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# Technologies for an Ecological Transition: A Faustian Bargain?

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WORKING PAPER

"Neither tales of progress nor of ruin tell us how to think about collaborative survival"

**— Anna Tsing[1]**

Since around 1970 the world has been living beyond Earth's capacity. Humanity currently operates at over 1.6 times Earth's regenerative biocapacity. In 2016 the Earth Overshoot Day — the day in a year when humanity's demand for environmental resources for that year exceeds Earth's capacity to regenerate those resources in that year — arrived on August 8, five days earlier than in 2015.[2] However, not everybody has been living equally beyond our common means. If everybody lived the standard of an average US or Gulf citizen, we would need 4-6 planets to sustain the human population.[3] As the effects of human-induced change to Earth's biophysical systems catalyze extreme weather patterns, floods, droughts, wildfires, accelerated species extinction, lower crop yields, and famines, the global poor are asked to soak up the cost of the change generated by the global rich. Without means to adapt and to mitigate the effects of climate change, regions of the world that were previously ravaged by imperial conquest, postcolonial instability, and now mounting environmental pressures are likely to see as many as 200 million "climate refugees" by 2050.[4]

**1** Anna Lowenhaupt Tsing, *The Mushroom at the End of the World: On The Possibility of Life in Capitalist Ruins* (Princeton: Princeton University Press, 2015.) 19.

**2** *Earth Overshoot Day.* http://www.overshootday.org/

**3** Varying footprints by nations can be explored at: "Ecological Wealth of Nations," Global Footprint Network http://www.footprintnetwork.org/ecological_footprint_nations/

**4** Koko Warner et al., "In Search of Shelter: Mapping the Effects of Climate Change on Human Migration and Displacement," Center for International Earth Science Information Network, Earth Institute, Columbia University (2009): http://ciesin.columbia.edu/documents/clim-migr-report-june09media.pdf

Yet, the costs of climate change are shared just as unequally within nations as across them. With structural adjustments and neoliberal restructuring, inequality and vulnerability are on also on the rise. Proletarianization has affected large segments of the population in the developed Global North and the urban poor and the vulnerable countryside are now feeling the effects of climate change as food and energy prices reverberate against a rising tide of climate disasters.[5] Nowhere is that double impact more readily observable than in Europe, where the rising conservative forces have pitted the surplus workforce left in the wake of post-socialist global re-ordering against the migrants escaping the plight of war and environmental degradation.

The historical trajectory of anthropogenic environmental transformation is well-established: the beginning of the industrial revolution and the discovery of fossil fuels allowed humans to tap into energy stocks much richer than anything hitherto available. By the 1800s industrial capitalism was rapidly transforming vast expanses of the world leading quickly to initial increases in atmospheric $CO_2$ concentration levels, land transformation and transformation of metabolic cycles, only to enter a period of Great Acceleration after World War II resulting in the present day $CO_2$ levels, depletion of soil and biodiversity loss.[6]

Against this background of anthropogenic environmental change, in this text I intend to discuss the role of technologies in two contrasting ecological transition scenarios. First, I will analyze the limits that beset the

**5** "World Food Situation," *Food and Agriculture Organization of the United Nations*, 2015, http://www.fao.org/worldfoodsituation/foodpricesindex/en/

**6** Will Steffen et al., "The Anthropocene: Conceptual and Historical Perspectives," *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 369.1938 (March 13, 2011): 842–67.

strategies of green innovation and green growth, which provide a foundation for much of international climate change policy — and which I understand to fall into the long lineage of dominant techno-developmentalist doxa. In line with that doxa, these strategies place inordinate expectations on process of innovation to help us out of the present planetary predicament. Second, I will indicate what are takeaways for a degrowth scenario from that analysis, cautioning against an all-too-facile cherry-picking of technology and exclusive focus on small-scale convivial technologies. I finish by proposing some elements of strategy that might after all be reasonable to adopt in a degrowth transition, where that transition is understood as a potentially turbulent and revolutionary process of transition to a mode of production, social organization and metabolic relation between humanity and environment that would no longer be premised on economic growth that both sustains the dynamic of capital's self-expansion and drives the ever larger extraction of Earth's natural resources.

## TECHNOLOGIES AND ENVIRONMENTAL CRISIS

Changes in the planetary and social environment have been in no small way enabled by the growing productivity of technologies. In the progressivist world-view that continues to dominate in the present, technoscience is regarded as the single most important factor in human development. Advances in health, lifespan, nutrition, housing, mobility, communication, education, and general material abundance are all cursorily attributed to scientific and technological development to the disregard of other transformative factors such as political struggles, social institutions, language, or play.

As Lewis Mumford contended half a century ago, the prevalent world-view of progress has an in-built bias that understands human evolution as the evolution of a uniquely tool-making and tool-wielding species.[7] On this view, informed by a mass of mechanical, fossil-fuel based inventions made in the nineteenth century, the human is understood primarily as homo faber. However, disregarding the fact that there are other animals that make and wield tools, this overlooks a truly unique human capacity of combining and amplifying tools with social and symbolic structures — foremost spoken language. And yet, that bias, which for the purposes of my analysis I call techno-developmentalism, has remained unperturbed by the fact that gains in productivity enabled by technology have presided over an unprecedented environmental crisis on planetary scale and, after a period of post-WWII contribution to prosperity built on the militancy of the labor, is now the driving factor of growing economic inequality.[8]

Technology is thus part of the problem. Yet, the techno-developmentalist common-sense, now returning greenwashed in the guise of green innovation and green growth narrative, would have us believe that technology is the only solution to the problem. Scenarios of decarbonization of the global economy, and the climate change policy decisions within the framework of the Paris Agreement that are based on them, hedge our future on an unprecedented acceleration in technological development. By leaving the structural interdependence of technological systems and carbon-based capitalist socio-metabolism unexamined, techno-fixes effectively gag

**7** Lewis Mumford, *The Myth of the Machine: Technics and Human Development* (San Diego, CA: Harcourt Brace Jovanovich, 1967).

**8** For a telling analysis of technology's contribution to inequality from no foes of technocapitalism see Erik Brynjolfsson and Andrew McAfee, *Race Against the Machine: How the Digital Revolution Is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy* (Lexington, Mass: Digital Frontier Press, 2012), ch. 3.

discussion of systemic change as politically inoperable. This political trap is further compounded by another contemporary doxa — one that considers that technological development in the present is best left to the private enterprise. Climate change thus can only be tackled if markets can be persuaded to provide a technological solution — or it will not be tackled at all.

## THE LIMITS OF TECHNO-DEVELOPMENTALISM

It is within these constraints of the ecological transition debate that the narratives of green innovation, green growth and green capitalism hold a particular appeal. They all start from the assumption that technological innovation, by creating green technologies that are carbon-neutral, more efficient, resource saving, recyclable, will lead the global economy out of the environmental predicament, occasion sustainable development, and thus make possible long-term green-growth.

Yet, if, unlike our political decision makers, we are willing to consider the interdependence of the contemporary technological apparatus with the operation of contemporary capitalism — the fact that technologies help capitalism reproduce at a world scale and that capitalist accumulation in turn directs the development of technologies, this green vision of techno-developmentalism gradually assumes a somber hue. The interdependence implies that promises of green innovation run up against a number of structural limits and limitations that shape the present-day capitalist world-system. In the following paragraphs, I'll first outline four sets of limits, as they also impose constraints on the broader ecological transition debate, before returning to the concrete technologies under discussion and their palliative role in the policy debate.

## CAPITALISM'S CONJUNCTURAL CRISIS

First, capitalism faces a conjunctural crisis that is not likely to be resolved by means of a green techno-developmentalist fix. Technologies in the present are not productive enough to help capitalism maintain constant levels of compound growth at the expanded scale of world economy. If we are to follow the analyses of the historians such as Robert Brenner, Wolfgang Streeck or Gopal Balakrishnan, since the 1970s global economic system has been experiencing drawn-out downturn.[9] Technological advances in fossil fuel extraction, computerization, and containerization have allowed capitalism to relocate production overseas, bring down the price of labor, and increase the productivity of capital. However, they have failed to catalyze the levels of growth and profit that were enabled by the general-purpose technologies of the immediate post-war period — primarily for reasons that the total volume of the economy has grown immensely. To maintain a healthy annual growth rate of 3 percent over a period of forty years means that the total volume of economic activity needs to increase by a 300 percent — three times the total value, three times the amount of goods and services, and roughly three times the energy and material throughput compared to forty years earlier.[10] There's little evidence that the green technologies, premised on reduction or stabilization of energy and material throughput, can do better to maintain that level of growth.

At the same time as new technologies of the 1960s and 1970s were

**9** Robert Brenner, T*he Economics of Global Turbulence: The Advanced Capitalist Economies from Long Boom to Long Downturn*, 1945-2005 (New York: Verso, 2006); Gopal Balakrishnan, "Speculations on the Stationary State," New Left Review 59 (2009): 5–26; Wolfgang Streeck, "How Will Capitalism End?," New Left Review 87 (2014): 35–64.

**10** The world consumption of energy has in fact grown almost three times since the 1970s, see the first graph here: "World Energy Consumption Since 1820 in Charts," Our Finite World, 13 March, 2012, https://ourfiniteworld.com/2012/03/12/world-energy-consumption-since-1820-in-charts/

failing to reproduce the growth levels of the post-WWII trente glorieuses, the effects of the relocation of production from the advanced capitalist economies to Asia were of limited success to capital. In spite of high rates of growth achieved in Asia over the last decades, low-wage economies are not rich enough to create levels of demand achieved in the West a couple of decades earlier. For several decades Western consumption was made possible by the expansion of private credit and financialization. Yet, with the onset of Great Recession of 2008, providing credit finance to consumption — or production for that matter — no longer seems a feasible option for capital. At this moment it prefers to keep US$13.4tn parked in the negative yielding bonds.[11] Instead of investing to achieve returns or sustain growth, at the moment it is less unprofitable to pay the interest to trustworthy borrowers who will keep the money safe.

All this signals that the capitalist world-system might have entered a steady-state of stagnation. Capitalist expansion has reached its limits. Capitalism is shifting away from the growth-premised model and this is bound to lead to social turbulence and shakeup of the political order. Under conditions of no growth the socio-economic system turns into a zero-sum game where gains in income and wealth entail direct impoverishment of some and accumulation of economic power for others. Extreme levels of inequality thus created can be maintained only by growing economic despotism, social policing and political authoritarianism whose outlines we can see forming all too clearly on the horizon. If nothing, this might prove conducive for public advocacy of an alternative, degrowth transition, one that might prevent the social transformation ahead of us from spiraling, as

**11** Robin Wigglesworth and Eric Platt, "Value of Negative-Yielding Bonds Hits $13.4tn," Financial Times, August 12, 2016, http://www.ft.com/cms/s/0/973b6060-60ce-11e6-ae3f-77baadeb1c93.html

Serge Latouche has cautioned, into barbarism.[12]

## UNEVEN DEVELOPMENT

Second, sustainable development premised on technological change might not be achievable due to limits imposed by uneven development. With asymmetries of wage and purchasing power between national economies diverging by orders of magnitude, global free trade facilitates an exchange between highly unequal economic areas. This allows more advanced economies to siphon off the products of labor and natural resources of less advanced economies at knockdown prices. What is seemingly a symmetric relation of trade, an exchange of goods for money, the magic of conversion through money-form of unequal physical units of labor and energy in equivalent symbolic units provides economies with a higher purchasing power with an easy way to extract resources from and externalize environmental costs onto those with a smaller purchasing power.[13]

As Arghiri Emmanuel, the originator of unequal exchange theory, has contended, the underdeveloped economies are caught in a spiral. In the international economic exchange they are forced to sell products of labor and natural resources cheaply and buy commodity and capital goods dearly, and are thus locked in underdevelopment while trying to catch-up.[14] The reason being that in developmental terms there are no technologies

**12** Serge Latouche, *Farewell to Growth* (Cambridge, UK: Polity, 2009), 8.

**13** Theory of unequal exchange expounded here, initially developed by Arghiri Emmanuel, in his *Unequal Exchange: A Study of the Imperialism of Trade* (London: New Left Books, 1972), has been adopted in environmental economics not only to explain economic, but also resulting environmental inequalities at the global scale – see in particular Alf Hornborg, *Global Magic: Technologies of Appropriation from Ancient Rome to Wall Street* (New York: Springer, 2016).

**14** Arghiri Emmanuel, *Appropriate or Underdeveloped Technology?* (London: John Wiley & Sons, 1982).

appropriate to their level of economic development other than the most productive and hence most expensive, which such countries cannot afford. In this way, they remain destined to use obsolete, less efficient, and environmentally damaging technologies.

Uneven development is thus additionally reinforced by varying levels of technological productivity. Labor and resources are extracted with inferior and inefficient technologies. If more developed economies would internalize the cost of uneven development by bringing wages and technologies of the underdeveloped economies to the same standard as theirs, the economic expansion altogether would likely grind to a halt. The consequence is that the developmentalist dynamic, which pushes all societies to try catching-up to the advanced capitalist nations, is purchased only at a price of unevenness, inefficient technologies and environmental injustice. Contrary to what green growth boosterism, pointing to a shiny example of Germany, would like us to believe, green capitalism in one country simply cannot work as it depends upon unevenness elsewhere. If green technologies should serve as a new frontier of economic expansion, they will not be equally available across varying levels of development.

## ENVIRONMENTAL TIME-BOMB

Third, there are extensive debates regarding the environmental limits to techno-developmentalism. Capitalism's downturn can also be attributed in part to the fact that the four "cheap natures" — food, energy, raw materials and human labor — are increasingly becoming more expensive to extract and secure. As Jason W. Moore has argued, capitalism has been able to appropriate by extra-economic means — conquest, slavery, plunder, uneven development — large contributions to its value production

that it has been able to keep off its accounts.[15] Colonialism, imperialism and neo-colonialism have thus provided an extra-economic fix to some of the inner contradictions and crises of maturing capitalism. In the process, they have transformed pre-capitalist regions around the world into an integrated capitalist world-system and planetary world-ecology that is now going through a fundamental phase-shift. Exponentially expanding food production, fossil fuel exploration, and raw material extraction from rich soils, stocks, and reserves have allowed capitalism to keep the cost of material inputs and labor power low in spite of its ever-growing throughput. However, as the environmental stresses on human habitats are rising, stocks of conventional oil are past their peak and reserves of many important minerals are reaching their limits, these resources are becoming more expensive to extract and secure, creating downward pressure on capitalism's growth. While capitalism has always depended on technological advances and accumulation by dispossession to secure these low-cost inputs, their reduced global availability in the face of still growing demand in the present calls for even more advanced technologies of extraction and mercantile neocolonialism that might environmentally and politically no longer be feasible.

Furthermore, viewed from the framework of bioeconomics, initially developed by Nicholas Georgescu-Roegen, all economic processes can be understood as entropic. The economic production transforms low entropy inputs of human labor, fuel and raw materials into high entropy outputs of commodity, heat and emissions — and as the inputs have a lower price than the products, the generation of economic value is premised on the

**15** Jason W. Moore, *Capitalism in the Web of Life: Ecology and the Accumulation of Capital* (New York: Verso Books, 2015).

dissipation of resources of energy and matter.[16] Given Earth's limited capacity of regeneration, this sets rigid biophysical limits on growth. There's a heated debate around the validity of Goergescu-Roegen's assumptions of a strong physical causation between growth and emissions. Improving carbon efficiency against GDP growth in advanced economies seems to suggest that decoupling growth from $CO_2$ emissions could be achievable through extended use of renewables and improvements in energy efficiency. But that evidence is only of limited value considering that the total emissions are not abating in the context of globally integrated production flows, which combine both efficient and inefficient technologies and entangle the national energy consumption of advanced economies with the energy diet of the rest of the world economy. Even if the global economy were to reduce emissions, with the continued growth that produces non-recyclable waste the entropy would persist. Regardless of the principled argument whether decoupling is in sum total possible or not, the efforts to reduce carbon emissions and the efforts to reduce the extraction of raw materials and depletion of soils are too slow for the time-bomb that is ticking away. The decarbonization and dematerialization is an extremely daunting task for the short time-window available to us before we enter the period of non-linear environmental change.

## SOCIO-TECHNOLOGICAL CONTINGENCIES

Last, there are specifically socio-technological limits to techno-developmentalism. Technological innovation is a complex process, requiring the synergy of technologists, regulators, financiers, businesses and institutions. On the technological side, technological systems depend

**16** Nicholas Georgescu-Roegen, "The Entropy Law and the Economic Process in Retrospect," *Eastern Economic Journal* 12.1 (1986): 3–25; Hornborg, Global Magic 26.

for their operation on integration with other technological systems. In fact, if we follow the influential historian of technology Thomas P. Hughes, much of the technological innovation principally reacts to critical problems of existing technological systems and optimization of their operation.[17] In other words, innovation is path dependent and alternatives cannot be easily willed into existence. On the social side, technological innovation is driven by critical problems of capital, military, administration, and population politics — and supported by institutions, financiers, and governments to that end.

While this does support the hopes that the development of technologies can be steered toward reduction of energy and material throughput, this also means that desirable technological systems cannot be easily decoupled from other technological systems on which they depend for operation. Thus it is unlikely that innovation will unfold smoothly if it is disruptive to the operation of current energetically and materially intensive systems and social interests entrenched into those technologies. We are thus back to the political trap of trying to institute a shift in the existing social metabolism while maintaining the business-as-usual of capitalist economy.

## A CURIOUS CASE OF NEGATIVE EMISSION TECHNOLOGIES

I have outlined four limits to green techno-developmentalism: conjunctural, developmental, environmental, and socio-technological. They strongly indicate, contrary to what the green growth narrative would like us to believe, that a green revolution through technological innovation cannot resolve the crisis of growth or the crisis of environment that the

**17** Thomas Parke Hughes, *Networks of Power: Electrification in Western Society*, 1880-1930 (Baltimore: Johns Hopkins University Press, 1993).

present-day capitalist system faces. In fact, if we examine more closely what climate change policy prefers technologically, we are confronted with clear evidence that decision makers are entering a moral hazard. They are placing their bets on the wondrous development of barely existing technologies in order to defer the politically costly measures of rapid decarbonization.

As Kevin Anderson and Glen Peters have forcefully argued in a recent Science opinion piece, the scenarios that inform policy decisions and form the basis for Paris Agreement voluntary pledges hide their continued commitment to high carbon emissions behind a large-scale deployment of negative emission technologies.[18] Negative emission technologies are mitigation technologies that make it possible to capture $CO_2$ created in the process of power generation or already existing in the atmosphere, and store it long-term in deep geological layers, oceans or mineral formations. The most common model of carbon capture and sequestration (CCS) used in transition scenarios is in combination with the power generation from biomass, which would produce clean renewable energy by burning the crops cultivated specifically for this purpose. If used in combination with fossil fuels such as coal, the CCS would enable a reduction of carbon emissions by up to 90 percent. And if used for the sequestration of atmospheric $CO_2$, it would wondrously expand our total carbon emission budget and allow us to continue with the business as usual.

All this looks highly promising. And yet, power generation with biomass is still in its early testing phase with only two power plants in operation. In addition, using large quantities of biomass required for the

**18** Kevin Anderson and Glen Peters, "The Trouble with Negative Emissions," *Science* 354.6309 (14 October, 2016): 182–83.

energy transformation on a global scale would require enormous masses of arable land — two times the area of India — with a number of adverse effects on land use, food security, and biodiversity.

On the other hand, pilot projects of power generation with CCS in combination with fossil fuels instead have so far proven economically unfeasible.[19] Moreover, the capture of atmospheric of $CO_2$ has not progressed far as a pilot project and also entails strong, adverse effects on the environment.[20] So, even if proven deployable at a globally relevant scale, negative emission technologies are likely decades away from full development and deployment. Yet, they form a cornerstone of decarbonization scenarios — according to IPCC by 2100 they might contribute as much as 55 percent of emission-cutting effort. This highly speculative techno-developmental fix helps decision makers to avoid radical, rapid and costly mitigation measures which would have to happen now: increase of energy efficiency, reduction in fossil fuel use and large-scale deployment of renewables. With the combined voluntary pledges made by the world's governments, we remain currently on track to a global temperature increase by at least 2.7°C, if not more.[21] So, should we continue to bet on negative emission technologies and these fail to live up to expectations, we might find ourselves in a much more dire situation than if immediate yet costly measures are undertaken now.

The blind techno-optimist belief of transition scenarios does not

**19** "Schwarze Pumpe Power Station," *Wikipedia*, 7 October, 2016, https://en.wikipedia.org/w/index.php?title=Schwarze_Pumpe_power_station&oldid=743035152

**20** Anderson and Peters, "The Trouble with Negative Emissions"

**21** Quirin Schiermeier, "Combined Climate Pledges of 146 Nations Fall Short of 2 °C Target," *Nature News*, 30 October, 2015, http://www.nature.com/news/combined-climate-pledges-of-146-nations-fall-short-of-2-c-target-1.18693

stop there. A number of models of deep decarbonization used in IPCC assessments have been recently reviewed by Peter J. Loftus, Armond M. Cohen, Jane C. S. Long and Jesse D. Jenkins.[22] It turns out that these scenarios almost universally make the assumption of efficiency gains and large-scale deployment of various forms of power generation that surpass anything we have seen over the previous four decades of technological development. Rates of annual change in energy efficiency assumed by the least ambitious group of models set average reductions for the next four decades (-1.5 to -1.8 percent/year) on par with the record yearly values and double the average for the last four decades (-0.8 percent /year), whereas the most ambitious set average efficiency gains four times that (-3.4 to 3.7 percent /year). Also levels of new installed capacity — depending on the model — of wind, ocean, solar, geothermal, CCS, biomass, nuclear and hydroelectric power generation assumed as main components of substitution of fossil fuels usually surpass by far what we have seen in the past.

All this leads to the conclusion that narratives of green growth, green innovation, and green capitalism ultimately depend on a number of techno-developmentalist assumptions that verge on political denial and bad faith. As I argued earlier, a number of conjunctural, environmental, developmental, and socio-technological limits indicate that humanity is living beyond the Earth's planetary means. We cannot simply hope to geo-engineer our way out of the predicament. What is needed is not only a radical change in the petro-capitalist technological apparatus, but also a parallel transformation of the relations of production and social reproduction. Yes, we need to

**22** Peter J. Loftus et al., "A Critical Review of Global Decarbonization Scenarios: What Do They Tell Us about Feasibility?," *Wiley Interdisciplinary Reviews: Climate Change* 6.1 (2015): 93–112.

rapidly instill into our current technological base greater energy efficiency; we need to massively build out renewables; and we need to find new ways to reduce $CO_2$ emissions, but we also need a transition from capitalist economies to an organization of social life that is premised on lower and different throughput, able therefore to stay in line with the regenerative biocapacities of our environment. And this is where degrowth comes into picture — as both a critical re-assessment and a practical redress of the techno-developmentalist vision.

## DEGROWTH AND TRANSITIONAL TECHNOLOGIES

Degrowth as theory advocates a systemic change. But as practice, it is leading by example, proposing and devising a number of pre-figurative and trans-formative concrete utopias that start from the present social metabolism. The more frugal, localized, and mutualist socio-economic system that degrowth envisions calls for a re-structuring of existing relations of production, modes of distribution, value accounting systems, and, relevant to us here, technologies. Autonomous, distributed, localized, energy saving, resource efficient, non-obsolescent, recyclable are just some of the qualities that degrowth seeks in technologies it deems either appropriate or appropriable.[23] Citizen energy co-ops, organic food production, passive house construction, micro-production, resource-sharing digital platforms, free software, distributed computer systems, open patent pools, and crypto-currencies are all part of that strategic vision.

While acknowledging the emancipatory import of the technologies

**23** For an overview of various dimensions of the technology debate within the degrowth movement see Linda Nierling, "A Normative Framework for the Development and Use of Technologies in the Degrowth Context," Degrowth Conference, Leipzig, 2014, https://www.degrowth.info/en/catalogue-entry/a-normative-framework-for-the-development-and-use-of-technologies-in-the-degrowth-context/

that the degrowth narrative embraces, my earlier analysis of limits to techno-developmentalism calls for caution also when considering what technologies can be conducive to degrowth. Caution is warranted against laying hopes in this or any specific inventory of technologies and caution is warranted against lionizing the specifically convivial, small-scale or distributed character of these technologies. Technologies are imbricated with their socio-economic ambient milieu. Our technological systems have largely co-evolved with the capitalist world-system. The integration and functioning of that world-system are only made possible by the existing technological apparatus. Globe-spanning and interlocking complex of computerization, containerization and fossil fuel extraction is essential for its continued reproduction. In return, technological systems are built for the scale of material and energy flows and intensity of capital investments that the capitalist world-system requires.

This has four significant implications. First, we cannot decouple technologies from the capitalist system of production, its scale of throughput and its capital intensity, and assume that they will continue to function as they do now. Take the example of personal computer — a highly useful, distributed, and autonomous technology. Its present functionality is dependent on a large-scale system of manufacture and centralized communication networks. Almost 25 percent of all email traffic is operated through Google's datacenters. Substituting these networks with the existing solutions for collectively-run distributed infrastructures and platforms would likely entail a scale-down effect, with potential fragmentation to much lower scales and substantial loss of social utility.

Second, the economic contraction would entail a de-intensification

of flows and investments into existing large technological systems and infrastructure, forcing the transitional process to search for different ways of dealing with the problem of maintenance. In a scenario where elements of the present mode of production are gradually replaced by various re-purposed and re-localized alternatives, this continues to pose a problem since not all infrastructures can be localized and maintained in a collectivized way. In addition, and particularly after decades of globalization and specialization of production, many parts of the world will still need to trade long distance to procure some essential goods they cannot source locally.

Third, the transitional process will be under pressure to innovate substitutions for technologies that will go defunct or become too expensive due to growing cost of material inputs that go into them. However, critical problems of technological systems do not always get solved and that means that sometimes technological systems need to be phased out with a certain loss of social utility.

Fourth, the transitional process being transitional means that it will have to start in parallel with the conditions of the existing mode of production. Not even revolutions can transform a mode of production overnight — thus new patterns of production can be developed and experimented with only under the compromised conditions of two competing modes of production.[24] This circumstance sets the operative horizon wherein technologies conducive to degrowth can be developed in the present — situated between two modes and dependent on the present technological base to create a future technological base.

**24** The notion of "competing modes of production" was proposed and developed by Michael Lebovitz; see *The Contradictions of "Real Socialism": The Conductor and the Conducted* (New York: NYU Press, 2012).

These implications, however, do not entail that technologies that are autonomous, distributed, localized, energy saving, resource efficient, non-obsolescent, and recyclable do not matter for a transition into a degrowth society, but rather that their development and deployment have to go hand in hand with broader social, economical and political upheaval and change, in the context of which such technologies could secure food, housing, energy, tools, and other basics needed for the virtuous reproduction of a transition to a more sustainable and equitable economy. We are moving into the zone where we cannot know what will actually work and what will fail. But the bottom line is that in an unlikely case a society decides to pursue a path of degrowth, the interdependence of technological systems and inability to secure operation of basic infrastructure might push it back onto a growth-oriented path.

## OUTLINE OF A DEGROWTH-ORIENTED TECHNOLOGICAL STRATEGY

Technologies alone thus cannot drive the post-capitalist transition. Nonetheless, technologies will necessarily be a part of any transitional process and practice. We live in a technological world, and we will obviously continue to live in a technological world. Although I have insisted that we should not put all our eggs in the technology basket, it is reasonable to think strategically about how to re-purpose and develop technologies that might prove useful and maintainable in and after the transition. So, what would a strategy of technological development conducive to a degrowth transition be?

Building on the work of Vasilis Kostakis and Michel Bauwens, who have developed a model of a networked collaborative economy that is situated

between the existing capitalist commodity production and transitional co-operativist production, I propose a more general model extending beyond the information economy — a wishlist of sorts.[25] Its normative outline would include the following aspects:

- Process of technological development: Methodologically, the development should prioritize innovations that can be developed globally, but applied locally. Internationally coordinated research efforts should result in localized, smaller-scale production technologies that can be easily adapted and installed under varying economic and environmental circumstances around the world. Innovations should go into an open pool of patents governed by licenses that are free for any non-commercial application, while non-free for corporate use. Patent fees from commercial applications should help subsidize further research and development.

- Focus of technological development: The earlier discussion leads to a conclusion that there are two general types of technology that need to be prioritized. One is focused on the decarbonization of power generation, industry and transportation, while the other on the re-structuring of our current production and consumption patterns. Increased energy efficiency and replacement of current power generation capacity should take precedence over a build-out of new capacities because the reduction of energy available for use will create more rapid decarbonization and prevent the rebound effect. What concerns the production and consumption patterns, recycling, repair, maintenance, and social reproduction should take precedence

**25** Michel Bauwens and Vasilis Kostakis, *Network Society and Future Scenarios for a Collaborative Economy* (London, New York: Palgrave Macmillan, 2015).

over the expansion of commodity production and internationalized trade.

- Governance of technological development: The agent of the development process should, on one side, be public research and industrial policy bodies, focusing in particular on the urgent goals of rapid and deep decarbonization. They should sensitize the public for this goal and they should be pressured by the public towards this goal. National and local governments, their infrastructural and communal services, should support — through procurement and technological infrastructure — a massive uptake of localizable and smaller-scale cooperative production methods — of renewable energy, organically grown food, sustainable housing, etc. They should carve out a policy space where the trans-local trade is encouraged only for goods that cannot be produced locally. They should provide accounting models in alternative currencies that address the problem of unequal purchasing power and support localization of economy. On the other side, the agent of the technological development process should also be self-determining producer, technologist and consumer communities who form multi-stakeholder associations and cooperatives, or form civil-public partnerships with public entities, pursuing the goals of globally collaborative development and localized deployment of new production technologies. Through localization of consumption, these communities can drive the demand and contribute financing, while the cooperative model of organization can instill elements of economic democracy into the localized production.

By reducing the geographic scale and intensity of production on the one hand, and by scaling up and trans-localizing the work on research and innovation on the other, these measures are tailored to lower the dependence of both socio-metabolic processes and processes of technological innovation on the global systems of commodity production. However, the feasibility of these measures hinges on their insertion into the anti-systemic strategies that are able to self-organize production and/or can influence policy on various levels of the political system. They are particularly suited for a troubled (semi-)periphery, where social movements and organized labor have a degree of know-how, some financial means to pursue them, outreach to the public decision-making process and a historic chance to articulate an alternative trajectory of social development. They are not a silver bullet, but they are a potential fall-back should the post-capitalist tomorrow dawn. If social and political movements fail to understand that technology conditions the transition, and that a cautious reconfiguration of our technological systems should be a part of their strategic register, judging by the experience of real existing socialisms, the day after the transition will increasingly start to revert back to the day before.

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