Blast furnace technology: A case study

Robert Gallagher shows how economic development is the history of distinct species of action, as LaRouche argues.

In northern New Jersey, there exists a monument of sorts, to the principles of the LaRouche-Riemann economic model. Any nearby state park ranger can give directions to the Longpond Iron Works, the decaying ruin of a mid-19th-century iron mill, along the Wanaque River. In an effort to compete with the more advanced anthracite-coal-fired mills of Pennsylvania, the firm's owners attempted to extend the backward technology of the water-wheel-powered and charcoal-fired blast furnace, beyond its range of effective action. As a result, they went bankrupt.

One encounters, in this Civil War-era industrial park, a kind of pyramid: a huge brick housing *for a water wheel, 150 feet in diameter,* intended to provide power for the air blast for two blast furnaces. The housing is so wide that a Mack truck could drive through it. Behind this structure, the proprietors constructed a canal, 4 feet deep and 15 feet broad, that runs for a distance of over a mile, to redirect the water of a nearby river, to power the water wheel. The huge wheel itself was never installed; the owners went out of business; the obsolete equipment was never used.

At that time, the U.S. iron industry was undergoing a *phase change,* deliberately created by the Philadelphia patriots, Nicholas and Thomas Biddle, to make the nation independent of the British iron industry. The new anthracite furnaces, products of the Biddles' dirigist intervention, existed in a different *phase space* of labor productivity and energy density, than the obsolete charcoal furnaces. The pathetic owners of Longpond could compete with Biddle's project about as well as the Egyptians could have reached the moon, using the level of technology which built pyramids.

Prior to the Biddles' intervention, the U.S. iron and steel industry was in crisis. In 1837 and 1838, the nation imported a total of $24 million in iron and steel products, primarily from the British. Were the supply available, this sum could have commanded, in each year, 292,000 tons of American iron, an amount 50% greater than total annual U.S. iron shipments at that time. America was dependent on British rails to build railroads. And northern patriots knew, on which side the British would stand, in the inevitable conflict with the South.

From colonial days to 1839, American iron production had been based on the antiquated charcoal-fueled blast furnace. These machines originally sprang up all over the colonies on farms and plantations, as an adjunct to agriculture, to produce implements. (George Washington's father owned one such furnace on his plantation.) But due to the low energy-flux-density through the furnace, productivity was rock-bottom and their scale of production could not practically be extended. The scarcity and high cost of charcoal, produced in a manual process from wood, made such extension of scale prohibitively expensive.

Though Pennsylvania was rich with anthracite coal, the energy densities achievable with the old techniques made use of anthracite in them impossible. In 1838, Nicholas Biddle offered the prize of $5,000 to the first person, who could sustain operation of a blast furnace fueled with anthracite, for at least three months. He added: "Old Pennsylvania has plenty of coal to warm her friends and can also make plenty of iron to cool her enemies." By the end of 1839, William Lyman's *Pioneer* furnace won the race: He heated the air of the blast to 600 degrees Fahrenheit, to achieve the energy density required to fire his furnace with anthracite coal. Thomas Biddle announced that the event represented "our second Declaration of Independence."

Anthracite-fired blast furnaces sprung up throughout the region near Pennsylvania's anthracite mines, made America independent of British iron, and helped defeat the South. With an energy flux-density twice that of the charcoal furnaces, labor productivity more than doubled, and the power available to the furnace operative, the output per unit of energy consumption, leaped four-fold. The metrical characteristics of the iron industry, the metrics of "man-hour," of "energy," underwent an abrupt, discontinuous shift forward. As Lyndon H. LaRouche, Jr. recently wrote (see *EIR,* May 14, 1985):

> When a true singularity, such as the indicated sort of discontinuity, is generated within an efficiently continuous process, that determines an alteration of the metrical characteristics of the local (or larger) physical space-time of the process affected. The characteristic action of the continuous function continues to operate, but the action occurs in a physical space-time whose metrical characteristics have been altered. . . .

The hyperbolic step functions shown in **Figure 1** illustrate these concepts. The figure is a plot of productivity (measured in tons of iron output per worker per year) as a function of the energy flux through a horizontal cross-sectional area of the furnace per unit time. The first hyperbolic curve shows this relationship for charcoal furnaces; the second, for anthracite furnaces; the remainder represent phase changes produced by further technology transformations.

LaRouche continues:

> In the sort of idealized economic process, which we have portrayed, at the flaring mouth of the hyperbola, a new hyperbolic curving, in an altered "economic physical space-time," begins. The second curve flares into a discontinuity, as did the first, with an analogous continuation of the function. And, so forth and so on. Relative to the time-axis, the interval between these discontinuities becomes shorter.

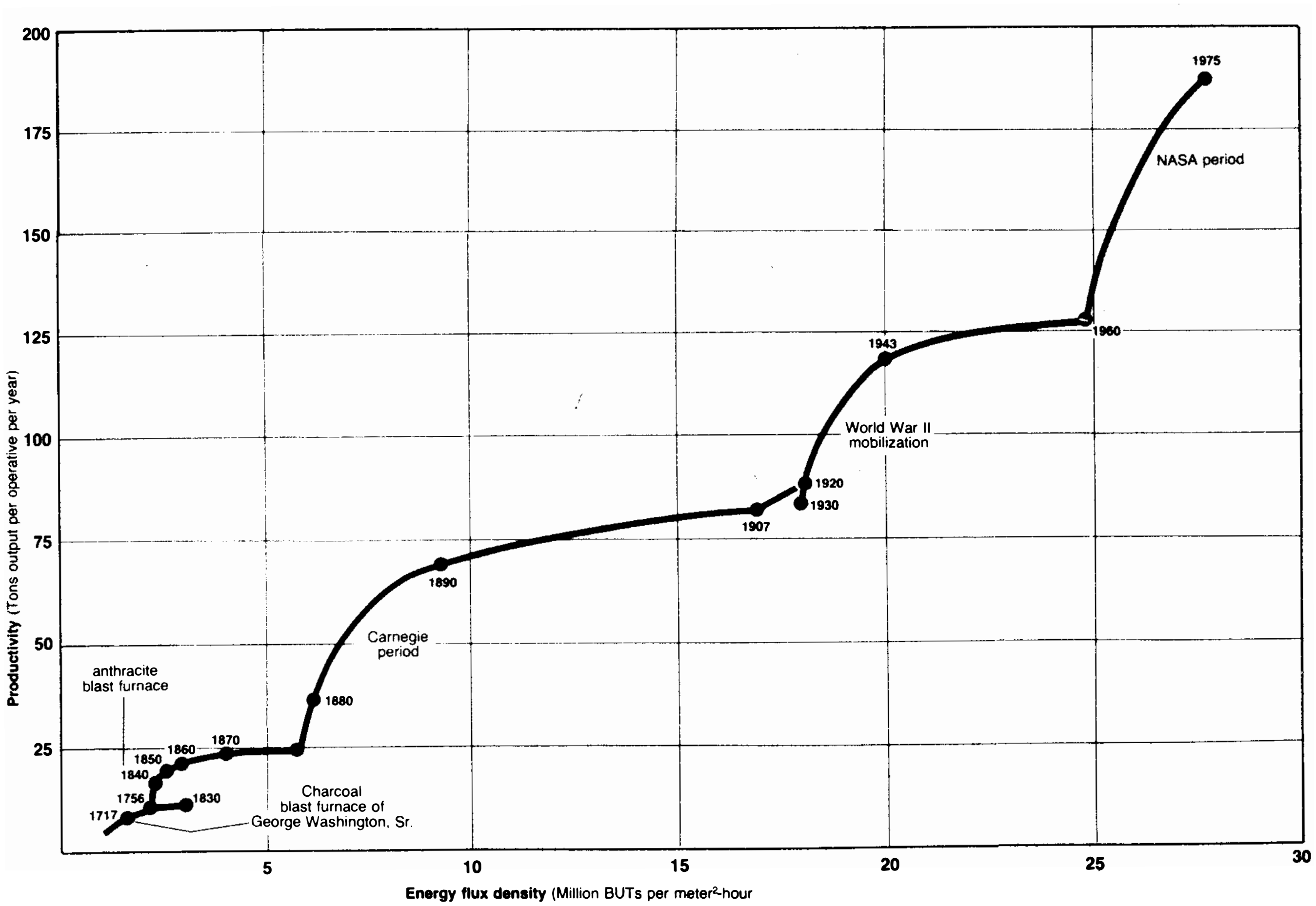
Were dates written in on Figure 1 for the individual data points, they would show the increasing density of these discontinuities. The development of the charcoal-fueled blast furnace occured over a 100 to 200 year period; that of the anthracite furnace, over a 40-year period (1830-70); the first phase of furnaces fueled by coke, over 30 years (1870-1900); the phase produced by the World War II mobilization, over 20 years (1940-60); and the phase associated with computerization during the Apollo program over only 10 years (1960-70).

The Carnegie era

The victory of the North in the Civil War set the stage for the superseding of the Biddle anthracite furnace with the tremendous developments in American iron and steel associated with the name of Andrew Carnegie. Having no respect for budgetary economics, Carnegie tore down old furnaces and replaced them with more advanced ones, as fast as he

Figure 1.

How technology elevated the power of labor in blast furnaces (1700-1974)



Productivity (iron output per worker per year) jumps with the introduction of new technologies as measured by energy flux density (EFD) in blast furnaces. The graph shows a series of hyperbolic relationships between the two parameters, one hyperbola for each of the following blast furnace types: charcoal fueled, anthracite-coal fueled, the coke-fueled furnaces build by Andrew Carnegie, the World War II period, and the period of the rocket program. EFD data measures total energy passing through a cross-section of the bosh of a blast furnace.

Source: Fusion Energy Foundation.

could apply new technology. The technological basis of the Carnegie "boom" in steel productivity (the third step function in Figure 1) was several-fold:

1) The invention of cooked bituminous coal ("coke") as the reductant of iron ore;

2) The use of steam engines, and eventually electricity, to lift materials and load them into blast furnaces; and

3) The use of a blast super-heated to 900 degrees F. and injected at high pressures.

The high energy flux densities achievable with these methods enabled the redesign of the hydrodynamic lines of the blast furnace, that determine the rate of descent of the ore, coke, and limestone, and, consequently, the rate of the reduction of the ore. In 1870, a furnace's interior had the shape of a bottle turned upside down, with a constricting throat above the hearth, the locus of the highest temperature, to slow the rate of descent, since furnaces were not able to reduce ore as fast as the material could fall. By 1907, typical furnace lines approximated a cylinder. In the course of these transformations, productivity went through the roof, until U.S. Steel bought out Carnegie around the turn of the century.

Species of 'energy'

Figure 1, however, does not adequately represent the phase changes, from one mode of ore reduction to another, nor the real time scale on which they occurred. To show this, it is necessary to display the data of Figure 1 in a way that represents the self-similar nature of economic growth and the transfinite succession of species of "man-hour" (productivity) and "energy" (reducing power, output per unit energy consumption). The man-hour of the skilled operative in a modern blast furnace is of a different *order* from that of the laborer who operated charcoal furnaces or other less advanced types. They are distinct *species* of labor. **Table II** shows this from one standpoint, by displaying the jumps in the productivity of labor with distinct furnace technologies.

Secondly, energy consumed in industrial processes is not homogeneous. The value of energy and the ability to perform work with it, are determined by technology. Available developed technology determines what is energy and what is not. Prior to Biddle's initiative, anthracite coal was not energy for blast furnaces; practically speaking, for blast furnaces, it was indistinguishable from rock. Because its value is truly determined by technology, energy cannot really be measured by calories or British Thermal Units; it does not have a heat content in any general sense. If it did, then the consumption of a given quantity of calories by machines of different species of technology, could, generally speaking, coincide with the performance of an equal amout of work, and different forms of energy would be interchangable among distinct species of machines.

Table I shows how ridiculous this conventional Helmholtzian notion of energy is. Per unit of "heat," modern blast furnaces produce 20 times more iron than the charcoal furnaces of the 18th century. Accordingly, charcoal furnaces broke down when operators tried to substitute anthracite coal for charcoal without otherwise raising the energy density of the furnace. A modern furnace "fueled" with charcoal would grind to a halt.

In **Figure 2,** we attempt to show this succession of species, these discontinuities in the metrics of "man-hour" and "energy" by overlaying distinct axes of energy flux density for distinct regimes of technology. This shows the progression of reducing power over time along a vertical axis of increasing labor productivity. Since development is always self-similar within a given technological regime, *all axes are logarithmic*. The result is a series of hyperbolae of increasing density. (Due to insufficient data, it was not possible to plot in Figure 1, the step function in productivity and energy flux density that resulted from the introduction of raw bituminous coal in furnaces in the Midwest just after the Civil War. A hyperbola for this regime is sketched in Figure 2 between the curves for anthracite and the Carnegie period.) Figure 2 begins to get at what LaRouche has termed "triply self-reflective, conic, self-similar spiral action":

Table 1.
The power of technology

Blast furnace type	Tons output per billion BTUs
Charcoal era	4
Anthracite era	16
Carnegie era	45
WWII era	75
Space era	80

Jumps in the power of the blast-furnace operative to perform work actually show the change in the metric of "energy" with changes in technology. The table shows tons output of iron per unit of energy consumption (in British thermal units) by blast-furnace type.

Source: Fusion Energy Foundation

Table 2.
The power of labor

Blast furnace type	Tons annual output per operative	Representative year
Charcoal era	10	1830
Anthracite era	21	1860
Carnegie era	70	1900
World War II era	120	1950
Space era	183	1970
Carter era	174	1980
Reagan era	148	1982

The jumps in the annual blast furnace output per worker per year shows the change in the metric of "man-hour" with changes in technology.

Source: Fusion Energy Foundation. (Figures for work force are "Primary Iron and Steel Wage Earners" in: U.S. Bureau of Census, *Historical Statistics of the United States*, and *Statistical Abstract of the United States*, various years.)

The growth of per-capita potential relative population density, generates a bell-mouthed horn, whose side-view cross-section describes an hyperbolic curve, seeming to zoom off into Cartesian "infinity." The central axis of that horn represents a uniform time-scale.

The crisis in steel today

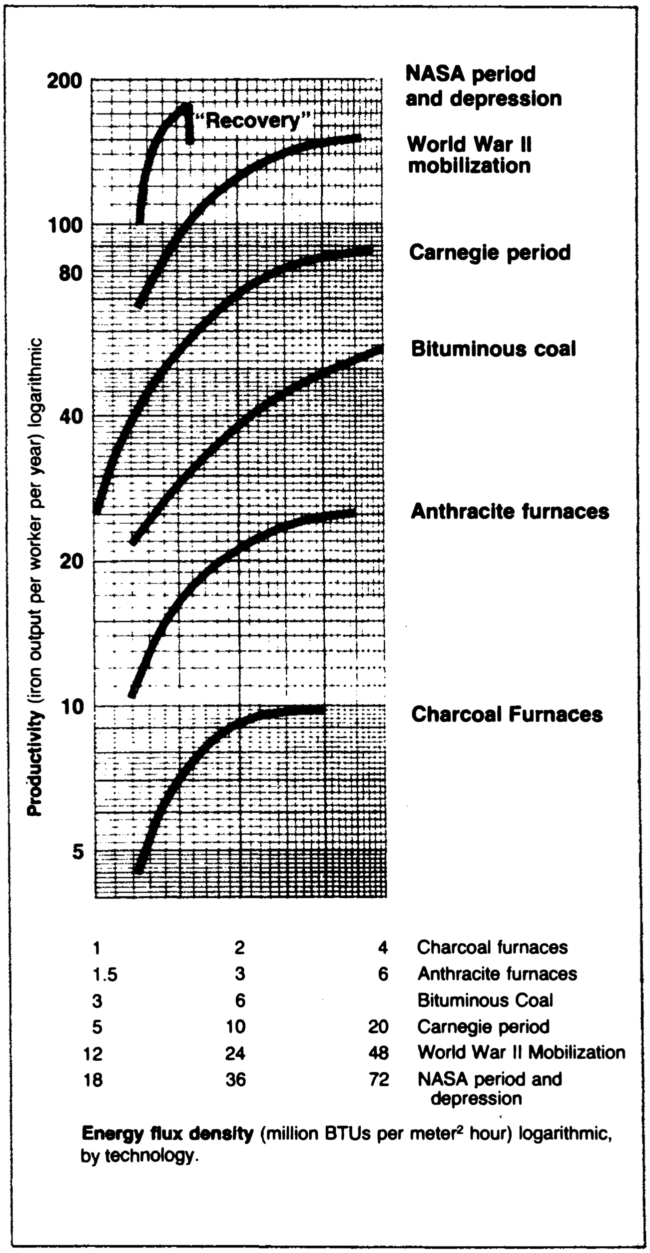
Not surprisingly, no development of significance, aside from decline, occurred through World War I and the Great Depression. In 1930, productivity was lower than in 1910 and the average energy flux-density of furnaces had remained approximately the same. The World War II mobilization reversed this trend, and took U.S. iron production into yet another phase-space lasting until 1960. The mobilization forced through further improvements in furnace design and operation along the lines begun by Carnegie. The replacement of raw ore in the furnace with treated, concentrated iron ore agglomerates, and the use of pure oxygen in the blast, produced a leap in furnace throughput and energy flux density that boosted productivity in the war and postwar years. In the 1960s, productivity took another leap with the widespread computerization of blast furnace operations. Since 1974, as is indicated in Table II, the industry has collapsed.

There are two reasons for this collapse. One is the post-1972 abandoning of technologically vectored economic growth in the United States. However, the increasing density of species transformations in basic industry, indicated in Figure 2, points to another problem facing economic development for all advanced sector nations, including Japan. The next great phase of economic development will likely require the creation of a new genus of reducing power, transcending even the impressive achievements of the Japanese industry, transcending the mere chemical-based reducing power that characterizes the entire succession of species of blast furnace technology developed to date. The obvious candidate for such an industrial process is the fusion torch, the reduction of ores in the plasma state to directly refine purified metals and other materials. Such a further transformation in man's reducing power, is the only human solution to the so-called population problem of the developing nations. To quote LaRouche:

> Whereas a primitive form of human society is capable of sustaining a worldwide population of not more than approximately 10 million individuals, there exist nearly 5 billion today. This growth in the potential relative population density of the human species, by nearly three orders of magnitude, is the most characteristic distinction of the human form from all inferior species. No lower species could willfully increase its potential relative population density by a single order of magnitude. No lower species can willfully improve its day-to-day behavior by aid of advances in scientific and related knowledge.

Figure 2.

Increasing density of technology transformations with economic development



The figure (at right) represents the data of Figure 1 in the form of a transfinite progression of species of reducing power, a series of increasingly dense transformations in the power of labor. To show the changes in the metric of "energy," there are six distinct logarithmic axes for "energy flux density" (million BTUs per meter-squared hour), one for each species of energy. Table I justifies this overlaying of energy flux density scales. It shows that the "energy" used by distinct technologies is incommensurable. The vertical axis represents time, measured in the development of the power of labor (iron output per worker, in tons). All axes are logarithmic to represent the self-similar nature of development.

Source: Fusion Energy Foundation.