Click here for Full Issue of EIR Volume 26, Number 2, January 8, 1999

Dino de Paoli

Carnot's theory of technology: the basis for the science of physical economy

If you look at any physics textbook, you will find Sadi Carnot's laws on thermo-machines, but nothing on the work of his father, Lazare, who developed the same law for mechanics and also inspired the formulation of his son's famous law, to the extent that I will use here a formulation valid both for Sadi and Lazare. The reason for this underplaying of Lazare Carnot—and of Gottfried Leibniz as well—is mainly because the science they had improved upon, has de facto disappeared. The mechanics they developed, a conscious alternative to Newton's, was part of a broader science which we call physical economy. Although this concept was still explicitly used during Carnot's time, it then disappeared until, to my present knowledge, Lyndon LaRouche rediscovered and extended it.

This specific school of mechanics includes students of Carnot such as Sadi Carnot, J.V. Poncelet, C.L.M. Navier, G. de Coriolis, and Charles Dupin—to limit ourselves to the French side. By "physical economy," we mean the study of the relationship between the existence of the human population and the optimal increase of physical free energy necessary for that existence. Mechanics becomes, then, the study of optimal conditions and the limits in obtaining such free energy from machines of all sorts, and the study of that process in relationship to more general laws of nature.

We start from the sacredness of our existence as human beings, from the necessary conditions to assure that, and we discover the laws of nature adequate and needed for it. We do not start from an abstract mathematical scheme of a universe in which we are not supposed to even exist. It is only in this framework, that one can understand the results and the intentions of Lazare Carnot's work and the reason why he linked it to Leibniz's and opposed it to Newton's.

Let me now give you a short scientific biography of Lazare Carnot.[1]

Born in 1753, he received his early education at the Oratorian college in Autun, and he learned about Jean Bernoulli and Leibniz through Charles Bossut. In 1771, he entered the military-engineering school in Mézières, where he studied under Gaspard Monge, and graduated in 1773. In 1777, the Academy of Sciences in Paris proposed a competition on "The Theory of Simple Machines with Regard to Friction." Carnot entered an essay in 1778, and, because nobody won, he resubmitted it in 1780, when he received an honorable mention, after Charles Augustin Coulomb, who won. (This essay was where Coulomb developed his law which links friction to weight—although today we know that this law had been written down much earlier by Leonardo da Vinci.) Carnot, in 1783, revised his essay into his first publication, *Essai sur les machines en général* (Essay on Machines in General).

In 1784, there was another competition, in Dijon, in the presence of Prince Henry of Prussia, about the famous economist and military engineer Marshal Sébastian de Vauban, which gave Carnot the occasion to present his *Eloge de Vauban* (In Praise of Vauban). This time, he received first place. It is said that on this occasion, Prince Henry offered Lazare a job in the Prussian Army.

In 1784, Carnot wrote an unpublished *Lettre sur les Aérostats* (Letter on Aerostatic Balloons), following the flight of the Montgolfier brothers. Here, he proposed the use of a steam engine to steer aerostatic balloons, and added, "Take note . . . how many arms will be spared in manufacturing, when the mechanics of fire is better known."

In 1785, he produced another document, this time for the Prussian Academy, printed in 1797 and translated into many languages: *Réflexions sur la métaphysique du calcul infinitésimal* (Reflections on the Metaphysics of the Infinitesimal Calculus).

In 1795, he founded the "Ecole Centrales des Travaux Publiques" (Polytechnique).

After Carnot left active politics, he published another round of scientific works. In one group, he developed the geometry linked to the theory of machines, culminating in 1803 with the *Géométrie de position* (Geometry of Position, translated into German in 1810). Around this central piece he also published *De la corrélation des figures de géométries* (On the Correlation of Figures in Geometry, 1801), *Théorie des transversales* (Theory of Transversals, 1806), and others.

In 1803, he reprinted, with little modification, his 1783 essays, under the new title *Principes fondamentaux de l'équilibre et du mouvement* (Fundamental Principles of Equilibrium and Movement).

---

[1] All biographical notes and quotations from Carnot and Laboulaye, unless otherwise specified, can be found in my article in *Nouvelle Solidarité*, July 2, 1981, reprinted in part in "Lazare Carnot's Grand Strategy for Political Victory," *EIR*, Sept. 20, 1996.

Gottfried Leibniz. Carnot learned about Leibniz's ideas from Charles Bossut, and immediately used them to counter Newton's silly concept of a perpetual motion machine.

From 1800 to 1815, Carnot was a member of the National Institute of France, whose purpose was to promote and review inventions in the realm of technology. In this period he wrote many reports, of which we mention two that influenced Sadi Carnot[2]: *Rapport sur la machine pyréolophore de J.N. Niepce* (Report on the Combustion Engine of J.N. Niepce, 1806), and *Sur la machine à feu de M. Cagnard* (On the Heat Engine of Mr. Cagnard, 1809).

In 1815, he went into exile, and died in 1823, in Magdeburg, Germany.

Carnot's scientific epistemology

On a famous portrait of Carnot, he himself inscribed four names around the border: Socrates, Archimedes, Cato, and Franklin. This list tells you more than 100 biographies about his ideals. We focus first on Benjamin Franklin.

Carnot's family was linked to Franklin, and this helps us simplify the political context of Carnot's work: the implementation of the "American System" in Europe. In a sense, this operation was politically a failure. The French Revolution, said Carnot, failed because it was largely led by an English operation to put the Orléans family in power, so as to prevent French industrialization. We know, contrary to the myth that everything in the past must be better, that even at that time it was screamed: "The Republic needs no scientists!" Ecologism is obviously older than Germany's Green Party Foreign Minister Joschka Fisher!

That Franklin's American Revolution was not fully successful in Europe was explicitly stated by Carnot in 1802: "Only one republic has been the work of philosophy: the U.S.A. There, prosperity grows every day in leaps . . . to the admiration of all other nations." And in 1815: "When the Americans founded a town or even a village, their first concern was always to bring a teacher, plus the necessary machines. The students of Franklin and Washington knew that to meet human physical needs, one has to cultivate the human mind. We in Europe are leaving the largest part of our society in ignorance."

My point here is not to focus on the success or failure in Europe of Franklin's projects, but to locate Carnot's work in that context. As we know, the "American System" was actually based on Leibniz, and it had at its center the apparently very simple idea that human economy, unlike animal ecology, starts with, and is based on, the use of an *invented* machine. For example, to use a French version of this theory, we quote freely from C. Laboulaye, a follower of Carnot, and the translator of Franklin: "Man acts on nature not as the animals do, but by his intelligence. . . . His discoveries accumulate and are retransmitted to future generations. . . . Civilization could develop only among people able to produce surplus value. This means that there cannot exist a single law of nature which should not find its application in industry, and that there should be no useful industrial process not based on a law of nature."

The Americans were already applying it; the Europeans were trying and fighting for it. To us, what is relevant here is the fact that, at the core of Franklin and Carnot's ideas, ecology and machines are two quite different things. For that reason, a more precise calculation of such relationships was required, and Carnot contributed in part to this, by clarifying some crucial parameters in the study of machines. We look at this now.

1. The theory of 'the machine in general'

I will try now to briefly summarize Carnot's theory, as elaborated in his various writings.[3]

---

[2] On the issue of Carnot at the Institute, see my article on "Lazare Carnot ou le savant-citoyen," in J.P. Charnay, *Colloque tenu en Sorbonne,* January 1988.

[3] Other aspects of Carnot's scientific work are elaborated in:

Dino de Paoli, Jacques Cheminade, et al., *La science de l'éducation républicaine—le secret de Monge et Carnot: Polytechnique et les arts et métiers* (Paris: Campaigner Publications, 1980).

Morris Levitt, "Lazare Carnot and the Leibnizian Machine," *Fusion,* December 1978.

C.C. Gillispie, *L. Carnot Savant* (Paris: Vrin, 1979). Here are reprinted the essays of 1778 and 1780.

I also used *Principes fondamentaux de l'équilibrie et du mouvement* (Paris: Imprim. Crapelet, an XI, 1803).

As we have seen, one of the names inscribed on Carnot's portrait was that of Archimedes, the originator of mechanics in Carnot's mind. (This is true enough, but Carnot did not forget Leonardo. Leonardo's manuscripts on mechanics were to be rediscovered some years later, by people around Carnot.)

Let us start by looking at what a machine is. For Carnot, a machine is any intermediate material body or system, serving to transmit and transform motion from a generic form of energy into useful work.[4] Useful for whom? For our society, for us, living in this universe, and not in outer space. So, you see from the start, the implicit "subjectivity" of this kind of science.

Carnot immediately specifies that in this realm we are not interested in Newton's abstract "forces." We must instead use the alternative mechanics put in place by Leibniz and Bernoulli, and be concerned with real transformation in nature, involving matter and energy.[5] The difference between Newtonian ideal mathematical systems, and real ones, can be grasped easily: In ideal cases, the same type of motion can go on forever, while in the Leibnizian cases, the fact of "doing work," imply considerations like "getting tired," or the "threshold of power" etc.[6] We then have to give a great deal of consideration to friction in all of its aspects.[7]

Let me sum up Carnot's general conclusions, in a simple scheme and using my own symbols: Let X equal motive power, either natural (e.g., falling water, wind) or artificial (e.g., a steam engine). Let Ep equal the energy level of X. M = machine. W = useful work produced or social free energy. This parameter is crucial for us, because it defines the necessary, although not sufficient, minimum condition for the LaRouchian potential population density parameter. Q = waste caused by friction or fatigue. The general equation is given by the aggregate work consumed per unit hour by the machine (Ep), and the aggregate useful work produced per unit of time (W), plus the work lost due to friction (Q).[8]

Benjamin Franklin outside his printing house and bookstore. Carnot, who knew Franklin, hoped to reproduce Franklin's American Revolution in France, complete with America's high level of literacy and love of scientific endeavor.

So, we can write: Ep = W+Q

All this led Carnot to the areas of potential and kinetic energy, of work and power, consumption and production, input and output relations, etc. He was really the first to use the equation of work, to measure what forces and powers do, or can do, and to be the unity in the equation of the conservation law. Carnot makes it clear that the relative values of W and Q depend on the geometrical construction, the constraints of the machine, and they can increase or decrease accordingly, in relation to the efficiency of the system. On the other side, the absolute values of W and Q are determined by the nature of X expressed in its potential (Ep). Carnot says that given the maximum ideal relationship defined by a pure transformation $Ep \rightarrow W$, assumed without a machine, then no machine could ever produce more W than the above. We will come back to this, but let us now specify some detail.

1.1. No perpetual motion

Leonardo, Leibniz, and Carnot all strongly attacked any idea of a *perpetuum mobile:* that is, a mechanical system

---

The sources of quotes in the section on machines, will be specified in this way:

Memoir 1778: A plus paragraph number
Memoir 1780: B plus paragraph number
Memoir 1783: C plus paragraph number
Memoir 1803: D plus paragraph number

[4] "Machines are very useful, not because they increase an effect of which powers are naturally capable, but in modifying this effect in the most advantageous way, according to the aim [of the machine]." (D, 266)

[5] "The science of the universal machine and of any mechanics comes down to the following issue: Given a virtual motion of any system of bodies—that is, the one the body would have if free—find the real motion which will take place . . . [but] considering it as it exists in nature." (C, 10)

[6] Carnot gives a concrete example. In an ideal machine, one man-hour plus another man-hour can have less net effect than two man-hours (two persons working together for one hour), because of the threshold effect. (B, 156)

[7] "Friction and other resistances . . . can be regarded as active forces." (A, 50)

[8] "Whatever the induced change, . . . the work consumed per unit of time is always equal to half the increase of the live force over the same time . . . minus half the quantity the live forces would have augmented over the same time, had the bodies moved freely over the path." (C, 293)

"The sum of the live forces after the shock . . . is equal to the sum of the live forces which would have been obtained if the bodies would have moved freely with a speed equal to the one they lost because of the shock." (D, 178)

Statue of Gaspard Monge in Beaune. The dedication to this colleague of Carnot's at the Ecole Polytechnique, reads: "To Gaspard Monge, His Students and His Fellow Citizens, 1849."

which could function permanently, conserving itself indefinitely. The reason for this emphasis will become clear if we use an image to represent Newtonian mechanics. Imagine a permanent lake, where the same water that exits (output) later re-enters the lake as input. This would be an ideal swimming pool for ecologists! No consumption of water and energy! But, they would be disappointed to realize that it is impossible to swim in such a lake. In an ideal mathematical system, there is no friction; nothing is lost, but also, no real work is possible.

Another example: It was realized that in a Newtonian ideal fluid, no bird could fly! But birds *do* fly, and they're not the only ones! So, the real world seems a bit different from the Newtonian one. In this context, you will fully realize the importance of Leonardo's work on vortices, i.e., friction.[9]

Leibniz had warned Newton: In our real world, he said, Newton's mechanical universe, faced with work, friction, and turbulence, would come to a halt. Carnot explains that this is true for *any* machine or mechanical system.[10] Machines have no magic power, he said, and left to themselves would come to a standstill—and, Carnot could *calculate* the precise instant when this would happen.[11]

Thus, in reality, the energy lost as a result of friction (Q) is not simply lost, but generates a non-linear effect on the system, de facto destroying it. If we think in terms of simple cycles, at each new cycle (for a fixed Ep), we will tend to *reduce* the free energy (W) and increase Q. This is the actual basis for the so-called "rate of diminishing return" in an economy.

1.2. Efficiency

If we were existentialists, we could stop here and just calculate the day of our funeral; but we are not, and for that reason, we have to add a few other things. To face the issue of conservation of real existence, as opposed to abstract entities, we have to face this paradox of the two sides of the same coin: work and fatigue.

This was actually the background of the fight of Leibniz against Descartes and Newton, which went under the general issue of what is it that really conserves the universe. We sidestep all the details and leap ahead to Carnot's conclusions.

Carnot was the first to generalize Leibniz's concept of the importance of the conservation of *vis viva,* or power to do work. But, he amplified it, made the concept of work more explicit, including, as we saw, the "work lost." All this, we summed up above with the equation $Ep = W+Q$, where we have to note that W is quantitatively smaller but qualitatively bigger than Ep, given that W can do a type of work for society which Ep cannot do. The ratio W//Ep measures the rate of efficiency. One can increase or diminish it, according to the quality of a given machine.

This is the real function of machines, and Carnot specifies a series of conditions or constraints to get such maximum efficiency. This was obtained by using the appropriate geometric designs to minimize the lost work:

"To obtain the maximum effect one has to avoid any possible shock . . . discontinuous change . . . or any loss resulting from work uselessly absorbed" (D, 280). And he calculated it.

The reciprocal relationship of maximum-minimum is very clear from the above, and this we now have to expand a bit.

1.3. The maximum effect is also a minimum action.

Carnot says that before him, the principle of least path, or least action, had been used mostly for virtual or ideal cases. He transformed it for application to real situations, and he called it *geometric motion*. He gives illustrations, for example: An ideal least path is a line, but for a real string in our world, the least path is a curve in the form of a *chain* [the catenary—ed.]! So, the curvature is linked to the minimum

---

[9] See my article on Leonardo's hydrodynamics in *Fusion,* January 1986.

[10] "Assume no acting motive force. . . . The speed will constantly decrease and so one looks in vain for a machine which could perpetually maintain its motion. Moreover, friction increases when the relative speed decreases; and the rate of lost speed at each instant will be greater and greater, so that the motion will not only become slower, but will stop completely." (D, 281)

[11] "Not only will any machine left to itself come to a stop, but I can calculate the precise instant when that will happen." (D, Introduction)

principle. For the sail of a ship, it is negative curvature which defines the best forms.

Geometric motions, although they have different definitions in Carnot's text, are generally those which do not modify the relative physical relationships among the elements of the system. That is, the relationships are kept constant when there is a minimal inner deformation, resulting from the absorption of work by the machine itself. These physical deformations are transformable in geometrical relationships as conservation of distances, metric, and curvature. As we shall see, Carnot indicates the need for a new science, better able to establish energy-work balances with geometry, and he points to topology, force-free fields, and reversible or irreversible transformations, which his son Sadi would in part develop.

Carnot, then, has linked the minimum path to the conservation of geometrical configurations and conservation of certain physical balances, which includes the lost work.[12] He has transformed the calculation of the maximum efficiency of a machine (maximum W), in a calculation of a geometrical minimal path and a minimal production of Q. Power has to be transmitted with minimal secondary effects. This was also his military conception.

We resume the work of Carnot, with a formulation that is also valid for his son:

"No engine can be more efficient than an ideal reversible engine [i.e., geometrical motion] working with the same energy potential [Ep]" (D, 257). For a given fixed energy potential, each machine has an inner relative upper limit, expressed as efficiency. This can be improved with new designs, but there is a more general limit given by the energy potential of the motive power itself, which no machine using that form of energy can overcome. This prevents any machine or mechanical system from being "non-entropic" or able to "create energy." We will come back to this.

2. The geometry behind it

Let me now quickly indicate what type of mathematics this mechanics requires. Like Kepler and Leibniz, Carnot starts, not from single particles and paths, but from the determination of the total configuration, or energy, of the system which defines the conditions or constraints for the paths or orbits, according to the principle of geometric motion seen above. This best path defines at the same time the issue of "conservation"; that is, what is relevant, and so has to be conserved, in the process. All this can be measured taking in consideration the "interval" or distances of the links between elements of the systems. The physical conservations are then translated into geometrical conservation in the form of metric (distances) and curvature (the form of the links). Carnot, treating universal machines, must use a very general set of links: rigid-linear, rigid-curved, flexible, and so on, thus arriving at issues of general curvature. At the same time, the geometrical motions are the ones which minimize the Q, that is the transfer of energy to the configuration of the machine. These are motions which are "reversible"; they do not produce or absorb energy, and can be considered "force free," which translates in geometry as geodesic paths.

All this needed a new geometry, and Carnot elaborated part of it in his various geometrical essays, summing it up best in his "Geometry of Position." We will not go into any details here, and in any case, the most interesting thing for us is in its introduction:

"Leibniz developed an analysis of situation [*Analysis Situs*—ed.], an idea which has not been really developed. . . . My work [on the geometry of position] is different, although analogous to Leibniz's idea. The geometry of situation treats of a class of questions which, although in the domain of geometry, seems not to be susceptible of algebraic analysis. . . . Motion and transpositions of the elements of the systems are an essential element of [the analysis of situation] . . . and so its relationship to mine is the same as that of motion to rest. Moreover, the analysis of situation is itself only a small part of a very important and much larger science, which has never been treated. This is, in general, the theory of motion, without taking into consideration the forces which produced and transmitted it, . . . [that is] of motions which I have called geometric motion . . . and whose theory is the passage between geometry and mechanics."

In other words, Carnot is saying that his geometry is a small part of Leibniz's project. Carl F. Gauss, who contacted Carnot on this issue, carried out the necessary elaboration, and Bernhard Riemann put it in the most general form. I have, in another location, given a summary of Leibniz's analysis of situation;[13] From here, let us proceed to the conclusion.

3. Beyond the limit

Regarding the theory of the simple machine, there would be nothing further to add. We have the physics and we have the geometry. We came to the conclusion that for any given motive power, the production of free energy will reach a maximum level and then decrease, and with it the potential population density. There is no easy way out of this, no real conservation—not to mention that evolution (as opposed to gains), can take place only from recycling or reallocating the same type of energy. No magic new investment will come from just reducing savings. To quote Laboulaye again: "There are different ways to obtain gains which have a personal value, but a small real social value. If the producer decreases wages, he will produce at lower cost at the expense of workers. If he

---

[12] "Among all those possible, the real motion which will take place is the geometric motion where the lost work is a minimum." (D, 185)

[13] See my article on Leibniz's *Analysis Situs* in *21st Century Science & Technology*, Fall 1997.

buys raw material at a stealing price . . . he gains, but for society the real increase of value is null. The transmission of wealth from one hand to another does not indicate any real creation of wealth."

There is no perpetual mechanical system and no self-developing mechanical system. But, if birds, contrary to Newton's law, *are* able to fly, real people also historically have shown the ability to constantly increase their population potential, and so the free energy available. Where, then, does that surplus of energy come from? We obviously have to introduce something else to Carnot's conservation laws (Ep = W+Q), if we want to conserve our world. If a machine cannot increase Ep on its own, then man can do it. So, in the energy equation, we have to introduce something "as if from outside." A process which must appear as *creation* of a new, higher form of Ep, and so of a higher quantity of free energy. But this "outside" event is not a result of Newton's *deus ex machina;* it must happen from inside this world, and it has happened in this way. That is why Leibniz called ours, the best of all possible worlds. This, our geometrical world, Carnot would add. Social economy can conserve itself because it evolves, and that is possible because there are not only machines, but also real human beings who *invent* them, and who define new motive powers, or better, as Carnot says, who create them.

"It is always a precious thing the discovery of a *new* motive power in Nature . . . especially when used to help the action of man. . . . The ancients knew only a few of such motive powers: water, wind, animals, etc. . . . The mechanical theory came to help in the evaluation of their effects. . . . But . . . machines can only transmit energy; they cannot increase it. The key is [in] the motive powers. We have discovered new motive powers, or better *we have created* them, because although the elements are already pre-existing in nature, their low density makes them not useful to man. Only artificially do they acquire the quality of motive powers, as in steam engines, gunpowder."[14]

For a given energy level Ep, we can obtain increases in efficiencies; The comparison and measure of such increases for different machines we call *the science of technology*. That is not enough to conserve and increase the population potential. We have to create new higher Ep, we have to discover new motive powers. Evolution is not given by generic investments, nor even by simple inventions, but only by inventions linked to the discovery of new laws of nature. As LaRouche says: "Real growth is evolution, not extension. It depends absolutely on considerations related to the role of science-driven effect expressed as axiomatically non-linear quality of technological changes."[15]

We have now, at the same time, a program and a measure for real economic growth. It is not investment in more efficient wind or water mills that will conserve our world, but, according to Carnot's law, the discovery of higher motive powers. And he would add that "higher," is something he could calculate. This is the science of physical economy, at its minimum. It defines the necessary, although not sufficient, condition for population potential growth.

Let us look at the last step.

Evolution is an output caused only by the human creative mind. But what is the input to the mind? What energy does the mind consume to generate ideas? Better food? Better infrastructure? Better education? Yes, all of that, but a bit more. Precisely "that bit more," Carnot was trying to foster by creating specific political, economic, and educational institutions, modelled on those of the U.S.A. To create a culture where "all individuals of the human species could be elevated to the dignity of a human being." The necessity of such institutions results from the paradoxical reformulation of Carnot's law: Creativity cannot be created; it is a given and a gift. But, it can and must be cultivated, activated, put in the condition to produce and solve the real problems of human existence. And those conditions, "I could calculate," Carnot would say. Creativity cannot be planned, but it can be constrained, says Carnot. Human beings can create only under conditions of freedom, but not the virtual, undifferentiated freedom of Newtonian space. Man is born free, but he must and can learn the "necessary condition" of existence. And those, but only those, "one could calculate." This is the geometry of evolution. Carnot wrote, in his *Eloge de Vauban:*

"There is a geometry more subtle than that of Euclid. This [new] natural geometry is genius itself applied to the science of measure. . . . It is through such a natural geometry that man sees, although as in a fog, the results of a new hypothesis, before any calculation. This natural geometry creates, the other just cleans; without the first, the second is useless."

In conclusion, Carnot would say, it is the moral concern to assure the necessary increase of the population potential (increase based on reasonable and calculable law of nature), that defines the real inner motive power of human creation. Carnot writes, again in the *Eloge de Vauban:*

"How rare it is that the wise man can enjoy the fruits of his labor! He is ahead of his century, and his language can only be heard by posterity; but that is enough to sustain him. . . . He is a friend of those yet to be born; he converses with them during his profound reflections. As citizen, he watches over the fatherland. . . . As philosopher, he has already overcome [all] barriers. . . ; he is a citizen of every land, a contemporary of all ages; he follows man . . . from the moment when, weak and alone, he was a plaything of the environment, up to the times when, reunited with all his fellow men in a unanimous concert of all the means allocated to his species, he commands the universe as a master."

---

[14] See the references in footnotes 1 and 2, which are specifically dedicated to this.

[15] LaRouche elaborates this in all his writings.