Changing networks of power: A theoretical approach to the study of capitalized power in contemporary energy transitions

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Abstract

This paper presents a theoretical approach to the study of power in energy transitions that builds upon Capital as Power (CasP) theory and the critique of neoclassical growth theory. The approach integrates an understanding of capitalist power relations and a consideration of changes in societal energy capture. The approach includes two levels of social power - a *deep* level, in which the socio-technical conditions of power accumulation are predetermined; and a *surface* level, in which social dynamics of creation, sabotage, and distribution unfold. It conceptualizes the relations between differential accumulation strategies, societal energy capture rates, and socio-technical change processes. Renewable-resource-based decarbonization is historically unprecedented, in two fundamental respects. First, since it seeks to replace, not augment, the established set of socio-technical practices, inversing the historical trajectory towards higher energy density systems. Second, since these processes threaten to reconfigure power relations that have historically exhibited a coupled growth in hierarchy and energy capture. Thus, a perspective on energy transitions is needed that accounts for the mutual effects of socio-technical change and organized power, under a set of specific historical conditions: global capital and the manifestation of planetary boundaries. To fully understand the power within energy transitions, we must study them from the perspective of differential accumulation – the driving force behind capital. With this context in mind, the dynamics of organized power and socio-technical change can become comprehensible.

Keywords: Energy transition, Power, Accumulation, Capital, Energy regime

1. Introduction

In recent decades, the concepts of *risk* and *transition* have become central the ways in which we think of our built environment and infrastructural systems (Henke & Sims, 2020; Jabareen, 2015). The causes and perils associated with climate change are at the heart of political and professional concerns regarding energy systems (Araújo, 2014). As part of the basic socio-technical infrastructure that supports the global social order, energy systems, and changes therein, are inherently related to social-power accumulation and redistribution (DiMuzio, 2015). However, the study of contemporary energy transitions lacks a perspective that systematically embeds it within two critical contexts – capitalist forms of power on one hand, and the spatio-physical boundaries within which these transitions develop on the other (Feola, 2020). We seek to address this theoretical gap by exploring the application of Capital as Power (CasP) theory and biophysical critique of neoclassical growth theory to the study of energy transitions.

The conflictual aspects of socio-technical transitions have prompted theorists to introduce the idea of power into energy transition theory (Köhler et al., 2019). The study of power in transitional processes has developed along two lines: One approach is based on a horizontal conception of different "types" of power (Ahlborg, 2017; Avelino, 2017), while the second approach develops hierarchical conceptions of power that focus on the ability of dominant actors to control and constrain transitional processes (Ford & Newell, 2021; Newell, 2021). Building on CasP theory, the perspective presented in this paper addresses capital as a hierarchical form of power, and the ways in which it shapes the industrial and creative potentials of transition.

The Capital as Power (CasP) approach is a theory of political economy that defines capitalism as a mode of power, rather than production and consumption (Bichler & Nitzan, 2009). CasP's power theory of value understands prices to be quantifications of organized power. This power is "rooted in… private ownership", which is a form of institutionalized exclusion (Bichler & Nitzan, 2009: 228). The approach incorporates Thorstein Veblen's distinction between business and industry, whereby he sees industry as a collective venture, based on the integration of social knowledge, technique, and activity, into the process of material production and distribution, with the aim of enhancing the community's welfare. Business, in contrast, is an institution of power. Its aim is monetary gain and profit, and it is concerned with the control of industry, rather than with production itself (Veblen, 1918; Veblen, 1923).

We contend that to understand the workings of power with relation to socio-technical change, we must examine how it is capitalized, and how capitalization shapes and constrains the horizon of transition. Furthermore, we understand socio-political dynamics of transition as conditioned by environmental, i.e., spatial and physical boundaries. From a biophysical perspective, global capital's spectacular growth regime is founded on an underlying energy regime (Hall & Klitgaard, 2018). Apart from acting as the engine behind capitalist growth, the energy sector itself is a central node of differential accumulation. Yet, in contrast to a renewable-energy-based decarbonizing transition, the trajectory of past transitions was directed at primary sources and prime movers with higher energy and power densities, respectively (Smil, 2010). Moreover, past transitions have tended to diversify the set of primary sources, adding to the overall energy capture[1] while retaining the use of legacy fuels, rather than fully replacing them (York & Bell, 2019). While Capitalist power accumulation is as much about redistribution as it is about growth, increasing accumulation may become socially risky if growth rates recede (Bichler & Nitzan, 2017). Thus, we regard industry-business-regulation relations as the core dynamics driving, shaping, and constraining contemporary energy transition, while conditioned by changes in societal energy capture rates.

Many prominent theories of socio-technical transition differentiate processes according to the scope and pace of change they harbour (Geels & Schot, 2007; Grubler et al., 2016; Kanger & Schot, 2018). This relates to an idea of transitional processes as occurring and embedded within different social contexts, across a micro-macro or infra-meta scale (Geels, 2014; Kanger & Schot, 2018). According to Feola (2020), the understanding of capitalism and its relation to energy regimes within this context is underdeveloped. The CasP approach offers both an understanding of the form power takes within capitalism, and a way in which to empirically study it. CasP has been previously applied to the study of energy (Bichler & Nitzan, 2002; DiMuzio, 2015). Yet, the business-industry-regulation dynamics of socio-technical changes in energy-related sectors have yet to be systematically researched from a CasP perspective. We contend that this perspective is essential to the understanding of both the mutual effects of power and socio-technical transition, and the scope and depth of transitional processes.

The paper contributes to the literature on energy transitions by presenting a perspective that accounts for the ways in which power is redistributed, as socio-technical transformations unfold within capitalist societies. It furthermore offers a generalized conceptualization of the relations between differential accumulation strategies, changes in societal energy capture rates, and socio-technical change processes.

The paper includes six sections. *Section 2* presents the previous study of power in energy transition literature; *Section 3* presents the CasP approach and its previous application to the study of energy; *Section 4* introduces the critique of neoclassical growth theory; In *Section 5* the framework is presented and discussed; *Section 6* is the conclusion.

2. Socio-technical regimes

The concept of socio-technical systems underpins contemporary energy transition literature (Köhler, et al. 2019). It relates to systems that encompass a wide range of complex interactions between humans, institutions, and technologies (Morgunova, 2021).

The socio-technical regime is defined as a stable and coherent set of institutions, practices, routines, and technologies, which have historically come to dominate the workings of a socio-technical system (Geels et al., 2017; Morgunova, 2021). The concept was articulated as part of the Multi-Level Perspective (MLP), to better describe and analyze transitional processes. The MLP framework presents a three-tiered structure, which includes the “macro” landscape level, the “meso” regime level, the “micro” niche level, and the relations between them as drivers of the stabilization and transformation of socio-technical systems (Geels et al., 2017).

Energy regimes can be defined as socio-technical regimes that shape socioeconomic energy flows; not only in terms of techno-physical conditions of conversion, but also in terms of socio-political conditions of decision-making regarding energy capture, distribution, and the ends and means of its use.

Another aspect of a regime’s stability is its “obduracy”, which is manifested in path-dependency and inertia (Bulkeley et al., 2018). These phenomena are associated with characteristic “lock-in mechanisms”, including sunk costs, economies of scale, sectoral interests, habitual use, and bureaucratization (Berkhout et al., 2003). Nevertheless, recent studies have pointed out that, under different circumstances, regime-level actors (i.e., incumbent firms and policy makers) may strategically engage in both restriction and promotion of innovation and change (Turnheim & Geels, 2019).

Early applications of MLP analysis have been criticised for their disproportionate emphasis on the niche level as the source of change and innovation (Berkhout et al., 2005; Turnheim & Geels, 2019). The "meso" level of the regime has served as an entrance point to a discussion of power in sustainability transition research (Köhler et al., 2019; Kuzemko, et al., 2017).

2.a. Regimes and power

Power has gradually been introduced into transition theory over the past two decades (Köhler et al., 2019).

Initially, power was brought in to explain regime resistance. Several accounts adopt *neo-Gramscian* concepts to address this phenomenon (Ford & Newell, 2021; Geels, 2014). In contrast to earlier literature, which focused on the conditions in which niche innovations penetrate "upwards" and set transitions in motion, these analyses concentrate on the ability of existing regime formations and incumbent actors to resist and block change (Geels, 2014). For Geels (2014), power is manifest in the hegemonic alliance of policymakers and incumbent firms. Not only do business and the state retain relations of mutual dependency (Kuzemco et al., 2017: Newell & Paterson, 1998), business has a structural advantage in that prevalent policy culture is dominated by neoliberal ideology and adapted to deal with large firms and experts, rather than with citizens.

Ford and Newell (2021) offer a more detailed account of power in maintaining regime stability. Drawing on neo-Gramscian concepts, they explore the ways in which business-government alliances exercise structural power to control and constrain transitional processes. Newell (2021) views struggles over current transitions as pertaining to the very future of global capitalism and industrialism.

The "Neo-Gramscian" accounts hold hierarchical conceptions of power, as opposed to horizontal conceptions that create typologies of power (see for example Ahlborg, 2017; Avelino, 2017). These accounts follow the tradition of differentiation between domination and emancipation, as distinct qualities of power, and deliberately contest hierarchical conceptions of power (Pansardi, 2012).

Several researchers address social power by studying the "political economy" of sustainable energy transitions. Some focus on regulation-and-public-policy-related power struggles, and the ways in which corporate-state coalitions block change when it contradicts the interests of powerful incumbent firms (Al-Sarihi & Cherni, 2023; Baker et al., 2014; Hanto, et al. 2022; Haas, 2019). Others emphasize the role of global elites in shaping and constraining transitional processes and potentials (Curran, 2020; Newell, 2021; Power, et al., 2016). Newell explicitly makes the case that the institutions of global capital clash with "the sorts of energy transitions now required" (Newell, 2021: 13).

Insights from the political economy of energy transition scholarship suggest that energy regimes are intimately related to modes of power, and that we must add to their analysis an understanding of capital, and the distinct features of power under its global regime. As elaborated below, the CasP approach offers a theory of political economy that not only "supplements" the study of the economy with that of social power, but views capital accumulation as a mode of power, rather than production and consumption (Bichler & Nitzan, 2009). This deep rejection of the the distinction between politics and the economy in the study of capital, provides both a unique definition of social power in capitalism and a systematic way in which to empirically study it.

Sovacool and Brisbois (2019) advocate for the study of elite power in energy transition. The CasP approach enables this in two fundamental ways. First, CasP is a theory of capital "from above", namely, capitalist power is conceptualized from the point of view of those who wield it. (Bichler & Nitzan, 2009: 29-30). Second, the CasP concept of dominant capital defines the ruling class and offers a way to study it empirically. While all capitalists (i.e., owners) are immersed in the power struggle, the dominant capital group is made up of those firms who attain the highest levels of differential capitalization and retain the greatest effective power over social reproduction (Bichler & Nitzan, 2009).

2.b. Regimes and transition

The energy transition literature offers various perspectives on the meaning of energy transition. Grubler et al. suggest that: "a transition is usefully defined as a change in the state of an energy system, as opposed to a change in an individual energy technology or fuel source" (Grubler et al., 2016: 18). "A change in the state of an energy system," however, could take on many forms. The ambiguity of "transition" stems from the ambiguous scale of the regime itself. For instance, is an electric power regime to be understood at the level of primary energy source? A "general configuration of the power generation and distribution system" (Berkhout et al., 2004:54)? A shift from AC to DC transmission?

Several theoretical approaches have been formulated to deal with this ambiguity. They all address the issues of scope and pace in transition: to what extent does change affect the dominant structure, features and relations within a system (scope); and whether the process is prolonged and incremental, or relatively swift and radical (pace).

Berkhout et al. (2003) suggest that transitions may be categorised according to coordination at the regime level (high/low and thus intended/unintended, respectively), and location of necessary resources (internal/external and thus superficial/deep, respectively). They suggest that when resources are internally available, transitions tend to be incremental and do not overturn structural relations, while externally resourced processes tend to be more radical.

Grubler et al. (2016) distinguish between three types of transition: "Grand" transitions are pervasive and affect the system on multiple levels; Substitution is the displacement of a certain aspect of the system (a dominant energy carrier or technology) and its replacement by another, which requires little or no accommodation of the overall system; Diffusion is a prolonged, incremental process of the gradual adoption and integration of a certain technology within a given system. This categorization is similar to Geels and Schot's (2007) concepts of substitution, transformation, reconfiguration, and de/re-alignment (Geels & Schot, 2007). Newell (2021) uses the Gramscian term *transformismo* to differentiate between transformative change, which challenges existing structures, and its accommodation through discourses and policies of "green growth" and "climate compatible development" that shield the system from any serious threat that might be posed by such challenges.

Finally, Kanger and Schot (2018) develop the concept of *deep transition*, which understands energy transitions as features of social change at-large. They suggest that socio-technical regimes are expressions of a limited number of meta-rules that drive and constrain system evolution, while deep transitions are those in which multiple processes of change in the same direction across different systems destabilize and alter the meta-regime (Kanger & Shot, 2018:1045).

Studying the ways in which socio-technical changes restructure social power may give us a sense of the quality of the transition at hand, and what scope of change it might harbour. While capitalist power relations are extremely dynamic, as is socio-technical development under capital, the major power institutions of capital – capitalization, investment, and private property – are remarkably resilient. Thus, the mutual effects of organized power and socio-technical change should be studied both at the level in which power is redistributed, and at the deeper level, where the conditions of accumulation are set. In other words, we ask whether transitional processes only affect the redistribution of power on the surface level, or do they also deepen, widen, or even negate capitalist power accumulation in itself?

3. Capital as Power

The Capital as Power (CasP) approach offers a theory of Capitalism's ruling class, and the ways in which power is organized under what Bichler and Nitzan term the capitalist mode of power[2]. The CasP approach rejects the economics/politics dichotomy. Capital is not understood as a productive economic entity, rather as a "symbolic representation of power" in itself (Bichler & Nitzan, 2009:7).

Powe in CasP theory is defined as "the ability to create formations against *resistance*" (Martin, 2019:3, emphasis in original). Power is thus essentially dialectic: it implies its own negation. Following Lewis Mumford (1967), Bichler and Nitzan describe modes of power as forms of social organization that are based primarily on social (rather than material) technologies and directed at reshaping society (rather than nature), with the exceptional incentive of exerting power over society for the sake of power itself (Bichler & Nitzan, 2009).

As will be elaborated below, capitalization and differential accumulation make up the basic mechanism and driving logic of capitalism, respectively.

3.a Capitalization is a quantifiable measure of power.

Capitalization is a mathematical algorithm - it discounts risk adjusted expected future earnings to present value. It is a common practice of all capitalists and can be understood as a measure of their power that is exerted over the social process as a whole: politics, society, culture, and social reproduction (Bichler & Nitzan, 2009). What is assessed and measured in capitalization is the ability to generate income, which is not material in essence but rather social - it is the power to shape and control all social processes which bear upon this ability. In capitalization, power is assessed and distributed based on a claim on the future, and the ability to foresee (and ensure) it. The capitalization formula is defined as follows:

$$1.\quad K_t = \frac{E \cdot H}{\delta \cdot r_c}$$

Where capitalization at a given time k_t equals expected future earnings (the product of actual earnings *E* and the Hype coefficient *H*), divided by the product of the risk coefficient δ and the normal rate of return r_c.

Transitional changes affect the "elementary particles" of capitalization (risk, hype and earnings), and are figured into the capitalization process.

3.b Capitalization is an operational symbol.

Capitalization can also be defined as an operational symbol, a formal system in which signification results from "some operation according to some rules" (Martin, 2019: 6). This operational symbol is not only generative but also self-reinforcing, in that problems created by these operations are addressed using further operations based on the same logic (Martin, 2019). Thus, capital is not merely a measure of power but also a generative mechanism, enabling the creation of "formations" that in turn reinforce that very same ability (Martin, 2019). This "self-reflexive use of power" forms the basis of the differential and expansionary attributes of capital accumulation. Power must always be *augmented* in relation to that of others - not only more but increasing - hence *differential* accumulation. Moreover, the "architecture of power" tends to gradually draw more and more members and spheres of society into its workings. Members are drawn into differential accumulation precisely because it is differential; since opting out would mean loss of relative power, and not immunity to it, while society's resources tend to turn into "means for those conflicts" (Martin, 2019: 4). Bichler and Nitzan term this tendency "the capitalization of everything" (2009: 158).

Furthermore, Martin (2019) sees the proliferation of bureaucratic institutions and procedures as deeply related to the expansion of capital, the two being intertwined. Thus, the state is deeply related to capital, not merely in the Marxist sense of being "a committee for managing the common affairs of the whole bourgeoisie" (Marx & Engles, 1955:12). The state is inseparable from capital, as is corporate from governmental power (Bichler & Nitzan, 2009). DiMuzio (2016) considers the state itself to be a capitalized entity: Governmental bond markets form the basis of global finance, and private bondholders receive interest payments from revenues generated by governmental practices. In addition, governmental action bears upon capital accumulation and gets figured into the capitalization process (Bichler & Nitzan, 2009). Braithwaite (2008) uses the term "regulatory capitalism", referring to the high dependence of global capital on bureaucratic regulatory procedures and institutions that makes the two impossible to separate.

3.c Differential accumulation regimes

Differential accumulation is the driving logic behind capitalism. Capitalists are constantly compelled to increase accumulation, yet accumulation in absolute terms is meaningless. It acquires significance only when measured against a benchmark. Differentials are thus ultimately the goal of accumulation, namely, the *difference* between growth rates of capitalized quantities (Bichler & Nitzan, 2009).

As the capitalization formula (Equation 1) shows, earnings are an important component of capitalization. To increase accumulation, firms must increase profits.

Bichler and Nitzan (2002) define profit as:

$$2. \quad P = breadth \cdot depth = E \cdot P/E$$

Where P is profit, and E is the number of employees, and P/E is profit per employee.

Profit is a consequence of both *depth* and *breadth*. *Breadth* refers to the size of the organization, i.e., the number of basic units controlled by the capitalist entity. *Depth* refers to the elemental power of the organization, i.e., the earnings per unit of organization. Capitalist organizations may expand either in size (breadth), or by extracting higher earnings per unit of organization (depth).

However, what is significant is *differential* profit, as mentioned above. One's earnings must grow faster than average, to increase differential accumulation. Thus, differential breadth is defined as the strategic increase of differential performance by the *relative* expansion in size. Differential depth is the strategic increase of differential performance by the *relative* deepening of "elemental power" (Bichler & Nitzan, 2009).

At any given moment in time, this can be expressed as:

3. $$DP = dif.breadth \cdot dif.depth = \frac{E_1}{E_2} \cdot \frac{P/E_{\ 1}}{P/E_{\ 2}}$$

Here, DP is differential profit, E1/E2 is differential employment, and P/E1 / P/E2 is differential profit per employee.

The concept of differential accumulation regimes stems from the understanding that accumulation is not necessarily the result of growth. Rather, dominant capital firms may alternate between different strategic paths to achieve differential accumulation. Firms may opt for *differential breadth* (expanding faster than others in basic units of organization), *differential depth* (raising earnings per basic unit of organization faster than others), or "by some combination of the two" (Bichler & Nitzan, 2009: 329). These paths can be further categorized as *internal* or *external.* The four generic paths are summarized in Table 1.

Table 1: Differential accumulation regimes

	External	***Internal***
Breadth	Greenfield	Mergers & Acquisitions
Depth	Stagflation	Cost cutting

Reproduced from: Bichler & Nitzan, 2009: 329.

External breadth hinges on differential greenfield development, i.e. building new capacity and hiring faster than others.

Internal breadth is based on expanding in size through mergers and acquisitions, i.e., acquiring existing capacity, and "inter-firm labour mobility" (Bichler & Nitzan, 2009: 330). This achieves the double goal of expanding in size and eliminating competition.

Internal depth involves cost-cutting to make operations more cost effective faster than other organizations.

External depth derives from stagflation, i.e., combined inflation and stagnation in production. Bichler and Nitzan argue that "Dominant capital, to the extent that it acts in concert, can benefit from higher prices, since, up to a point, the relative gain in earnings per unit outweighs the relative decline in volume" (Bichler & Nitzan, 2009: 330).

They claim that breadth and depth regimes tend to move counter-cyclically, with internal breadth (mergers and acquisitions) and external depth (stagflation) constituting the most effective paths to achieve differential accumulation. This is due both to the drawbacks of greenfield development (external breadth), like the threat of excess capacity and the negative effect on prices, and hence on depth; and to the difficulty of leveraging cost-cutting (internal depth) to beat the average, i.e., the difficulty of protecting technological innovations and controlling input prices.

3.d Differential accumulation is achieved through strategic sabotage.

The imperative of differential accumulation explains the motivation to sabotage and undermine opponents and production in general· If we accept the premise that it is not material or productive-economic value that gets accumulated, but rather power, rooted in the institution of private ownership, then a whole new relationship between capital and production unfolds.

Following Thorstein Veblen, Bichler and Nitzan define "strategic sabotage" as the ability to "restrict, limit and inhibit the autonomy of those with less or no power", as well as human creativity and productivity, for the purpose of increasing profit (Bichler & Nitzan, 2017: 2). This framing is based on Veblen's distinction between business and industry. Veblen (1908, 1923) understands industry to be a collective venture, rooted in cooperation and the integration of social activity, designed to form a "systematic organization of production and the reasoned application of knowledge" (Bichler & Nitzan, 2009:219). Industry draws on the "technological heritage" of a society, which is common and accumulative by nature. It gives meaning to, and coordinates, the amassment of bio-physical, technical, and energetic components, which are "brought within the sweep of the community's knowledge of ways and means" (Veblen 1908: 329). Business, in contrast, is an institution of power. It is solely concerned with profit and accumulation, i.e., with distribution, and as such stands in opposition to industry, although under capitalism the two are deeply related. Business lays claims to industrial processes, substituting the collective enhancement of well-being with the sectorial quest for differential accumulation (Veblen, 1908, 1932).

Capital has come to lean heavily on certain infrastructure regimes, particularly on the centralised fossil fuels-based energy regime (Christophers, 2022; Malm, 2016). This is not to say that "the hand-mill gives you society with the feudal lord; the steam-mill, society with the industrial capitalist" (Marx, 1957: 122). But rather, that the selection between techniques - their promotion, restriction and manipulation - is of political significance in capitalism. Directing industry becomes an act of power.

3.e Energy and CasP

The study's framework incorporates the CasP approach into the literature of energy transition, pursuing a line of CasP research into issues of energy, capital, and power. In this line of research, core concepts and measures of CasP are used to analyse changes in the social technique of energy capture, and its relation to social power.

First, power accumulation and redistribution dynamics in the energy sector were examined. Bichler and Nitzan (2002), for example, base their analysis of energy crises in the Middle East on the concepts of differential accumulation and differential inflation. They argue that energy conflicts generate differential inflation, whereby oil prices rise faster than the prices of other commodities. This, in turn, boosts the differential accumulation of dominant energy firms. This feeds into a self-reinforcing cycle, as the revenues are then used to acquire weapons, which augments the differential accumulation of dominant arms industry firms, and enables the next round of bloodshed-cum-differential-accumulation. Thus, war is understood to be a form of sabotage that drives differential inflation, and thus differential accumulation processes. War is not an external shock, but part of the internal workings of power that get capitalized - i.e., added to calculations that determine the relative value of capital.

Second, the general relations between energy capture and social form were theorized. Blair Fix's (2015a) work explores the general relation between historical rates of energy consumption and hierarchical growth. His perspective and empirical approach challenge the basic assumptions of neoclassical growth theory. The neoclassical perspective understands growth in terms of "utility," meaning that a growing economy[3] supposedly implies growth in the "amount" of utility or "wellbeing" produced and available within a given nation state at a given period (Alexander, 2012). Fix, however, understands and measures growth in biophysical, and power-based terms, namely energy capture, and the degree of social hierarchy, respectively.

Both biophysical and power related dimensions are excluded from neoclassical analysis, in which the biophysical is taken for granted and unaccounted for, and power is deemed external to the economy. Fix's study establishes a "three-way link between profit, hierarchy, and growth" (Fix, 2015a: 26). These findings raise the question of the nature of the relations between the social technique of energy capture and social form. Exploring these relations is crucial to considering energy transition and understanding the socio-material dynamics that shape these systems, and drive or hinder change (Fix, 2021)[4]. An investigation of the relations between energy capture and social form highlights the need for a multi-level perspective of power in energy transitions. One that can account for both the *surface* level, in which power is accumulated and redistributed between groups, and the *deeper* level, in which the terms of accumulation are set. For example, when studying decarbonization processes, we should examine both the control of new technologies, revenue streams, and subsidies, and changes in the overall control of energy capture processes.

Finally, the relations between change and power in the energy sector are explored. Tim DiMuzio (2012) attempts to discern the relations between energy transition, its potential, and the capitalization of conventional energy firms. The rationale behind DiMuzio's endeavour is that differential capitalization represents the differential power of social entities, and that this power is leveraged for shaping and reshaping social reproduction (in this case, towards the persistence of energy-intensive growth). DiMuzio studies the power of fossil-capital through the differential capitalization of conventional energy firms and of "alternative" energy firms, as representatives of a potentially successive energy regime. In doing so, he tries to gauge capitalists' degree of confidence in the persistence of the current energy regime, and the extent of the efforts they will put into sustaining it. In the same vein, Brett Christophers (2022) argues that an analysis of the valuation and investment trajectories of dominant capital indicates that fossil fuels are yet to be forsaken, and are still viewed as profitable, i.e., "sustainable". The declining price of renewable technologies does not imply an increase in differential expected earnings associated with them.

In this study, we continue the CasP line of inquiry presented above, developing a theoretical approach for the empirical study of capitalized power in energy transition processes. To achieve this end, we rely on energy transition theory, in addition to CasP literature. We suggest two different levels of analysis in the study of energy transition: the *surface* level, of business-industry sabotage within an already constructed and changing realm of social technique; and the *deep* level, of pre-setting the conditions of accumulation through the basic institutions of capital and the underlying conditions of energy capture. This suggests that the relation of power to socio-technical change is far from deterministic - sabotage of industry may occur on different levels and with different consequences regarding the distribution of power. Below, we introduce a conceptual framework of the dialectics of power and techno-physical change, path-dependency and energy transition.

4. Energy and the economy

Another theoretical field that is significant to any study of energy transitions that seeks to address issues of socio-technical change, social power, and energy, is the critique of neoclassical growth theory, with regards to the relations between energy and the economy.

Biophysical, environmental, steady-state, and entropy economics all contest the dominant perspective of orthodox, and many heterodox, economic theories, which downplay, or utterly ignore, the biophysical underpinnings of socio-economic systems (Daly, 2014; Hall and Klitgaard, 2018; Smith & Smith, 1996).

These economic theories apply the laws of thermodynamics[5] to the study of economic systems, understanding the economy to be an open system, namely a system that exchanges both energy and matter with the environment (Smith & Smith, 1996). System thinking is central to these approaches, as it emphasizes the irreducibility of the whole to its components, and the complexity arising from the system's internal and external dynamics (King, 2021).

Defining the economy as an open system implies the inherent disequilibrium of growth-oriented economic systems, which are dependent on the environment as source and sink. Moreover, the concept of "throughput", in the form of energy and material inputs, heat and waste outputs, and entropy, becomes central to the understanding of socio-economic systems.

More specifically, energy (as the capacity to do work[6]) is considered the basis of biological, and therefore social, activity (Daly, 2014). Useful work can be defined as "performing activity in the real world that necessitates physical exertion" (King, 2021: 28). The transfer of energy enables work. Thus, the significance of energy is understood to be much greater than its share of GDP (as assumed in neoclassical theory). It is understood to be the conditioning factor without which no economic activity can take place (Keen et al., 2019). Consequently, energy capture, and particularly the explosion in the rate and scale of energy conversion associated with the discovery of fossil fuels, is considered the main driver of the phantastic rates of growth and exceptional dynamism associated with capitalism (DiMuzio, 2015).

Biophysical and spatial attributes of the environment are conditioning and limiting factors to economic systems and their growth (Hall and Klitgaard, 2018). Consequently, degrowth approaches reject the notions of "green growth" and absolute decoupling of economic output from material throughput and argue instead that downscaling the economy is necessary to achieving equitable sustainability (Barth, 2019; Kallis et al., 2018).

Blair Fix adds a dimension of social power to these insights. He argues that "external (resource) constraints can describe the long-run behaviour of the economy, but internal (social) constraints dominate the short-run" (Fix, 2015b: 113-114). These internal constraints are not to be understood as anomalies to an otherwise equilibrium-forming economic system, but as the inherent features of a power-driven social order which is itself spatio-physically conditioned.

All approaches presented above agree that energy is paramount to economic growth. Fix (2015a) goes as far as to suggest using energy itself as a growth metric. To do so, we must first be able to measure energy consumption. Understanding that energy extraction itself requires energy, the measure of Energy Return On Investment (EROI) is used to quantify the ratio of primary energy produced to energy required for extraction (King, 2021). The concept of *useful work* attempts to account for further energy losses and requirements in the primary and secondary conversion to end-use energy. Ayres and Warr (2009) developed an initial measure of the annual average energy conversion efficiencies of five generalised end-use energy categories. The energy consumed annually by each end-use category, multiplied by the respective annual average energy conversion efficiency, gives us an approximation of *useful work* performed by a system. This is but one example of several approaches to the measurement of societal exergy[6] (Sousa et al., 2017).

The aforementioned insights form the theoretical basis for the integration of spatio-physical analysis into the study of energy transition. Andreas Malm (2013) incorporates both spatio-physical and power-related factors into his analysis of the transition from water to steam in 19th century British cotton industry. Malm contends that, contrary to claims that the transition was driven by scarcity, it was in fact class struggle that shaped and drove the transition. He argues that the advantages of steam lay not in coal's relative abundance or cost-effectiveness, but in steam's spatial and temporal flexibility, which enabled industrialists to more effectively control and discipline labour. Accounting for the spatio-physical conditions of powering the British cotton industry during the period of transition, Malm explores the broad class interests (as opposed to interests of a specific incumbent actor) that drove socio-technical change.

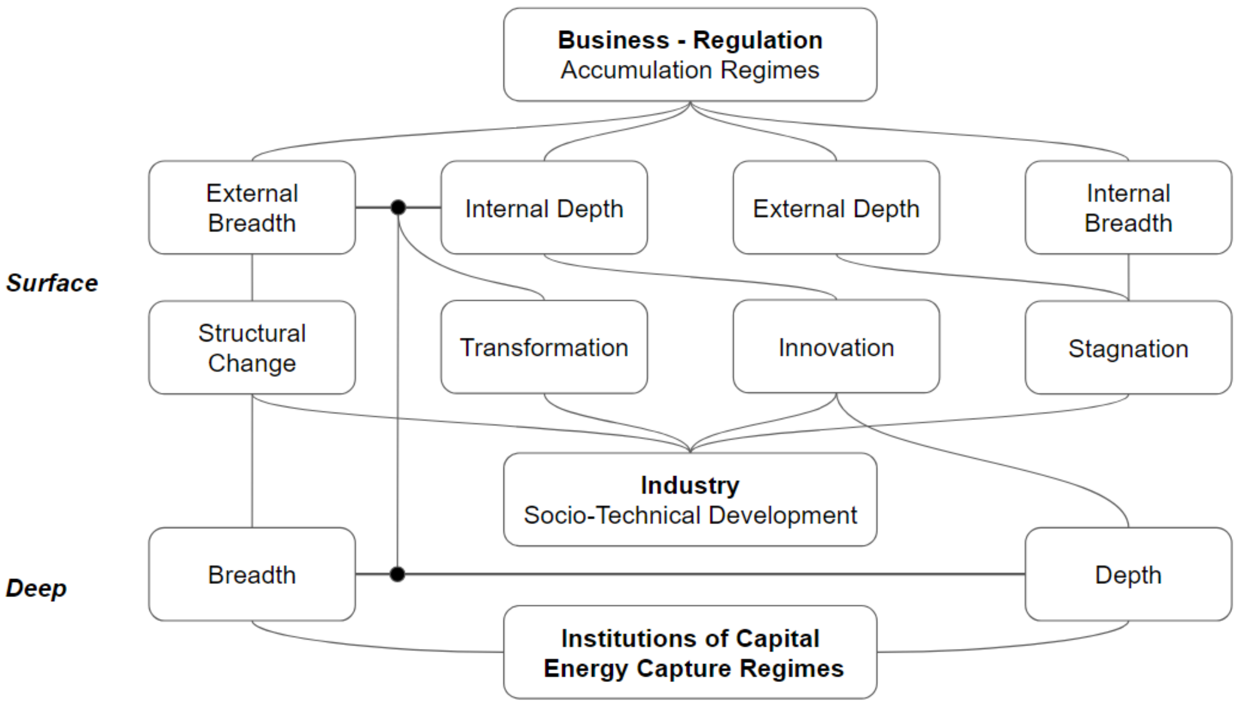
5. The Power over Energy perspective

In this section, we present our approach to the study of energy transition and power. Energy regimes are deeply related to modes of power (see Section 3). The (re)production and (re)distribution of energy systems and their desired and undesired products are both a capitalized phenomenon and a precondition of capitalization. Thus, power is introduced into the perspective on two levels: on the *deep* level, of pre-setting the conditions of accumulation; and on the *surface*, as business-industry-regulation dynamics. Power over energy can be asserted and contested both on the *deep* level of directing energy capture and on the *surface* level of capitalizing energy-related industries.

On the *deep* level (Figure 1, lower tier), social power institutions, socio-technical possibilities, and spatio-physical conditions co-determine the scope, pace and limits of power accumulation (see Sections 3d and 4). The basic institutions of social power, namely private property, investment and capitalization, drive and constrain the reproduction and transformation of energy regimes, yet they depend on spatio-physical and socio-technical energy capture conditions (see Sections 3 and 4). Two main fields interact within this level:

Energy capture regimes delimit the material conditions of energy extraction, conversion, and utilization. This category includes energy, and any other related material resources, and the socio-technical means of its capture. Rooted in the institutions of private ownership, investment, and capitalization, power accumulation in capitalism is contingent on the command and expansion of energy capture. The scope and limits of accumulation, both within a given sector and on a wider social scale, are thus partly set by biophysical factors, their given spatial distribution, and the finite character of planetary space itself (see Section 4).

Figure 1: The Power over Energy Perspective on Energy Transitions



Energy capture can expand (or contract) through breadth, depth, or a combination of the two (see Figure 1). By breadth we refer to primary energy consumption (measured in Joules). By depth we refer to net energy measures, and measures of conversion efficiency (expressed as a percentage) (see Section 4). Thus, expansion in breadth would include intensification and diversification of primary energy extraction and consumption, like in the wider use of natural gas as energy source, enabled by the development of compressors and steel pipes (Smil, 2017). An increase in depth would entail higher EROI, or greater conversion efficiency, as in the rise in EROI for oil and gas production in the USA during the first half of the 20th century (Guilford et al., 2011), or the high efficiency of combined-cycle gas turbines in relation to other technologies (Smil, 2017). An example of increase in both breadth and depth is the transition to steam, which included both a leap in the breadth of coal consumption and in conversion efficiency of fossil-based prime movers (Smil, 2017).

The institutions of capital form the basis of the "particular configuration" of power relations and social reproduction in capitalism (Bichler & Nitzan, 2009: 280). Every social order depends on the natural environment and social production to sustain itself. Within hierarchical societies, however, it is not merely production, but its control, that defines the social order. Under capitalism, the institutions of private property, investment and capitalization channel reproductive and transitional processes (Bichler & Nitzan, 2017). Continuous accumulation and hierarchical expansion are coupled with growth in energy capture (see Section 4). Changes in the breadth and depth of energy capture redefine the conditions of accumulation, its scope, and its limits.

Next, we will explore the *surface* level (Figure 1, upper tier) of the framework, where business-industry-regulation dynamics play out (see Section 3.e). The word *surface* does not indicate superficiality or insignificance, but rather that groups in this level, namely dominant capital, capitalists, and workers, struggle to achieve and sustain differential power within an industrial terrain already conditioned by *deep* level factors.

The **business-regulation component** represents the two primary intertwined organizational bodies of capital - corporations and government organs (Figure 1, upper tier. See Section 3.b and 3.d). Bichler & Nitzan (2009) identify four differential accumulation strategies associated with it: external breadth, internal depth, external depth, and internal breadth. These are strategies dominant capital can employ to increase differential accumulation (see Section 3.c). The **industry component** represents socio-technical development and is inherently connected to business-regulation strategies. We define four generalized types of socio-technical processes resulting from business-industry dynamics: structural change, transformation, innovation, and stagnation. Innovation and stagnation can be defined as path-reproducing processes, in that they deepen path-dependency, while structural change and transformation can be defined as path-altering processes (see Section 2).

Innovation is the reconfiguration and improvement of a certain socio-technical configuration. It does not transform, but rather enhances, an existing socio-technical path. Business engages in selection and promotion of specific technologies and upgrades, while simultaneously repressing others. This process is related to *internal depth* strategies, like cost-cutting, and may increase the *depth*, i.e., efficiency, of energy capture. For example, the promotion and continued development of the internal combustion engine, over other possible motive power sources like the electric motor, in the early automobile industry can be seen as innovative (Hadjilambrinos, 2021).

Stagnation relates to processes of sectoral power concentration which block innovation, green-field development, and change. This process is related to *internal breadth* and *external depth* strategies, i.e., mergers and acquisitions, and stagflation, respectively. Dominant capital finds these paths to be more differentially rewarding, yet they reinforce path-dependency and inhibit development. For example, the current under-investment in research and development and "innovative insufficiency" of the oil sector (Matkovskaya et al., 2021: 5), which is dominated by a handful of "oil majors", can be seen as stagnation.

Structural change is a socio-technical process in which scale and breadth play a central role. It includes large-scale infrastructure developments, and the mutual reconfiguration of already-established technologies. This process is related to external breadth, i.e., green-field investment, and typically consolidates oligopolies which take advantage of economies-of-scale, as well as to rapidly rising breadth in energy consumption. For example, the interrelated industrialization, private-automobile proliferation, suburbanization, and massive transportation infrastructure development that characterised early 20th century urbanization could be seen as a process of socio-technical structural change (Mattioli et al., 2021).

Transformation is a process of deep, path-altering socio-technical change. It includes the introduction and expansion of new technologies, primary sources, and/or socio-technical conditions. It is associated with both rapidly increasing depth and breadth expansion in energy capture, namely, increased EROI, and primary resource consumption, respectively. It is related with a combination of internal depth and external breadth, i.e., cost-cutting and green-field development, respectively. This strategic combination is a diversion from the more prevalent cycle of internal breadth-external depth (see Section 3.c). For example, the transition to steam and the advent of extensive fossil-fuel consumption can be seen as transformative (Malm, 2016). In a sense, 18-19th century proletarization processes can also be understood as an energy-related socio-technical transformation, as they included an increase in both the breadth and depth of labour exploitation, combined with industrial innovation and green-field development (Thompson, 1963).

A distinction can be made between deep transitions, which include changes in the depth and breadth of energy capture, thus changing the preconditions of accumulation and hierarchical growth (see Section 3.e), and *surface* level processes, which may result in the redistribution of power between social groups (see Section 2.a). Growth in capitalist societies is contingent on rising energy consumption (see Section 4), and so is the stability of continuous power accumulation processes (see Section 3.e). Thus, in a broad sense, power accumulation in capitalism is also contingent on concentration and control of energy capture and utilization. From a business-industry perspective, a consideration of the changes in the potential scope of energy capture, illuminates and clarifies the dynamics of sabotage, power redistribution, and industrial change in energy transitions. Bichler and Nitzan single out internal breadth and external depth as the two main strategies of differential accumulation. These strategic sabotage patterns shape and constrain the scope and pace of socio-technical change (see Section 2.b). We suggest that in the rare cases where socio-technical change includes a combined increase in energy capture breadth and depth (transformation), or a significant rise in breadth (structural change), external breadth and internal depth become viable paths for differential accumulation, giving rise to transformative socio-technical processes (see Figure 1).

From the perspective of social power over energy, deep transitions would be those which alter the basic configuration of power, energy capture and the institutions of capital. These include the examples we presented under the *transformation* and *structural change* categories. Surface transitions would be those which affect dominant groups' ability to foresee and secure future conditions and alter power relations within the energy-related industrial sectors (see Section 2.a). An example of the latter is the introduction of alternating current for electricity transmission in the late 19^{th} century that enabled the mergers of small direct-current-based stations and the consolidation of large-scale, centralized utilities (Hughes, 1983).

As Malm (2016) argues, the transition to steam brought about a new social order in which fantastic growth rates, based on increasing fossil-fuel consumption, could be sustained, labour could be more effectively controlled, and the institutions of private property, investment, and capitalization could be refined and developed (see Section 4). Thus, the scope of social power accumulation itself was simultaneously redefined, alongside the rise of new industrial elites. In contradiction, Christophers (2022), DiMuzio (2016), and Newell (2021) have all demonstrated dominant capital's ability to restrict and appropriate contemporary transitional processes. This sustained ability indicates that changes were not significant enough to enable combined green-field-and-cost-cutting-based destabilization or threaten their dominance (see Sections 2.a. and 3.e). Nevertheless, renewable-energy-based decarbonization may prove unique when examined from the perspective presented above. If carried out significantly, the process may imply a combined decrease in depth and breadth of energy capture, i.e., declining EROI and decreasing energy consumption due to fossil-fuel phase-out, respectively. Resulting in declining energy capture rates, this process would also alter the conditions of accumulation, yet in a power negating rather than power enhancing way (see Section 4).

We contend that to fully understand the power-driven sabotage of industry, we must study both deep and surface level developments from the perspective of differential accumulation – the driving force behind capital. With this tension in mind, the dynamics of organized power and socio-technical change become comprehensible – the goal of dominant actors is not to block change but to preserve and increase their differential power.

The literature has acknowledged the need to understand the workings of power in energy transitions under capitalism (see Section 2.b). Defining power as "the ability to create formations against resistance" (Martin, 2019: 3) frees us to interpret different social phenomena, such as cooperation coordination, as distinct, and even power-negating, forms of social organization. Power is not understood merely as a feature of incumbent firms' resistance to change. It is itself a goal. To understand transition under capitalism, we must look at transition's dialectical relation to capitalization – how transition affects power accumulation, and how capitalization affects transition.

Furthermore, evaluating the relationship between energy capture and social form is crucial to the discussion of energy transition (Fix, 2021). The issue has hitherto been explored at a high level of abstraction, namely the general relation between hierarchical social form and energy capture. The proposed perspective develops this line of inquiry further by tracing relations between differential accumulation strategies and changes in potential societal energy capture.

An elaboration of the approach at the empirical level is necessary but is beyond the scope of this paper. The next step would be to develop specific formulas to assess differential measures within a transitioning energy sector. The power over energy perspective enables us to explore the ways in which ownership structures, income distribution, energy capture, and strategic sabotage play out in the political economy of energy transitions.

6. Conclusion

In this paper, we presented an analytical perspective for the study of contemporary energy transitions that accounts for the specific forms power takes in capitalist societies. In our contribution to the debate about the introduction of power into energy transition theory, we built upon CasP and the critique of neoclassical growth theory, to suggest a framework that integrates both an understanding of capitalist power relations and a consideration of societal energy capture.

The paper contributes to two ongoing theoretical endeavours, namely the application of hierarchical conceptions of power to the study of energy transitions, and the line of critical CasP inquiry into issues of energy, capital, and power.

We outlined two levels of social power in this paper: a *deep* level, in which the socio-technical conditions of accumulation are predetermined, and a *surface* level, in which business-industry dynamics of creation, sabotage, and distribution unfold. We moreover present a generalized conceptualization of the relations between differential accumulation strategies, changes in societal energy capture rates, and socio-technical change processes.

A renewable-resources-based decarbonizing transition is historically unprecedented: firstly, in that it seeks to replace, not augment, the established set of socio-technical practices, and inverses the trajectory of movement towards higher energy and power density systems; secondly, in that these processes threaten to reconfigure power relations, which have historically exhibited a coupled growth in hierarchy and energy capture. This suggests that a perspective on energy transitions is required, which focuses on the dialectical relations between differential accumulation and socio-technical change. We contend that the CasP concept of power, and a critique of neoliberal growth theory may provide just that.

Our suggested theoretical framework is merely the first step towards an empirical study of the issues and is designed to support the concrete exploration of contemporary developments in energy related industries. Although the approach is theoretical, it may act as a guideline to the identification of industry-specific components, and mapping out of relations between them, in the analysis of contemporary processes. Our work must now be expanded and used to support rigorous empirical analysis. The framework should be applied to different energy-related sectors in transition, as we intend to do in the case of electricity sector decarbonization. Such further investigations, and more rigorous empirical studies, will help develop and refine it.

The perspective presented in this paper is decisively limited. It does not assume to propose a grand, generalized theory of energy transition, nor to suggest a universal dynamic. Neither does it seek to explain the source of social innovation. Rather, it offers the beginning of a systematic study of social power, and changes in societal energy capture potentials, in an age of global capital and anthropogenic environmental crises. It proposes an integration of CasP in the analysis of contemporary energy transitions. Furthermore, it should be noted that the breakdown of this framework into concrete, workable components, is contingent on the industry and geopolitical contexts of the field to be examined. However, while local differences in business-industry-regulation configurations may occur, the global expansion of capital accumulation, and its reliance on energy consumption growth, requires us to account for this specific form of power in the analysis of contemporary energy transitions.

[1] Energy capture denotes primary energy conversion into useful energy and energy required for this process (Morris, 2013).

[2] A mode of power is a feature of all hierarchical societies. It denotes the "specific architecture" of power relations and reproduction within them (Bichler & Nitzan, 2009:311).

[3] Typically, measures such as "real GDP", which denotes inflation adjusted goods and services produced at a certain period, are used to study growth.

[4] Fix (2021) identifies three approaches by which to understand these relations. The materialist approach contends that growth in energy capture unintentionally drives the growth of hierarchy. As surplus production grows, elites spring-up by disproportionately appropriating it. The functional approach suggests that hierarchical organization is necessary to achieve higher energy capture. Hierarchy is a historical-evolutionary solution to the constraints of human cognition in functioning in large groups. The wasteful approach contends that the growth

of hierarchy depends on growth in energy capture. Energy is "wasted" on the sabotage necessary to reproduce power and withstand resistance (Bichler & Nitzan, 2017).

[5] According to the law of conversion of energy, while energy can be transferred, it cannot be created or destroyed. Entropy represents the quantity of "high grade" energy (i.e., energy available for conversion into work, as opposed to heat) within a system. It is also a measure of randomness, as it is assumed that the creation and sustenance of order requires work and thus, energy inputs (Smith & Smith, 1996).

[6] Ayres and Warr use the term exergy rather than energy. Exergy denotes the potential of a system to do work. It is defined as "the maximum amount of work that can theoretically be recovered from a system as it approaches equilibrium with its surroundings reversibly" (Ayres & Wart, 2009: 78). As this is not a technical paper, we use the more generally known concept of energy.

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