It's not (all) about efficiency: Powering and organizing technology from a degrowth perspective

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It's not (all) about Efficiency:
Powering and Organizing Technology from a Degrowth Perspective

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Highlights

Various philosophical positions on technology are introduced and discussed.

A framework to assess suitability of technologies for degrowth is developed.

Structures that support suitable technologies for degrowth are elaborated on.

A matrix to assess ownership of technologies in a degrowth context is discussed.

Questions of agency missing from the degrowth discourse are raised.

Abstract

Transgressions of ecological boundaries and increasing social inequality question the paradigm of continual economic growth guided by technological efficiency - often cited as the only solution to these crises. This paper develops a critical and diversified viewpoint on technology for degrowth. 'Classical perspectives' of Illich's convivial society, Elull's critique of technique, Mumford's tools and machines, and Schumacher's critique of gigantic techno-infrastructures are explored and combined with Arendt's instrumentality of technologies and Marxist perspectives on ownership. Two questions are posed regarding technology. First, which technologies are 'suitable' for a degrowth context? Previous frameworks by Illich and Schumacher are extended by ecological aspects to assess the suitability of technologies. Second, how should 'suitable' technologies be structured to enable egalitarian utilization? Here, Schumacher's "intermediate technologies" and ownership are central elements. The frameworks and analysis add value for degrowth activists and bridge the gap scientifically between Marxist views and those of degrowth. In conclusion, technologies in degrowth are suitable if they reduce ecological impact, enhance autonomy and conviviality, and are structurally available in an egalitarian way based on open-access regimes. In the discussion further research questions are posed regarding transforming agents and power relations between grassroots and the state. Limitations of the framework include the role of digital technologies for communication, here treated as electric tools, and the focus on industrialized societies.

1. Introduction

Technological inputs and innovations are a key driver of long term economic growth (Solow, 1957). Through technological advancements, increasing efficiencies, and a shift from the industrial to the service sector various countries in the Global North have improved wealth and development indicators whilst ostensibly decoupling greenhouse gas emissions from economic growth (OECD, 2012). This seeming success is often cited to encourage expanding economic growth and technocratic efficiency solutions to lift millions out of poverty while simultaneously paving the way for future environmental improvements, emission reductions, and dematerialization of the economy (Naam, 2013).

However, increasing material and energy efficiencies have actually *increased* total throughput by reducing costs of production (Sorrell, 2009). Despite efficiency gains and regional decoupling the total amount of CO_2-emissions globally have increased almost steadily between 1990 and 2013 (Friedlingstein et al., 2014). The same is observed for the total global resource appropriation of biomass, fossil energy carriers, metal ores, tailings, and industrial and construction material which has potentiated from 7.1 billion tons in 1900 to 59.5 billion tons in 2005 (Krausmann et al., 2009).

Further, technological advancements played a crucial part in this development. For instance, the industrial synthesis of ammonia from atmospheric dinitrogen known as Haber-Bosch process has significantly altered the global nitrogen cycle leading to an unintentional loss of biodiversity and the decline of water quality whilst creating dependency on the process itself (Erisman et al., 2008). As far back as 20 years ago this had already added “at least as much fixed N to terrestrial ecosystems as do all natural sources combined” (Vitousek et al., 1997: 497).

Coinciding with such technological advancements are the breaching of planetary boundaries (Rockström et al., 2009) and overshooting of planetary biocapacity (WWF, 2012). 15 out of 24 assessed ecosystem services are being used unsustainably (MEA, 2005). Simultaneously, relocating industrial production has increased international trade while displacing negative environmental, ecological, and social externalities (Peters et al., 2011), creating environmental distribution conflicts (Gerber, 2011; www.ejolt.org), and resulting in cost shifting. These issues pose questions of fairness, distribution, and equity often times completely absent from deliberations on technology.

In a world characterized by scarcity, technological progress presents shifts, not solutions by substituting one resource for another, e.g. uranium for oil (Heinberg, 2007). These substitutes are themselves scarce, even in the case of being ‘renewable.’ For instance, production of solar panels, wind turbines, or batteries requires lithium and other rare earths. Thus, biophysical limits of natural resources imply limitation to the expansion of the economic sphere and material consumption (Daly and Farley, 2011; Meadows et al., 1972). In light of these findings it is necessary to reassess the role of technology and the (failed) expectations towards it.

Commonly, degrowth advocates propose a sufficiency strategy, realized through reduction of production (Hueting, 2010). Instead of 'better' machines restrictions in the need for resources are required to alleviate ecological degradation and resource exploitation (Paech, 2012). According to Alcott (2010) transformation strategies should address ecological impacts directly through caps, limits, and restrictions rather than indirectly through technological fixes.

After discussing the employed methodology (Section 2) this paper takes a step back and reviews philosophical concepts related to technology common and uncommon in the degrowth discourse (Section 3). 'Classical perspectives' of conviviality (Illich, 1973), critique of technique (Ellul, 1964), tools and machines (Mumford, 1934), and gigantic techno-infrastructures (Schumacher, 1973) are explored and combined with perspectives on technological instrumentality (Arendt, 1998) and ownership (Marx, 1962). From that suggestions are derived on *which* technologies might be suitable for a degrowth society (Section 4) and *how* these technologies might be organized (Section 5). Questions of agency and power conclude the article (Section 6).

2. Method

The objective of the paper is to answer two questions a) *which* technologies are suitable for the degrowth context; and b) *how* they could be structured. For this purpose existing literature on the topics of degrowth and technology was exploratively reviewed. Here, Ellul's *The Technological Society*, Illich's *Tools for Conviviality*, Schumacher's *Small is Beautiful*, and Mumford's *Technics and Civilization* emerged as 'classical perspectives' on technology within degrowth. In search for outside perspectives, the topics of ownership and instrumentality surfaced. The former is represented in this paper by Marxist arguments (Marx, 1962; Roth, 2010; Schleifstein, 1980), and the latter by Arendt's *The Human Condition*.

A framework is constructed identifying 'suitable' technologies, their structure, and their ownership regimes for the degrowth context. The framework's elements were identified hermeneutically utilizing *preparing interpretation* within qualitative content analysis (Mayring, 2010). Here, concepts of conviviality (Illich), intermediate technologies (Schumacher), ownership (Marxist), the means-end category (Arendt), and Mumford's emphasis to redesign technologies have materialized as central categories to assess technology. They are accompanied by ecological impacts as a major source for degrowth (Latouche, 2009). This inductive category development was followed by deductive category application (Mayring, 2010) onto three kinds of tools powered by labor, electricity, and fossil fuels.

While this framework is certainly not the only possible operationalization it does represent central categories utilized within degrowth as demonstrated in the overviews provided by D'Alisa et al. (2015) and Demaria et al. (2013). Combining ‘classical’ and distant perspectives this framework is able to provide a heuristic and well-adjusted view on technology enhancing scientific understanding.

3. Different Views on Technology

This section introduces philosophical deliberations on technology which are later employed to develop a framework to answer the questions on suitable technologies in a degrowth context. The proposed concepts and categories are *conviviality* (Illich, 1973), *self-perpetuating technique* (Ellul, 1964), *tools and machines* (Mumford, 1934), *gigantic and intermediate technologies* (Schumacher, 1972), *labor, work, and utilitarianism* (Arendt, 1998), and lastly *ownership* of technology (e.g., Marx, 1962).

3.1 Conviviality

Illich’s (1973) concept of conviviality is based on individual creativity, autonomy, and freedom, and poses a radical alternative to and critique of the industrial society. It is based on the structure and use of “tools” which are broadly defined to include simple hardware (e.g., pots), complex machines (e.g., cars), institutions producing tangible commodities (e.g., industrial factories) and intangibles (e.g., schools and hospitals), as well as infrastructure (e.g., transportation). According to him, the industrial use of tools is exploitative, because it is based predominantly on efficiency, negating human creativity, impairing their autonomy, and reducing them to mere consumers and machine operators. “The hypothesis was that machines can replace slaves. The evidence shows that, used for this purpose, machines enslave men. Neither a dictatorial proletariat nor a leisure mass can escape the dominion of constantly expanding industrial tools” (Illich, 1973: 16-17).

Regarding their structure Illich contrasts “manipulative tools” and “convivial tools.” Manipulative tools produce more costs than benefits. They are highly exclusive and limit independence, because additional items and investments (e.g., cars) are needed to use them (e.g., fast transportation). This exclusion reduces autonomy and democratic control. In its extreme, manipulative tools become “radical monopolies.” These appear “when one industrial production process exercises an exclusive control over the satisfaction of a pressing need, and excludes nonindustrial activities from competition" (Illich, 1973: 62). By defining what it means to be "educated" or "healthy" together with the exclusive power to diagnose, treat, and measure success experts in compulsory schools and the healthcare system have created structures that are almost impenetrable. Convivial tools on the other hand are accessible to anyone in society. An infrastructure of telephone booths for example enables everyone "who can afford a coin" to talk to people of their choice (Illich, 1973: 30). The same holds true for open-source programming if computers are provided on a similar scale. Thus, convivial tools increase autonomy and enhance creativity. However,

> [w]hat is fundamental to a convivial society is not the total absence of manipulative institutions and addictive goods and services, but the balance between those tools which create the specific demands they are specialized to satisfy and those complementary, enabling tools which foster self-realization. (Illich, 1973: 32)

The industrial society, according to Illich, is based upon the ultimate end of increasing produced goods and services. This creates a culture of dependency on machines, centralization, and capital intensification which is indoctrinated into people's minds through manipulative tools like the compulsory school preaching personal accumulation of goods and services. "Our vision of the possible and the feasible is so restricted by industrial expectations that any alternative to more mass production sounds like a return to past oppression or like a Utopian design for noble savages" (Illich, 1973: 6). Thus, it is not surprising that a country's state of development is measured in industrial production and technological integrations into growing arenas of physical, biological, psychological, and social life; and that progress and well-being are being equated with increased energy and material consumption.

As an alternative Illich proposes retreat from industrialization, particularly for the so-called "underdeveloped" countries. His vision of a "convivial" society is one "*in which modern technologies serve politically interrelated individuals rather than managers*" (Illich, 1973: 6, italics in original). Illich terms a convivial society as one which recognizes and accedes to "natural" limits. The pursuit of efficiency gains, expansion of technological know-how, and modification of the environment for human comforts through technologies can be structured in a convivial fashion to serve the means of humans without creating enslavement from machines. However, such an enterprise cannot be undertaken without considerations of scales and limits, which often result in transition to second watersheds. Thus a central theme in structuring a convivial world, for Illich, is exploring safe operating spaces rather than pursuing continual growth.

3.2 Self-perpetuating technique

In *The Technological Society* Jacques Elull (1964) develops a comprehensive social philosophy of the technical civilization and offers a framework within which relationships between technology and human society can be examined. Here, Ellul posits a cultural fixation with increasing efficiency and technical solutions which has become independent of reflexion and alternatives. Ellul (1964: xxv, italics in original) defines technique as "*totality of methods rationally arrived at and having absolute efficiency* (for a given stage of development) in *every* field of human activity." Technique as a systematic and totalitarian arrangement is thus separated from what is most frequently equated with it: the machine. Indeed, "technique transforms everything it touches into a machine" (Ellul, 1964: 4), but technique itself is seen as a "sociological phenomenon" – a way of organizing and structuring, the search for the "one best way" to achieve any objective and end, with the objective becoming less and less relevant for the sake of increasing efficiency. Thus, Ellul's critique focuses more on underlying societal structures having become uncontrolled, self-perpetuating, and independent of human needs.

> Technical elements combine among themselves, and they do so more and more spontaneously. In the future, man will apparently be confined to the role of a recording device; he will note the effects of techniques upon one another, and register the results. […] In reality, it is not the "wishes" of the "producers" which control, but the technical necessity of production which forces itself on the consumers. Anything and everything which technique is able to produce *is* produced and accepted by the consumer. The belief that human producer is still master of production is a dangerous illusion. (Ellul, 1964: 93, accentuations in original)

Simultaneously, technique inevitably produces "secondary effects" or unintended consequences, e.g. in the form of ecological degradation, resulting in new challenges. These challenges are answered by the employment of yet new forms of technique, creating an ever-recurrent cycle of technique-made challenges and technical "solutions" (see *self-augmentation*).

Elull identifies several major characteristics exhibited by all forms of modern technique. Firstly, technique is characterized by *automatism*, being based solely on a mathematically calculated or rationally derived "one best way." Elull (1964: 82) states that "the choice between methods is no longer made according to human measure, but occurs as a mechanical process which nothing can prevent." This strips humans of their ability to choose, since every choice is predetermined according to efficiency.

Secondly, technique exhibits the characteristic of *self-augmentation*. Humans become increasingly irrelevant for the advancements of technique. Instead, "technique engenders itself. When a new technical form appears, it makes possible and conditions a number of others" (Ellul, 1964: 87). Thus, technique irreversibly penetrates multiple dimensions of society becoming more and more totalitarian.

The third characteristic, *universalism*, implies such a progression beyond geographical boundaries, and an embeddedness into societies and practices around the world. Technique is posited here as overpowering traditional social, cultural, and economic systems into a universal "technical civilization" – a civilization that is "constructed *by* technique, *for* technique, and *is* exclusively technique" (Ellul, 1964: 128). This leads to the situation where

> we unquestioningly accept that new is better, that new means are better than older ones, that technological change is inevitable and good, and that any problems that arise will allow a technological solution. We now generally, if sometimes grudgingly, accept new technology. (Hanks and Hanks, 2015: 466)

Finally, technique is characterized by *autonomy*. Once technique takes root in society it operates according to its own "internal necessities" rather than external necessities of society or individuals. Technique is independent of moral and spiritual values, since its continuous progress is not determined by anything outside of technical determinants and criteria. Thus, it is useless to moan about apparent "evil" uses of technique.

Although technique permeates all domains of human society it is particularly dominant in the economy, because a capitalist economy cannot function in standstill, and technique provides the motor for the dynamic state of evolution. This evolution with its continuous introduction of new products however is detached from human needs. Technical autonomy and self-augmentation increase the magnitude and costs of technique which in turn requires centralization of capital. Thus, small scale decentralized enterprises are incompatible with technical progress and will ultimately give way to an "economy of corporations or to a state economy" (Ellul, 1964: 154). In fact, "the idea of effecting decentralization while maintaining technical progress is purely utopian" (Ellul, 1964: 194).

3.3 Tools and machines

In *Technics and Civilization* Lewis Mumford (1934) classifies technologies as tools, machines, and machine-tools[1]. His classification is based upon the degree of flexibility in utility or the "degree of independence in operation from the skill and motive power of the

[1] Mumford (1934: 10) describes machine-tools as those that offer the accuracy of machines, but those that require the "skilled attendance of the skilled workman" for their operation.

operator: the tool lends itself to manipulation, the machine to automatic action" (Mumford, 1934: 10). Machines, in their operation, require a higher degree of specialization, outside sources of power for operationalization, and are restricted in their applications. Mumford also elaborates on the need to acknowledge tools, rather than machines, as "the most effective adaptations of the environment." Like Schumacher and Illich, Mumford does not advocate simply discarding all modern forms of technology for the primitive, but rather suggests that a deeper understanding into the utility, functionality, and social impacts of machines is required: "[t]he rebuilding of the individual personality and the collective group, and the re-orientation of all forms of thought and social activity towards life" (Mumford, 1934: 433). He also discusses the need for structuring and organizing tools in new manners. "[F]or we will have to re-write the music in the act of playing it, and change the leader, and re-group the orchestra at the very moment that we are re-casting the most important passages" (Mumford, 1934: 435). Mumford also discusses the current intentional submission of organic life by mechanical processes. He describes the introduction of technology in every aspect of modern life is a symptom of what he refers to as the "third wave" in line with Illich's "second watershed."

In conclusion, Mumford's classification of tools, machines, and machine-tools is sensitive to current ecological and social conditions and provides a suitable frame for the degrowth context. His views on added value through technology align with convivial arguments by Illich (1973).

3.4 Gigantic and intermediate technologies

In *Small is Beautiful* E.F. Schumacher (1973) elaborates that the industrial society needs to reorient its usage of technology. He critiques the predatory nature of the industrial society and the large technologies that facilitate it. Nature and natural resources are being treated as "income" to be spent on meeting consumption needs, rather than as capital to be conserved. This treatment of natural capital emerges from the misconception of manmade capital being able to replace natural capital when there is need for it. Similarly, Georgescu-Roegen (1975: 349) calls the belief "that man will forever succeed in finding new sources of energy and new ways of harnessing them to his benefit" an economic myth. Schumacher (1973) limits his discussion of technologies to physical machinery used in the industrial process. He condemns the usage of "gigantic" technologies, which are limited in access and control to a monetarily wealthy elite hence resulting in estrangement of people from autonomous decision making regarding the applications of said technologies. Schumacher's concerns with regard to large technologies extend to both ecological and social realms. From an ecological perspective, he points to biophysical limits, also referred to as "planetary boundaries" (Rockström et al., 2009), which are quickly being breached; socially, he discusses the increased distancing between people and decision making on usage of large technologies.

According to Schumacher, large technologies have allowed reduction of total social time in the productive sector of the economy. As a result of “gigantic” technologies, far fewer numbers of people are contributing directly to productive work such as agriculture. The efforts of most are redirected to managerial, accounting, and other such tasks. Further, actual productive work is not considered to be something respectable anymore. Thus, there is an increasing need to improve productivities. Schumacher argues that larger numbers of people being employed in actual gainful productive employment would reduce the need for ever increasing technological efficiencies. However, in line with Illich and Elull, he does not propose technophobia, a complete lack of technological usage, or even a return to what he refers to as “primitive technologies.” Instead, he proposes to develop “intermediate technologies” or “technologies with a human face.” Schumacher proposes three criteria for intermediate technologies that are not predatory on nature. First, tools and machines must be priced relative to income levels of societies where they are going to be used in order to be accessible to all. Second, they should be feasible for small scale applications, and third, they should be designed so as to enhance human creativity through their applications.

In conclusion, Schumacher (1973) calls for decentralization of technology, their widespread availability, and a reduction in their complexity and costs to enhance accessibility. Hence, Schumacher aligns with the fundamental perspective of conviviality to which he adds ecological deliberations.

3.5 Labor, work, and utilitarianism

In *The Human Condition* Hannah Arendt (1998) proposes three distinct human activities – labor, work, and action – which are different forms of living together and interacting. She poses a philosophical critique of modern society and its promise of wealth through industrialization and automation. For the purpose of discussing technology the focus lies on the first two conditions, labor and work.

Labor sustains and reproduces the human organism. Products of labor “come and go, are produced and consumed, in accordance with the ever-recurrent cyclical movement of nature” (Arendt, 1998: 96), indistinguishable in time. Those occupied solely with labor are exclusively bound to necessity and thus unfree. This enslaved mode of existence Arendt calls *animal laborans*. It is opposed by *homo faber*, “the fabricator of the world”, whose existence is based on work, the second condition of the *vita activa* (Arendt, 1998: 126). Unlike labor the work process has “a definitive beginning and a definitive, predictable end” (Arendt, 1998: 143) with its result being durable, objective, and withstanding. This provides stability since humans can relate to the same object over time as opposed to the relentless "ever-recurrent cyclical movement" of nature. As such, work is revolutionary. Through work, *homo faber* erects a world of his own based on instrumentality and the means-end category.

However, his man-made world shatters with the dominance of utilitarianism. The virtue of utility is inflicted even on the supposed end products of the work process turning them into means themselves. At this point industrialization and automation enter. To illustrate Arendt distinguishes between tools and machines. Tools have been produced by *homo faber* as a means to fabricate things as ends. In his world they are always guided by instrumentality. Machines on the other hand

> demand that the laborer serve them, that he adjust the natural rhythm of his body to their mechanical movement. […] [A]s long as the work at the machines lasts, the mechanical process has replaced the rhythm of the human body. Even the most refined tool remains a servant, unable to guide or to replace the hand. Even the most primitive machine guides the body's labor and eventually replaces it altogether. (Arendt, 1998: 147)

Guided by utilitarianism *homo faber* has created automated processes without a clearly distinguishable beginning and end. This "has shattered the very purposefulness of the world, the fact that objects are the ends for which tools and implements are designed" (Arendt, 1998: 150). This begs the question "whether machines still serve the world and its things, or if, on the contrary, they and the automatic motion of their processes have begun to rule and even destroy world and things" (Arendt, 1998: 151). In the second case *homo faber* is reduced to the *animal laborans*, enslaved by automated processes built by himself.

In conclusion, through work the modern mode of existence, *homo faber*, has created a world of things using tools as means. With the rise of utilitarianism this means-end category has lost its reliance since every end is questioned with regard to further utility. Externally controlled machines mimic natural processes degrading *homo faber* to the enslaved *animal laborans*.

3.6 Ownership

For Karl Marx technological advancements and machines represent *means of production* used together with human labor to produce *surplus value*. Both technology and human labor are thus inextricably linked to the capitalist *relations of production*, i.e. the separation of ownership and labor. Within his framework machines allow higher gains in productivity which in turn enables the capitalist increase the relative surplus value and thus accumulate more capital. According to Schleifstein (1980: 63) "not technology or science pose a threat to humanity, but their capitalist misuse […]." Once the capitalist mode of production is overcome and replaced by socialism technology serves the people.

> Neither technology and science nor economic growth is a fetish in the socialist society. They are only *means* to satisfy the *needs* of people, means for the increase of material and cultural quality of life, and for the relief and creative configuration of working conditions. (Schleifstein, 1980: 72; own translation, italics in original)

Aberrations of science and technology are thus a result of the exploitation of labor and nature. From that observation should derive a critique of capitalism and not a critique of science and technology. Thus, the "right" development of science and technology, in Marxist terms, relies on their planned and deliberate application.

In capitalism the relationship of human labor and technology is a dialectic one. In *The Capital* Marx (1962) argues that labor gives an object value when traded as a commodity; it is their hidden common denominator. With gains in productivity the value of commodities decreases, because less labor is needed to produce the same amount as before. Simultaneously, gains in productivity create more *relative surplus value* and incentivize the capitalist to employ more machines relative to humans. This results in the theoretical extreme where machines with infinite productivity produce value-less commodities, one of the inherent contradictions of capitalism. For capitalists, technology is thus boon and bane; the source of increases in the accumulation of capital and of the diminution of value.

Additionally, machines are capital-intensive which results in falling rates of profits for capitalists. To counteract capitalists tend to increase exploitation of workers. For them increased use of technology means denser working days and external control (Roth, 2010). The concept of alienation adds another layer to the view on technology. Marx' materialism ascribes the surroundings and objective reality a defining role in shaping human feelings and inner workings. Accordingly, humans see themselves reflected in nature and create their surroundings with their labor. In capitalist relations they become alienated from their products, their labor, other people, and finally themselves (Marx, 1968b). Psychologically the alienation of the worker reaches its peak in mechanical large-scale industry. "In capitalist production the work equipment becomes a means of subjugation, exploitation, and impoverishment of the worker; the societal combination of work processes a means for the suppression of his [sic] individual liveliness, freedom, and autonomy" (Schleifstein, 1980: 63, own translation).

Schleifstein (1980: 60) sees *means of production* and *relations of production* as interdependent. The proletariat operating means of production is the driving factor in great societal transformations and will force the relations of productions to adapt. Their counterpart is the capitalists who influence possible developments regarding means of productions with their ideas, wishes, and investments.

In conclusion, ownership of technology is a major aspect for a Marxist perspective which needs to be addressed in order to create a more egalitarian society freed from alienation and coercion of the capitalist mode of (re)production.

3.7 Convergence of philosophical positions

First, the philosophers approach technology with its benefits and problems from different positions. For Illich and Schumacher the question of structure and accessibility is paramount; for Marxists the question of ownership; for Arendt their accordance with the means-end category of *homo faber* to create a world; and for Ellul methods to create a totalitarian regime of efficiency mechanizing life and operating outside the realm of benefit and malignity. Ellul and Illich explicitly state that ownership is secondary if not irrelevant for technology and technique to expand and subordinate, posing direct critiques of Marxist focus on relations of production.

Despite differing starting points, some agreement is reached regarding the critique of the industrialized status quo. Marx' concept of alienation, although based on ownership, is compatible with Arendt's destruction of the world *homo faber* has created, Mumford's and Illich's loss of autonomy, and Ellul's description of humans as mere "recording devices" adapting to technique. All refer to psycho-sociological and cultural effects stemming from the loss of some concept of what it means to "be human" and present critical views on technologies.

Additionally, self-perpetuating processes linked with technology are shared. For Arendt machines mimic natural processes outside the means-end category; for Ellul technique inevitably creates new technique penetrating multiple facets of society (*self-augmentation*); Schumacher sees technology deprived of any "self-limiting principle"; and for Marxists self-perpetuity derives from the accumulation of capital by increasing surplus value via technological advancement.

4. Suitability of Technologies

The first question that arises regards *which* technologies ought to be employed in a degrowth society. Of the abundance of technologies employed today not all are suited to the degrowth context. Autonomous, frugal, and solidary structures ought to be constructed reducing external dependencies and a certain totalitarianism resulting from fixation on economics, development, and progress (Latouche, 2004).

With greenhouse gas emissions, environmental degradation, and resource scarcity as main issues of sustainability technologies are categorized based on their power sources. Technologies are differentiated on the basis of being driven by a) human labor (e.g., sickles, bicycles) which do not require the utilization of fossil fuels; b) electricity (e.g., robot-mowers, computers) which are amenable to utilizing renewable sources of power; and c) fossil fuels (e.g., ride-on lawnmowers, cars) which depend in their operation on fossil energy carriers. This distinction roughly aligns with Mumford's (1934) categorization into tools, machine-tools, and machines based on autonomies in operation and dependency of external power sources for operation. This additionally expands the framework proposed by Illich (1973: 29) distinguishing *hand tools* "which adapt man's metabolic energy to a specific task" from *power tools* which "are moved, at least partially, by energy converted outside the human body." In his framework Illich neglects sustainability aspects such as renewability of energy sources. This article thus expands existing frameworks by integrating social and ecological perspectives for determining the suitability of technologies.

For ecological considerations the indicator 1) *ecological impact* is used. For social considerations the concepts of conviviality (Illich, 1973), intermediate technologies (Schumacher, 1973), and Mumford's (1934) classification of machines are combined. According to these sources technologies should 2) be *accessible* to a large number of people, 3) enhance human *autonomy*, 4) allow *decentralized* and unspecialized application, and 5) improve creativity and *innovative* handling (see Section 3). The proposed 5-point framework is applied to labor, electric, and fossil fuel tools examining their a) production, b) operation, and c) maintenance. All types of tools exhibit some value on each of the categories. No tool is completely ecologically neutral or absolutely accessible to everyone anytime. Thus, the focus lies on a comparison between the different types of tools and their relative values on the dimensions. That way, *general tendencies* in the impacts, accessibility, autonomy, decentralizability, and innovative capacity of the types of tools are explored and compared. These are underscored with specific examples to illustrate the line of argument without claims to be complete.

4.1 Labor tools

Technologies based on human labor are what Hannah Arendt refers to as *tools*. In her framework they allow autonomous handling and the creation of a world of permanence while abiding to the means-end category. Labor tools also align with Illich's *hand tools* and can be excluded from Schumacher's category of *gigantic technologies*.

4.1.1 Ecological impact. The ecological impact for the production of labor tools varies according to the materials used. Electric and fossil fuel tools might be utilized to produce labor tools, particularly if metals are involved. However, generally it requires significantly fewer inputs than that of equivalent electric or fossil fuel tools. Bicycle production, for example, requires aluminium with certain ecological impacts, but is still much less resource-intensive than the production of a (electric or diesel) car. Similar relations can be observed for sickles, knives, and door knobs compared to industrial harvesting equipment, electric kitchen appliances, and automatic doors. While there are examples of impactful production of labor tools the general tendency seems to assign lower ecological impacts than the production of electric or fossil fuel tools.

Operation of every tool requires energy. In the case of labor tools human energy obtained from food consumption is utilized which is inherently renewable. Two factors limit this renewability. First, current forms of agricultural production are highly resource-intensive being dependent on fossil fuels in pesticides, fertilizers, and heavy machinery. Second, a meat-based, non-regional, non-seasonal diet requires much more energy and land resources than a vegetarian, regional, seasonal one (Bailey et al., 2014). Operation of labor tools is also more labor and time-intensive than operation of other tools reducing its relative scale of ecological impacts. Axes are much less efficient than chainsaws in woodcutting while both impact the forest as ecosystem. Some labor tools also require a certain infrastructure to be operated successfully. A bicycle without sealed surface is difficult to operate. This increases their impact in absolute terms. However, relative to the infrastructures needed for the operation of equivalent electric or fossil fuel tools (e.g., asphalt roads and petrol or recharging stations for cars) this impact is lower.

Maintaining labor tools produces most likely fewer ecological impacts than maintaining other tools, because materials required are mostly (though not exclusively) labor tools. Bicycle repair for example can be achieved utilizing screwdrivers and other labor tools whilst car repair nowadays often-times requires automated auto-hoists and software updates. However, given the cheaper costs of labor tools it is questionable whether they are properly maintained and repaired rather than discarded and replaced by new ones. Simultaneously, labor tools are not as prone to fashion and status symbolism as electric or fossil fuel tools reducing the effect of psychological obsolescence (Box, 1983). Thus, labor tools might be utilized until their functionality wears off.

4.1.2 Accessibility. With lower energy and resource requirements production of labor tools becomes cheaper and seemingly more accessible. However, within capitalist relations people are on a large scale deprived of means of production based on the reign of private property (see Section 6). Further, fossil fuel subsidies and incentives to large scale production induce production and artificial cost reduction of other forms of tools.

The comparably lower price of labor tools potentially enables widespread access to their operation. In capitalist relations it is still necessary to sell one's own labor power on the market to trade the pay for labor tools. However, no other equipment aside from one's own body is required to operate labor tools. This also enhances the accessibility in the operation of labor tools. Three factors limit the accessibility of operation. First, large sections of populations have become increasingly deskilled with manual labor. Thus, incentives to expand labor tools should include reskilling workshops. Second, upward social mobility is associated with acquiring higher material and energy intensive tools and let others, including "energy slaves" (Illich, 1973), work for oneself. Third, promoting labor tools limits the accessibility of other need satisfactions like travel to distant locations or digital communication. In this sense labor tools might be seen as retrogressive. Thus, intensified operation of labor tools might not be accepted because of psychological factors like status, needs, and identity. However, specific subsidies could incentivize the production, operation, and maintenance of such tools (Caulfield and Leahy, 2011). Bike-sharing programs outside the realm of market interactions might serve as alleviations and increase accessibilities (DeMaio, 2009). The Swiss community platform *Pumpipumpe* applies the sharing concept to other, partially exotic, household equipment like tripods, sleighs, or woks (www.pumpipumpe.ch). These form new identities and thus enable a shift towards accessibility and acceptance of labor tools.

Accessibility of maintaining labor tools depends upon their design, repair infrastructure, and incentives to re-use instead of replacing them. Reskilling of people in the maintenance is another crucial aspect which needs to be considered if the use of labor tools is to be expanded.

4.1.3 Autonomy. For Illich (1973) external control of tools limits the autonomy of individuals. Thus, starting with the production process as many stages in the tools' life cycles should be controlled by "autonomous individuals and primary groups" (Illich, 1973: 17). The industrial society accordingly reduces people to mere consumers of externally provided needs and products negating individual autonomy, creativity, and freedom. Autonomous production of tools should thus be expanded. For Schumacher (1973) mechanical production lacks humanitarian elements. Thus, production of labor tools utilizing labor tools is essential for Schumacher's concept of autonomy. In order to increase autonomy the accessibility to labor tools should be expanded, e.g. by lowering costs and providing skill sharing opportunities.

For Illich (1973) autonomy in the operation is highest for labor tools, because it requires no external energy source. Thus, any person or group can use it autonomously. "People need new tools to work with rather than tools that "work" for them" (Illich, 1973: 17).

However, utilization of labor tools is more time-consuming and labor-intensive, exemplified by the washboard arguably limiting autonomy compared to the washing machine. Many less labor-intensive and thus efficient tools are acclaimed as rightfully liberating humans from “[a]ll unintellectual labour, all monotonous, dull labour, all labour that deals with dreadful things, and involves unpleasant conditions” (Wilde, 1891). Such liberating views on machines beg the question how gains in “disposable time” are spent (e.g., Santarius, 2015) and whether ostensibly increased autonomy indeed translates into real one.

Maintaining labor tools is highly autonomous, because it often times requires only other labor tools which are operated autonomously. Because of reduced complexity maintenance also requires lower expertise which enhances autonomy. Repair of labor tools is thus also expected to be cheaper than that of other tools.

4.1.4 Decentralizability. Production of labor tools can be decentralized to a larger extent than other tools due to lower input costs and skill requirements, although they, too, require a certain infrastructure in order to be employed gainfully.

Since operation of labor tools relies solely on human labor they can be completely decentralized without the need for additional infrastructure.

Maintaining labor tools requires lower input costs, skill requirements, and specialized equipment increasing its decentralizability. Repair cafés for labor tools can be established without much effort and investments.

4.1.5 Innovation. Innovation here is understood procedurally and includes technological, organizational, and structural elements whereby individuals or communities manage existing shortcomings by “reregistering the environment […] and moving beyond the paradigms in which they begin their analysis and within which, without such a reformation, they must inevitably end” (Brown & Duguid, 1991: 51). Given high accessibility and autonomy, low costs, and little required expert knowledge, innovations are likely to occur in the production of labor tools. This can allow tinkerers to become professional inventors.

Many tools serve a very specific purpose. However, given their widespread accessibility labor tools are likely to be reconfigured or cobbled together gaining additional or different functionality. Thus, labor tools enhance creativity in their innovative operation.

The same can be argued for maintenance. Low skill requirements and widespread accessibility enhance creative potentials to maintain and repair labor tools.

4.2 Electric tools

Electric tools are powered by sources external to humans and are thus part of Illich's *power tools*, Arendt's *machines* and can fall in the category of *gigantic technologies* (Schumacher). They activate energy exceeding human capacity and are thus able to increase productivity contributing to the exploitation of surplus value in capitalist relations.

4.2.1 Ecological impact. Electric tools require significantly larger inputs of material and energy, embedded energy in R&D, and upstream costs of production as compared to labour tools. Rare earths and other minerals are required for production of batteries, cables, or generators, and their extraction is accompanied by large ecological impacts (Humsa and Srivastava, 2015).

In their operation electric tools require energy converted into electricity from either fossil fuels or renewables. Thus, operating these tools potentially reduces greenhouse gas emissions compared to fossil fuel tools. However, conversion, generation, and storage of "renewable energy" are often associated with heavy reliance on scarce materials like lithium, neodymium, or cobalt which in turn are non-renewable (Prior et al., 2012). They also produce significant ecological impacts. Hydroelectric dams for example produce methane in flooded tropical areas and deteriorate water quality (Lima et al., 2008). Thus, the infrastructure to produce electricity itself is in either case often times intensive in capital, materials, and energy. Lastly, operating electric tools also requires widespread infrastructure of accessible electricity or effective storage to be used en route. This most likely increases ecological impacts compared to labor tools where this infrastructure is not necessary.

In maintenance either labor or electric tools could be employed with varying levels of implications and energy requirements. However, in many cases the electric tool necessitates maintenance with other electric tools (e.g., software updates) increasing the ecological impact. Two more substantial factors need to be accounted for. First, electronic waste is associated with large ecological impacts (Robinson, 2009). If electric tools are not redesigned to reduce waste (Latouche, 2009) then additional technologies are needed to process discarded electronic wastes and reduce their ecological impact, exemplifying Ellul's (1964) self-augmenting technique. Second, electric tools are prone to technical and psychological obsolescence. Though their longevity depends on the materials used and the quality of manufacture, it is either technically reduced or newer products are marketed making durability, maintenance, and repair less desirable. Both aspects are due to the capitalist need to increase profits through sales of new products (Bulow, 1986), and both in different ways demotivate repair and increase waste. This can lead to landfills and dumping sites with potentially hazardous waste and land use changes.

4.2.2 Accessibility. Production of electric tools occurs in capitalist relations to the largest extent in private property regimes which are inaccessible for outsiders. Aside from this production also requires expert knowledge about electric circuits and special equipment. Much of this remains unattainable for many people. In order to make production of electric tools accessible knowledge exchange and sharing of equipment should be expanded.

Operation of electric tools has become more accessible with increased diffusion of electricity worldwide over the past decades (IEA & OECD, 2009: 19). However, the needed infrastructure of reliable wires and batteries is still unavailable to at least 1.2 billion people around the world and intermittently available to a much larger number of people (IEA, 2016). Thus, further diffusion of electricity is fundamental to equitable access to the operation of electric tools.

Access to maintenance of electric tools is currently impaired by irreparable designs or technical obsolescence. Built-in batteries for example reduce the ability of users (and even experts) to repair electric devices. Thus, redesigning electric tools, e.g. in modular structures, might be a way to enable access to their maintenance. This needs to be accompanied by widespread skill and tool sharing for empowerment and increased self-efficacy.

4.2.3 Autonomy. Autonomy in electric tool production is limited by knowledge of electric currents, access to metal resources, and at least some degree of specialization. Additionally, electric tools can rarely be produced utilizing solely labor tools further reducing autonomy.

Autonomy in operating electric tools is reduced because it requires external energy sources. Thus, electric tools are dependent upon a widespread electricity infrastructure which is prone to introduce a "radical monopoly." The energy needed to operate electric tools is mostly not produced autonomously. Instead, even renewable energy is produced in highly centralized state or privately owned facilities despite efforts to liberalize markets (Moreno et al., 2012). Decentralized alternatives like home solar systems are currently still cost-intensive for individual households (Nafeh, 2009).

Yet, some electric tools have the ability to enhance autonomy for people despite non-autonomous operation. Washing machines for example free time compared to handwashing. Other examples are computers and the internet which can be used to fulfil various needs and enhance human interaction particularly over long distances. Combined with open-source programming, easy internet access, and digital commons computers can easily enhance autonomy given technical knowhow and affordable hardware. This structural aspect will further be discussed in Section 6. Easily accessible databases like Wikipedia or "social media" allow for mutual exchange on an individual level and share information on a scale impossible for previous technologies to achieve. In recent upheavals of the Arab Spring Twitter and Facebook particularly have played a central role in coordinating the already politicized protests (Wolfsfeld et al., 2013). In other regions social media" are used for disobedience and criticism resulting in oppression by governments (e.g., Joseph, 2012). Here autonomy is enhanced and revolutionary potential unleashed. This might evidence a first watershed. Simultaneously, the influence of "social media" is ever-increasing particularly to the political sphere. This expansion might create a coercion to participate since a non-user is excluded from certain societal and political participation, thus impeding her autonomy. "Social media" like most forms of communication are also the target of large-scale surveillance from state oppression. These factors might evidence the approach of a second watershed. Additionally, the social sphere of human interaction might be fundamentally changed when electric tools are increasingly being used as mediators. Direct interpersonal contact and the codes generated in it might be impaired which sediments on distorted self-images and community identification. Thus, "the internet could function as another successive layer of alienation built on the material economy" (CrimethInc, 2011: 180). To counteract Illich (1973: 21) argues that people have to "relearn to depend on each other rather than on energy slaves."

The autonomy of maintaining electric tools is restricted by dependence on professional repair often provided by the producers. This dependence can be modified by re-skilling of consumers. However, many electric tools are designed in a way to impair reparability. Built-in batteries for example make it harder to repair electric tools. Here, redesigning tools to enhance reparability combined with skill sharing workshops are possible levers to enhance autonomy.

4.2.4 Decentralizability. Production of electric tools requires expert knowledge and large capital and energy inputs limiting its decentralizability. Because of these factors production currently is organized in centralized facilities using extensive inputs of fossil fuel tools. Further, given high capital inputs, most electric tool production is oligopolized, allowing and compelling the few corporations to establish centralized structures. Although laptops, fridges, washing machines, and the like can be produced by start-ups high input costs and recognition of incumbents create barriers for entry resulting in concentrated markets with few corporations. Structural changes could allow for enhancing the potential of decentralizability. These include, for instance, limiting oligopolistic tendencies, and removing barriers of access to knowledge for production of tools.

Operation of electric tools varies in the potential for decentralizability since they require a certain infrastructure of generators, landlines, cables, or at least batteries. This can be challenging especially for rural areas. Their costs even though decreasing are still significant particularly for poor households. Computers, mobile phones, and home appliances require capital investment which limits their decentralizability. This is partly due to oligopolistic structures and capitalist means of production. A needs-based approach might allocate electric tools which enhance autonomy more appropriately. However, the infrastructure supporting electricity needs to be decentralized first.

Maintenance of electric tools is currently largely controlled and centralized by producers. Skilling and access to decentralized repair cafés could shift this to be under the power of individuals.

4.2.5 Innovation. Innovation in the production of electric tools tends to be facilitated through and limited by high capital, energy inputs, and expert knowledge.

In their operation, electric tools have varying degrees of innovation potential. Some like washing machines have limited capacity for user innovation; others like plasma televisions are designed as status symbols and feature unidirectional communication rather than enhancing autonomy, information exchange, or community building. These cases often coincide with large oligopolistic structures and patent wars centralizing and hindering innovation potential. Contrariwise, within the realm of digital commons, open-source programming, and the embedded community building the potential of low-cost, low-capital, and decentralized innovation is high. In contrast to unidirectional television rhizomatic networking platforms like YouTube enable exchange, foster creativity, and become animated through their users (Hardt and Negri, 2000). Collaborative, open-access databases like Wikipedia have resulted in rendering previous unidirectional encyclopedias almost obsolete. Thus, electric tools built on sharing and community increase convivial innovation potential.

In their maintenance innovation of electric tools remains limited by expert knowledge and capital and energy intensive infrastructures. However, through reskilling, innovation in maintenance could potentially be enhanced to larger degrees.

4.3 Fossil fuel tools

Fossil fuel tools are powered by coal, oil, gas, and their close substitutes. Thus, they are included in Illich's *power tools*, Arendt's *machines*, and can fall into Schumacher's category of *gigantic technologies* (e.g., in the form of factories). They activate energy far exceeding human capacity and are thus able to amplify productivity.

4.3.1 Ecological impact. Production of many fossil fuel tools is extremely resource and energy-intensive and thus more damaging to the environment and ecosystems as compared to labor tools. Fossil tools often times require engines or other combustion devices made out of large amounts of steel and other metals. Additionally, fossil fuel tools are often times larger expanding to the size of container ships or factories and thus in need of additional materials.

In their operation, fossil fuel tools necessarily require fossil fuels which have large ecological impacts from production till utilization. Fossil fuels have been central in increasing atmospheric CO_2-levels contributing to climate change posing questions of intergenerational equity. Conventional oil production is expected to peak no later than 2030 (Sorrell and UKERC, 2009), while the discovery of major new oil reserves has already peaked in the 1960s despite advancements in exploration, drilling, and extraction techniques (ASPO, 2009). Although abundance and geographical distribution of coal is expected to compensate for the declining oil reserves CO_2-emissions will continue to increase if fossil energy carriers are furthermore utilized. McGlade and Ekins (2015) have forecast that 33 % of oil, 50 % of gas, and 80 % of coal reserves should remain unutilized in order keep global average temperature rise below 2 °C. Extraction, transport, and refinery of oil have caused massive ecological degradation. Well-known cases are Texaco's operation in Ecuador (Kimberling, 2005) or Royal Dutch Shell in Nigeria (Opukri and Ibaba, 2008). Unconventional techniques of extraction like fracking are accompanied by toxic substances and their own ecological impacts (Wood et al., 2011).

Maintenance of many fossil fuel tools requires specialized instruments which itself is often resource and energy-intensive. Like electric tools the disposal of fossil fuel tools involves large ecological impacts, and requires significant changes in the process of redesigning, recycling, and reusing material inputs (Latouche, 2009). These factors increase the ecological impact of maintenance compared to labor tools.

4.3.2 Accessibility. Production of fossil fuel tools requires capital, specialized equipment, expert knowledge, and non-flammable materials, which are not easily accessible to everyone.

Many fossil fuel tools (e.g., cars, airplanes, or factories) are quite expensive and difficult to access. Others (e.g., coal ovens or mopeds) are more easily accessible for operation. However, they do necessitate a "gigantic" infrastructure (e.g., asphalt streets or airports). Additionally, they all depend on access to fossil fuels. Private production of fossil fuels by far exceeds households' budgets, but access to gasoline and coal is fairly widespread. Oligopolized cartel structures in oil refinery and distribution can regulate prices; together with approaching peak oil (Sorrell and UKERC, 2009) this could increase prices limiting access. Sharing initiatives might increase accessibility while reducing energy consumption. However, these need to be scaled up to have a tangible effect.

Maintaining fossil fuel tools, like their production, requires capital, specialized equipment, and expert knowledge being non-accessible to many people.

4.3.3 Autonomy. Production of fossil fuel tools like steam engines and their containers in the form of airplanes, container ships, or assembly lines is immensely capital-intensive and highly centralized. Thus, autonomous production of these fossil fuel powered means of transport is almost impossible. Even simpler tools like ride-on lawnmowers require expert knowledge about steam engines and access to processed metals and minerals.

Operating fossil fuel tools relies on infrastructure like gas stations or airports which lie completely out of control of the individual. However, a restricted form of autonomous operation is possible. A driver, for example, can choose between an abundance of destinations. Even far distances are reachable with fossil fuel tools like airplanes. However, this degree of autonomy in Illich's sense is not even close to that of two feet or even a bicycle. For once, a massive infrastructure of drivable roads is needed to enable such autonomy. Second, this autonomy is limited to privileged few at the cost of non-autonomy for most. In Arendt's terms fossil fuel tool or machines force humans to adapt to their own rhythm. Being automated the "tool" becomes an element of artificial nature outside the means-end category.

Maintaining fossil fuel tools and their supporting "gigantic" infrastructure (Schumacher, 1973) lies out of individual control limiting individual autonomy. Even previously repairable tools like cars or motorboats have become so complex that their maintenance relies heavily on expert knowledge. This does not even account for maintaining the needed infrastructure of roads and harbors. Yet, without supporting infrastructure many fossil fuel tools would become useless.

4.3.4 Decentralizability. Production of fossil fuel tools is highly centralized, given capital intensity, expertise, and required access materials and power sources. Decentralized factories will most likely make production less efficient if not impossible.

Operation of some fossil fuel tools, e.g. cars or coal ovens, can be decentralized given widespread infrastructure of energy supply. However, many fossil fuel tools like factories and their industrial machinery can neither be moved nor disassembled impairing decentralization.

Maintenance of fossil fuel tools is often times centralized in maintenance facilities. Since expert knowledge and specialized equipment are required such a structure is more appropriate than decentralized repair.

4.3.5 Innovation. Given material and cost-intensity, required expert knowledge, and limited accessibility innovations of fossil fuel tool production are highly specialized to particular contexts like R&D departments of capital-intensive corporations. This arguably limits the potential to generate innovative processes.

The same can be observed for operation and maintenance of fossil fuel tools. Here, the operator is often not wanted to interfere with the machine's own rhythm and workings. Such a role is reserved for experts.

4.4 Conclusion

Any tool is called 'suitable' if its use extends the autonomy and self-efficacy of humans while simultaneously obliging to general positions of the degrowth context. That means uncontrolled expansion and increasing resource intensity should be restricted, and tools re-thought and re-designed in a way that they are easily repaired, reused, and recycled (Latouche, 2009). This aligns with the concepts of right-sizing (Tokic, 2012), i.e. the reduction of economic activity until the "safe operating space" (Rockström et al., 2009) is reached, and Illich's (1973) first and second watershed, i.e. the situation in which tools prove their desired effects at first before turning inefficient and exclusive. Thus, labor tools and those electric tools enhancing autonomy should be improved and developed further while other electric tools and most fossil fuel tools should be dismantled adequately. This aligns with policy proposals by D'Alessandro et al. (2010) and Nørgård's (2013) transition to a labor-based "amateur economy." However, suitable tools should be embedded in corresponding structures extending conviviality (Illich) and widespread access (Schumacher). The proposed multidimensional matrix for suitability assessment is thus a first step to account for the complexity of ecological, social, and economic crises. The sole criterion of efficiency (Ellul, 1964) to assess technology is inadequate in such a situation. This underscores the value of this matrix providing a framework for technology assessment in the degrowth context. Additional work might accentuate its value and adapt certain aspects.

5. Structure of 'Suitable' Technologies

Having introduced criteria to identify 'suitable' technologies for the degrowth setting this section is dedicated to their structure. Many concepts introduced in Section 4 focus on the structure in which technologies are employed, e.g. conviviality (Illich), intermediate technologies (Schumacher), ownership (Marx), or the means-end category (Arendt). Building particularly on Illich and Schumacher, prerequisites of tools in their ability to enhance conviviality are firstly discussed. Secondly, ownership is discussed based on classical economics and their Marxist critique.

5.1 Prerequisites of degrowth technologies

According to Illich (1973) tools must be structured in a manner that promotes their convivial utilization. A convivial society enhances autonomy and self-determination through tools with open access. Their production and consumption is based on equality, justice, and on the needs of its members, not unlike the Marxist ideal of free people affirming each other mutually through their production for each other's needs (Marx, 1968a: 462). For analyzing prerequisites of 'suitable' technologies the characterization of Schumacher's (1973) intermediate technologies is adopted: 1) being priced relative to income levels, 2) being feasible for small scale applications, and 3) enhancing human creativity.

5.1.1 Affordability. Based on notions of equity and egalitarianism, tools and technologies should be affordable for everyone or at least for a vast majority of the population (Schumacher, 1973). Thus, technologies requiring large inputs of economic capital, energy, or materials should be dismantled; whereas low cost technologies available to large sections of the population should be promoted. Economic costs of technologies should be managed at levels comparable to average incomes in the society in which they are used to prevent disproportionate access and accumulation of wealth and power by the already privileged (Schumacher, 1973).

For technologies maintaining knowledge resources free, widespread distribution seems most desirable, e.g. through "open access" regimes in academic literature which protect authors against plagiarism by ensuring copyrights whilst enabling free availability to the public with internet access and author's consent (Suber, 2007; see also Section 6.2).

5.1.2 Feasibility for small-scale operation. "Intermediate" technologies (Schumacher, 1973) which are feasible for small-scale applications can limit the scale of operation and extent of ecological degradation whilst reducing monopolistic and oligopolistic tendencies by being decentralizable. Correspondingly, these technologies are "relatively non-violent," because they significantly reduce negative social and ecological effects compared to "gigantic" technologies (Schumacher, 1973). Thus, "intermediate" technologies should be promoted rather than capital-intensive, centralized "gigantic" technologies. Following an "intermediate" structure, technologies can be limited in scale of ecological degradation in production and operation, compatible with non-experts, as well as easier to repair by people directly involved in their application thus allowing longer life spans for utility. Intermediate technologies are compatible with a convivial society and could be much more successful than gigantic ones regarding the scale of negative ecological and social impacts.

5.1.3 Enabling utilization of human creativity. Schumacher's idea of creativity is based on autonomous work utilizing one's own hands and brains with a greater purpose in mind. It is opposed to the fragmented production of modern societies which hinders creativity by reducing workers to mere operators. This aligns with Arendt's loss of the means-end category and Ellul's dystopia of reduced humans. Products of such "gigantic" technologies cannot be produced by individual people and reduce their users to passive recipients of technological output rather than allow for active interaction with technologies. This can be understood by comparing the analog consumer to the digital consumer (Lessig, 2004). The analog consumer, "passive, programmed and broadcast to" (Lessig, 2004: 2), is not capable of utilizing personal creativity, whereas the digital consumer is active in interacting with technology to consistently renovate it. Structures that disperse passive technologies need to be dismantled in favor of structures that promote active technologies.

5.2 Ownership of degrowth technologies

In classical economics every good is equipped with the attributes *excludability* and *rivalry* characterizing ownership structures (Romer, 1990). In rivalry, consumption by one entity inhibits another entity's consumption. For instance, food consumed by one person is no longer available for another person. This inability to be shared in utilization creates competition. Excludability of an economic good is based on the legal framework and the owner's ability to "prevent others from using it" (Romer, 1990: S74). Patented medicine or copyrighted computer codes are solely excludable, and can easily be turned into non-excludable goods enabling access by everyone. Thus, particularly excludability closely relates ownership with power. It is also the attribute not entirely determined by the good itself but by social relations and contracts, making it subject to potential change. Together rivalry and excludability form a matrix of goods with corresponding ownerships regimes and varying consequences discussed below (Figure 1) (Musgrave and Musgrave, 1973).

Based again on egalitarian access to 'suitable' technologies two ownership structures are particularly problematic from a Degrowth perspective. First, the dominance of individualization and private ownership in modern societies makes many goods increasingly *seem* rivalrous when they in fact can be shared (see *Pumpipumpe*). Second, the dominance of excludability established by certain legal frameworks including intellectual property rights (IPR) artificially prevents access to certain goods as evidenced by impaired scientific knowledge flow (Murray and Stern, 2007). Systems that promote non-excludability and shared ownership and management of goods are to be preferred in the degrowth context. Thus, structured expansion of open access, commons, social enterprises and non-market capitals (Johanisova et al., 2013), and public goods needs to be implemented.

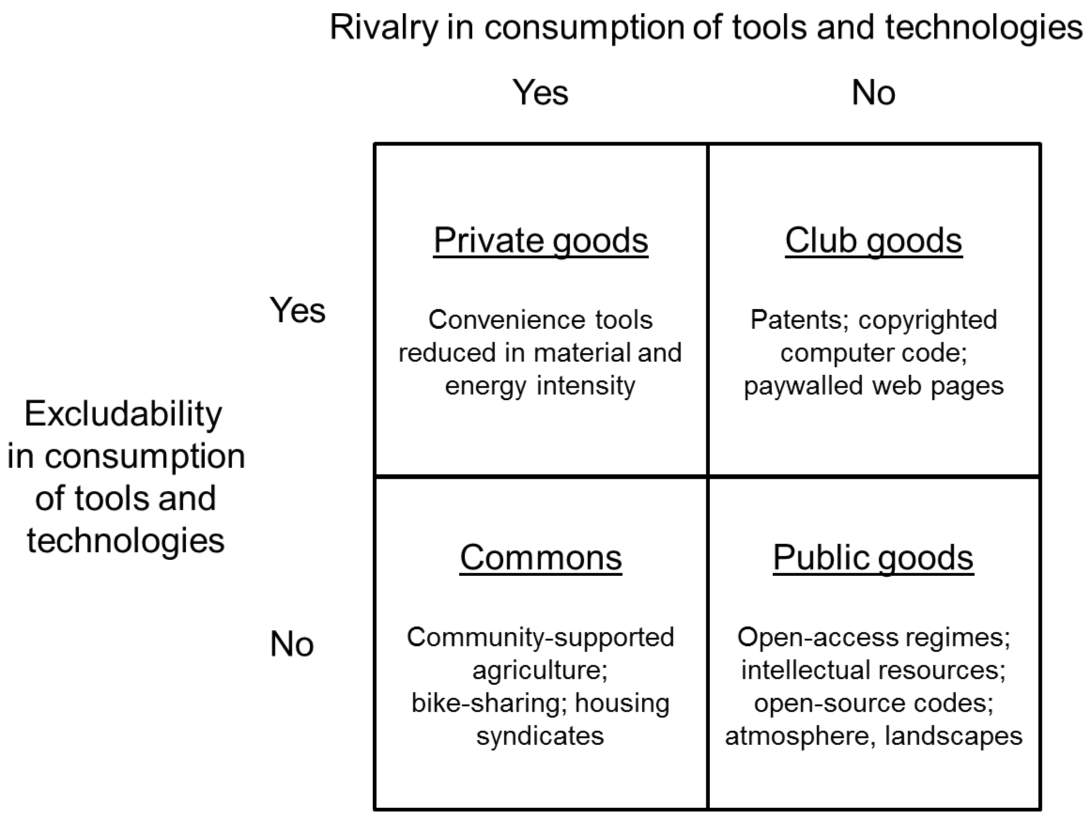

Figure 1. Ownership Regimes for the Consumption of Tools and Technologies

Following Marx, private property, particularly of means of production, enables accumulation of capital, exploitation of workers through increased productivity and surplus value, alienates people from their surroundings, and finally promotes economic growth. Thus, private property stands in contrast with many demands from degrowth proponents such as working time reduction and limiting environmental and ecological impacts (Sekulova et al., 2013). In terms of the matrix above (Figure 1), degrowth proponents should try to transition private goods, particularly productive technology, into commons or public goods. Lietaert (2010: 576) exemplifies this with cohousing, the mixture of "private and common dwellings to recreate a sense of community." Simultaneously, there is a need to reflect upon power structures between capitalists and workers. Accordingly, van Griethuysen (2012) has criticized the "property-based economic rationale" subordinating social and ecological affairs to the expansion of capital. Instead, he proposes "more radical alternatives, such as non-property, possession-based institutional arrangements and partnerships" (van Griethuysen: 262). Such a radical transformation of the market-based, privatized status quo is mirrored by Klitgaard (2013: 281) who states "[o]ne could not pursue strategies of degrowth and the steady-state, while leaving the institutional arrangements of monopoly capitalism in place without creating a human disaster of unemployment and poverty."

A good example is provided by “social media.” These are electric tools and hence inaccessible to large numbers of people who cannot attain basic infrastructure like hardware, electricity, and internet connection (IEA, 2016). To everyone possessing such equipment “social media” offer a convivial structure of widespread accessibility and mutual exchange, gain relevance in political and societal discourses, and foster autonomy and creativity in their ‘digital consumers’ (Lessig, 2004). They also theoretically enable relatively equitable non-discriminatory participation. However, as capitalist enterprises Facebook, Twitter, etc. answer primarily to investors, and are embedded in structures that prescribe profit generation. These incentives can already be visualized in two significant forms: increasing advertisements and sharing of personal data with companies as well as governments for marketing and surveillance purposes (Fuchs, 2012; Korolova, 2011). These are neither black sheep nor bad apples, but systematic results from capitalist ownership. If deemed ‘suitable’ for degrowers “social media” might have to be re-structured from being privately owned in hierarchical power relations to a common or public good.

A comparable transition has occurred in “Information Commons” (IC) which enable access, ability for dynamic modification and input provision, and management in a non-privatized manner. Depending on particularities, their ownership ranges from commons to open access regimes (Kranich, 2004: 11). Commons based IC are structured around principles of “open and free access for designated communities, self-governance, collaboration, free or low cost, and sustainability” (Kranich, 2004: 15). In some cases like Wikipedia access is open and free to the public, but modification and governance are reserved for community members. Open access IC like the internet have generally no limitation in access, but also “lack the clearly defined group governance that is characteristic of common property regime” (Kranich, 2004: 15). Such structures come closest to Marx’ ideal of producing “as humans,” since programmers and developers work creatively seeing themselves in the world through their products that belong to the community. These structures also satisfy Schumacher’s criteria for “intermediate technologies” and Illich’s conditions of accessibility, creativity, and autonomy.

6. Agency

In previous sections criteria for the type and structure of technologies (un-)suitable for the degrowth context have been discussed. Doing so a fundamental question has been avoided, namely that of agency. Who has the ability and power to decide upon which technologies ought to be employed in which way? And how are these decisions implemented via which means? These questions are central to the success and initiation of the Great Transformation. However, in depth coverage of this topic lies outside the scope of this article. Thus, only some topics of further inquiry are suggested.

Degrowth literature is surprisingly silent about transforming agents. Many authors argue for democratic decision-making (Deriu, 2012) or rebuilding democracy generally (Romano, 2012), but there has been no account of the size and role of the state, police, or the distribution of rights and powers between different organizational units. Propositions about decentralized, self-governed structures (e.g., Latouche, 2009; Paech, 2012) remain vague about their interaction, representation, and relative power, particularly in the political sphere. More elaborate versions of these ideas date back more than a century to philosophers like Pierre-Joseph Proudhon (1989) with his federalist principle based on medium-sized communities, and it is surprising that these ideas haven't been adapted and introduced into the discourse. Thus, a degrowth vision of decentralization has to be elaborated further in order to form a goal to move towards. This should be accompanied by the identification of a revolutionary subject more concrete than "grass roots movements" or "civil society." Marxism has its proletariat, but degrowth is lacking a unified agent of change. It is even lacking a unified position on how radical the change ought to be with propositions ranging from conservative reformist approaches (e.g., Jackson, 2009; Seidl and Zahrnt, 2010) to revolutionary anti-capitalist ones (e.g., Trainer, 2012; van Griethuysen, 2012). Thus, degrowth authors should debate fundamentally about structures and assumptions particularly regarding the political sphere. Here, it is worth looking beyond the established degrowth horizon and finding allies in fields such as eco-socialism. In his overview on eco-socialist discourses Wall (2010: 136-140) has provided an entire chapter on agency for change promoting alliances between indigenous communities, workers, unions, and even selected parliamentary groups. A more detailed account of similarities and differences between degrowth and eco-socialism will be provided by the authors elsewhere, and hopefully bridges the gap between and thus bolsters both discourses.

7. Conclusion

This paper has introduced and elaborated several philosophical concepts regarding technology to the degrowth discourse. These have been instrumental in answering the two questions (1) *which* technologies ought to be employed in a degrowth society and (2) *how* these 'suitable' technologies should be structured. Particularly in the integration of ownership (Marx) and the means-end category (Arendt) the previous horizon of degrowth sources is expanded. The answers propose a framework distinguishing between labor, electric, and fossil fuel tools based on the power source of the respective technologies.

According to this analysis, technologies relying solely on fossil fuels should be dismantled and technologies based on labor power expanded. With respect to electric tools the structure and context are decisive. Simply converting all technologies and tools run on fossil fuels to electricity will not suffice given resource scarcity and conditions of conviviality.

The structure of electric tools is evaluated on the basis of first, Illich's conviviality and Schumacher's criteria for intermediate technologies and second, on questions of ownership primarily posed by Marxists. In conclusion, technologies should be structured to be affordable, feasible for small-scale operations, and enable utilization of human creativity. Simultaneously, technologies currently available primarily as private property should be brought under more convivial structures such as commons or open access regimes. In general, commons, open access structures should be preferred to private, individual, or club ownership. Lastly, convivial tools enhancing autonomy in their users and holding transformative powers should be socialized to prevent transgression of their "second watershed" (Illich, 1973). This case is made for "social media."

Within the framework of a steady-state or degrowing economy technological efficiency might aid to respect (ecological) boundaries and resource use. However, under current conditions, as Ellul (1964) has argued, efficiency is not anymore a means to a greater end, but has instead become an end in itself. Thus, the means-end category needs to be restored for efficiency to be employed sensibly. An alternative assessment of values and technologies themselves needs to accompany such a transition. Then, efficiency could release hardship labor, enhance leisure and autonomy, lower ecological footprints, spread accessibility, and increase the potential for decentralizability. The proposed framework presents one step in this direction by introducing several assessment criteria and theoretical deliberations on technology. It also provides transformative strategies to apply the findings to real-world examples. Thus, this article contributes to synergies between theory and praxis.

7.1 Limitations

The proposed framework presents one approach, among many, to structure and analyze technologies. Thus, alternative approaches might generate more insights in areas neglected in the present analysis. Digital technologies for communication might present such an example. This paper subsumes digital tools under the category of electric tools. However, digital forms of communication and their particular role in shaping societal discourses and narratives is likely qualitatively different from the examples of electric cars or kitchen appliances. Further deliberations are needed to elaborate on this.

Additionally, further research might enhance the understanding of tools in different cultural contexts. This paper focuses, like the degrowth discourse, mostly on industrialized countries where all types of tools are fairly disseminated. However, perspectives from the Global South might enhance the understanding of "technological development" from a degrowth perspective and provide paths forward to sustainability.

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