ensuring the appropriate socio-political stability and cohesion by rationalising, legitimising, inscribing and policing specific class-racist-sexist stratifications/hierarchies/divisions of particular populations locally (in metropolises) and globally (in colonies) (Stoler 2002). These technologies were among the most crucial for managing certain socio-political and economic crises to prevent any radical destabilising of the order to the detriment of capitalist accumulation and the global imperial system. They enabled a substantially more oversight of the minutiae of subjugated populations and a quicker, more efficient way of ideologically/coercively/economically crushing their collective resistances. The violence, death and destruction that they could help to enact on the subjugated populations could be equally bloody as the genocides of the early European colonial periods and the pre-capitalist primitive accumulation. However, they proved to be even more crucial in enacting punishment on resisting populations that took the appearance of the 'normal' functioning of commodity and financial markets that engineered ultra-destructive famines which crushed these communities and negatively affected them for decades. The case in point being the British-engineered famines in the 19th and 20th centuries in colonial Ireland and India that had millions upon millions of victims (Davis 2017).

ICTs became also indispensable for managing domestic populations in the sense of (re)establishing the cohesion and stability, thus becoming central to the ideological dimension of power. Newspapers, leaflets and other print products were inextricably linked with the novel wired and wireless electronic communication and information technologies (telegraph, telephone, photography, radio, film-cinema) to promote the Empire's beneficial effects for the well-being of the nation. The latter was at the same time established by the working of various systems utilising the reach of novel ICTs as the central collective identity of industrial capitalism that functioned as a perceived equaliser and homogeniser of the interests of the capitalist elites and the workers and other subjugated populations. Being under the control of oligopolistic corporations and/or the capitalist state, the electric ICTs along with the older ones became key technologies for capitalist propaganda and the censorship of revolutionary ideas and movements and for 'selling' the idea of a great democratisation that would become possible with these novel ICTs (Dickel and Schrape 2017; Schwarzkopf 2009). Here, the latter notion has always concealed the fact that the ownership, design, nature, implementation and functioning of novel ICTs is aligned with the existing asymmetrical relations of power, that they reproduce or even strengthen the existing hierarchies, privileges, exclusions and expropriations, together with the control and surveillance of ordinary citizens and workers (Dickel and Schrape 2017; Levine 2019).

ICTs became crucial for the production process itself as they were harnessed by the novel advertisement industry and the reorganised media companies to create and expand commodity markets. They were central in producing consumers directly tied to the factory system's need to continuously establish novel markets for the ever-expansive production of commodities. ICT supercharged advertising and media industries must be viewed as integral to the capitalist production process ever since its global consolidation. They manufacture and perpetuate consumption patterns, create needs and/or desires, form and normalise habits and lifestyles, ultimately reproducing capitalist institutions. The media and advertising industries are chiefly industries that jointly create a specific set of commodities. This makes it reductive and partly misleading to understand media companies including the contemporary central online media corporations (e.g., Google, Facebook) as being solely information circulators (Joseph 2022). Even though these corporations have organised the flow of everyday information and are central in producing specific cultural representations, via their fundamental interlinkage with the advertising industry they have been formed around the imperative of creating audiences as commodities (see Smythe 1981). These provide the input required for advertisers to manufacture the demand that is central for capitalist accumulation. From newspapers, radio and television stations to modern online platforms, media companies use content to produce consumers as audiences-commodities to be sold to various buyers (manufacturers of goods and services). While the deep connections between newspapers, radio and the advertising industry had to be established post festum, the television as the first central screen-based ICT was from the outset imagined and used as "an extension of corporate governance and the capitalist sales effort" (McGuigan 2023).

The continuous expansion and increasingly complex nature of industrial capitalism required and fostered the development of an ever more complex process of segmenting potential consumers into more and more specialised categories able to be comprehensively monitored, analysed, sliced and managed on the collective and individual levels (Joseph 2022). The capitalist media-advertising assemblage must be seen as being among the central set of practices that categorises people and specific elements of their lives according to their perceived worth (economic, political, cultural), in turn reproducing hierarchies, inequalities, privileges and discriminations (based on gender, race, class, region) for the central purpose of surplus extraction (McGuigan 2023).

These categorisation processes necessitated the development and utilisation of previously impossible technologically enabled capabilities of data gathering and analysing that complemented capitalists' needs and desires to predict, plan and organise the production and consumption present in the factory systems and the obsession and desires for the predictability, control, surveillance and discipline of populations, the individual but also the natural environments present in the state apparatuses above all but not exclusively in the military. The American

military apparatus of the Second World War proved decisive for establishing the parameters and fostering the development of computer and management sciences and modern computational technologies that form the bedrock of the contemporary capitalist system. It was in this context and the 1950s that the origins of today's US-led data-driven, surveillance-based digital capitalism can be found. Modern computational thinking, computer technologies, and Internet technologies were a firmly fixed part of the US state repressive apparatus since they were developed as instruments for optimising the war effort during Second World War and later in the various wars and upheavals against the imperial order as instruments of optimising war and counterintelligence, as well as for preventing, tackling and crushing domestic and foreign resistance to the existing imperialist-capitalist national and global order (Levine 2019; McGuigan 2023).

The gradual yet all-pervasive computerisation was predicated on the state playing a central role not only in determining the path of technological development but also in securing the legitimacy and stability of the wider capitalist system in its normal operation and in the contexts of substantial transformations that are often inextricably linked to the implementation and effects of novel technologies. The development and utilisation of modern computer technologies is quite in line with previous technologies of surveillance, control, disciplining and automation, and was carried out in contexts defined by radical asymmetries of power produced by capitalism in its industrial-imperial form where the rights of individuals could be suspended or were non-existent due to racist-sexist systems such as the (neo)colonial settings, total institutions (e.g., prisons) and ghettos in the metropolises. These contexts acted as the laboratories of surveillance and control technologies and novel military technologies while the (resisting) marginalised populations living in them were the guinea pigs.[2] However, these technologies never remain isolated in these contexts because they are always adapted and applied to surveil and control the general population in the metropolises (the central states of the world capitalist system) in a boomerang-like effect (Stoler 2002). Crucially, as these technologies are fundamentally capitalist, they are also always utilised in the production of commodities to maximise outputs and efficiency for maximising the exploitation of workers.

There is a tendency in capitalist regimes to create either state or private oligopoly/monopoly corporations to control the flows of information and develop and implement these capitalist technologies. Capitalist states and their corporations nevertheless radically differ and have differed with regard to their capabilities inextricably linked to their position in the hierarchically structured capitalist global order established during Western imperialism. Control over superior capitalist technology was (is) acts as the anchor of the military, ideological and

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[2]   This is why Israeli companies are leading in developing cutting edge computer surveillance technologies as they are developing them in the context of the Israeli apartheid and occupation regime where the Palestinian people play the role of involuntary guinea pigs (see Lowenstein 2023).

economic supremacy of particular capitalist states. Such control played a central role in the genesis and consolidation of the American hegemony that especially relies on the establishment and continuity of the supremacy of its Silicon Valley (CA) computer-tech corporations and the technologies they develop and control. Following the Second World War, the values, ideas, logic and imperatives of Silicon Valley capitalist technological elites and corporations have begun to exert a dominant influence on the global capitalist system. At the outset of this process, California was an internal colony of the nascent American empire where, similar to other colonial contexts, various experimentations took place concerning the development and implementation of different technologies. Cities, factories, corporations, local governments, and the population in California still represent an important context where American tech corporations experiment with their novel technologies (to be later implemented elsewhere) with impunity regarding the negative effects these technologies may have on communities, individuals and the environment (Harris 2023; Levine 2019; Marx 2022; Spencer 2018).

Yet the fact is there would not be a Silicon Valley at all without the USA's (already) established dominance over global transportation systems and logistics networks, a developed factory system and control over global supply chains, dominance over existing global information and communication networks (later further expanded), existing centralised stable and predictable supply of fossil fuels, and the existence of centralised, firmly controlled electricity/power generating infrastructures, but also without industrialised agriculture, adapted education and healthcare systems and especially the American state's continuous intervention and support. Through its trade, financial and economic policies, along with its international treaties (e.g., free trade), and by developing specific international/global legal and political regimes (e.g., concerning patents and intellectual property rights) to secure the dominance of American technologies and corporations, legally, politically and economically preventing and destroying alternative non-American technologies and corporations, and making their development and rise difficult or less possible the American state has facilitated the global dominance of American (technological) corporations and their technologies. In turn, this global dominance of both American technological corporations and technologies has helped consolidate the dominant position and hegemony held by the American state in the global neo-imperial capitalist system and further developed and strengthened the dominance of American corporations over the living conditions round the world. This explains why the USA, its capitalist class and its corporations cannot tolerate the rise and proliferation of non-American controlled technologies, why the rapid technological development of China is seen as immanently threatening, and why local and global resistance to American computer and other ICT technologies is perceived as existentially dangerous.

Still, the contemporary challenges to the American global hegemony can be considered as only challenges to the existing configuration of the US- led industrial capitalist global system. They do not challenge the underlying characteristics

of today's hegemonic computational and management-operational thinking that has overdetermined modern computational technologies and their design, development, implementation and centrality in capitalist accumulation processes and capitalist policies for addressing its inherent contradictions and inevitable crises since the Second World War. It was then that scientists-engineers, corporations, capitalist elites, and state bureaucracies started to imagine human activity as a set of elements that can be computerised and consequently built machines and computational (statistical, algorithmic) models to predict, regulate, discipline and emulate human behaviour and thinking to imagine and act upon the wider (natural) world as a set of inherently computable processes. The guiding principle here has been the fantasy that in an inherently complex and contingent world all of its presumably stable processes can be predicted, and all of the unstable ones controlled (Bridle 2018; McGuigan 2023).

Models of computerised inference and prediction were, by being normalised in various central sectors of industrial capitalism (from production to advertisement and logistics), established as an apt representation of reality to be used for the control, surveillance and maximisation of profits. Models ranging from those simulating and predicting the weather to the models presumably simulating the human mind ("A.I."), and particular societal spheres (e.g., the economy, finance), to domestic and global social, political and economic processes, have made these simulations appear real and as such adding a fresh set of capabilities for capitalists, corporations and states to prevent and manage resistance to the present order. Common citizens (as capitalist elites themselves) have gradually been indoctrinated to believe that computers render the world clearer and more efficient by reducing its complexity, which supposedly allows us to develop better solutions to the issues we face (Bridle 2018; McGuigan 2023).

Yet the world established by models is characterised by its reactionary nature since it reifies the existing capitalist structures, institutions, relationships, interests and values. It obfuscates the asymmetrical power relations in place and the various choices made while developing these models, their implicit characteristics, preferences, and the embedded interests and values in those choices.

These models of computation and their societal proliferation did not expand the agency of common citizens but were the vehicle for making the further concentration of power even more opaque. Specifically, the reimagining of the human mind as a computer has enabled the uncontested transfer of decision-making from humans to computer systems also in the field and concerning cases/processes based on inherently value-based judgments. It has made decisions appear ever more neutral, objective and unassailable despite their inherently (by design and application) biased nature that has reproduced the socially existing hierarchies, stereotypes, privileging, discrimination, dispossession, and exploitation. This has enabled the continuous consolidation of asymmetries of power between the capitalist elites and the professional-managerial classes and everybody else (Weizenbaum 1993).

With the rapid acceleration of our lives following the widespread adoption of Internet technologies and mobile digital devices, computerized decision-making has penetrated practically all aspects of our lives. This has transformed our general understanding of the world and the role computation should play in it. The general societal offloading of many of our everyday cognitive tasks to computer systems has been rationalised not merely by notions of optimisation, emancipation or control and prediction, but by the notion of convenience as well. The latter is insidious in the sense of being uncritically accepted by most regardless of their structural position in societal hierarchies. The effect of this has been that computation has become the foundation of 'rational' human thought. We have been conditioned to think as computers and have left major decisions up to computers. Crucially, on the level of society the use of computation has been established as preferable to simpler solutions; solutions that are mechanical, physical, social and political (Bridle 2018).

Faced with the intensification of the poly-crisis this is highly problematic. It becomes even more problematic and outright dangerous when we consider that computational thinking and its applications are inherently conservative as concerns the possible future, visions of the future, and limits the actions available to realise this future. For social and natural processes to be computable they must follow the already established parameters (Bridle 2018). If they do not map on these established patterns, if they are ambiguous, radically contingent, and uncertain like the case today, they cannot be properly computed and properly accounted for, thereby leading to very problematic predictions and policies (e.g., climate economics and their fantasy projections of the impact of climate change on GDP).

The existing computerised industrial capitalist system is thus not primarily problematic due to its non-novel surveillance nature (see Zuboff 2020) or its non-novel authoritarian, quasi-feudal oligopolistic and monopolistic nature (see Varoufakis 2024) since these are evolutions of 'traditional' capitalist imperatives and logic (Doctorow 2023; Morozov 2022). It is existentially problematic because its operation and further development calls for the unprecedented extraction of natural resources and control and domination of populations to reach the expected exponential growth required to ensure more and more extreme profits. The computerisation of more and more processes of capitalist (re)production and the extended and greater reliance on computational models to solve various issues requires an expansion of the "means of computation" (cf. Doctorow) that necessitates unprecedented levels of mining, production, energy generation, water use, and pollution. It is increasingly influencing our behaviours and entangling us in the techno-social form of the US-led global industrial capitalist system of accumulation, domination and unparalleled destruction.

CONCLUSION

The article has sought to address one of the central lacunas of contemporary visions of a radically different emancipatory sustainable socio-political and economic order; namely, their almost complete lack of a comprehensive critical reflection on the fundamental mutually constitutive and co-dependent relationship between capitalism and its central technologies. We argued that this is a fundamental analytical step without which we cannot properly understand the contemporary capitalist order and the radically transformative effects it has on individuals, societies, and their interrelationship with nature and on natural environments themselves. Accordingly, we first developed a comprehensive materialist, neo-Luddite analytical framework built on a tri-dimensional conceptualisation of capitalist power relative to technology; that is, the economic, ideological and repressive and a neo-Luddite understanding of technology and technological development as a non-neutral, interest-based set of choices regarding design, characteristics, functioning and implementation that follows specific capitalist imperatives and logics. The limited scope of the article meant that we focused our analysis on the economic dimension of the relationship. By focusing on the central technologies of the genesis and consolidation of industrial capitalism, the capitalist social form that radically transformed our socio-ecological relationships, we gained insights into the key role played by the gradual development and implementation of technologies of the factory system, the modern fossil-fuel powered transportation and logistics system, and the modern information and communication systems in these processes of radically and irreversibly altering the planet's ecology and fundamentally altering our conditions of living, our bodies and our mind. The crucial takeaway is that our social reproduction is conditioned and dependent on industrial capitalism and its social ecology. And that its socio-technical systems and central technologies are not neutral means of (re)production, but are themselves immanently capitalist as regards their inherent imperatives and logic and the possible range of their uses. This is especially relevant for imagining potential emancipatory sustainable social forms that must avoid the two central pitfalls of emancipatory visions.[3] The first pitfall refers to socialist/communist ecomodernist visions that solely focus on changing the ownership of the means of production without changing their inherent characteristics and development, without radically transforming these (authoritarian, dehumanising, technocratic) technological means of production in a way that makes them emancipatory, sustainable and democratic. The second pitfall is the idealism of most visions of self-sufficient local communities, visions of "the world of many worlds" that fail to account for the fact that the industrial capitalist system's dismantling will be extremely hard not only due to the repressive and ideological power of capitalists and capitalist states but also due to

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[3] For a longer critical discussions of the pitfalls and an interesting vision of a future sustainable communist society see P.A. Neal and N. Chavez (2024) *Forest and Factory*.

its economic power. The latter has created specific conditions that make the precarious survival of most global communities depend on the functioning of capitalist techno-social systems that will have to be carefully, albeit fundamentally restructured and re-created on the global level to not only ensure a global and local sustainable emancipatory order but to prevent a catastrophic breakdown of living conditions as well.

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TEHNOLOGIJA IN/V KAPITALIZEM(U) – GENEZA IN RELEVANTNOST RAZMERJA ZA SODOBNO EKOLOŠKO NEVZDRŽNO UREDITEV

Povzetek. *Članek analizira osrednje razmerje med kapitalizmom in tehnologijo(ami) v njegovi zgodovinski, utemeljujoči in okolje radikalno spreminjajoči se dimenziji. Pri tem izpostavlja, da je to razmerje v prevladujočem politološkem raziskovanju in tudi v progresivnih in emancipatornih kritikah netrajnostne, izkoriščevalske narave kapitalizma deležno premalo pozornosti. To stanje pripisuje naivnemu, poenostavljenemu in problematičnemu razumevanju tehnologij kot nevtralnih inštrumentov. Na temelju materialističnih in neoludističnih kritik članek razvije in uporabi celovito analitičen okvir za kritično preizpraševanje geneze in narave omenjenega razmerja v njegovih različnih razsežnostih in kontekstih. Osredini se na rojstvo tovarniškega sistema, modernega transporta in modernih IKT-jev. Pri tem pokaže, da so analizirani tehnološki sistemi inherentno kapitalistični in netrajnostni ter da bi morala biti njihova radikalna transformacija v samem temelju katerekoli vizije prihodnje naravno vzdržne ureditve.*

Ključni pojmi: *tehnologija, kapitalizem, industrializacija, materialistična kritika, neoludizem, okoljska kriza.*