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The magic of money and the illusion of biofuels: toward an interdisciplinary understanding of technology*

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Abstract. For several centuries, the dominant worldview in industrial societies has held that various problems —such as those recently identified as relating to sustainability— can be solved through technological progress. Technological progress has been conceived as the fruits of engineering science, new knowledge, and innovation. While knowledge of the principles of physics is certainly a necessary condition for technological development, it is not a sufficient condition. Technology is not only a product of engineering, but, ultimately, also of asymmetric transfers of biophysical resources. In other words, the feasibility of technological progress is contingent on world market prices. The history of technology has been written from the perspective of advancing ingenuity, rather than that of unequal global exchange. The implicit world view underlying dominant historiography and economic science ignores the deepening global inequalities which are prerequisite to what some sectors of world society can celebrate as technological progress, including visions of replacing fossil fuels with biofuels and other renewable energy sources. This observation should prompt us to conceptualize technological progress as an inherently unequal capacity to locally save time and space at the expense of human time and natural space lost elsewhere. It implies that the physical agency of technology ultimately rests on prices, *i.e.* subjective human conceptions about the value of market commodities, and thus finally on the magical artifact we know as money. The purpose of this article is to show how current deliberations on biofuels illustrate the insufficiencies of mainstream understandings of the phenomenon of technology, and to indicate why an adequate understanding of technology must be interdisciplinary, combining insights on both Nature and Society.

1 Introduction

Since the 1970s I have spent most of my spare time managing a farm on the east coast of Sweden. After having raised sheep (at most close to 190 ewes) and beef cows to keep its around 40 hectares of fields and pastures from reverting to forest, I currently find it more economically rational to approach these surfaces as huge lawns to be polished with a machine resembling a large lawn-mower mounted on my tractor. Each year, vast volumes of grass are simply left rotting on the ground. I keep reminding myself that these same 40 hectares (and the waters and woods around them) a century ago provided subsistence for eight large households —around 50 people— on the farm itself, in addition to producing a continuous flow of foodstuffs (mostly dairy products) to the nearest urban centers. I am aware that the situation is quite similar throughout agriculturally marginal areas of Europe and North America, while millions of people in Africa and South America are malnourished and in desperate need of agricultural land. It inevitably makes me wonder about the societal and cultural processes which in some parts of the world have reduced "land" from a resource crucial to human survival to lawns which we spend our spare time pruning like golf courses. It has also made me wonder about the proposal, some years back, of planting willow (*Salix*) on agricultural land for energy production. Through what kind of convoluted rationality could there now be serious advocates of encouraging the shrub lands that our ancestors struggled so hard to keep out of their fields? What does it tell us about historical changes in European attitudes to land, and ultimately also about our cornucopian understanding of technology? Could the combustion of willow bushes really yield enough energy to compensate for the energy expenditures in the production of machines for

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planting, fertilizing, harvesting, transporting, chipping, and burning these shrubs, as well as the consumption of fuels and fertilizers? What is the role of money and economics in promoting such counter-intuitive schemes for resource management?

In this article, I will discuss the concept of "biofuels" from an interdisciplinary perspective. I am not a physicist, but an anthropologist who has struggled for decades to develop interdisciplinary perspectives on the global human predicament of decreasing sustainability [1–3]. The facts of decreasing sustainability are incontrovertible. To a large extent, the dilemmas of unsustainability hinge on the technologies of human energy use. In order to grasp our current sustainability impasse, we need to consider 1) the history of human energy use, 2) the extent to which "technological progress" in energy use is really a matter of displacing environmental burdens to other populations, and 3) how the concepts and assumptions that frame our discussions on energy policy reflect partial and insufficient understandings of the global societal exchanges and inequalities on which the feasibility of specific energy policies rest. Rather than addressing the technicalities of using biofuels to provide for modern energy needs, a topic that I am not equipped to deal with, I will thus discuss the historical, political, and cultural contexts of the modern concern with biofuels. I shall intentionally avoid presenting any figures to substantiate the points I make, as I know from experience that figures can be contested endlessly, but instead confine myself to theoretical arguments.

2 The world-historical context of the notion of "biofuels"

We can begin by observing that the derivation of mechanical energy from biological organisms was ubiquitous prior to the Industrial Revolution. For thousands of years, the use of wind and water power (and the use of peat by the Dutch in the early modern period) were marginal complements to the ancient and fundamental dependence on human labor, draft animals, firewood, and charcoal, forms of organic energy which all implied harnessing contemporary solar radiation. Coal had been used for heating in medieval Britain and elsewhere, but with the exception of Dutch peat the main energy sources in pre-industrial manufacturing processes were renewable. No premodern person would ever have thought of food, fodder, or charcoal as "biofuels", although they represent the same principle. While occasional visionaries like Rudolf Diesel envisaged running diesel engines on vegetable oil from the colonies already a century ago, the modern concept of "biofuels" was conceived after more than two hundred years of using fossil fuels, as an alternative energy source that might replace fossil fuels in order to mitigate climate change and substitute for them as fossil deposits become scarce. Proponents of biofuels generally do not think of them as representing a regression to pre-industrial times, but both their rationale and the problems they raise revitalize the logistics and dilemmas of human life prior to the Industrial Revolution.

The turn to fossil fuels and steam technology in the late 18th-century Britain should not simply be understood as a Promethean breakthrough in engineering, but as 1) propelled by domestic land constraints and 2) contingent on global economic processes and trade relations. To derive energy from beneath the surface of the earth was a highly successful option in a landscape characterized by shortages of agricultural land, wood, and reliable watercourses within easy reach of urban centers. The development of steam technology occurred to satisfy the demands of the cotton textile industry, which in turn developed in response to the great global demand for cotton textiles. This demand largely derived from the Atlantic slave trade. Not only did slave traders in West Africa find that industrially produced British cotton textiles successfully competed with manually produced Indian ones in the purchase of African slaves, but the owners of American plantations also required cotton clothing for their slaves [4,5]. In other words, the very slaves who provided inexpensive labor for harvesting raw materials for the British cotton industry were purchased and clothed with the products of that industry. Without slavery there would have been a much smaller market for the British textile factories. The fact that the Industrial Revolution, after all, was contingent on the toil of human bodies [6,7] gives us reason to pause and reflect on our assumptions about the conditions and implications of "technological progress".

Such were the historical origins of fossil-fuel technology. To that vast majority of people who believe that new technologies merely hinge on the successful implementation of discoveries about the physical nature of things, the most important lesson is that they also require *money*, and that this is a mystified way of saying that they constitute profitable social strategies for *redistributing* biophysical resources (such as embodied land, labor, materials, and energy) in the world-system. As an anthropologist, I must conclude that the currently mainstream conception of "technology", in not acknowledging its dependence on asymmetric resource flows, is a biased *cultural category* generated by historical developments in Europe in the 18th century.

3 Energy technologies as instruments of environmental load displacement

In not recognizing its political-economic dimension, most modern people tend to project unrealistic hopes and expectations onto technology and engineering science. The question is generally not *if* a particular problem can be solved by engineering science, but *when*. We thus confidently await improved versions of technologies for harnessing renewable energy, convinced that there can be no *intrinsic* obstacle to running a previously fossil-fueled modern society on photovoltaic energy or biofuels. From a purely physical perspective, there may not appear to be any such intrinsic obstacles. But our energy technologies are not just physical phenomena, they are embedded in global societal exchange relations which should be just as significant for determining what is feasible and sustainable as purely physical calculations. An analysis of the prospects of biofuels as a future alternative to fossil fuels must thus necessarily be interdisciplinary.

There were tangible biophysical reasons why the historical impact of fossil fuels as a source of mechanical energy was so revolutionary. Coal, oil and natural gas are very concentrated energy sources, embodying millions of years of solar radiation. Fossil energy made entirely new technological achievements possible —from railways to space shuttles— which simply had not been feasible using pre-industrial energy sources. Harnessing them also meant not having to use significant parts of the land surface to capture solar radiation in the production of organic energy through, *e.g.*, horse fodder and charcoal. What we know as "modern" society —for a long time confined to the world-system cores of Europe and North America— has for two hundred years become accustomed to an incessant succession of technological innovations made possible by fossil fuels and the economic growth based on their combustion. Over these two centuries, mainstream views of economic development have also been conditioned by the use of fossil fuels, as evident, *e.g.*, in the conventional understanding of "land" —ever since David Ricardo— as a substitutable factor of production, and of agriculture as a marginal or even primitive pursuit.

Geopolitically, as mentioned, the British adoption of fossil-fueled steam technology was both contingent on and instrumental in generating global shifts in the flows of biophysical resources. It granted Britain "ecological relief" [8] not only by liberating large parts of its land surface from the production of fodder, firewood and charcoal, but also by providing access, through the sale of British exports abroad, to vast amounts of land, labor, and materials on other continents. Through colonialism and world trade, British export production can be seen as a strategy of not only displacing *workloads* to plantations and mines in the periphery, but also of *environmental* load displacement. By the end of the 19th century, Britain had access to the produce of a land area several times that of its own national territory. With the exception of mines (but not of the miners), the land (and labor) appropriated through colonialism represented means of harvesting the organic products of contemporary sunlight. Steam technology, in other words, was a means of commercially converting fossil energy into bioenergy and materials derived from vast land surfaces processing solar radiation.

Against this background, the idea of mitigating the pernicious consequences of fossil fuels by replacing them with biofuels seems *naïve* and profoundly flawed. A critique of this scheme can be conducted at two distinct analytical levels. It can either focus on the structural contradictions of the proposal itself, which revitalize the metabolic impasse of pre-industrial Britain, or on the various deleterious effects of its implementation. At the first level, the resort to bioenergy as a general replacement for fossil energy can be shown to be fundamentally unfeasible, while at the second level, the actual practice of modern bioenergy production can be shown to have highly problematic economic, political, and ecological repercussions. Many of the latter repercussions are expressions of the structural contradictions inherent in the very idea of post-fossil bioenergy.

4 Flaws in the vision of replacing fossil fuels with biofuels

At the level of fundamental oversights, the suggestion that we can replace the use of energy representing millions of years of sunlight with that of current solar radiation does not recognize the crucial significance of the vast time-spans required to concentrate the energy in fossil fuels. To believe that the energy embodied in harvests of contemporary organisms could substitute for the energy we now derive from the fossilized remains of the entire history of organic life on Earth is simply misguided. This is of course not to say that energy cannot be retrieved from crops, as humans have been doing for millennia, but that there are physical and logistic constraints which will preclude humankind from deriving more than a small fraction of its current energy use from biofuels. A tangible such constraint is that there simply is not enough ecologically productive space on Earth to replace a significant share of the current use of fossil energy with biofuels, even if we do not reckon with alternative uses of land for the production of food and materials. A less tangible but no less serious constraint is the issue of *net energy* or Energy Return On Investment (EROI) [9]. To calculate the potential of bioenergy we must subtract the energy spent on producing, harvesting, and processing it. It is certainly physically and technically possible to produce ethanol from maize, but the question is how much energy is expended in the process, in relation to the quantity of energy that can be derived from the ethanol produced [10]. To the extent that net energy or EROI is very low or even negative, such energy production is feasible only as long as there is *money* directed to maintaining it, in effect subsidizing the use of maize ethanol with other sources of energy, predominantly the fossil energy that currently accounts for about 86% of total global energy consumption [11]. Given the "artificial" nature of such energy production —which in terms of net energy is not energy production at all— it is legitimate to ask *whether one hectare of ethanol maize will yield more horse-power of mechanical energy than using that hectare to produce fodder for horses.*

The combustion engines through which we have harnessed fossil energy have established a conceptual lock-in or path dependency in engineering science, founded on the assumption that a return to organic energy must nevertheless continue to be based on the technological advances of the age of fossil fuels. But combustion engines may be as awkward a means of harnessing the energy of maize as horses are of harnessing that of coal. The physical relations between inorganic versus organic energy sources and the feasible means of harnessing them has not changed since pre-industrial times, regardless of centuries of engineering science assuming that revolutionary new forms of harnessing energy are around the corner. To abandon fossil fuels may mean abandoning the combustion engine as the central source of mechanical energy. It may mean having to accept that the age of fossil-fueled industrialism will have been a brief historical discontinuity, an interlude of a few centuries between two very long periods of human social development based primarily on organic energy. There is as yet no reason to believe that the quantitative metabolic logistics framing the latter of these two periods will differ substantially from those of the former. Textbooks in engineering science do not dissolve the fundamental difference between organic and inorganic energy.

The ultimate rationale of contemporary visions of high-tech renewable energy production, whether biofuels or photovoltaic electricity (both based on the idea of harnessing contemporary sunlight), may be to shield engineering science from the traumatic implications of its historical dependency on the fossil fuels that world leaders at COP21 in December 2015 decided to abandon. Harnessing contemporary sunlight was precisely what our 18th-century ancestors were very efficient at doing. The notion that humankind shall devise technologies for harvesting sunlight with higher EROI than direct use of the products of photosynthesis is an example of the kinds of hubris inspired by its historically recent turn to fossil energy. The sooner we realize this, the greater is the chance that our civilization will be able to organize a voluntary transition to a sustainable organic energy regime, rather than succumb to unanticipated collapse [12].

As with photovoltaics, I am not denying that energy can be accessed through biofuel technologies, merely that these modes of harnessing energy cannot be viewed as possible replacements for fossil energy to any significant extent. The several problematic consequences of recent experiments with biofuel production have made this abundantly clear: these schemes have been criticized for displacing poor people from the land they depend on, for leading to higher food prices and concomitant increases in rates of malnutrition, for aggravating biodiversity loss, and even for generating greenhouse gases at rates comparable to those of fossil energy production [13]. The COP21 agreement to rely on future "negative emissions" of greenhouse gases based on bioenergy with carbon capture and storage (BECCS) may require one-third of current total arable land on the planet [14]. No less than the fossil energy technologies it was meant to replace, a large-scale production of bioenergy will be contingent on the displacement of problems to other populations, landscapes, and generations.

5 Toward an interdisciplinary understanding of technology

The current energy impasse provides the conditions for fundamental theoretical progress in achieving an interdisciplinary reconceptualization of modern "technology". When we refer to the existence of a particular kind of technology, we tend to equate it with a corpus of know-how, a state of engineering, a set of ideas about how something can be achieved. To be sure, this cognitive aspect of technology is a necessary condition for its existence, but it is not a *sufficient* condition. Another prerequisite for some modern technologies, approached as physical phenomena, is an unequal or asymmetric societal exchange of resources such as embodied labor, energy, land, or materials [15]. Like biological organisms, technological systems are ontologically unfeasible without specific structures of material exchange with their environments. Just as the existence of the organism is contingent on certain flows of energy, water, oxygen, and so on, the existence of a technological system is contingent on specific flows of energy and materials, and at specific rates. These latter flows are organized by the economy. Technologies are thus contingent on the rates at which energy, materials, and other inputs and outputs are exchanged in human societies. In accordance with the Second Law of Thermodynamics, we know that the output of any technological system will represent less available energy or productive potential than the input required for its production [16]. To be viable, in other words, a technological system must be reproduced through biophysically asymmetric resource flows.

Technological progress, in this view, is not merely a matter of politically innocent breakthroughs in engineering, but of devising new and profitable systems for displacing work and environmental pressures to other populations and geographical areas. This may be viewed as an essential, although not necessarily conscious, rationale of globalized technological systems. Rather than merely an index of generalized human progress —the pure, transcendent knowledge epitomized by the myth of Prometheus— technology since the Industrial Revolution may to some extent be understood as an arrangement for redistributing resources in global society. Many modern technologies require not just ingenuity and specialized knowledge, but also global discrepancies in market prices. Like the money that engenders them, globalized technologies are thus inextricably social. The phenomenon of money cannot be grasped without recognizing its function as a mystification of unequal exchange, and the phenomenon of modern, globalized technology cannot be grasped without recognizing its reliance on money. To complete the syllogism, the *total social phenomenon of modern technology cannot be grasped without recognizing its reliance on unequal exchange*. It is against this background that we must ask under which market circumstances, for instance, it is feasible to fuel European cars with sugarcane ethanol from Brazil or Africa.

The paradigm change that current deliberations on energy policy could lead to ultimately hinges on our capacity to dissolve the tough membrane that for centuries has insulated our thinking about Nature from our thinking about Society. Whereas the science of economics has been justifiably criticized for theorizing resource management as if there was no Nature [17, 9], I would add that engineering science has theorized resource management as if there was no global Society. Contemporary fantasies about fueling modern, high-tech society with bioenergy illustrate this illusion.

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