*Ruth Schwartz Cowan, "The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology." Pp. 261-280 in Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch. The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology. Cambridge: MIT Press. 1987.

The Consumption Junction: A Proposal for Research Strategies in the Sociology of Technology

Ruth Schwartz Cowan

The sociology of technology, if it is ever to justify its existence as a subdiscipline, should take as its proper domain of study those aspects of social change in which artifacts are implicated. The processes by which one artifact supplants another (technological change) or by which an artifact reorganizes social structures (technological determinism) or by which an artifact diffuses through society (technological diffusion) are fundamentally sociological in character, subsets, as it were, of the larger topic of social change. Properly constituted historical investigations can be used (and indeed must be used) as the raw material for studies of social change, but many historians of technology have had cause to wonder what "properly constituted" could possibly mean in this particular context.

In their contribution to this volume Trevor Pinch and Wiebe Bijker have provided some useful guidance on this matter. A properly constituted history of science, they remind us, should be impervious to the question of whether or not the ideas being examined historically are true or false by current standards. Similarly, they argue, a properly constituted history of technology should consider artifacts that were "failures" on the same par with artifacts that were "successes." The task of such a historical investigation is not to glorify the successes but to understand why some artifacts succeed and others fail. To fulfill this obligation, historians of technology must be careful, as they have not often been, to track down all the possible technological solutions that have been offered to a given social problem, and then they must be equally careful to examine those solutions in the context of the time period in which the choices were being made. Today's "mistake" may have been yesterday's "rational choice."

Pinch and Bijker go one or two steps further, however. They assert that historical case studies, which can provide new methods for studying technology and new theories for the sociology of technology, must also be alert to the existence of what they call relevant social groups,

groups that influence the creation, the demand for, the production, the diffusion, the acceptance, or the opposition to new technologies. In the history of science, they remind us, this prescription is relatively easy to fulfill because science is generated by and fills the needs of relatively circumscribed social groups; no more than a handful of European males were, for example, responsible for the destruction of the Ptolemaic universe and the construction of the Copernican. Four or five centuries later the same could still be said about those who created, confirmed, and affirmed the neo-Darwinian synthesis or the theory of plate tectonics, to cite other examples. In the history of technology the situation is different—and potentially infinitely confusing—because a large number of relevant social groups are involved in the success or failure of any given artifact (ranging, for example, from the small group of craftsmen or engineers who may be responsible for innovation to the somewhat larger group of managers who may make decisions about the innovation, to the even larger group of production experts who must turn the innovation into an artifact, to the even larger group of people who must distribute, market, and sell it, and then to the potentially even larger group of people who will consume it). Any one of those groups, or individuals acting within the context of their group identity or (worse) combinations of those groups or (even worse yet) some other group not yet enumerated (such as purchasing agents for governments), may be responsible for the success or failure of any given artifact. How is the historian of technology who wishes to become "properly constituted" going to cope with such an infinitely expandable universe of relevant social groups? Pinch and Bijker have given us a prescription but precious few suggestions about how it might be filled.

In my own work I have found it possible to begin filling the prescription by focusing on the actual or potential consumer of an artifact and imagining that consumer as a person embedded in a network of social relations that limits and controls the technological choices that she or he is capable of making. The concept of network that I utilize is similar to the one defined by John Law and by Michel Callon in their separate contributions to this volume—a temporal association between heterogenous and interacting elements—but I differ from Law and Callon (and also from Hughes, Bodewitz et al., and MacKenzie in their contributions) in my effort not only to place the consumer in the center of the network (at the consumption junction) but also to view the network from the consumer's point of view. Law wants to know what holds networks together; Callon wants to know why some engineers are such effective network builders; Hughes wants to understand how networks come to be built; MacKenzie and Bodewitz et al. describe for us the ways in which elements of the network interact with each other. These are investigations of networks from the outside in; the investigators are asking questions with which the people embedded in the network may never have been concerned. My enterprise is somewhat different. I focus on the consumption junction, the place and the time at which the consumer makes choices between competing technologies, and try to ascertain how the network may have looked when viewed from the inside out, which elements stood out as being more important, more determinative of choices, than the others, and which paths seemed wise to pursue and which too dangerous to contemplate.

There are many good reasons for focusing on the consumption junction. This, after all, is the interface where technological diffusion occurs, and it is also the place where technologies begin to reorganize social structures. If technological change is goal directed (and who can doubt that it is?), then a positive consumption decision at the consumption junction is in fact the goal, and an investigation that focuses on the consumer is thus heuristically justified. Such a focus brings into relief (perhaps more clearly than other foci can) the variables that have governed the behavior of all those relevant social groups who influence consumers' choices. It also frees the investigator from the bonds of needing to know, through hindsight, what the consumer could not possible know with certainty, that is, which choices would turn out to be "right" and which "wrong." The historian need evaluate only those elements of the network that caused consumers to act in the particular ways they did, rather than worry about whether in the long run those actions were right or wrong.

The single most worrisome complicating factor in this mode of analysis is, however, the obvious fact that consumers themselves come in many different shapes and sizes; indeed any single given human being can enter the consumption junction under a number of different guises, depending on what it is that is being consumed. The same individual may, for example, have one set of interests when entering the consumption junction as the Director of the Ordnance Department of the US Army and a quite different set when acting as a homeowner in need of a new basement furnace. Once recognized, this complicating factor can add rather than detract from the usefulness of consumer-focused analysis, because it reminds us that we must define consumers in terms of the artifact about which they are making choices (as, for example, "a prospective purchaser of a washing machine") as well as by other appropriate socioeconomic variables

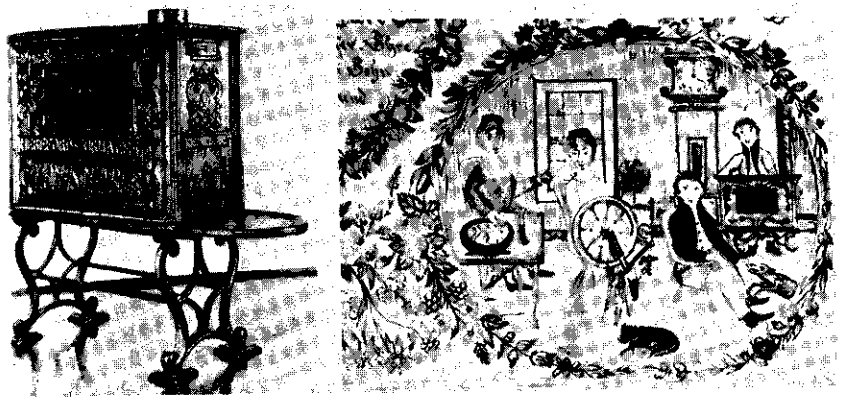
(for example, "middle class," or "rural"). Market researchers and advertising agencies are quite accustomed to this form of categorization; sociologists of technology might do well to adopt the practice.

In this chapter I hope to demonstrate the usefulness of consumer-focused analysis first by using it to solve a historical puzzle that I first encountered when studying the history of home heating systems in the United States (a puzzle that previous forms of analysis had failed either to notice or to resolve) and, second, by using it to generate hypotheses about other aspects of that same historical development that warrant further study. I begin with a quick introduction to the history of the artifacts and the technological systems that Americans have been using to keep their food cooked and their bodies warm from the colonial period to the present.

The History of Home Heating and Cooking Systems in the United States

Over the course of the last 250 years Americans made a transition first from open hearths to cast iron stoves and then from cast iron stoves to coal-fired furnaces and then from coal-fired furnaces to gas, oil, or electric forms of central heating.[1] These transitions were more complicated than one might initially suspect because they involved changes in implements as well as changes in the nature of fuel and fuel-delivery systems. In the American colonies and in the United States before 1800, the vast majority of structures, whether domestic or public (such as churches, schools, and inns), were heated by wood, which was burned in open fireplaces; most cooking and baking was done in such a fireplace or its attendant ovens. Sometime between 1810 and 1840 cast iron stoves began to replace open hearths. This transition began in public buildings and (following much the same pattern that the personal computer is following today) subsequently spread to the domestic setting. Owners of older structures began to brick in their hearths and plumb stove pipes directly into their chimneys; new structures came to be built without hearths and mantels or, rather, with only decorative hearths and mantels.

During these years the cooking stove began to be differentiated from the heating stove. The open hearth had served both functions and, following suit, so had the earliest cast iron stoves; heating stoves were adapted to cooking by the addition of enclosed boxes adjacent to the firebox (for baking or for warming) and of potrings on the top surfaces (figure 1). Within a few years, however, the cooking stove and the heating stove began to evolve along separate pathways,



a *b*

Figure 1
(a) An early form of the enclosed cast iron stove, intended for both cooking and heating, made in Pennsylvania in 1767. (b) The same type of stove depicted in use in a detail from *Birth and Baptismal Certificate of Margaret Munch*, by Carl Munch, 1826 (National Gallery of Art, gift of Edgar William and Bernice Chrysler Garbisch).

the cooking stove becoming larger and taking on a characteristically stepped appearance (hence the name "range") and the heating stove becoming smaller and more compact as the years progressed (figure 2).

Just as this differentiation was occurring, fuels were changing as well. Wood was becoming increasingly expensive, especially in urban areas, and consumers were beginning to substitute coal (which was becoming cheaper as the cost of transporting it fell). Bituminous coal, which is much easier to ignite than anthracite, became easier to acquire as the canals and then the railroads eased access to the areas west of the Appalachians, where it is abundant. On the western frontiers, particularly on the western plains, variant fuels, such as buffalo chips and corn husks, were used when coal was either unavailable or too expensive. The earliest cast iron stoves were sold with convertible grates to allow for the use of either wood or coal, but later in the century this was no longer standard practice, as coal increasingly displaced wood from shore to shore. By the end of the nineteenth century coal was the principal fuel used for household heating, and heating and cooking implements had been differentiated from each other.

Other variant implements and fuels appeared during the second half of the nineteenth century. Since early in the century inflammable gases had been manufactured in most American cities. Most of this

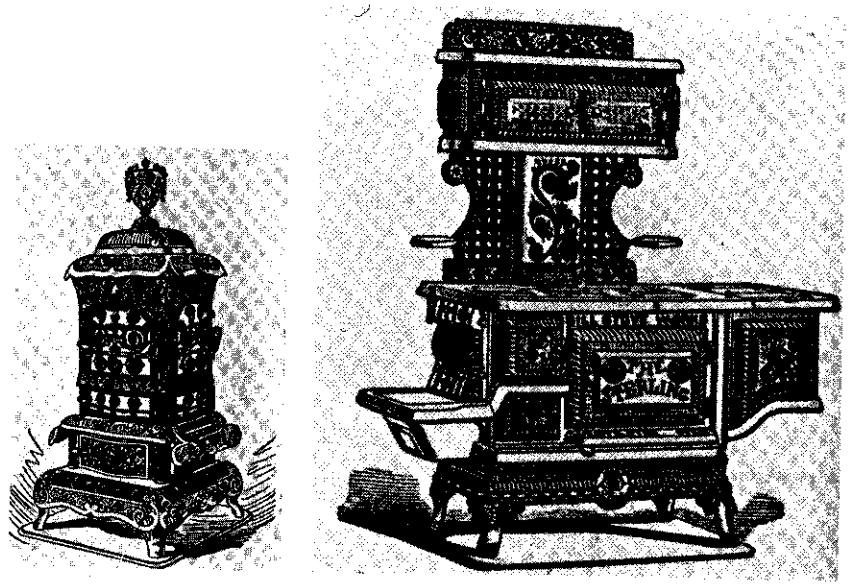


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Figure 2
The heating stove (a) and the cooking stove (b) have been differentiated (from an advertisement of the 1880s).

gas was used either for lighting or for industrial purposes, but after the Civil War some manufacturers did develop and market domestic boilers that produced hot water for household consumption, using inflammable gases as the fuel. Petroleum had been discovered in Pennsylvania in 1859, and after the Civil War several entrepreneurs went into the business of refining and transporting it. The most important petroleum product in those years was kerosene (used principally for lighting), but some households purchased suitably constructed stoves in which kerosene could also be used for cooking and for heating. Some urban households (those that were exceedingly wealthy) acquired the advantages of central heating in those years; basement furnaces were installed (coal-burning) as well as peripheral implements (vents and registers, if it was a warm air system; pipes and radiators if it was steam or hot water) for distributing the heat throughout the dwelling.

During the first half of the twentieth century central heating diffused down the economic ladder, although the poorer half of the population did not benefit from its comforts until after World War II. During most of that time coal remained the dominant fuel for heating, although manufactured, and natural gas came to replace it for cooking. As gas supplanted coal for cooking, the form of the kitchen range altered, losing its characteristically stepped appearance (because the gas flame could be regulated and there was no longer any need to move pots and pans from one burner to another in order to vary cooking temperatures), becoming more compact, and acquiring a porcelainized finish and automatic thermostatic regulation of the oven. After World War II gas cooking lost place to electric cooking (especially in those suburban tracts to which gas service had not previously been provided); the electric range took on the features that the gas range had already acquired. In a similar fashion electric, gas, and oil systems (all of them automatic) came to displace coal systems for central heating, the electric systems being the ones with the most radically different morphology because they were not, strictly, central systems at all. By the last quarter of the century most Americans, whether they lived in privately owned homes or in multiple dwellings, whether they were rural, suburban, or urban, indeed whether they were rich or poor, enjoyed the benefits of automatic central heating and relatively clean, more or less automatic cooking; even the substantial increase in energy prices that occurred during the 1970s did not deter more than a tiny (and now decreasing) fraction of the population from the pursuit of this particular benefit of industrialization.

On the surface the transitions that I have just described seem rather straightforward; unfortunately, a number of historical puzzles appear as soon as one delves below the surface. The first of these puzzles concerns the diffusion pattern of the cast iron stove. I first began to understand the usefulness of the consumption junction as a locus of analysis when I tried to unravel this particular puzzle.

The Cast Iron Stove

The cast iron stove achieved popularity in the nineteenth century; by most indicators (newspaper advertisements, patent records, analysis of surviving structures, statistics on production, statistics on the number of firms entering the business), the transition from hearths to stoves can be said to have occurred, at least in the northeastern United States, by the outbreak of the Civil War in 1860 (Goldmann 1982). Yet stoves were not a nineteenth-century invention. Dutch settlers had built brick and tile stoves in New Amsterdam in the seventeenth century; German and Scandinavian settlers had brought cast iron stoves with them in the eighteenth century (Pierce 1951).

Indeed, perhaps the single most famous stove of all, Benjamin Franklin's Pennsylvanian Fireplace, was invented and advertised in the 1740s (Franklin 1960 [1740]). The advantages of a stove over a hearth were numerous, and Franklin as well as others clearly recognized them. First, by controlling the passage of air over the burning fuel (usually wood), a stove permitted much greater fuel efficiency—a not insignificant matter for people who were cutting, hauling, and chopping their fuel for themselves or were paying others to do it for them. Second, the stove provided more comfort for the amount of fuel that it used because it could be placed in a central position in a room and heated by convection rather than by radiation. Third, because the fire in the stove was enclosed, a stove, although not without ash, was potentially cleaner than a fireplace. Given all these advantages and the fact that eighteenth-century iron producers, especially in Pennsylvania, were actually making small quantities of stove plates, how can we possibly explain the fact that the vast majority of nineteenth century Americans failed to adopt the stove? Why was the transition from the hearth to the stove delayed until the nineteenth century? What considerations, other than efficiency, comfort, and cleanliness (which we would value highly today), governed the behavior of ordinary householders in the eighteenth century?

Those few historians who have considered the history of the stove have dealt with this question in one of two ways: either by ignoring it or by appealing to the ethnic prejudices of the English segment of the American population. The open fire, it was said, was uniquely and symbolically English, and the foods that could be cooked on an open fire, also uniquely and symbolically English, particularly roast beef, could not be duplicated on the stove (which bakes instead of roasts): "Would our Revolutionary fathers have gone barefooted and bleeding over snows to defend air tight stoves and cooking ranges?" inquired Harriet Beecher Stowe (an ardent defender of English tradition) in 1864. The open fire, she averred, with "its roaring hilarious voice of invitation, its dancing tongue of flames ... called to them through the snows of that dreadful winter to keep up their courage [and] made their hearts warm and bright with a thousand reflected memories" (Stowe 1864, p. 42).

Given the vast number of ethnic symbols that have fallen by the wayside on the North American continent, it seems a bit strange that this particular symbol remained potent even in the face of the increased comfort and lowered costs that could have been achieved if its power had been dissipated. Indeed, the history of the Franklin stove itself

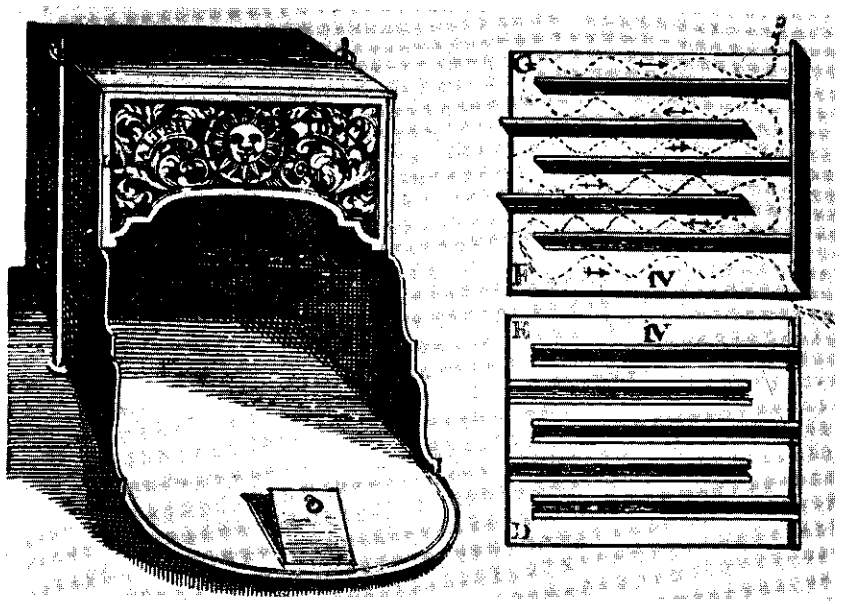

Figure 3
The original form of Benjamin Franklin's cast iron stove, the Pennsylvania Fireplace (c. 1750).

suggests that the ethnic explanation is wanting. The Pennsylvanian Fireplace (figure 3) was designed by Franklin as a compromise between the best aspects of the open hearth and the best aspects of the enclosed stove. It was a cast iron box with an open front constructed in such a way that the combustion gases released when wood was burned in front traveled through a chamber before passing out of the room; thus Franklin's fireplace provided some heat through convection as well as through radiation from the fire itself, the sight of which its inventor called, "in itself a pleasant thing" (Franklin 1960 [1740], p. 432). Thus the Pennsylvanian Fireplace was meant to overcome the ethnic prejudices of the English segment of the population; yet it was a commercial failure. So few were purchased that, when Franklin wanted one sent to him in London, his agent in Philadelphia, Hugh Roberts, had to tell him that the furnace in which it was originally cast had stopped production (Bining 1938, p. 97). Something other than ethnic prejudice must have been at work.

To discover what that "something" might have been, one need only focus on the average American consumer of fireplaces in the mid-eighteenth century, asking both what interests such a consumer might have had and what sort of network might have existed at that time to

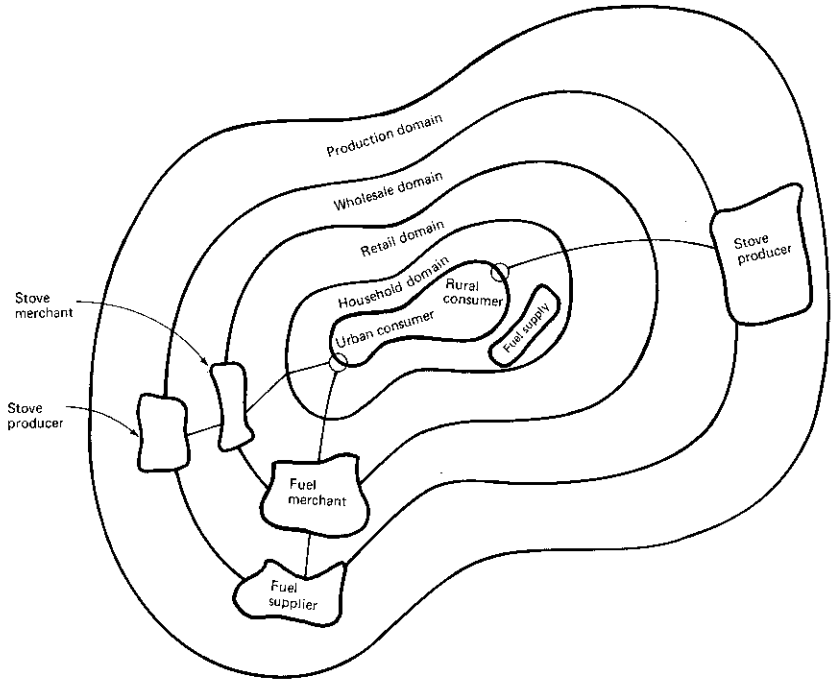

Figure 4
Network sketch of urban and rural consumers considering purchase of a stove c. 1760. The open circle represents the consumption junction.

bring a stove into a home. Figure 4 is an effort to draw a sketch of such a network. It distinguishes urban from rural consumers and reminds us that consumers, located in the household domain, were not producers of this particular commodity. In addition, urban consumers certainly and rural consumers possibly obtained such commodities through intermediaries who were located in the wholesale and the retail domains. A glance at figure 4 easily suggests the possibility that features of the production, wholesale, and retail domains could easily have affected the willingness of a consumer to purchase a stove.

In the eighteenth century stoves were produced on iron plantations, large tracts of land that were the site of the iron mines themselves, the furnaces that were used for smelting and resmelting, the forges, the wood lots that supplied the fuel for furnace and forge, the homes of the iron workers, and the farms that supplied workers and their families with food (Bining 1938; Paskoff 1983). Stove plates were cast directly from the initial smelting of iron, from the molten iron, which, if cast into bars, would have been called pig iron. Of necessity, iron plantations tended to be located far from centers of

settlement, and thus the manufacturer of stove plates was bound to be located at a considerable distance from the potential purchasers of them. The cost of transportation would have driven up the cost of the stove, and in the American colonies in the eighteenth century the cost of transportation was high. Thus all iron goods, and stoves in particular, were expensive when sold at retail. "This stove," one of Franklin's contemporaries remarked about the Pennsylvanian Fireplace, "is an invaluable acquisition to the richer part of the world, but the poor can never enjoy it" (Bining 1938, p. 99).

Safety was another "interest" that, along with cost, may have been on the minds of eighteenth-century consumers when contemplating stoves, for the stoves were widely regarded, to use the language of the day, as "insalubrious." Under the heat generated in the firebox, cracks sometimes developed in the stove plates, and such a crack could (and apparently occasionally did) have fatal consequences for the inhabitants of a household. The continuous draft of air that is needed to feed an open hearth also served to drive the poisonous gases that resulted from combustion directly up the chimney, but a stove had no such draft. Open hearths were, of course, also dangerous, but their dangers were dangers with which people had coped for centuries; the risks of stoves were new and thus potentially more worrisome. In addition, many people believed that the drafts that accompanied open fires were beneficial to health, whereas the airtight stove made a room so dry and so stuffy as to be dangerous. Franklin's stove was intended to correct these defects (because the firebox was open), but it did so only at the cost of creating another defect: The open stove could not be used, as a closed stove could, for cooking. Thus the average eighteenth-century consumer, whether rural or urban, who was interested in purchasing a stove had to make a choice between one that was potentially dangerous as well as exceedingly expensive and one that was clearly not so dangerous but that would increase (rather than decrease, as its inventor claimed) fuel consumption in the household (because the kitchen hearth would still have to be fueled for cooking at the same time that the Pennsylvanian Fireplace was being fueled for heating). In 1796 the American Philosophical Society in Philadelphia organized a contest meant to encourage stove innovation, and one proposal sent to the society summed up the quandary faced by the average consumer at that time:

> The close-iron stove was invented to save fuel by casting heat with the least possible loss. But it is far from solving the question in full latitude. By being unattended with free circulation of air it is insalubrious. It is also expensive

and admits not of cooking. To remedy some of the inconveniences of the close-stove . . . Franklin invented his open-iron-stove. This by its openness gives a free circulation of air and by its projection into the room . . . causes but a little waste of heat produced by the fuel. But at the same time it increases the consumption of fuel beyond the close stove. It also is expensive and does not admit of cooking. ("An essay on warming rooms," 1796; reprinted in Bining (1938), p. 99)

The innovation that finally resolved these multifaceted problems was not a profound alteration in the design of the stove but rather an alteration in the structure of the industry that manufactured them, an alteration in the production domain. Sometime in the late 1820s a New York coal merchant and stove maker (someone who assembled stoves from plates cast at a furnace and then subsequently sold the stoves at retail), Jordan Mott, began to experiment with casting stove plates himself from pig iron, which he resmelted in a copula furnace using coal as fuel (Bishop 1966 [1868], p. 576). According to contemporary accounts, Mott became the first stove maker who actually made stoves instead of just assembling them. His innovation was important because it profoundly lowered the cost of stoves: A copula furnace was rather small, did not require great capital investment, and could be profitably located in or near an urban area because it burned coal rather than charcoal. The resmelted pig iron, as it turned out, was also less likely to crack under the heat generated in a stove firebox. "Mott's operation gained the attention of iron men and before the close of the year [1835] copula furnaces began to be erected and soon spread over the cities and villages of the Union" (Bishop 1966 [1868], p. 577).

A boom period for the manufacture of cast iron stoves began. Consumers who were emigrating west purchased them because they could be transported disassembled and then placed in operation quickly to provide more efficient heating and cooking, especially in locales that did not have abundant supplies of wood. Consumers who remained in the east began to purchase them and plumb them into their kitchen hearths with increasing frequency as the price of the appliance fell and the price of one fuel (wood) continued to rise. Stoves became even more attractive when, as the result of improvements in rail transport, coal became a lower-priced fuel than wood and bituminous coal became as easy to obtain as anthracite. Fully one-third of all the cast iron products reported in the *Census of Manufactures, 1860* were stoves; and most of those had been made, not on traditional iron plantations but by single-product stove manufacturers. Of such establishments, 220 were reported in the *Census*,

which was the first to enumerate stove manufacturing as a branch of business separate from general iron founding (Temin 1964, p. 38). Mott's innovation was thus a part of the gradual process of differentiation in the iron industry itself; a group of businesses was created that specialized in manufacturing one product and serving only one kind of consumer, the householder.

Historians who have examined the history of the stove also have not looked at the history of the industry that was producing them (Giedion 1948; Wright 1964; Keep, n.d.; Pierce 1951), and historians who have examined the history of the industry (Temin 1964; Paskoff 1983) have almost never considered stove production as worthy of more than passing attention (railroad tracks, yes; stoves, no). Thus a perusal of the existing literature would not have led a scholar to the hypothesis that the history of the industry would have had such a significant impact on the history of the implement. I was initially able to see the value of combining these two perspectives by imagining a diagram such as the one illustrated in figure 4. This kind of consumer-focused diagram led me to evaluate the universe of choices that was open first to an eighteenth- and then to a nineteenth-century consumer, in terms of the consumption-production network in which such consumers might have been embedded. Who sold stoves? In 1760? In 1860? At what price? Were there wholesalers? How were stoves transported? How were they used on a daily basis in the home? Only after asking questions of this sort did it occur to me that the reason for the failure of the stove in the eighteenth century (and its subsequent success in the nineteenth) might have had something to do, not with the technical character of the implement, but with its price; only then did I come to realize that what was "better" in technical terms was not necessarily "better" in consumption terms.

Using Networks to Generate Hypotheses

Such an analysis—focused on the consumer, extending its causal reach into other socioeconomic realms, open to various criteria for "betterness"—seems to me to be essential in making sense out of the history not only of stove technology but of all technologies. All technologies have consumers, and all technological development is oriented toward a positive consumption decision, whether the ultimate consumers are located in the consumption domain (as householders are) or in some other domain (wholesale, retail, or production). Different kinds of consumer, making choices about artifacts other than stoves in time periods other than the ones already dis-

cussed, would no doubt need to be sketched in quite different ways; but the basic principles on which such a network diagram might be constructed need not alter. One needs to move from the consumer domain to the household domain and to evaluate the ways in which the special social and physical relations of the household might influence consumption choices; then one should move from the household to the retail domain; then from the retail to the wholesale; and then from the wholesale to the production domain—all the while evaluating the pressures and the interests that may be affecting actors in each domain, understanding, in particular, that the criteria for "betterness" are different in each domain. One also needs to be aware that, although the network diagram may be focused on the individual consumer, consumers of different types can appear in almost any domain. These principles of diagram construction and analysis can be illustrated through two examples, again drawn from the history of home heating and cooking.

The gas cooking range did not diffuse quickly in the United States (Bacon 1942, pp. 75–80). Devices utilizing manufactured inflammable gases as fuel for cooking were on the market during the first half of the nineteenth century, and they became quite popular in England during the second half (Wright 1964; Ravetz 1968), but the gas range (which is, basically, not a terribly much more complicated device than a Bunsen burner) did not begin to supplant the coal cooking stove in the United States until roughly 1920. This was true, apparently, even in cities that were well supplied with manufactured gas. During the early decades of the twentieth century the American gas cooker also underwent several rather radical changes in design (Busch 1983), a sure sign that its market was expanding: Additional burners were provided (the earliest American models had only one or two); then ovens were added; then thermostats; then the surface was porcelainized; and finally the arrangement of burners, ovens, and broiling trays was altered so as to create the now familiar tabletop design. Why was the American consumer in 1918 (say) considerably more interested in purchasing a gas range than her or his forebears in 1870? And why were American consumers in 1870 considerably less interested in a gas cooker than their English cousins? A sketch such as the one illustrated in figure 5 can help at least to develop some hypotheses about how that question can be answered.

Figure 5 reminds us that the availability and the price of fuel may have something to do with the diffusion rates of implements that burn fuel; hence the difference between American and English acceptance of the gas cooker may have something to do with the spread of gas

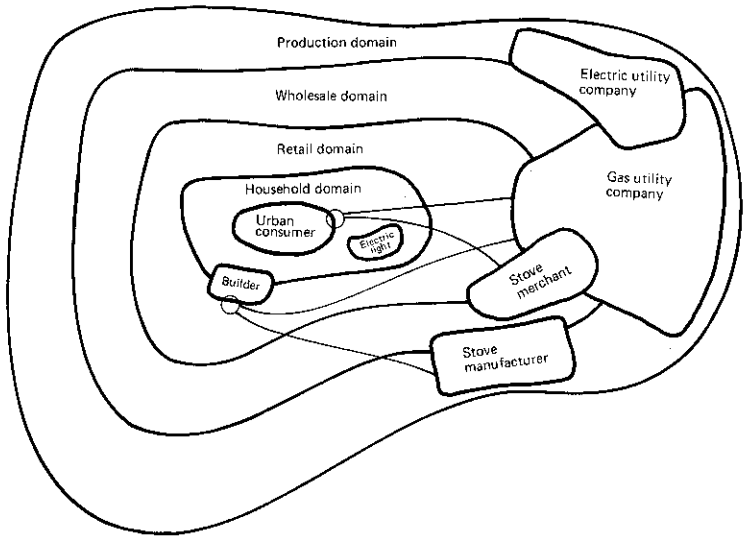

Figure 5
Network sketch for urban consumers considering purchase of a gas range c. 1920. The open circle represents the consumption junction.

service in English cities and the price of coal in both nations. In addition, the sketch also reminds us that in the early decades of the twentieth century there were two easily distinguishable consumers on the market for cooking devices in the United States. The first type was the traditional individual consumer, located in the household domain, who was purchasing directly for use. The second type was what might be called multiple consumers—landlords and real estate developers—who were purchasing for tenants and home buyers. My diagram needs, therefore, to include at least two consumption junctions. At the retail level gas stoves were being sold principally by the organizations that manufactured gas, that is, by the gas utility companies, who themselves appear to have been buying directly from the same kind of single product stove manufacturers who were also, simultaneously, producing coal stoves (as well as kerosene and oil cookers). The existence of the gas utility companies at the retail level reminds us, however, that this was precisely the historic period (between 1880 and 1920) in which the American gas companies were losing a considerable part of their market to a new competitor, the electric companies (Hughes 1983). And thereby hangs my hypothesis.

Perhaps the gas cooking range became popular in the United States, eventually displacing the coal stove, in large part because the gas utilities, under pressure to salvage a declining business, developed

various techniques to enlarge the market for their product: perhaps by selling the stoves at or below cost to individual consumers, perhaps by entering into wholesale arrangements with landlords and real estate developers, perhaps by creating advantageous rate schedules for householders who purchased gas ranges (and gas water heaters). All these techniques were tried by at least one major utility company, about which a history has been written (F. Collins 1934). The fact that the trade association of gas companies, the American Gas Association, is known to have sponsored developmental work on a thermostat for gas ranges, to have marketed gas ranges under its own name (AGA), and to have developed cooperative advertising schemes with the manufacturers of gas ranges makes this hypothesis even more likely (Busch 1983). At the least this hypothesis suggests a strategic research site at which the puzzle of the delayed diffusion of the American gas range might be solved: not the patent records, as one might initially think, but rather the records of the gas utility companies and the publications that were addressed to them (as well as, perhaps, the publications that served the community of apartment house owners and real estate developers). By itself, figure 5 cannot solve the riddle of the gas cooker, but it can help us to generate plausible hypotheses that can be investigated, as well as plausible hypotheses that, because they deal with the interests of actors who operate in different social domains, are sociologically meaningful.

Figure 6 is another sketch, this one constructed in an effort to understand the shift from coal to gas, oil, and electricity (for home heating) that occurred, in the United States, within two decades after the end of World War II. In 1940, 55 percent of all the residences in the country were heated with coal or coke (77 percent of the central heating systems); by 1950, just five years after the end of hostilities, that figure had dropped to 35 percent, and by 1970 to 2 percent of the total (US Bureau of the Census, 1940, 1950, 1970). If one can rely on the accuracy of the consumer price indexes, the price of coal remained roughly on a par with the price of electricity, gas, and fuel oil during this period. What, then, can explain the flight from coal?

Figure 6 reminds us that there was a housing boom in the two decades immediately following the end of World War II, which means that, during the years in which coal was declining as the fuel of choice for home heating, a significant portion of the consumers who were on the market for home heating systems were multiple consumers—builders and developers. As with the gas range, this suggestion produces a research strategy that involves discovering the nature of the relationship between builders of tract housing and

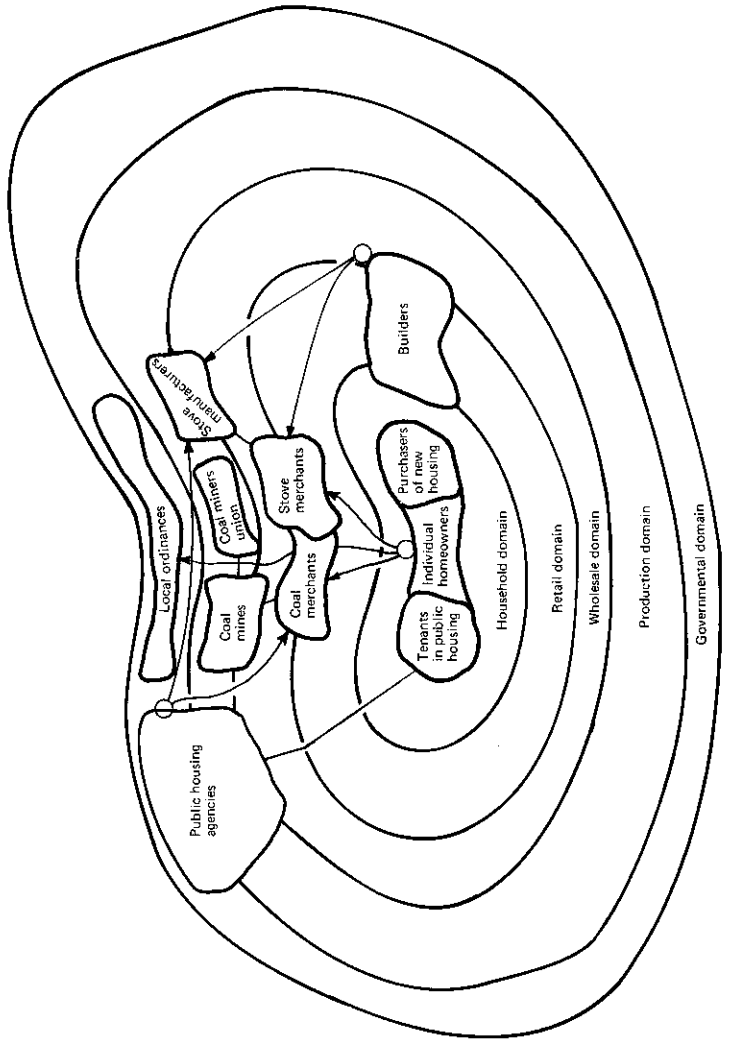

Figure 6
Network sketch of various consumers making decisions about coal-burning furnaces c. 1950. The open circle represents the consumption junction.

manufacturers of the presumably "more advanced" heating systems. But the sketch also reminds us of something more: Another significant domain must be added to figure 6 because some of the consumers on the market for home heating systems in the postwar years were neither individual nor multiple consumers but government agencies involved in the construction of public housing. Such governmental agencies may have had interests similar to those of the builders (the best heating system for the lowest cost), but they almost certainly had other interests as well: Some may have been required by local political conditions to opt for one fuel source rather than another (natural gas, for example, because the gas utility companies may have been politically powerful; or waste steam, for another example, because the municipality already owned electrical generating plants), and some may have been expressly prevented by local ordinance from using coal because of the threat of air pollution (Tarr and Lamperes 1980). In the production domain figure 6 also calls attention to a factor that might otherwise be overlooked: labor relations in coal mining. The Coal Miners Union, then under the leadership of John L. Lewis, was one of the most militant unions in the country, repeatedly calling its members out on strike between 1940 and 1960—and thus repeatedly reminding consumers (of all types) of the possibility of shortages in the supply of coal. Consumer preferences for heating systems that were automatic and clean no doubt also contributed to the rapid disappearance of coal stoves and furnaces in American homes, but figure 6 suggests the not unreasonable hypothesis that there were other factors in the decline of coal that are worthy of investigation.

Conclusion

In the preceding examples I have tried to explain why a focus on the consumer and on the network of relations in which the consumer is embedded can not only produce historical case studies that will be valuable grist for the mill of the sociology of technology but also generate hypotheses worthy of investigation. This form of analysis does not penetrate deeply into the processes of invention, innovation, development, and production (the initial stages in the evolution of a technological system), but it can open up the "black box" of diffusion (the final stage). Most artifacts have different forms (as well as different meanings) at each stage in the process that ends with use, so that an analysis that ignores the diffusion stage does so only at its peril. In any event, a consumer-focused analysis that deals properly with the diffusion stage can also shed important light on invention,

innovation, development, and production. This last feature was demonstrated in the case of the cast iron stove; focusing on the consumer revealed that the diffusion of the stove was dependent not so much on the inventions that altered the form of the stove but rather on innovations that altered the pattern of its production.

Consumer-focused analysis also satisfies many of the criteria of social constructivist sociology outlined by Pinch and Bijker. Technological systems that eventually fail (such as the open hearth) are put on an equal footing with those that eventually succeed (such as the cast iron stove) because, when seen from the perspective of those who were faced with making consumption choices between them in any given historical period, the outcome of the historical process (success or failure) becomes irrelevant to the analysis (because the consumer could not possibly have known what the outcome would be). Careful attention to the network in which the consumer is embedded necessitates that attention be paid to various social groups (and their interests) who might not have been otherwise considered (because of their apparent distance from the process), for example, the possible importance of public housing agencies in the postwar flight from coal.

At the least, this form of analysis suggests research strategies with which to broach any given historical topic, strategies that stand a good chance of producing sociologically sophisticated results, if by "sophisticated" we mean moving smoothly and sensibly between several levels of social structure. This is why no one who had attended only to the historical literature on the evolution of the stove could possibly have succeeded in constructing an explanation for its popularity in the United States in the nineteenth century that would be satisfying to an inquisitive sociologist; to be admissible, such an explanation requires attention not just to the history of the artifact itself but also to economic history (the price of fuels), demographic history (growth of cities, western expansion), and industrial history (alterations in iron production).

Yet one more virtue, at least to my mind, of consumer-focused analysis is that it allows room for the one characteristic without which no sociological or historical explanation should be taken seriously: the "unintended consequence." By detailing the network of social relations in which a consumer is embedded, this form of analysis reminds us that different social groups, acting in what they perceive to be their own best interests, can, because they are embedded in a complex network, produce effects that may be quite different, perhaps even diametrically opposed, to what they intended. The striking coal miners, for example, certainly did not intend their actions to under-

mine the market for coal, but that may have been precisely what they ended up doing in the long run. Every perceptive historian understands that history is laden with unintended consequences—they are as inevitable as death and taxes—but few sociological models have been adept at generating explanations for them, especially not in the history and sociology of technology. Network analyses (no matter what they are focused on) have the potential for bridging the gap, often gaping, between historians who like to tell good stories and sociologists who would like to turn those stories into case studies.

Note

1. The material summarized in this section is derived from my book (1983, ch. 3, 4), as well as from the following works: Bacon (1942), Ferguson (1974a), Giedion (1948), Handlin (1980), Keep (1916), Peirce (1951), Strasser (1982), and Wright (1964).

Seeing with Sound: A Study of the Development of Medical Images

Edward Yoxen

This chapter is a contribution to a growing debate on the sociology of technological innovation. It is organized around a case study that describes some of the stages in the origination of a medical technology, the ultrasound scanner. In particular, I discuss differing ways of trying to generate two-dimensional images using high-frequency sound waves in the 1940s and 1950s. Some of these attempts were productive, and some were unsuccessful, in the sense that no fully functional equipment that could perform to the standards of diagnostic accuracy required was produced by the group concerned. However, to write of success and failure in this way only poses the problem to be explained. That is to say, the variation in design objectives, development strategy, institutional and professional background, and tenacity in pursuing the research objectives forces us, first, to ask what it means when one says that a particular technological artifact "works" and, second, to try to explain both success and failure without taking the definition of either as self-evident. As Pinch and Bijker (1984) have argued, one of the lessons of the sociology of scientific knowledge for the sociology of technology is that the selection of technological forms early in the innovation cycle and the "stabilization" of such forms are social phenomena requiring explanation, analogous to the formation of a consensus in science. Questions of inventive success and failure can be made sense of only by reference to the purposes of the people concerned.

In the case of clinical ultrasound we may be tempted to think of doctors and engineers as being the only people whose perceptions of innovative success would be important. If a piece of equipment generates information of demonstrable diagnostic value, then we could say that it "works." However, those asked by doctors to operate the equipment may find it burdensome or demeaning to do so, and their enthusiasm for and evaluation of the technology will differ. Thus in some UK hospitals midwives resist the idea that they should