THE HOMEBREW INDUSTRIAL REVOLUTION

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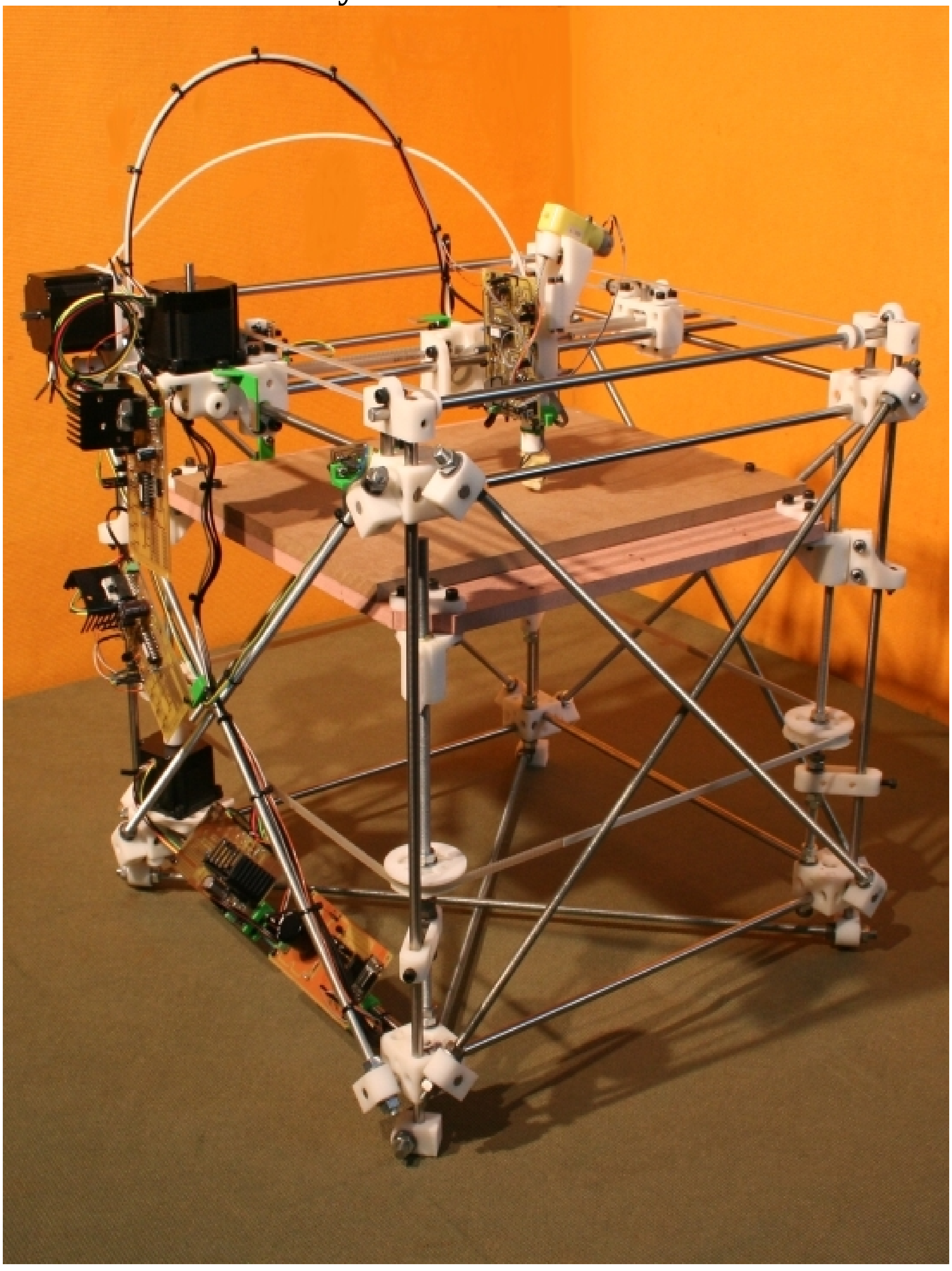

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Neighborhood and Backyard Industry

A recurring theme among early writers on decentralized production was the community workshop, and its use in particular for repair and recycling. Even in the 1970s, when the price of the smallest machine tools was much higher in real terms, it was feasible by means of cooperative organization to spread the capital outlay cost over a large pool of users.

Kirkpatrick Sale speculated that neighborhood recycling and repair centers would put back into service the almost endless supply of defunct appliances currently sitting in closets or basements; as well as serving as "remanufacturing centers" for (say) diesel engines and refrigerators.[1]

Writing along similar lines, Colin Ward suggested "the pooling of equipment in a neighborhood group."

> Suppose that each member of the group had a powerful and robust basic tool, while the group as a whole had, for example, a bench drill, lathes and a saw bench to relieve the members from the attempt to cope with work which required these machines with inadequate tools of their own, or wasting their resources on under-used individually-owned plant. This in turn demands some kind of building to house the machinery: the Community Workshop.
>
> But is the Community Workshop idea nothing more than an aspect of the leisure industry, a compensation for the tedium of work?[2]

In other words, is it just a "hobby"? Ward argued, to the contrary, that it would bridge the growing gap between the worlds of work and leisure by making productive activity in one's free time a source of real use-value.

> Could [the unemployed] make a livelihood for themselves today in the community workshop? If the workshop is conceived merely as a social service for 'creative leisure' the answer is that it would probably be against the rules.... But if the workshop were conceived on more imaginative lines than any existing venture of this kind, its potentialities could become a source of livelihood in the truest sense. In several of the New Towns in Britain, for example, it has been found necessary and desirable to build groups of small workshops for individuals and small businesses engaged in such work as repairing electrical equipment or car bodies, woodworking and the manufacture of small components. The Community Workshop would be enhanced by its cluster of separate workplaces for 'gainful' work. Couldn't the workshop become the community factory, providing work or a place for work for anyone in the locality who wanted to work that way, not as an optional extra to the economy of the affluent society which rejects an increasing proportion of its members, but as one of the prerequisites of the worker-controlled economy of the future?
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> Keith Paton..., in a far-sighted pamphlet addressed to members of the Claimants' Union, urged them not to compete for meaningless jobs in the economy which has thrown them out as redundant, but to use their skills to serve their own community. (One of the characteristics of the affluent world is that it denies its poor the opportunity to feed, clothe, or house *themselves*, or to meet their own and their families' needs, except from grudgingly doled-out welfare payments). He explains that:
>
> *...[E]lectrical power and 'affluence' have brought a spread of intermediate machines, some of them very sophisticated, to ordinary working class communities. Even if they do not own them (as many claimants do not) the possibility exists of borrowing them from neighbours, relatives, ex-workmates. Knitting and sewing*

1 Kirkpatrick Sale, *Human Scale* (New York: Coward, McCann, & Geoghegan, 1980), p. 406.
2 Colin Ward, *Anarchy in Action* (London: Freedom Press, 1982), p. 94.

machines, power tools and other do-it-yourself equipment comes in this category. Garages can be converted into little workshops, home-brew kits are popular, parts and machinery can be taken from old cars and other gadgets. If they saw their opportunity, trained metallurgists and mechanics could get into advanced scrap technology, recycling the metal wastes of the consumer society for things which could be used again regardless of whether they would fetch anything in a shop. Many hobby enthusiasts could begin to see their interests in a new light.[3]

Karl Hess also discussed community workshops—or as he called them, "shared machine shops”—in *Community Technology*.

> The machine shop should have enough basic tools, both hand and power, to make the building of demonstration models or test facilities a practical and everyday activity. The shared shop might just be part of some other public facility, used in its off hours. Or the shop might be separate and stocked with cast-off industrial tools, with tools bought from government surplus through the local school system... Work can, of course, be done as well in home shops or in commercial shops of people who like the community technology approach....
>
> Thinking of such a shared workshop in an inner city, you can think of its use... for the maintenance of appliances and other household goods whose replacement might represent a real economic burden in the neighborhood....
>
> ...The machine shop could regularly redesign cast-off items into useful ones. Discarded refrigerators, for instance, suggest an infinity of new uses, from fish tanks, after removing doors, to numerous small parts as each discarded one is stripped for its components, which include small compressors, copper tubing, heat transfer arrays, and so on. The same goes for washing machines....[4]

Sharing is a way of maximizing the utilization of idle productive goods owned by individuals. Just about any tool or appliance you need for a current project, but lack, is probably gathering dust on the shelf of someone within a few blocks of where you live. If the pooling of such idle resources doesn't seem like much of a deal for the person with the unused appliances, keep in mind first that he isn't getting anything at all out of them now, second that he may trade access to them for access to other people's tools that *he* needs, and third that the arrangement may increase the variety of goods and services he has to choose from outside the wage system.

The same idea has appeared more recently in the San Francisco Bay area, albeit in a commercial rather than communitarian form, as TechShop:[5]

> TechShop is a 15,000 square-foot membership-based workshop that provides members with access to tools and equipment, instruction, and a creative and supportive community of like-minded people so you can build the things you have always wanted to make....
>
> TechShop provides you with access to a wide variety of machinery and tools, including milling machines and lathes, welding stations and a CNC plasma cutter, sheet metal working equipment, drill presses and band saws, industrial sewing machines, hand tools, plastic and wood working equipment including a 4' x 8' ShopBot CNC router, electronics design and fabrication facilities, Epilog laser cutters, tubing and metal bending machines, a Dimension SST 3-D printer, electrical supplies and tools, and pretty much everything you'd ever need to make just about anything.

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3 Keith Paton, *The Right to Work or the Fight to Live?* (Stoke-on-Trent, 1972), in Ward, *Anarchy in Action*, pp. 108-109.
4 Karl Hess, *Community Technology* (New York, Cambridge, Hagerstown, Philadelphia, San Francisco, London, Mexico City, Sao Paulo, Sydney: Harper & Row, Publishers, 1979), pp. 96-97.
5 <http://techshop.ws/>.

Hess linked his idea for a shared machine shop to another idea, "[s]imilar in spirit," the shared warehouse:

> A community decision to share a space in which discarded materials can be stored, categorized, and made easily available is a decision to use an otherwise wasted resource....
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> The shared warehouse... should collect a trove of bits and pieces of building materials.... There always seems to be a bundle of wood at the end of any project that is too good to burn, too junky to sell, and too insignificant to store. Put a lot of those bundles together and the picture changes to more and more practical possibilities of building materials for the public space.
>
> Spare parts are fair game for the community warehouse. Thus it can serve as a parts cabinet for the community technology experimenter....
>
> A problem common to many communities is the plight of more resources leaving than coming back in.... The shared work space and the shared warehouse space involve a community in taking a first look at this problem at a homely and nonideological level.[6]

This ties in closely with Jane Jacobs' recurring themes of the development of local, diversified economies through the discovery of creative uses for locally generated waste and byproducts, and the use of such innovative technologies to replace imports.[7]

The potential for such common workspaces increases by an order of magnitude or more, of course, with the kinds of small, cheap, computerized machine tools we will consider later in this paper.

The building, bottom-up, of local economies based on small-scale production with multiple-purpose machinery might well take place piecemeal, beginning with such small shops, at first engaged primarily in repair and remanufacture of existing machinery and appliances. As Peak Oil and the degradation of the national transportation system cause corporate logistic chains for spare parts to dry up, small garage and backyard machine shops may begin out of sheer necessity to take up the slack, custom-machining the spare parts needed to keep aging appliances in operation. From this, the natural progression would be to farming out the production of components among a number of such small shops, and perhaps designing and producing simple appliances from scratch. (An intermediate step might be “mass customization,” the custom design of modular accessories for mass-produced platforms.) In this manner, networked production of spare parts by small shops might be the foundation for a new industrial revolution.

As Jacobs described it, the Japanese bicycle industry had its origins in just such networking between custom producers of spare parts.

> To replace these imports with locally made bicycles, the Japanese could have invited a big American or European bicycle manufacturer to establish a factory in Japan... Or the Japanese could have built a factory that was a slavish imitation of a European or American bicycle factory. They would have had to import most or all of the factory's machinery, as well as hiring foreign production managers or having Japanese production managers trained abroad....
>
> ...[Instead], shops to repair [imported bicycles] had sprung up in the big cities.... Imported spare parts

6 Hess, *Community Technology*, pp. 96-98.
7 Jane Jacobs, *The Economy of Cities* (New York: Vintage Books, 1969, 1970)

> were expensive and broken bicycles were too valuable to cannibalize the parts. Many repair shops thus found it worthwhile to make replacement parts themselves—not difficult if a man specialized in one kind of part, as many repairmen did. In this way, groups of bicycle repair shops were almost doing the work of manufacturing entire bicycles. That step was taken by bicycle assemblers, who bought parts, on contract, from repairmen: the repairmen had become "light manufacturers."[8]

Karl Hess and David Morris, in *Neighborhood Power*, suggested a progression from retail to repair to manufacturing as the natural model for a transition to relocalized manufacturing. They wrote of a process by which "repair shops begin to transform themselves into basic manufacturing facilities..."[9] Almost directly echoing Jacobs, they envisioned a bicycle collective's retail shop adding maintenance facilities, and then:

> After a number of people have learned the skills in repairs in a neighborhood, a factory could be initiated to produce a few vital parts, like chains or wheels or tires. Finally, if the need arises, full-scale production of bicycles could be attempted.

The same process could be replicated in many areas of production. Retail collectives might support community-supported agriculture as a primary source of supply, followed by a small canning factory and then by a glass recycling center to trade broken bottles and jars for usable ones on an arrangement with the bottling companies.[10] Again, the parallels with Jane Jacobs are striking:

> Cities that replace imports significantly replace not only finished goods but, concurrently, many, many items of producers' goods and services. They do it in swiftly emerging, logical chains. For example, first comes the local processing of fruit preserves that were formerly imported, then the production of jars or wrappings formerly imported for which there was no local market of producers until the first step had been taken. Or first comes the assembly of formerly imported pumps for which, once the assembly step has been taken, parts are imported; then the making of parts for which metal is imported; then possibly even the smelting of metal for these and other import-replacements. The process pays for itself as it goes along. When Tokyo went into the bicycle business, first came repair work cannibalizing imported bicycles, then manufacture of some of the parts most in demand for repair work, then manufacture of still more parts, finally assembly of whole, Tokyo-made bicycles. And almost as soon as Tokyo began exporting bicycles to other Japanese cities, there arose in some of those customer cities much the same process of replacing bicycles imported from Tokyo, ...as had happened with many items sent from city to city in the United States.[11]

A directly analogous process of import substitution can take place in the informal economy, with production for barter at the household and neighborhood level using household capital goods (about which more below) replacing the purchase of consumption goods in the wage economy.

Paul and Percival Goodman wrote, in *Communitas*, of the possibility of decentralized machining of parts by domestic industry, given the universal availability of power and the ingenuity of small machinery, coupled with assembly at a centralized location. It is, they wrote, "almost always cheaper to transport material than men."[12]

A good example of this phenomenon in practice is the Japanese "shadow factories" during World

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8 Ibid., pp. 63-64.

9 Karl Hess and David Morris, *Neighborhood Power: The New Localism* (Boston: Beacon Press, 1975), p. 69.

10 Ibid., p. 142.

11 Jacobs, *Cities and the Wealth of Nations: Principles of Economic* Life (New York: Vintage Books, 1984), p. 38.

12 Paul and Percival Goodman, *Communitas: Means of Livelihood and Ways of Life* (New York: Vintage Books, 1947, 1960), p. 83.

War II. Small shops attached to family homes played an important role in the Japanese industrial economy, according to Nicholas Wood. Many components and subprocesses were farmed out for household manufacture, in home shops consisting of perhaps a few lathes, drill presses or milling machines. In the war, the government had actively promoted such "shadow factories," distributing machine tools in workers' homes in order to disperse concentrated industry and reduce its vulnerability to American strategic bombing.[13] After the war, the government encouraged workers to purchase the machinery.[14] As late as the late fifties, such home manufacturers were still typically tied to particular companies, in what amounted to industrial serfdom. But according to Wood, by the time of his writing (1964), many home manufacturers had become free agents, contracting out to whatever firm made the best offer.[15] The overhead costs of home production, after the war, were reduced by standardization and modular design. For example, household optical companies found it impossible at first to produce and stock the many sizes of lenses and prisms for the many different models. But subsequently all Japanese companies standardized their designs to a few models.[16]

A similar shadow factory movement emerged in England during the war, as described by Goodman: "Home manufacture of machined parts was obligatory in England during the last war because of the bombings, and it succeeded."[17]

The Chinese pursued a system of localized production along roughly similar lines in the 1970s. According to Lyman van Slyke, they went a long way toward meeting their small machinery needs in this way. This was part of a policy known as the "Five Smalls," which involved agricultural communes supplying their own needs locally (hydroelectric energy, agro-chemicals, cement, iron and steel smelting, and machinery) in order to relieve large-scale industry of the burden. In the case of machinery, specifically, van Slyke gives the example of the hand tractor:

> ...[O]ne of the most commonly seen pieces of farm equipment is the hand tractor, which looks like a large rototiller. It is driven in the field by a person walking behind it.... This particular design is common in many parts of Asia, not simply in China. Now, at the small-scale level, it is impossible for these relatively small machine shops and machinery plants to manufacture all parts of the tractor. In general, they do not manufacture the engine, the headlights, or the tires, and these are imported from other parts of China. But the transmission and the sheet-metal work and many of the other components may well be manufactured at the small plants. Water pumps of a variety of types, both gasoline and electric, are often made in such plants, as are a variety of other farm implements, right down to simple hand tools. In addition, in many of these shops, a portion of plant capacity is used to build machine tools. That is, some lathes and drill presses were being used not to make the farm machinery but to make additional lathes and drill presses. These plants were thus increasing their own future capabilities at the local level. Equally important is a machinery-repair capability. It is crucial, in a country where there isn't a Ford agency just down the road, that the local unit be able to maintain and repair its own equipment. Indeed, in the busy agricultural season many small farm machinery plants close down temporarily, and the work force forms mobile repair units that go to the fields with spare parts and tools in order to repair equipment on the spot.
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> Finally, a very important element is the training function played in all parts of the small-scale industry spectrum, but particularly in the machinery plants. Countless times we saw two people on a machine. One was a journeyman, the regular worker, and the second was an apprentice, a younger person, often a young

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13 Nicholas Wood, "The 'Family Firm'—Base of Japan's Growing Economy," *The American Journal of Economics and Sociology*, vol. 23 no. 3 (1964), p. 316.
14 Ibid., p. 319.
15 Ibid., p. 317.
16 Ibid., p. 318.
17 Paul Goodman, *People or Personnel*, in *People or Personnel* and *Like a Conquered Province* (New York: Vintage Books, 1965, 1967, 1968), p. 95.

woman, who was learning to operate the machine.[18]

It should be stressed that this wasn't simply a repeat of the disastrous Great Leap Forward, which was imposed from above in the late 1950s. It was, rather, an example of local ingenuity in filling a vacuum left by the centrally planned economy. If anything, in the 1970s—as opposed to the 1950s—the policy was considered a painful concession to necessity, to be abandoned as soon as possible, rather than a vision pursued for its own sake. Van Slyke was told by those responsible for small-scale industry, "over and over again," that their goals were to move "from small to large, from primitive to modern, and from here-and-there to everywhere."[19] Aimin Chen, in 2002, reported that the government was actually cracking down on local production under the "Five Smalls" in order to reduce idle capacity in the beleaguered state sector.[20] The centrally planned economy under state socialism, like the corporate economy, can only survive by suppressing small-scale competition.

The raw materials for such relocalized production are already in place in most neighborhoods, to a large extent, in the form of unused or underused appliances, power tools gathering dust in basements and garages, and the like. It's all just waiting to be integrated onto a local economy, as soon as producers can be hooked up to needs, and people realize that every need met by such means reduces their dependence on wage labor by an equal amount—and probably involves less labor and more satisfaction than working for the money. The problem is figuring out what's lying around, who has what skills, and how to connect supply to demand. As Hess and Morris put it,

> In one block in Washington, D.C., such a survey uncovered plumbers, electricians, engineers, amateur gardeners, lawyers, and teachers. In addition, a vast number of tools were discovered; complete workshops, incomplete machine-tool shops, and extended family relationships which added to the neighborhood's inventory—an uncle in the hardware business, an aunt in the cosmetics industry, a brother teaching biology downtown. The organizing of a directory of human resources can be an organizing tool itself.[21]

Arguably the neighborhood workshop and the household microenterprise (which we will examine later in this study) achieve an optimal economy of scale, determined by the threshold at which a household producer good is fully utilized, but the overhead for a permanent hired staff and a stand-alone dedicated building is not required.

The various thinkers quoted above wrote on community workshops at a time when the true potential of small-scale production machinery was just starting to emerge.

The Expansion of the Desktop Revolution and Peer Production into the Physical Realm

We already saw, in C4SS Paper No. 2[22], how the desktop revolution has destroyed initial capital outlay costs for production in the cultural and information industries, and radically altered the balance between human and physical capital.

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18 Lyman P. van Slyke, "Rural Small-Scale Industry in China," in Richard C. Dorf and Yvonne L. Hunter, eds., *Appropriate Visions: Technology the Environment and the Individual* (San Francisco: Boyd & Fraser Publishing Company, 1978) pp. 193-194.
19 Ibid., p. 196.
20 Aimin Chen, "The structure of Chinese industry and the impact from China's WTO entry," *Comparative Economic Studies* (Spring 2002) <http://www.entrepreneur.com/tradejournals/article/print/86234198.html>.
21 Hess and Morris, *Neighborhood Power*, p. 127.
22 Carson, "'Intellectual Property': A Libertarian Critique," Center for a Stateless Society Research Paper No. 2 (Second Quarter 2009) <http://c4ss.org/wp-content/uploads/2009/05/intellectual-property-a-libertarian-critique.pdf>.

Since the desktop revolution of the 1970s, computers have promised to be a decentralizing force on the same scale as electrical power a century earlier. The computer, according to Michel Piore and Charles Sabel, is “a machine that meets Marx's definition of an artisan's tool: it is an instrument that responds to and extends the productive capacities of the user.”

> It is therefore tempting to sum the observations of engineers and ethnographers to the conclusion that technology has ended the domination of specialized machines over un- and semiskilled workers, and redirected progress down the path of craft production. The advent of the computer restores human control over the production process; machinery again is subordinated to the operator.[23]

As Johan Soderberg argues, “[t]he universally applicable computer run on free software and connected to an open network... have [sic] in some respects leveled the playing field. Through the global communication network, hackers are matching the coordinating and logistic capabilities of state and capital.”[24]

As we saw in C4SS Paper No. 2, the computer itself is the primary item of capital equipment in a growing number of industries, like music, desktop publishing and software design. The desktop computer, supplemented by assorted packages of increasingly cheap printing or sound editing equipment, is capable of doing what previously required a minimum investment of hundreds of thousands of dollars.

But although peer production first emerged in the immaterial realm—i.e., information industries like software and entertainment—its transferability to the realm of physical production is also a matter of great interest.

1. Open-Source Design: Removal of Proprietary Rents from the Design Stage, and Modular Design. One effect of the shift in importance from tangible to intangible assets is the growing portion of product prices that reflects embedded rents on “intellectual property” and other artificial property rights, rather than the material costs of production.

The radical nature of the peer economy, especially as “intellectual property” becomes increasingly unenforceable, lies in its potential to cause the portion of existing commodity price that results from such embedded rents to implode.

Open source hardware refers, at the most basic level, to the development and improvement of designs for physical goods on an open source basis, with no particular mode of physical production being specified. The design stage ceases to be a source of proprietary value, but the physical production stage is not necessarily affected. To take it in Richard Stallman's terms, 'free speech” only affects the portion of beer's price that results from the cost of a proprietary design phase: open source hardware means the design is free as in free speech, not free beer. Although the manufacturer is not hindered by patents on the design, he must still bear the costs of physical production. Edy Ferreira defined open-source hardware as

> any piece of hardware whose manufacturing information is distributed using a license that provides specific

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23 Michael J. Piore and Charles F. Sabel, *The Second Industrial Divide: Possibilities for Prosperity* (New York: HarperCollins, 1984), p. 261.
24 Johan Soderberg, *Hacking Capitalism: The Free and Open Source Software Movement* (New York and London: Routledge, 2008), p. 2.

> rights to users without the need to pay royalties to the original developers. These rights include freedom to use the hardware for any purpose, freedom to study and modify the design, and freedom to redistribute copies of either the original or modified manufacturing information....
>
> In the case of open source software (OSS), the information that is shared is software code. In OSH, what is shared is hardware manufacturing information, such as... the diagrams and schematics that describe a piece of hardware.[25]

At the simplest level, a peer network may develop a product design and make it publicly available; it may be subsequently built by any and all individuals or firms with the necessary production machinery, without coordinating their efforts with the original designer(s). A conventional manufacturer may produce open source designs, with feedback from the user community providing the main source of innovation.

Karim Lakhani describes this general phenomenon, the separation of open-source design from an independent production stage, as "communities driving manufacturers out of the design space," with

> users innovating and developing products that can out compete traditional manufacturers. But this effect is not just limited to software. In physical products..., users have been shown to be the dominant source of functionally novel innovations. Communities can supercharge this innovation mechanism. And may ultimately force companies out of the product design space. Just think about it—for any given company—there are more people outside the company that have smarts about a particular technology or a particular use situation then [sic] all the R&D engineers combined. So a community around a product category may have more smart people working on the product then [sic] the firm it self. So in the end manufacturers may end up doing what they are supposed to—manufacture—and the design activity might move... into the community.[26]

As one example, Vinay Gupta has proposed a large-scale library of open-source hardware designs as an aid to international development:

> An open library of designs for refrigerators, lighting, heating, cooling, motors, and other systems will encourage manufacturers, particularly in the developing world, to leapfrog directly to the most sustainable technologies, which are much cheaper in the long run. Manufacturers will be encouraged to use the efficient designs because they are free, while inefficient designs still have to be paid for. The library could also include green chemistry and biological solutions to industry challenges.... This library should be free of all intellectual property restrictions and open for use by any manufacturer, in any nation, without charge.[27]

One item of his own design, the Hexayurt, is "a refugee shelter system that uses an approach based on "autonomous building" to provide not just a shelter, but a comprehensive family support unit which includes drinking water purification, composting toilets, fuel-efficient stoves and solar electric

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25 "Open Source Hardware," *P2P Foundation Wiki* <http://www.p2pfoundation.net/Open_Source_Hardware>.

26 Karim Lakhana, "Communities Driving Manufacturers Out of the Design Space," *The Future of Communities Blog*, March 25, 2007 <http://www.futureofcommunities.com/2007/03/25/communities-driving-manufacturers-out-of-the-design-space/>.

27 Vinay Gupta, "Facilitating International Development Through Free/Open Source," <http://guptaoption.com/5.open_source_development.php> Quoted from Beatrice Anarow, Catherine Greener, Vinay Gupta, Michael Kinsley, Joanie Henderson, Chris Page and Kate Parrot, Rocky Mountain Institute, "Whole-Systems Framework for Sustainable Consumption and Production." Environmental Project No. 807 (Danish Environmental Protection Agency, Ministry of the Environment, 2003), p. 24. <http://files.howtolivewiki.com/A%20Whole%20Systems%20Framework%20for%20Sustainable%20Production%20and%20Consumption.pdf>

lighting."[28] The basic construction materials for the floor, walls and roof cost about $200.[29]

Michel Bauwens, of the P2P foundation, provides a small list of some of the more prominent open-design projects:

> The Grid Beam Building System, at http://www.p2pfoundation.net/Grid_Beam_Building_Syste
> The Hexayurt, at http://www.p2pfoundation.net/Hexayurt
> Movisi Open Design Furniture, at http://www.p2pfoundation.net/Movisi_Open_Design_Furniture
> Open Cores, at http://www.p2pfoundation.net/Open_Cores and other Open Computing Hardware, at http://www.p2pfoundation.net/Open_Hardware
> Open Source Green Vehicle, at http://www.p2pfoundation.net/Open_Source_Green_Vehicle
> Open Source Scooter http://www.p2pfoundation.net/Open_Source_Scooter
> The Ronja Wireless Device at http://www.p2pfoundation.net/Twibright_Ronja_Open_Wireless_Networking_Device
> Open Source Sewing patterns, at http://www.p2pfoundation.net/Open_Source_Sewing_Patterns
> Velomobiles http://www.p2pfoundation.net/Open_Source_Velomobile_Development_Project
> Open Energy http://www.p2pfoundation.net/SHPEGS_Open_Energy_Project[30]

One of the most ambitious attempts at such an open design project is Open Source Ecology, which is developing an open-source, virally reproducible, vernacular technology-based "Open Village Construction Set" in its experimental site at Factor e Farm.[31] (Of course OSE is also directly involved in the physical implementation of its own designs; it is a manufacturing as well as a design network.) We will examine it in greater detail in the Appendix.

A more complex scenario involves the coordination of an open source design stage with the production process, with the separate stages of production distributed and coordinated by the same peer network that created the design. Dave Pollard provides one example:

> Suppose I want a chair that has the attributes of an Aeron without the $1800 price tag, or one with some additional attribute (e.g. a laptop holder) the brand name doesn't offer? I could go online to a Peer Production site and create an instant market, contributing the specifications..., and, perhaps a maximum price I would be willing to pay. People with some of the expertise needed to produce it could indicate their capabilities and self-organize into a consortium that would keep talking and refining until they could meet this price.... Other potential buyers could chime in, offering more or less than my suggested price. Based on the number of 'orders' at each price, the Peer Production group could then accept orders and start manufacturing....
>
> As [Erick] Schonfeld suggests, the intellectual capital associated with this instant market becomes part of the market archive, available for everyone to see, stripping this intellectual capital cost, and the executive salaries, dividends and corporate overhead out of the cost of this and other similar product requests and fulfillments, so that all that is left is the lowest possible cost of material, labour and delivery to fill the order. And the order is exactly what the customer wants, not the closest thing in the mass-producer's warehouse.[32]

In any case, the removal of proprietary control over the implementation of designs means that the

28 <http://www.p2pfoundation.net/Hexayurt>.
29 <http://hexayurt.com/>.
30 Michel Bauwens, "What kind of economy are we moving to? 3. A hierarchy of engagement between companies and communities," *P2P Foundation Blog*, October 5, 2007 <http://blog.p2pfoundation.net/what-kind-of-economy-are-we-moving-to-3-a-hierarchy-of-engagement-between-companies-and-communities/2007/10/05>.
31 "Clarifying OSE Vision," *Factor e Farm Weblog*, September 8, 2008 <http://openfarmtech.org/weblog/?p=325>.
32 Dave Pollard, "Peer Production," *How to Save the World*, October 28, 2005 <http://blogs.salon.com/0002007/2005/10/28.html#a1322>.

production phase will be subject to competitive pressure to adopt the most efficient production methods—a marked departure from the present, where “intellectual property” enables privileged producers to set prices as a cost-plus markup based on whatever inefficient production methods they choose.

The most ambitious example of an open-source physical production project is the open source car, or “OScar.”

> Can open-source practices and approaches be applied to make hardware, to create tangible and physical objects, including complex ones? Say, to build a car?...
>
> Markus Merz believes they can. The young German is the founder and "maintainer" (that's the title on his business card) of the OScar project, whose goal is to develop and build a car according to open-source (OS) principles. Merz and his team aren't going for a super-accessorized SUV—they're aiming at designing a simple and functionally smart car. And, possibly, along the way, reinvent transportation.[33]

As of June 2009, the unveiling of a prototype—a two-seater vehicle powered by hydrogen fuel cells—was scheduled in London.[34]

Well, actually there's a fictional example of an open-source project even more ambitious than the OScar: the open-source moon project, a volunteer effort of a peer network of thousands, in Craig DeLancy's "Openshot." The project's ship (the *Stallman*), built largely with Russian space agency surplus, beats a corporate-funded proprietary project to the moon.[35]

A slightly less ambitious open-source manufacturing project, and probably more relevant to the needs of most people in the world, is Open Source Ecology's open-source tractor (LifeTrac). It's designed for inexpensive manufacture, with modularity and easy disassembly, for lifetime service and low cost repair. It includes, among other things, a well-drilling module, and is designed to serve as a prime mover for machinery like OSE's Compressed Earth Block Press and saw mill.[36]

When physical manufacturing is stripped of the cost of proprietary design and technology, and the consumer-driven, pull model of distribution strips away most of the immense marketing cost, we will find that the portion of price formerly made up of such intangibles will implode, and the remaining price based on actual production cost will be as much as an order of magnitude lower.

Just as importantly, open-source design reduces cost not only by removing proprietary rents from “intellectual property,” but by the substantive changes in design that it promotes. Eliminating patents removes legal barriers to the competitive pressure for interoperability and reparability. And interoperability and reparability promote the kind of modular design that is most conducive to networked production, with manufacture of components distributed among small shops producing a common design.

Modular design enables a peer network to break a physical manufacturing project down into discrete sub-projects, with many of the individual modules perhaps serving as components in more than one larger appliance. According to Christian Siefkes,

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33 Bruno Giussani, "Open Source at 90 MPH," *Business Week*, December 8, 2006 <http://www.businessweek.com/innovate/content/dec2006/id20061208_509041.htm?>. See also the OS Car website, <http://www.theoscarproject.org/>.
34 Lisa Hoover, “Riversimple to Unveil Open Source Car in London This Month,” *Ostatic*, June 11, 2009 <http://ostatic.com/blog/riversimple-to-unveil-open-source-car-in-london-this-month>.
35 Craig DeLancey, "Openshot," *Analog*, December 2006, pp. 64-74.
36 "LifeTrac," Open Source Ecology wiki <http://openfarmtech.org/index.php?title=LifeTrac>.

> Products that are modular, that can be broken down into smaller modules or components which can be produced independently before being assembled into a whole, fit better into the peer mode of production than complex, convoluted products, since they make the tasks to be handled by a peer project more manageable. Projects can build upon modules produced by others and they can set as their own (initial) goal the production of a specific module, especially if components can be used stand-alone as well as in combination. The Unix philosophy of providing lots of small specialized tools that can be combined in versatile ways is probably the oldest expression in software of this modular style. The stronger emphasis on modularity is another phenomenon that follows from the differences between market production and peer production. Market producers have to prevent their competitors from copying or integrating their products and methods of production so as not to lose their competitive advantage. In the peer mode, re-use by others is good and should be encouraged, since it increases your reputation and the likelihood of others giving something back to you....
>
> Modularity not only facilitates decentralized innovation, but should also help to increase the longevity of products and components. Capitalism has developed a throw-away culture where things are often discarded when they break (instead of being repaired), or when one aspect of them is no longer up-to-date or in fashion. In a peer economy, the tendency in such cases will be to replace just a single component instead of the whole product, since this will generally be the most labor-efficient option (compared to getting a new product, but also to manually repairing the old one).[37]

Siefkes is wrong only in referring to producers under the existing corporate system as “market producers,” since absent “intellectual property” as a legal bulwark to proprietary design, the market incentive would be toward designing products that were interoperable with other platforms, and toward competition in the design of accessories and replacement parts tailored to other companies' platforms. And given the absence of legal barriers to the production of such interoperable accessories, the market incentive would be to designing platforms as broadly interoperable as possible.

This process of modularization is already being promoted within corporate capitalism, although the present system is struggling mightily—and unsuccessfully—to keep itself from being torn apart by the resulting increase in productive forces. As Eric Hunting argues, the high costs of technical innovation, the difficulty of capturing value from it, and the mass customization or long tail market, taken together, create pressures for common platforms that can be easily customized between products, and for modularization of components that can be used for a wide variety of products. And Hunting points out, as we already saw in regard to flexible manufacturing networks in C4SS Paper No. 4, that the predominant "outsource everything" and "contract manufacturing" model increasingly renders corporate hubs obsolete, and makes it possible for contractees to circumvent the previous corporate principals and undertake independent production on their own account.

> Industrial ecologies are precipitated by situations where traditional industrial age product development models fail in the face of very high technology development overheads or very high demassification in design driven by desire for personalization/customization producing Long Tail market phenomenon [sic]. A solution to these dilemmas is modularization around common architectural platforms in order to compartmentalize and distribute development cost risks, the result being 'ecologies' of many small companies independently and competitively developing intercompatible parts for common product platforms—such as the IBM PC.
>
> The more vertical the market profile for a product the more this trend penetrates toward production on an individual level due [to] high product sophistication coupled to smaller volumes.... Competitive

37 Christian Siefkes, *From Exchange to Contributions: Generalizing Peer Production into the Physical World* Version 1.01 (Berlin, October 2007), pp. 104-105.

> contracting regulations in the defense industry (when they're actually respected...) tend to, ironically, turn many kinds of military hardware into open platforms by default, offering small businesses a potential to compete with larger companies where production volumes aren't all that large to begin with. Consequently, today we have a situation where key components of some military vehicles and aircraft are produced on a garage-shop production level by companies with fewer than a dozen employees.
>
> All this represents an intermediate level of industrial demassification that is underway today and not necessarily dependent upon open source technology or peer-to-peer activity but which creates a fertile ground for that in the immediate future and drives the complementary trend in the miniaturization of machine tools.[38]

In other words, the further production cost falls relative to the costs of design, the greater the economic incentive to modular design as a way of defraying design costs over as many products as possible.

Hunting added, in an email to the Open Manufacturing list, that this process—"the modularization of product design, which results in the replacement of designs by platforms and the competitive commoditization of their components"—

> is the reason why computers, based on platforms for modular commodity components, have evolved so rapidly compared to every other kind of industrial product and why the single-most advanced device the human race has ever produced is now something most anyone can afford and which a child can assemble in minutes from parts sourced around the world.[39]

Michel Bauwens, in commenting on Hunting's remarks, notes among the "underlying trends... supporting the emergence of peer production in the physical world,"

> the 'distribution' of production capacity, i.e. lower capital requirements and modularisation making possible more decentralized and localized production, which may eventually be realized through the free self-aggregation of producers.[40]

Modular design is an example of stigmergic coordination. As defined in the Wikipedia entry, stigmergy is

> a mechanism of spontaneous, indirect coordination between agents or actions, where the trace left in the environment by an action stimulates the performance of a subsequent action, by the same or a different agent. Stigmergy is a form of self-organization. It produces complex, apparently intelligent structures, without need for any planning, control, or even communication between the agents. As such it supports efficient collaboration between extremely simple agents, who lack any memory, intelligence or even awareness of each other.[41]

The development of the platform is a self-contained and entirely self-directed action by an individual or a peer design group. Subsequent modules are developed with reference to the platform, but the design of each module is likewise entirely independent and self-directed; no coordination with the platform

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38 Hunting comment under Michel Bauwens, "Phases for implementing peer production: Towards a Manifesto for Mutually Assured Production," P2P Foundation *Forum*, August 30, 2008 <http://p2pfoundation.ning.com/forum/topic/show?id=2003008%3ATopic%3A6275&page=1&commentId=2003008%3AComment%3A6377&x=1#2003008Comment6377>

39 Eric Hunting, "[Open Manufacturing] Re: Why automate? and opinions on Energy Descent?" September 22, 2008 <http://groups.google.com/group/openmanufacturing/browse_thread/thread/1f40d031453b94eb>.

40 Michel Bauwens, "Contract manufacturing as distributed manufacturing," *P2P Foundation Blog*, September 11, 2008 <http://blog.p2pfoundation.net/contract-manufacturing-as-distributed-manufacturing/2008/09/11>.

41 "Stigmergy," *Wikipedia* <http://en.wikipedia.org/wiki/Stigmergy> (accessed September 29, 2009).

developer or the developers of other modules takes place. The effect is to break design down into numerous manageable units.

2. Reduced Transaction Costs of Aggregating Capital. We will consider the cheapening of actual physical tools in the next section. But even when the machinery required for physical production is still expensive, the reduction of transaction costs involved in aggregating funds is bringing on a rapid reduction in the cost of physical production. In addition, networked organization increases the efficiency of physical production by making it possible to pool more expensive capital equipment and make use of “spare cycles.” This possibility was hinted at by proposals for pooling capital outlays through cooperative organization even back in the 1970s, as we saw in the first section. But the rise of network culture takes it to a new loevel (which, again, we will consider in the next section). As a result, Stallman's distinction between “free speech” and “free beer” is eroding even when tools themselves are costly. Michel Bauwens writes:

> • P2P can arise not only in the immaterial sphere of intellectual and software production, but wherever there is access to distributed technology: spare computing cycles, distributed telecommunications and any kind of viral communicator meshwork.
>
> • P2P can arise wherever other forms of distributed fixed capital is [sic] available: such is the case for carpooling, which is the second mode of transportation in the U.S.....
>
> • P2P can arise wherever financial capital can be distributed. Initiatives such as the ZOPA bank point in that direction. Cooperative purchase and use of large capital goods are a possibility....[42]

As the reference to “distributed financial capital” indicates, the availability of crowdsourced and distributed means of aggregating dispersed capital is as important as the implosion of outlay costs for actual physical capital.

Jed Harris, at *Anomalous Presumptions* blog, reiterates Bauwens' point that peer production makes it possible to produce without access to large amounts of capital. “The change that enables widespread peer production is that today, an entity can become self-sustaining, and even grow explosively, with very small amounts of capital. As a result it doesn’t need to trade ownership for capital, and so it doesn’t need to provide any return on investment.”[43]

Charles Johnson adds that, because of the new possibilities the Internet provides for lowering the transaction costs entailed in networked mobilization of capital, peer production can take place even when significant capital investments are required—without relying on finance by large-scale sources of venture capital:

> it’s not just a matter of projects being able to expand or sustain themselves with little capital.... It’s also a matter of the way in which both emerging distributed technologies in general, and peer production projects in particular, facilitate the aggregation of dispersed capital—without it having to pass through a single capitalist chokepoint, like a commercial bank or a venture capital fund.... Meanwhile, because of the way that peer production projects distribute their labor, peer-production entrepreneurs can also take advantage of spare cycles on existing, widely-distributed capital goods—tools like computers, facilities like offices and houses, software, etc. which contributors own, which they still would have owned personally or

42 Bauwens, "The Political Economy of Peer Production," *CTheory*, December 2005 <http://www.ctheory.net/articles.aspx?id=499>.
43 Jed, "Capitalists vs. Entrepreneurs," *Anomalous Presumptions*, February 26, 2007 <http://jed.jive.com/?p=23>.

professionally whether or not they were contributing to the peer production project.... So it's not just a matter of cutting total aggregate costs for capital goods...; it's also, importantly, a matter of new models of aggregating the capital goods to meet whatever costs you may have, so that small bits of available capital can be rounded up without the intervention of money-men and other intermediaries.[44]

So network organization not only lowers the transaction costs of aggregating capital for the purchase of physical means of production, but also increases the utilization of the means of production when they are expensive.

3. Reduced Capital Outlays for Physical Production. As described so far, the open-source model only removes proprietary rents from the portion of the production process—the design stage—that has no material cost, and from the process of aggregating capital. As Stallman put it, to repeat, it's about "free speech" rather than "free beer." Simply removing proprietary rents from design, and removing all transaction costs from the free transfer of digital designs for automated production will have a revolutionary effect by itself. Marcin Jakubowski, of Factor e Farm, writes:

> The unique contribution of the information age arises in the proposition that data at one point in space allows for fabrication at another, using computer numerical control (CNC) of fabrication. This sounds like an expensive proposition, but that is not so if open source fabrication equipment is made available. With low cost equipment and software, one is able to produce or acquire such equipment at approximately $5k for a fully-equipped lab with metal working, cutting, casting, and electronics fabrication, assisted by open source CNC.[45]

But as Jakubowski's reference to the declining cost of fabrication equipment suggests, the revolution in open-source manufacturing goes beyond the design stage, and promises to change the way physical production itself is organized.

Even without the latest generation of low-cost digital fabrication machinery, the kind of flexible manufacturing network that exists in Emilia-Romagna or Shenzen is ideally suited to the open manufacturing philosophy. Tom Igoe writes:

> There are some obvious parallels here [in the *shanzhai* manufacturers of China] to the open hardware community. Businesses like Spark Fun, Adafruit, Evil Mad Scientist, Arduino, Seeed Studio, and others thrive by taking existing tools and products, re-combining them and repackaging them in more usable ways. We borrow from each other and from others, we publish our files for public use, we improve upon each others' work, and we police through licenses such as the General Public License, and continual discussion between competitors and partners. We also revise products constantly and make our businesses based on relatively small runs of products tailored to specific audiences.[46]

The intersection of the open hardware and open manufacturing philosophies with the current model of flexible manufacturing networks will be enabled, Igoe argues, by the availability of

> **Cheap tools.** Laser cutters, lathes, and milling machines that are affordable by an individual or a group. This is increasingly coming true. The number of colleagues I know who have laser cutters and mills in their

44 Charles Johnson, "Dump the rentiers off your back," *Rad Geek People's Daily*, May 29, 2008 <http://radgeek.com/gt/2008/05/29/dump_the/>.
45 Marcin Jakubowski, "OSE Proposal—Towards a World Class Open Source Research and Development Facility," v0.12, January 16, 2008 <http://openfarmtech.org/OSE_Proposal.doc> (accessed August 25, 2009).
46 Tom Igoe, "Idle speculation on the shan zhai and open fabrication," *hello* blog, September 4, 2009 <http://www.tigoe.net/blog/category/environment/295/>.

> living rooms is increasing (and their asthma is worsening, no doubt). There are some notable holes in the open hardware world that exist partially because the tools aren't there. Cheap injection molding doesn't exist yet, but injection molding services do, and they're accessible via the net. But when they're next door (as in Shenzen), you've got a competitive advantage: your neighbor.[47]

And the flexible manufacturing network, unlike the transnational corporate environment, is actively conducive to the sharing of knowledge and designs.

> **Open manufacturing information.** Manufacturers in this scenario thrive on adapting existing products and services. Call them knockoffs or call them new hybrids, they both involve reverse engineering something and making it fit your market. Reverse engineering takes time and money. When you're a mom & pop shop, that matters a lot more to you. If you've got a friend or a vendor who's willing to do it for you as a service, that helps. But if the plans for the product you're adapting are freely available, that's even better. In a multinational world, open source manufacturing is anathema. Why would Nokia publish the plans for a phone when they could dominate the market by doing the localization themselves? But in a world of networked small businesses, it spurs business. You may not have the time or interest in adapting your product for another market, but someone else will, and if they've got access to your plans, they'll be grateful, and will return the favor, formally or informally.[48]

The availability of modestly priced desktop manufacturing technology (about which we will see more immediately below), coupled with the promise of crowdsourced means of aggregating capital, has led to a considerable shift in opinion in the peer-to-peer community, as evidenced by Michel Bauwens:

> I used to think that the model of peer production would essentially emerge in the immaterial sphere, and in those cases where the design phase could be split from the capital-intensive physical production sphere....
>
> However, as I become more familiar with the advances in Rapid Manucturing [sic]... and Desktop Manufacturing..., I'm becoming increasingly convinced of the strong trend towards the distribution of physical capital.
>
> If we couple this with the trend towards the direct social production of money (i.e. the distribution of financial capital...) and the distribution of energy...; and how the two latter trends are interrelated..., then I believe we have very strong grounds to see a strong expansion of p2p-based modalities in the physical sphere.[49]

The conditions of physical production have, in fact, experienced a transformation almost as great as that which digital technology has brought about on immaterial production. The "physical production sphere" itself has become far less capital-intensive. If the digital revolution has caused an implosion in the physical capital outlays required for the information industries, the revolution in desktop production tools promises an analogous effect almost as great on many kinds of manufacturing. The radical reduction in the cost of machinery required for many kinds of manufacturing has eroded Stallman's distinction between "free speech" and "free beer." Or as Chris Anderson put it, "Atoms would like to be free, too, but they're not so pushy about it."[50]

The same production model sweeping the information industries, networked organization of people who own their own production tools, is expanding into physical manufacturing. A revolution in cheap,

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47 Ibid.

48 Ibid.

49 Michel Bauwens post to Institute for Distributed Creativity email list, May 7, 2007. <https://lists.thing.net/pipermail/idc/2007-May/002479.html>

50 Chris Anderson, *Free: The Future of a Radical Price* (New York: Hyperion, 2009), p. 241.

general purpose machinery, and a revolution in the possibilities for networked design made possible by personal computers and network culture, according to Johann Soderberg, is leading to

> an extension of the dream that was pioneered by the members of the Homebrew Computer Club [i.e., a cheap computer able to run on the kitchen table]. It is the vision of a universal factory able to run on the kitchen table.... [T]he desire for a 'desktop factory' amounts to the same thing as the reappropriation of the means of production.[51]

Clearly, the emergence of cheap desktop technology for custom machining parts in small batches will greatly lower the overall capital outlays needed for networked physical production of light and medium consumer goods.

We've already seen the importance of the falling costs of small-scale production machinery made possible by the Japanese development of small CNC machines in the 1970s. That is the technological basis of the flexible manufacturing networks we examined in the last chapter.

When it comes to the “Homebrew” dream of an actual desktop factory, the most promising current development is the Fab Lab. The concept started with MIT's Center for Bits and Atoms. The original version of the Fab Lab included CNC laser cutters and milling machines, and a 3-D printer, for a total cost of around $50,000.[52]

Open-source versions of the Fab Lab have brought the cost down to around $2-5,000. One important innovation is the multimachine, an open-source, multiple-purpose machine tool that includes drill press, lathe and milling machine; it can be modified for computerized numeric control. The multimachine was originally developed by Pat Delaney, whose YahooGroup has grown into a design community and support network of currently over five thousand people.[53]

As suggested by the size of Delaney's YahooGroup membership, the multimachine has been taken up independently by open-source developers all around the world. The Open Source Ecology design community, in particular, envisions a Fab Lab which includes a CNC multimachine as "the central tool piece of a flexible workshop... eliminating thousands of dollars of expenditure requirement for similar abilities" and serving as "the centerpieces enabling the fabrication of electric motor, CEB, sawmill, OSCar, microcombine and all other items that require processes from milling to drilling to lathing."[54]

> It is a high precision mill-drill-lathe, with other possible functions, where the precision is obtained by virtue of building the machine with discarded engine blocks....
>
> The central feature of the Multimachine is the concept that either the tool or the workpiece rotates when any machining operation is performed. As such, a heavy-duty, precision spindle (rotor) is the heart of the Multimachine—for milling, drilling and lathing applications. The precision arises from the fact that the spindle is secured within the absolutely precise bore holes of an engine block, so precision is guaranteed simply by beginning with an engine block.
>
> If one combines the Multimachine with a CNC XY or XYZ movable working platform—similar to ones

51 Johan Soderberg, *Hacking Capitalism: The Free and Open Source Software Movement* (New York and London: Routledge, 2008), pp. 185-186.
52 MIT Center for Bits and Atoms, “Fab Lab FAQ” <http://fab.cba.mit.edu/about/faq/> (accessed August 31, 2009).
53 “Multimachine,” *Wikipedia* <http://en.wikipedia.org/wiki/Multimachine> (accessed August 31, 2009>; <http://groups.yahoo.com/group/multimachine/>.
54 "Multimachine & Flex Fab--Open Source Ecology" <http://openfarmtech.org/index.php?title=Multimachine_%26_Flex_Fab>.

being developed by the Iceland Fab Lab team[55], RepRap[56], CandyFab 4000[57] team, and others—then a CNC mill-drill-lathe is the result. At least Factor 10 reduction in price is then available compared to the competition. The mill-drill-lathe capacity allows for the subtractive fabrication of any allowable shape, rotor, or cylindrically-symmetric object. Thus, the CNC Multimachine can be an effective cornerstone of high precision digital fabrication—down to 2 thousandths of an inch.

> Interesting features of the Multimachine are that the machines can be scaled from small ones weighing a total of ~1500 lb to large ones weighing several tons, to entire factories based on the Multimachine system. The CNC XY(Z) tables can also be scaled according to the need, if attention to this point is considered in development. The whole machine is designed for disassembly. Moreover, other rotating tool attachments can be added, such as circular saw blades and grinding wheels. The overarm included in the basic design is used for metal forming operations.
>
> Thus, the Multimachine is an example of appropriate technology, where the user is in full control of machine building, operation, and maintenance. Such appropriate technology is conducive to successful small enterprise for local community development, via its low capitalization requirement, ease of maintenance, scaleability and adaptability, and wide range of products that can be produced. This is relevant both in the developing world and in industrialized countries.[58]

The multimachine, according to Delaney, "can be built by a semi-skilled mechanic using just common hand tools," from discarded engine blocks, and can be scaled from "a closet size version" to "one that would weigh 4 or 5 tons."[59]

In developing countries, in particular, the kinds of products that can be built with a multimachine include:

> AGRICULTURE:
> Building and repairing irrigation pumps and farm implements.
>
> WATER SUPPLIES:
> Making and repairing water pumps and water-well drilling rigs.
>
> FOOD SUPPLIES:
> Building steel-rolling-and-bending machines for making fuel efficient cook stoves and other cooking equipment.
>
> TRANSPORTATION:
> Anything from making cart axles to rebuilding vehicle clutch, brake, and other parts....
>
> JOB CREATION:
> A group of specialized but easily built MultiMachines can be combined to form a small, very low cost, metal working factory which could also serve as a trade school. Students could be taught a single skill on a specialized machine and be paid as a worker while learning other skills that they could take elsewhere.[60]

More generally, a Fab Lab (i.e. a digital flexible fabrication facility centered on the CNC multimachine along with a CNC cutting table and open-source 3-D printer like RepRap) can produce

55 <http://smari.yaxic.org/blag/2007/11/14/the-routing-table/> (note in quoted text).
56 <http://reprap.org/bin/view/Main/RepRap>. (note in quoted text).
57 <http://www.makingthings.com/projects/CandyFab-4000> (note in quoted text).
58 Jakubowski, "OSE Proposal."
59 <http://groups.yahoo.com/group/multimachine/?yguid=234361452>.
60 <http://opensourcemachine.org/node/2>.

virtually anything—especially when coupled with the ability of such machinery to run open-source design files.

> Flexible fabrication refers to a production facility where a small set of non-specialized, general-function machines (the 5 items mentioned [see below]) is capable of producing a wide range of products if those machines are operated by skilled labor. It is the opposite of mass production, where unskilled labor and specialized machinery produce large quantities of the same item (see section *II, Economic Base*). When one adds *digital fabrication* to the flexible fabrication mix—then the skill level on part of the operator is reduced, and the rate of production is increased.
>
> Digital fabrication is the use of computer-controlled fabrication, as instructed by data files that generate tool motions for fabrication operations. Digital fabrication is an emerging byproduct of the computer age. It is becoming more accessible for small scale production, especially as the influence of open source philosophy is releasing much of the know-how into non-proprietary hands. For example, the Multimachine is an open source mill-drill-lathe by itself, but combined with computer numerical control (CNC) of the workpiece table, it becomes a digital fabrication device.
>
> It should be noted that open access to digital design—perhaps in the form a global repository of shared open source designs—introduces a unique contribution to human prosperity. This contribution is the possibility that data at one location in the world can be translated immediately to a product in any other location. This means anyone equipped with flexible fabrication capacity can be a producer of just about any manufactured object. The ramifications for localization of economies are profound, and leave the access to raw material feedstocks as the only natural constraint to human prosperity.[61]

Open Source Ecology, based on existing technology, estimates the cost of producing a CNC multimachine with their own labor at $1500.[62] The CNC multimachine is only one part of a projected "Fab Lab," whose total cost of construction will be $2,000.

> 1. CNC Multimachine—Mill, drill, lathe, metal forming, other grinding/cutting. This constitutes a robust machining environment that may be upgraded for open source computer numerical control by OS software, which is in development.[63]
> 2. XYZ-controlled torch and router table—can accommodate an acetylene torch, plasma cutter, router, and possibly CO_2 laser cutter diodes
> 3. Metal casting equipment—all kinds of cast parts from various metals
> 4. Plastic extruder—extruded sheet for advanced glazing, and extruded plastic parts or tubing
> 5. Electronics fabrication—oscilloscope, circuit etching, others—for all types of electronics from power control to wireless communications.
>
> This equipment base is capable of producing just about anything—electronics, electromechanical devices, structures, and so forth. The OS Fab Lab is crucial in that it enables the self-replication of all the 16 technologies.[64]

(The "16 technologies" refers to Open Source Ecology's entire line of sixteen products, including not only construction and energy generating equipment, a tractor, and a greenhouse, but using the Fab Lab to replicate the five products in the Fab Lab itself. See the extended material on OSE in the Appendix.)

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61 Jakubowski, "OSE Proposal."
62 Marcin Jakubowski, "Rapid Prototyping for Industrial Swadeshi," Factor e Farm Weblog, August 10, 2008 <http://openfarmtech.org/weblog/?p=293>. "Open Source Fab Lab," Open Source Ecology wiki (accessed August 22, 2009) <http://openfarmtech.org/index.php?title=Open_Source_Fab_Lab>.
63 Open source CNC code is being developed by Smari McCarthy of the Iceland Fab Lab, <http://smari.yaxic.org/blag/2007/11/14/the-routing-table/>.
64 Jakubowski, "OSE Proposal."

The 3-D printer, a major component of the Fab Lab, sells at a price starting over $20,000 for commercial versions. The RepRap, an open-source 3-D printer, has reduced the cost to around $500.[65] It's especially useful for making casting molds. Antique car enthusiast Jay Leno, in a recent issue of *Popular Mechanics*, described the use of a combination 3-D scanner/3-D printer to create molds for out-of-production parts for old cars like his 1907 White Steamer.

> The 3D printer makes an exact copy of a part in plastic, which we then send out to create a mold....
>
> The NextEngine scanner costs $2995. The Dimension uPrint Personal 3D printer is now under $15,000. That's not cheap. But this technology used to cost 10 times that amount. And I think the price will come down even more.[66]

Well, yeah—especially considering RepRap can *already* be built for around $500 in parts.

Automated production with CNC machinery, Jakubowski points out, holds out some very exciting possibilities for producing at rates competitive with conventional industry.

> It should be pointed out that a particularly exciting enterprise opportunity arises from automation of fabrication, such as arises from computer numerical control. For example, the sawmill and CEB discussed above are made largely of DfD, bolt-together steel. This lends itself to a fabrication procedure where a CNC XYZ table could cut out all the metal, including bolt holes, for the entire device, in a fraction of the time that it would take by hand. As such, complete sawmill or CEB kits may be fabricated and collected, ready for assembly, on the turn-around time scale of days....
>
> The digital fabrication production model may be equivalent in production rates to that of any large-scale, high-tech firms.[67]
>
> The concept of a CNC XYZ table is powerful. It allows one to prepare all the metal, such as that for a CEB press or the boundary layer turbine, with the touch of a button if a design file for the toolpath is available. This indicates on-demand fabrication capacity, at production rates similar to that of the most highly-capitalized industries. With modern technology, this is doable at low cost. With access to low-cost computer power, electronics, and open source blueprints, the capital needed for producing a personal XYZ table is reduced merely to structural steel and a few other components: it's a project that requires perhaps $1000 to complete.[68]

(Someone's actually developed a CNC XYZ cutting table for $100 in materials, although the bugs are not yet completely worked out.)[69]

Small-scale fabrication facilities of the kind envisioned at Factor e Farm, based on CNC multimachines, cutting/routing tables and 3D printers, can even produce motorized vehicles like passenger cars and tractors, when the heavy engine block is replaced with a light electric motor. Such electric vehicles, in fact, are part of the total product package at Factor e Farm.

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65 RepRap site <http://reprap.org/bin/view/Main/WebHome>; "RepRap Project," Wikipedia <http://en.wikipedia.org/wiki/RepRap_Project> (accessed August 31, 2009).
66 Jay Leno, "Jay Leno's 3-D Printer Replaces Rusty Old Parts," *Popular Mechanics*, July 2009 <http://www.popularmechanics.com/automotive/jay_leno_garage/4320759.html?page=1>.
67 Jakubowski, "OSE Proposal."
68 Ibid.
69 "CNC machine v2.0—aka 'Valkyrie'," *Let's Make Robots*, July 14, 2009 <http://letsmakerobots.com/node/9006>.

The central part of a car is its propulsion system. *Fig. 6* shows a *fuel* source feeding a *heat generator*, which heats a flash steam generator *heat exchanger*, which drives a *boundary layer turbine*, which drives a *wheel motor* operating as an electrical generator. The electricity that is generated may either be fed into *battery storage*, or controlled by *power electronics* to drive 4 separate wheel motors. This constitutes a hybrid electric vehicle, with 4 wheel drive in this particular implementation.

This hybrid electric vehicle is one of intermediate technology design that may be fabricated in a small-scale, flexible workshop. The point is that a complicated power delivery system (clutch-transmission-drive shaft-differential) has been replaced by four electrical wires going to the wheel electrical motors. This simplification results in high localization potential of car manufacturing.

The first step in the development of open source, Hypercar-like vehicles is the propulsion system, for which the boundary layer turbine hybrid system is a candidate. Our second step will be structural optimization for lightweight car design.[70]

Building on our earlier speculation about networked small machine shops and hobbyist workshops, new desktop manufacturing technology offers an order of magnitude increase in the quality of work that can be done for the most modest expense.

Kevin Kelly argues that the actual costs of physical production are only a minor part of the cost of manufactured goods.

....material industries are finding that the costs of duplication near zero, so they too will behave like digital copies. Maps just crossed that threshold. Genetics is about to. Gadgets and small appliances (like cell phones) are sliding that way. Pharmaceuticals are already there, but they don't want anyone to know. It costs nothing to make a pill.[71]

If, as Kelley suggests, the cheapness of digital goods reflects the imploding cost of copying them, it follows that the falling cost of “copying” physical goods will follow the same pattern.

There is a common thread running through all the different theories of the interface between peer production and the material world: as technology for physical production becomes feasible on increasingly smaller scales and at less cost, and the transaction costs of aggregating small units of capital into large ones fall, there will be less and less disconnect between peer production and physical production.

It's worth repeating one last time: the distinction between Stallman's "free speech" and "free beer" is eroding. To the extent that embedded rents on "intellectual property" are a significant portion of commodity prices, "free speech" (in the sense of the free use of ideas) will make our "beer" (i.e., the price of manufactured commodities) at least a lot cheaper. And the smaller the capital outlays required for physical production, the lower the transaction costs for aggregating capital, and the lower the overhead, the cheaper the beer becomes as well.

The Microenterprise

We have already seen, in C4SS Paper No. 4, the advantages of low overhead and small batch

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70 Jakubowski, “OSE Proposal.”

71 Kevin Kelly, "Better Than Free," *The Technium*, January 31, 2008 <http://www.kk.org/thetechnium/archives/2008/01/better_than_fre.php>.

production that lean, flexible manufacturing offers over traditional mass-production industry.[72] The household microenterprise offers these advantages, but increased by another order of magnitude. As we saw Charles Johnson suggest above, the use of “spare cycles” of capital goods people own anyway results in enormous cost efficiencies.

Consider, for example, the process of running a small, informal brew pub or restaurant out of your home, under a genuine free market regime. Buying a brewing vat and a few small fermenters for your basement, using a few tables in a remodeled spare room as a public restaurant area, etc., would require a small bank loan for at most a few thousand dollars. And with that capital outlay, you could probably make payments on the debt with the margin from one customer a day. A few customers evenings and weekends, probably found mainly among your existing circle of acquaintances, would enable you to initially shift some of your working hours from wage labor to work in the restaurant, with the possibility of gradually phasing out wage labor altogether or scaling back to part time, as you built up a customer base. In this and many other lines of business (for example a part-time gypsy cab service using a car and cell phone you own anyway), the minimal entry costs and capital outlay mean that the minimum turnover required to pay the overhead and stay in business would be quite modest. In that case, a lot more people would be able to start small businesses for supplementary income and gradually shift some of their wage work to self employment, with minimal risk or sunk costs.

But that’s *illegal*. You have to buy an extremely expensive liquor license, as well as having an industrial sized stove, dishwasher, etc. And that level of capital outlay can only be paid off with a large dining room and a large kitchen-waiting staff, which means you have to keep the place filled or the overhead costs will eat you alive—in other words, Chapter Eleven. These high entry costs and the enormous overhead are the reason you can’t afford to start out really small and cheap, and the reason restaurants have such a high failure rate. It's illegal to use the surplus capacity of the ordinary household items we have to own anyway but remain idle most of the time (including small-scale truck farming): e.g. RFID chip requirements and bans on unpasteurized milk, high fees for organic certification, etc., which make it prohibitively expensive to sell a few hundred dollars surplus a month from the household economy. As Roderick Long put it,

> In the absence of licensure, zoning, and other regulations, how many people would start a restaurant today if all they needed was their living room and their kitchen? How many people would start a beauty salon today if all they needed was a chair and some scissors, combs, gels, and so on? How many people would start a taxi service today if all they needed was a car and a cell phone? How many people would start a day care service today if a bunch of working parents could simply get together and pool their resources to pay a few of their number to take care of the children of the rest? These are not the sorts of small businesses that receive SBIR awards; they are the sorts of small businesses that get hammered down by the full strength of the state whenever they dare to make an appearance without threading the lengthy and costly maze of the state’s permission process.[73]

Shawn Wilbur, an anarchist writer with half a lifetime in the bookselling business, describes the resilience of a low-overhead business model: “My little store was enormously efficient, in the sense that it could weather long periods of low sales, and still generally provide new special order books in the same amount of time as a Big Book Bookstore.” The problem was that, with the state-imposed paperwork burden associated with hiring help, it was preferable—i.e. less complicated—to work sixty-

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72 Carson, “The Decline and Fall of Sloanism,” Center for a Stateless Society Paper No. 4 (August 2009) <http://c4ss.org/content/1030>.
73 Roderick Long, “Free Market Firms: Smaller, Flatter, and More Crowded,” *Cato Unbound*, November 25, 2008 <http://www.cato-unbound.org/2008/11/25/roderick-long/free-market-firms-smaller-flatter-and-more-crowded/>.

hour weeks.[74] The state-imposed administrative costs involved in the cooperative organization of labor amount to an entry barrier that can only be hurdled by the big guy. After some time out of the business of independent bookselling and working a number of wage-labor gigs in chain bookstores, Wilbur has recently announced the formation of Corvus—a micropublishing operation that operates on a print-on-demand basis.[75] In response to my request for information on his business model, Wilbur wrote:

> In general..., Corvus Editions is a hand-me-down laptop and a computer that should probably have been retired five years ago, and which has more than paid for itself in my previous business, some software, all of which I previously owned and none of which is particularly new or spiffy, a $20 stapler, a $150 laser printer, a handful of external storage devices, an old flatbed scanner, the usual computer-related odds and ends, and the fruits of thousands of hours of archival research and sifting through digital sources (all of which fits on a single portable harddrive.) The online presence did not involve any additional expense, beyond the costs of the free archive, except for a new domain name. My hosting costs, including holding some domain registrations for friendly projects, total around $250/year, but the Corvus site and shop could be hosted for $130.
>
> Because Portland has excellent resources for computer recycling and the like, I suspect a similar operation, minus the archive, using free Linux software tools, could almost certainly be put together for less than $500, including a small starting stock of paper and toner—and perhaps more like $300.

The cost of materials is some 20% of Wilbur's retail price on average, with the rest of the price being compensation free and clear for his labor: "the service of printing, folding, stapling and shipping...." There are no proprietary rents because the pdf files are themselves free for download; Wilbur makes money entirely from the convenience-value of his doing those printing, etc., services for the reader.[76]

The lower capital outlays and fixed costs fall, the more meaningless the distinction between being "in business" and "out of business" becomes.

We can expect the long-term structural reduction in employment and the shortage of liquidity, in the current Great Recession or Great Malaise—the trends we examined in the previous paper—to lead to rapid growth of an informal economy based on the kinds of household microenterprises we described above. Charles Hugh Smith, after considering the enormous fixed costs of conventional businesses and the inevitability of bankruptcy for businesses with such high overhead in a period of low sales, draws the conclusion that businesses with low fixed costs are the wave of the future. Here is his vision of the growing informal sector of the future:

> **The recession/Depression will cut down every business paying high rent and other fixed costs like a razor-sharp scythe hitting dry corn stalks....**
>
> **...[H]igh fixed costs will take down every business which can't remake itself into a low-fixed-cost firm....**

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74 Comment under Shawn Wilbur, "Who benefits most economically from state centralization" *In the Libertarian Labyrinth*, December 9, 2008 <http://libertarian-labyrinth.blogspot.com/2008/12/who-benefits-most-economically-from.html>.
75 Shawn Wilbur, "Taking Wing: Corvus Editions," *In the Libertarian Labyrinth*, July 1, 2009 <http://libertarian-labyrinth.blogspot.com/2009/07/taking-wing-corvus-editions.html>; Corvus Distribution website <http://www.corvusdistribution.org/shop/>.
76 Shawn Wilbur, "Re: [Anarchy-List] Turnin' rebellion into money (or not... your choice)," email to *Anarchy List*, July 17, 2009 <http://lists.anarchylist.org/private.cgi/anarchy-list-anarchylist.org/2009-July/003406.html>.

For the former employees, the landscape is bleak: there are no jobs anywhere, at any wage....

So how can anyone earn a living in The End of Work? Look to Asia for the answer. The MSM snapshot of Asia is always of glitzy office towers in Shanghai or a Japanese factory or the docks loaded with containers: the export machine.

But if you actually wander around Shanghai (or any city in Japan, Korea, southeast Asia, etc.) then you find the number of people working in the glitzy office tower is dwarfed by the number of people making a living operating informal businesses.

Even in high-tech, wealthy Japan, tiny businesses abound. Wander around a residential neighborhood and you'll find a small stall fronting a house staffed by a retired person selling cigarettes, candy and soft drinks. Maybe they only sell a few dollars' worth of goods a day, but it's something, and in the meantime the proprietor is reading a magazine or watching TV.

In old Shanghai, entire streets are lined with informal vendors. Some are the essence of enterprise: a guy buys a melon for 40 cents, cuts it into 8 slices and then sells the slices for 10 cents each. Gross profit, 40 cents.

In Bangkok, such areas actually have two shifts of street vendors: one for the morning traffic, the other for the afternoon/evening trade. The morning vendors are up early, selling coffee, breakfasts, rice soup, etc. to workers and school kids. By 10 o'clock or so, they've folded up and gone home.

That clears the way for the lunch vendors, who have prepared their food at home and brought it to sell. In some avenues, a third shift comes in later to sell cold drinks, fruit and meat sticks as kids get out of school and workers head home.

Fixed costs of these thriving enterprises: a small fee to some authority, an old cart and umbrella--and maybe a battered wok or ice chest.

So this is what I envision happening as the Depression drives standard-issue high-fixed cost "formal" enterprises out of business in the U.S.:

1. The mechanic who used to tune your (used) vehicle for $300 at the dealership (now gone) tunes it up in his home garage for $120--parts included.

2. The gal who cut your hair for $40 at the salon now cuts it at your house for $10.

3. The chef who used to cook at the restaurant that charged $60 per meal now delivers a gourmet plate to your door for $10 each.

4. The neighbor kids' lemonade stand is now a permanent feature; you pay 50 cents for a lemonade or soft drink instead of $3 at Starbucks.

5. Used book sellers spread their wares on the sidewalk, or in fold-up booths; for reasons unknown, one street becomes the "place to go buy used books."

6. The neighborhood jazz guy/gal sets up and plays with his/her pals in the backyard; donations welcome.

7. The neighborhood chips in a few bucks each to make it worth a local Iraqi War vet's time to keep an eye on things.

8. When your piece-of-crap Ikea desk busts, you call a guy who can fix it for $10 (glue, clamps, a few ledger strips and screws) rather than go blow $50 on another particle board P.O.C. which will bust anyway. (oh, and you don't have the $50 anyway.)

9. The guy with a Dish runs cables to the other apartments in his building for a few bucks each.

10. One person has an "unlimited" Netflix account, and everyone pays him/her a buck a week to get as many movies as they want (he/she burns a copy of course).

11. The couple with the carefully tended peach or apple tree bakes 30 pies and trades them for vegtables, babysitting, etc.[77]

The crushing costs of formal business (State and local government taxes and junk fees rising to pay for unaffordable pensions, etc.) and the implosion of the debt-bubble economy will drive millions into the informal economy of barter, trade and "underground" (cash) work.

As small businesses close their doors and corporations lay off thousands, the unemployed will of necessity shift their focus from finding a new formal job (essentially impossible for most) to fashioning a livelihood in the informal economy.

One example of the informal economy is online businesses--people who make a living selling used items on eBay and other venues. Such businesses can be operated at home and do not require storefronts, rent to commercial landlords, employees, etc., and because they don't require a formal presence then they also fly beneath all the government junk fees imposed on formal businesses.

I have mentioned such informal businesses recently, and the easiest way to grasp the range of possibilities is this: whatever someone did formally, they can do informally.

Chef had a high fixed-cost restaurant which bankrupted him/her? Now he/she prepares meals at home and delivers them to neighbors/old customers for cash. No restaurant, no skyhigh rent, no employees, no payroll taxes, no business licenses, inspection fees, no sales tax, etc. Every dime beyond the cost of food and utilities to prepare the meals stays in Chef's pocket rather than going to the commercial landlords and local government via taxes and fees.

All the customers who couldn't afford $30 meals at the restaurant can afford $10. Everybody wins except commercial landlords (soon to be bankrupt) and local government (soon to be insolvent). How can you bankrupt all the businesses and not go bankrupt yourself?

As long as Chef reports net income on Schedule C, he/she is good to go with Federal and State tax authorities. [And if Chef doesn't, fuck 'em.]

Now run the same scenario for mechanics, accountants, therapists, even auto sales--just rent a house with a big yard or an apartment with a big parking lot and away you go; the savvy entrepreneur who moves his/her inventory can stock a few vehicles at a time. No need for a huge lot, high overhead, employees or junk fees. It's cash and carry.

Lumber yard? Come to my backyard lot. Whatever I don't have I can order from a jobber and have delivered to your site.

This is the result of raising the fixed costs of starting and running a small business to such a

77 Charles Hugh Smith, “End of Work, End of Affluence III: The Rise of Informal Businesses,” *Of Two Minds*, December 10, 2009 <http://www.oftwominds.com/blogdec08/informal12-08.html>.

backbreaking level that few formal businesses can survive.[78]

Appendix
Case Studies in the Coordination of Networked Fabrication and Open Design

Open Source Ecology/Factor e Farm. Open Source Ecology, with its experimental demo site at Factor e Farm, is focused on developing the technological building blocks for a resilient local economy—both through a comperehensive package of open-source designs suited to the needs of a resilient community, and through the micromanufacturing capability to produce as much of the package as possible on-site.

> We are actively involved in demonstrating the world's first replicable, post-industrial village. We take the word *replicable* very seriously—we do not mean a top-down funded showcase—but one that is based on ICT, open design, and digital fabrication—in harmony with its natural life support systems. As such, this community is designed to be self-reliant, highly productive, and sufficiently transparent so that it can truly be replicated in many contexts—whether it's parts of the package or the whole. Our next frontier will be education to train Village Builders—just as we're learning how to do it from the ground up.[79]

> Open Source Ecology's latest core message is "Building the world's first replicable, open source, modern off-grid global village—to transcend survival and evolve to freedom."...
>
> Replicable means that the entire operation can be copied and 'replicated' at another location at low cost.
>
> Open source means that the knowledge of how it works and how to make it is documented to the point that others can "make it from scratch." It can also be changed and added to as needed....
>
> Permafacture: A car is a temporarily useful consumer product—eventually it breaks down and is no longer useful as a car. The same is true for almost any consumer product—they are temporary, and when they break down they are no longer useful for their intended purpose. They come from factories that use resources from trashing ecosystems and using lots of oil. Even the "green" ones. Most consumer food is grown on factory farms using similar processes, and resulting in similar effects. When the resources or financing for those factories and factory farms dries up they stop producing, and all the products and food they made stop flowing into the consumer world. Consumers are dependent on these products and food for their very survival, and every product and food they buy from these factories contributes to the systems that are destroying the ecosystems that they will need to survive when finances or resources are interrupted. The more the consumers buy, the more dependent they are on the factories consuming and destroying the last of the resources left in order to maintain their current easy and dependent survival. These factories are distributed all over the world, and need large amounts of cheap fuel to move the products to market through the global supply and production chain, trashing ecosystems all along the way. The consumption of the products and food is completely disconnected from their production and so consumers do not actually see any of these connections or their interruptions as the factories and supply chains try hard to keep things flowing smoothly, until things reach their breaking point and the supply of products to consumers is suddenly interrupted. Open Source Ecology aims to create the means of production and reuse on a small local scale, so that we can produce the machines and resources that make survival trivial without being dependent on global supply and production chains, trashing ecosystems, and cheap oil.[80]

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78 Smith, "Trends for 2009: The Rise of Informal Work," *Of Two Minds*, December 30, 2009 <http://www.oftwominds.com/blogdec08/rise-of-informal12-08.html>.
79 "Clarifying OSE Vision," *Factor e Farm Weblog*, September 8, 2008 <http://openfarmtech.org/weblog/?p=325>.
80 Jeremy, "What is Open Source Ecology?" *Factor e Farm Weblog*, March 20, 2009 <http://openfarmtech.org/weblog/?

The focus of OSE is to secure “right livelihood,” according to founder Marcin Jakubowski, who cites Vinay Gupta's “The Unplugged” as a model for achieving it:

> The focus of our *Global Village Construction program* is to deploy *communities* that live according to the intention of *right livelihood*. We are considering the *ab initio* creation of nominally 12 person communities, by networking and marketing this *Buy Out at the Bottom* (BOAB) package, at a fee of approximately $5k to participants. *Buying Out at the Bottom* is a term that I borrowed from Vinay Gupta in his article about The Unplugged—where *unplugging* means the creation of *an independent life-support infrastructure and financial architecture--a society within society—which allowed anybody who wanted to "buy out" to "buy out at the bottom" rather than "buying out at the top."*
>
> Our Global Village Construction program is an implementation of *The Unplugged* lifestyle. With 12 people *buying out* at $5k each, that is $60k seed infrastructure capital.
>
> We have an option to stop feeding invading colonials, from our own empire-building governments to slave goods from China. Structurally, the more self-sufficient we are, the less we have to pay for our own enslavement—through education that dumbs us down to producers in a global workforce—through taxation that funds rich peoples' wars of commercial expansion—through societal engineering and PR that makes the quest for an honest life dishonorable if we can't keep up with the Joneses. [81]

Several of the most important projects interlock to form an “OSE Product Ecology.”[82] The solar steam generator supplies electrical power for lighting and appliances. The Solar Power Generator, via a hydraulic pump, powers the LifeTrac Open Source Tractor, which acts as prime mover for Fabrication (i.e., the machine shop, in which the Multi-Machine features prominently), and the Compressed Earth Block Press and the Sawmill, which in turn are the basic tools for housing construction. The LifeTrac also functions, of course, as a tractor for hauling and powering farm machinery.

Like LifeTrac, the Power Cube—a modular power-transmission unit—is a multi-purpose mechanism designed to work with several of the other projects.

> Power Cube is our open source, self-contained, modular, interchangeable, hydraulic power unit for all kinds of power eguipment. It has an 18 hp gasoline engine coupled to a hydraulic pump, and it will later be be powered by a flexible-fuel steam engine. Power Cube will be used to power MicroTrac (under construction) and it is the power source for the forthcoming CEB Press Prototype 2 adventures. It is designed as a general power unit for all devices at Factor e Farm, from the CEB press, power take-off (PTO) generator, heavy-duty workshop tools, even to the LifeTrac tractor itself. Power Cube will have a quick attachment, so it can be mounted readily on the quick attach plate of LifeTrac. As such, it can serve as a backup power source if the LifeTrac engine goes out....
>
> The noteworthy features are modularity, hydraulic quick-couplers, lifetime design, and design-for-disassembly. Any device can be plugged in readily through the quick couplers.
>
> It can be maintained easily because of its transparency of design, ready access to parts, and design for disassembly. It is a major step towards realizing the true, life-size Erector Set or Lego Set of heavy-duty,

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p=595>.

81 “Organizational Strategy,” Open Source Ecology wiki, February 11, 2009 <http://openfarmtech.org/index.php?title=Organizational_Strategy> (accessed August 28, 2009).

82 Marcin Jakubowski, “CEB Proposal—Community Supported Manufacturing,” *Factor e Farm* weblog, October 23, 2008 <http://openfarmtech.org/weblog/?p=379>.

industrial machinery in the style of Industrial Swadeshi.[83]

Among projects that have reached the prototype stage, the foremost is the Compressed Earth Block Press, which can be built for $5000—some 20% of the price of the cheapest commercial competitor.[84] In field testing, the CEB Press demonstrated the capability of producing a thousand blocks in eight-hours, on a day with bad weather (the expected norm in good weather is 1500 a day).[85] On August 20, 2009, Factor e Farm announced completion of a second model prototype, its most important new feature being an extendable hopper that can be fed directly by a tractor loader. Field testing is expected to begin shortly.[86]

> The speed of the CEB Press was recently augmented by the prototyping of a complementary product, the Soil Pulverizer.
>
> Initial testing achieved 5 ton per hour soil throughput, while The Liberator CEB press requires about 1.5 tons of soil per hour....
>
> Stationary soil pulverizers comparable in throughput to ours cost over $20k. Ours cost $200 in materials —which is not bad in terms of 100-fold price reduction. The trick to this feat is modular design. We are using components that are already part of our LifeTrac infrastructure. The hydraulic motor is our power take-off (PTO) motor, the rotor is the same tiller that we made last year—with the tiller tines replaced by pulverizer tines. The bucket is the same standard loader bucket that we use for many other applications....
>
> It is interesting to compare this development to our CEB work from last year—given our lesson that soil moving is the main bottleneck in earth building. It takes 16 people, 2 walk-behind rototillers, many shovels and buckets, plus backbreaking labor—to load our machine as fast as it can produce bricks. We can now replace this number of people with 1 person—by mechanizing the earth moving work with the tractor-mounted pulverizer. In a sample run, it took us about 2 minutes to load the pulverizer bucket—with soil sufficient for about 30 bricks. Our machine produces 5 bricks per minute—so we have succeeded in removing the soil-loading bottleneck from the equation.
>
> This is a major milestone for our ability to do CEB construction. Our results indicate that we can press 2500 bricks in an 8 hour day—with 3 people.[87]

The MicroTrac, a walk-behind tractor, has also been prototyped. Its parts, including the Power Cube, wheel, quick-attach motor and cylinder are interchangeable with LifeTrac and other machines. “We can take off the wheel motor from MicroTrac, and use it to power shop tools.”[88]

OSE's planned facilities for replication and machining are especially exciting, including a 3-D printer and a Multi-Machine with added CNC controls.

> There is a significant set of open source technologies available for rapid prototyping in small workshops. By combining 3D printing with low-cost metal casting, and following with machining using a computer

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83 Jakubowski, “Power Cube Completed,” *Factor e Farm* weblog, June 29, 2009 <http://openfarmtech.org/weblog/?p=814>.
84 "CEB Phase 1 Done," Factor e Farm Weblog, December 26, 2007 <http://openfarmtech.org/weblog/?p=91>.
85 Jakubowski, "The Thousandth Brick: CEB Field Testing Report," *Factor e Farm Weblog*, Nov. 16, 2008 <http://openfarmtech.org/weblog/?p=422>.
86 Jakubowski, “CEB Prototype II Finished,” *Factor e Farm Weblog*, August20, 2009 <http://openfarmtech.org/weblog/?p=1025>.
87 Jakubowski, “Soil Pulverizer Annihilates Soil Handling Limits,” *Factor e Farm Weblog*, September 7, 2009 <http://openfarmtech.org/weblog/?p=1063>.
88 Jakubowski, “MicroTrac Completed,” *Factor e Farm Weblog*, July 7, 2009 <http://openfarmtech.org/weblog/?p=852>.

controlled Multimachine, the capacity arises to make rapid prototypes and products from plastic and metal. This still does not address the feedstocks used, but it is a practical step towards the post-centralist, participatory, distributive economy with industrial swadeshi on a regional scale....

> The interesting part is that the budget is $500 for RepRap, $200 for the casting equipment, and $1500 for a Multimachine with CNC control added. Using available knowhow, this can be put together in a small workshop for a total of about $2200—for full, LinuxCNC computer controlled rapid fabrication in plastic and metal. Designs may be downloaded from the internet, and local production can take place based on global design.

> This rapid fabrication package is one of our near-term (one year) goals. The research project in this area involves the fabrication and integration of the individual components as described....

> Such a project is interesting from the standpoint of localized production in the context of the global economy—for creating significant wealth in local economies. This is what we call industrial swadeshi. For example, I see this as the key to casting and fabricating low-cost steam engines ($300 for 5 hp) for the Solar Turbine—as one example of Gandhi's mass production philosophy.[89]

The entire Fab Lab project aims to produce "the following equipment infrastructure, in order of priorities...":

* 300 lb/hour steel melting Foundry—$1000
* Multimachine-based Lathe, mill, and drill, with addition of CNC control—$1500
* CNC Torch Table (plasma and oxyacetylene), adaptable to a router table
* RepRap or similar 3D printer for printing casting molds—$400
* Circuit fabrication—precise xyz router table
* Open Source Wire Feed Welder[90]

As of August 2009, Lawrence Kincheloe has moved to Factor e Farm in August 2009 under contract to build the torch table in August and September.[91] In addition to the steel casting functions of the Foundry, Jakubowski ultimately envisions the production of aluminum from clay as a key source of feedstock for relocalized production. As an alternative to "high-temperature, energy-intensive smelting processes" involving aluminum oxide (bauxite), he proposes "extracting aluminum from clays using baking followed by an acid process."[92]

OSE's flexible and digital fabrication facility is intended to produce a basic set of sixteen products, five of which are the basic set of means of fabrication themselves:

1. *Boundary layer turbine* – simpler and more efficient alternative to most external and internal combustion engines and turbines, such as gasoline and diesel engines, Stirling engines, and air engines. The only more efficient energy conversion devices are bladed turbines and fuel cells.
2. *Solar concentrators* – alternative heat collector to various types of heat generators, such as

89 Jakubowski, "Rapid Prototyping for Industrial Swadeshi," *Factor e Farm Weblog*, August 10, 2008 <http://openfarmtech.org/weblog/?p=293>.
90 "Open Source Fab lab," Open Source Ecology wiki (accessed August 22, 2009) <http://openfarmtech.org/index.php?title=Open_Source_Fab_Lab>.
91 Marcin Jakubowski, "Moving Forward," Factor e Farm Weblog, August 20, 2009<http://openfarmtech.org/weblog/?p=1020>; "Lawrence Kincheloe Contract," August 19, 2009 <http://openfarmtech.org/index.php?title=Lawrence_Kincheloe_Contract>; "Torch Table Build," *Open Source Ecology* wiki (accessed August 22, 2009 <http://openfarmtech.org/index.php?title=Torch_Table_Build>.
92 Jakubowski, "OSE Proposal—Towards a World Class Open Source Research and Development Facility" v0.12, January 16, 2008 <http://openfarmtech.org/OSE_Proposal.doc> (accessed August 25, 2009).

petrochemical fuel combustion, nuclear power, and geothermal sources

3. *Babington*[93] *and other fluid burners* – alternative heat source to solar energy, internal combustion engines, or nuclear power
4. *Flash steam generators* – basis of steam power
5. *Wheel motors* - low-speed, high-torque electric motors
6. *Electric generators* – for generating the highest grade of usable energy: electricity
7. *Fuel alcohol* production systems – proven biofuel of choice for temperate climates
8. *Compressed wood gas* – proven technology; cooking fuel; usable in cars if compressed
9. *Compressed Earth Block* (CEB) press – high performance building material
10. *Sawmill* – production of dimensional lumber
11. *Aluminum from clay* – production of aluminum from subsoil clays

Means of fabrication:

12. *CNC Multimachine*[94] – mill, drill, lathe, metal forming, other grinding/cutting
13. *XYZ*-controlled torch and router table – can accommodate an acetylene torch, plasma cutter, router, and possibly CO_2 laser cutter diodes
14. *Metal casting* equipment – various metal parts
15. *Plastic extruder*[95] – plastic glazing and other applications
16. *Electronics fabrication* – oscilloscope, multimeter, circuit fabrication; specific power electronics products include battery chargers, inverters, converters, transformers, solar charge controllers, PWM DC motor controllers, multipole motor controllers.[96]

The Solar Turbine, as it was initially called, uses the sun's heat to power a steam-driven generator, as an alternative to photovoltaic electricity.[97] It has since been renamed the Solar Power Generator, because of the choice to use a simple steam engine as the heat engine instead of a Tesla turbine.[98]

The Steam Engine, still in the design stage, is based on a simple and efficient design for a 3kw engine, with an estimated bill of parts of $250.[99]

The Sawmill, which can be built with under $2000 in parts (a “Factor 10 cost reduction”), has “the highest production rate of any small, portable sawmills.”[100]

OSE's strategy is to use the commercial potential of the first products developed to finance further development. As we saw earlier, Jakubowski speculates that a fully equipped digital fabrication facility could turn out CEB presses or sawmills with production rates comparable to those of commercial manufacturing firms, cutting out all the metal parts for the entire product with a turn-around time of days. The CEBs and sawmills could be sold commercially, in that case, to finance development of other products.[101]

And in fact, Jakubowski has made a strategic decision to give priority to developing the CEB Press

93 http://www.aipengineering.com/babington/Babington_Oil_Burner_HOWTO.html
94 <http://opensourcemachine.org/>.
95 See Extruder_doc.pdf at <http://www.fastonline.org/CD3WD_40/CD3WD/INDEX.HTM>.
96 Jakubowski, “OSE Proposal.”
97 "Solar Turbine--Open Source Ecology" <http://openfarmtech.org/index.php?title=Solar_Turbine>.
98 Marcin Jakubowski, “Factor e Live Distillations—Part 8—Solar Power Generator,” *Factor e Farm Weblog*, February 3, 2009 <http://openfarmtech.org/weblog/?p=507>.
99 Nick Raaum, “Steam Dreams,” *Factor e Farm* weblog, January 22, 2009 <http://openfarmtech.org/weblog/?p=499>.
100 Jeremy, “Sawmill Development,” *Factor e Farm* weblog, January 22, 2009 <http://openfarmtech.org/weblog/?p=498>.
101 Jakubowski, “OSE Proposal.”

as rapidly as possible, in order to leverage the publicity and commercial potential as a source of future funding for the entire project.[102]

OSE's goal of replicability, once the first site is completed with a full range of production machinery and full product line, involves hosting interns who wish to replicate the original experiment at other sites, and using fabrication facilities to produce duplicate machinery for the new sites.[103] Jakubowski recently outlined a more detailed timeline:

> Based on our track record, the schedule may be off by up to twenty years. Thus, the proposed timeline can be taken as either entertainment or a statement of intent—depending on how much one believes in the project.
>
> 2008 - modularity and low cost features of open source products have been demonstrated with LifeTrac and CEB Press projects
>
> 2009 - First product release
>
> 2010 - TED Fellows or equivalent public-relations fellowship to propel OSE to high visibility
>
> 2011 - $10k/month funding levels achieved for scaling product development effort
>
> 2012 - Global Village Construction Set finished
>
> 2013 - First true post-scarcity community built
>
> 2014 - OSE University (immersion training) established, to be competitive with higher education but with an applied focus
>
> 2015 - OSE Fellows program started (the equivalent of TED Fellows, but with explicit focus of solving pressing world issues)
>
> 2016 - First productive recursion completed (components can be produced locally anywhere)
>
> 2017 - Full meterial [sic] recursion demostrated (all materials become producible locally anywhere)
>
> 2018 - Ready self-replicability of resilient, post-scarcity communities demonstrated
>
> 2019 - First autonomous republic created, along the governance principles of Leashless
>
> 2020 - Ready replicability of autonomous republics demonstrated[104]

In August 2009, some serious longtime tensions came to a head at OSE, as the result of personality conflicts beyond the scope of this work, and the subsequent departure of members Ben De Vries and Jeremy Maso. As of September, the project seemed to be functional and on track, with new member Lawrence Kincheloe on contract to construct an open-source CNC XYZ plasma torch table.

100kGarages. Another very promising open manufacturing project, besides OSE's, is

102 Ibid.
103 “Organizational Strategy.”
104 Jakubowski, “”TED Fellows,” *Factor e Farm Weblog*, September 22, 2009 <http://openfarmtech.org/weblog/?p=1121>.

100kGarages—a joint effort of ShopBot and Ponoko. ShopBot is a maker of CNC routers.[105] Ponoko is both a network of designers and a custom machining service, that produces items as specified in customer designs uploaded via Internet, and ships them by mail, and also has a large preexisting library of member product designs available for production.[106] 100kGarages is a nationwide American network of fabbers aimed at “distributed production in garages and small workshops”[107]: linking separate shops with partial tool sets together for the division of labor needed for networked manufacturing, enabling shops to contract for the production of specific components, or putting customers in contact with fabbers who can produce their designs. Ponoko and ShopBot, in a joint announcement, described it as helping 20,000 creators meet 6,000 fabricators, and specifically to put them in touch with fabricators in their own communities.[108] As described at the 100kGarages site:

> 100kGarages.com is a place for anyone who wants to get something made ("Makers") to link up with those having tools for digital fabrication ("Fabbers") used to make parts or projects.... At the moment, the structure is in place to for Makers to find Fabbers and to post jobs to the Fabber community.... We're working hard to provide software and training resources to help those who want to design for Fabbers, whether doing their own one-off projects or to use the network of Fabbers for distributed manufacturing of products (as done by the current gallery of designers on the Ponoko site).
>
> In the first few weeks there have been about 40 Fabbers who've joined up. In the beginning, we are sticking to Fabbers who are ShopBotters. This makes it possible to have some confidence in the credibilty and capability of the Fabber, without wasting enormous efforts on certification.... But before long, we expect to open up 100kGarages.com to all digital fabrication tools, whether additive or subtractive. We're hoping to grow to a couple of hundred Fabbers over the next few months, and this should provide a geographical distribution that brings fabrication capabilities pretty close to everyone and helps get the system energized.[109]
>
> As we all are becoming environmentally aware, we realize that our environment just can't handle transporting all our raw materials across the country or around the world, just to ship them back as finished products. These new technologies make practical and possible doing more of our production and manufacturing in small distributed facilities, as small as our garages, and close to where the product is needed. Most importantly our new methods for collaboration and sharing means that we don't have to do it all by ourselves ... that designers with creative ideas but without the capability to see their designs become real can work with fabricators that might not have the design skills that they need but do have the equipment and the skills and orientation that's needed to turn ideas into reality … that those who just want to get stuff made or get their ideas realized can work with the Makers/designers who can help them create the plans and the local fabricators who fulfill them.
>
> To get this started ShopBot Tools, Makers of popular tools for digital fabrication and Ponoko, who are reinventing how goods are designed, made and distributed, are teaming-up to create a network of workshops and designers, with resources and infrastructure to help facilitate “rolling up our sleeves and getting to work.” Using grass roots enterprise and ingenuity this community can help get us back in action, whether it's to modernize school buildings and infrastructure, develop energy-saving alternatives, or simply produce

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105 <http://www.shopbottools.com/>.
106 <http://www.ponoko.com/>.
107 “What's Digital Fabrication?” 100kGarages website <http://100kgarages.com/digital_fabrication.html>.
108 Ted Hall (ShopBot) and Derek Kelley (Ponoko), “Ponoko and ShopBot announce partnership: More than 20,000 online creators meet over 6,000 digital fabricators,” joint press release, September 16, 2009. Posted on Open Manufacturing email list, September 16, 2009 <http://groups.google.com/group/openmanufacturing/browse_thread/thread/fdb7b4d562f5e59d?hl=en>.
109 100KGarages founder Ted Hall, “100kGarages is Open: A Place to Get Stuff Made,” *Open Manufacturing* email list, September 15, 2009 <http://groups.google.com/group/openmanufacturing/browse_thread/thread/ae45b45de1d055a7?hl=en#>.

great new products for our homes and businesses.

> There are thousands of ShopBot digital-fabrication (CNC) tools in garages and small shops across the country, ready to locally fabricate the components needed to address our energy and environmental challenges and to locally produce items needed to enhance daily living, work, and business. Ponoko's web methodologies offer people who want to get things made an environment that integrates designers and inventors with ShopBot fabricators. Multiple paths for getting from idea to object, part, component, or product are possible in a dynamic network like this, where ideas can be realized in immediate distributed production and where production activities can provide feedback to improve designs.[110]

Although all ShopBot CNC router models are quite expensive compared to the reverse-engineered stuff produced by hardware hackers (most models are in the $10-20,000 range, and the two cheapest are around $8,000), ShopBot's recent open-sourcing of its CNC control code evoked much fanfare in the open manufacturing community.[111] And as the 100kGarages site says, they plan to open up the network to machines other than routers, and to “home-brew routers” other than ShopBot, as the project develops. Ponoko already had a similar networking project among owners of CNC laser cutters.[112]

Interestingly, this was almost identical to the relocalized manufacturing model described by John Robb:

> It is likely that by 2025, the majority of the "consumer" goods you purchase/acquire, will be manufactured locally. However, this doesn't likely mean what you think it means. The process will look like this:
>
> 1. You will purchase/trade for/build a design for the product you desire through online trading/sharing systems. That design will be in a standard file format and the volume of available designs for sale, trade, or shared openly will be counted in the billions.
>
> 2. You or someone you trust/hire will modify the design of the product to ensure it meets your specific needs (or customize it so it is uniquely yours). Many products will be smart (in that they include hardware/software that makes them responsive), and programmed to your profile.
>
> 3. The refined product design will be downloaded to a small local manufacturing company, co-operative, or equipped home for production. Basic feedstock materials will be used in its construction (from metal to plastic powders derived from generic sources, recycling, etc.). Delivery is local and nearly costless.

The relocalization of manufacturing will be promoted among other things, Robb says, by the fact that

> [l]ocal fabrication will get cheap and easy. The cost of machines that can print, lathe, etch, cut materials to produce three dimensional products will drop to affordable levels (including consumer level versions). This sector is about to pass out of its "home brew computer club phase" and rocket to global acceptance.[113]

It's impossible to underestimate the revolutionary significance of this development. As Lloyd Alter put it, “This really does change everything.”[114]

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110 “Our Big Idea!” 100kGarages site <http://100kgarages.com/our_big_idea.html>.
111 Gareth Branwyn, “ShopBot Open-Sources Their Code,” *Makezine*, April 13, 2009 <http://blog.makezine.com/archive/2009/04/shopbot_open-sources_their_code.html>.
112 “What's Digital Fabrication?”
113 John Robb, “The Switch to Local Manufacturing,” *Global Guerrillas*, July 8, 2009 <http://globalguerrillas.typepad.com/globalguerrillas/2009/07/journal-the-switch-to-local-manufacturing.html>.
114 Lloyd Alter, “Ponoko + ShopBot = 100kGarages: This Changes Everything in Downloadable Design,” *Treehugger*,

Back in January, Eric Hunting considered the slow takeoff in the open manufacturing/Making movement on the Open Manufacturing email list.

> There seem to be a number of re-occurring questions that come up—openly or in the back of peoples minds- seeming to represent key obstacles or stumbling blocks in the progress of open manufacturing or Maker culture....
>
> Why are Makers still fooling around with toys and mash-ups and not making serious things? (short answer; like early computer hackers lacking off-the-shelf media to study, they're still stuck reverse-engineering the off-the-shelf products of existing industry to learn how the technology works and hacking is easier than making something from scratch)
>
> Why are Makers rarely employing many of the modular building systems that have been around since the start of the 20th century? Why do so few tech-savvy people seem to know what T-slot is when it's ubiquitous in industrial automation? Why little use of Box Beam/Grid Beam when its cheap, easy, and has been around since the 1960s? Why does no one in the world seem to know the origin and name of the rod and clamp framing system used in the RepRap? (short answer: no definitive sources of information)
>
> Why are 'recipes' in places like Make and Instructibles most [sic] about artifacts and rarely about tools and techniques? (short answer; knowledge of these are being disseminated ad hoc)
>
> Why is it so hard to collectivize support and interest for open source artifact projects and why are forums like Open Manufacture spending more time in discussion of theory rather than nuts & bolts making? (short answer; no equivalent of Source Forge for a formal definition of hardware projects—though this is tentatively being developed—and no generally acknowledged definitive channel of communication about open manufacturing activity)
>
> Why are Fab Labs not self-replicating their own tools? (short answer; no comprehensive body of open source designs for those tools and no organized effort to reverse-engineer off-the-shelf tools to create those open source versions)
>
> Why is there no definitive 'users manual' for the Fab Lab, its tools, and common techniques? (short answer; no one has bothered to write it yet)
>
> Why is there no Fab Lab in my neighborhood? Why so few university Fab Labs so far? Why is it so hard to find support for Fab Lab in certain places even in the western world? (short answer; 99% of even the educated population still doesn't know what the hell a Fab Lab is or what the tools it's based on are)
>
> Why do key Post-Industrial cultural concepts remain nascent in the contemporary culture, failing to coalesce into a cultural critical mass? Why are entrepreneurship, cooperative entrepreneurship, and community support networks still left largely out of the popular discussion on recovery from the current economic crash? Why do advocates of Post-Industrial culture and economics still often hang their hopes on nanotechnology when so much could be done with the technology at-hand? (short answer; no complete or documented working models to demonstrate potential with)
>
> Are you, as I am, starting to see a pattern here? It seems like there's a Missing Link in the form of a kind of communications or media gap. There is Maker media—thanks largely to the cultural phenomenon triggered by Make magazine. But it's dominated by ad hoc individual media produced and published on-line to communicate the designs for individual artifacts while largely ignoring the tools. People are learning by making, but they never seem to get the whole picture of what they potentially could make because they

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September 16, 2009 <http://www.treehugger.com/files/2009/09/ponoko-shopbot..php>.

> aren't getting the complete picture of what the tools are and what they're capable of.
>
> We seem to basically be in the MITS Altair, Computer Shack, Computer Faire, Creative Computing, 2600 era of independent industry. A Hacker era. Remember the early days of the personal computer? You had these fairs, users groups, and computer stores like Computer Shack basically acting like ad hoc ashrams of the new technology because there were no other definitive sources of knowledge. This is exactly what Maker fairs, Fab Labs, and forums like this one are doing....
>
> There are a lot of parallels here to the early personal computer era, except for a couple of things; there's no equivalent of Apple (yet..), no equivalent of the O'Reily Nutshell book series, no "##### For Dummies" books.[115]

100kGarages is a major step toward the critical mass Hunting wrote about. Although there's as yet no Apple of CNC tools (in the sense of the CAD file equivalent of a user-friendly graphic user interface), there is now an organized network of entrepreneurs with a large repository of open designs. As Michel Bauwens puts it, "Suddenly, anyone can pick one of 20,000 Ponoko Designs (or build one themselves) and get it cut out and built just about anywhere."[116] This is essentially what Marcin Jakubowski referred to above, when he speculated on distributed open source manufacturing shops linked to a "global repository of shared open source designs." To get back to Lloyd Alter's theme ("This changes everything"):

> Ponoko is the grand idea of digital design and manufacture; they make it possible for designers to meet customers, "where creators, digital fabricators, materials suppliers and buyers meet to make (almost) anything." It is a green idea, producing only when something is wanted, transporting ideas instead of physical objects.
>
> Except there wasn't a computerized router or CNC machine on every block, no 3D Kinko's where you could go and print out your object like a couple of photocopies. Until now, with the introduction of 100K Garages, a joint venture between Ponoko and ShopBot, a community of over six thousand fabricators.
>
> Suddenly, anyone can pick one of 20,000 Ponoko Designs (or build one themselves) and get it cut out and built just about anywhere.[117]

The answer to Hunting's question about cooperative entrepreneurship seems to have come to a large extent from outside the open manufacturing movement, as such. And ShopBot and Ponoko, if not strictly speaking part of the committed open manufacturing movement, have grafted it onto their business model. This is an extension to the physical realm of a phenomenon Bauwens remarked on in the realm of open-source software:

> ...[M]ost peer production allies itself with an ecology of businesses. It is not difficult to understand why this is the case. Even at very low cost, communities need a basic infrastructure that needs to be funded. Second, though such communities are sustainable as long as they gain new members to compensate the loss of existing contributors; freely contributing to a common project is not sustainable in the long term. In practice, most peer projects follow a 1-10-99 rule, with a one percent consisting of very committed core individuals. If such a core cannot get funded for its work, the project may not survive. At the very least, such individuals must be able to move back and forth from the commons to the market and back again, if their engagement is to be sustainable.

115 Eric Hunting, "Toolbook and the Missing Link," *Open Manufacturing*, January 30, 2009 <http://groups.google.com/group/openmanufacturing/msg/2fccdde02f402a5b>.
116 Michel Bauwens, "A milestone for distributed manufacturing: 100kGarages," *P2P Foundation Blog*, September 19, 2009 <http://blog.p2pfoundation.net/a-milestone-for-distributed-manufacturing-100k-garages/2009/09/19>.
117 Alter, op. Cit.

> Peer participating individuals can be paid for their work on developing the first iteration of knowledge or software, to respond to a private corporate need, even though their resulting work will be added to the common pool. Finally, even on the basis of a freely available commons, many added value services can be added, that can be sold in the market. On this basis, cooperative ecologies are created. Typical in the open source field for example, is that such companies use a dual licensing strategy. Apart from providing derivative services such as training, consulting, integration etc., they usually offer an improved professional version with certain extra features, that are not available to non-paying customers. The rule here is that one percent of the customers pay for the availability of 99% of the common pool. Such model also consists of what is called benefit sharing practices, in which open source companies contribute to the general infrastructure of cooperation of the respective peer communities.
>
> Now we know that the world of free software has created a viable economy of open source software companies, and the next important question becomes: Can this model be exported, wholesale or with adaptations, to the production of physical goods?[118]

I think it's in process of being done right now.

Besides Ponoko, a number of other commercial firms have appeared recently which offer production of custom parts to the customer's digital design specifications, at a modest price, using small-scale, multipurpose desktop machinery. Two of the most prominent are Big Blue Saw[119] and eMachineShop.[120] The way the latter works, in particular, is described in a *Wired* article:

> The concept is simple: Boot up your computer and design whatever object you can imagine, press a button to send the CAD file to Lewis' headquarters in New Jersey, and two or three weeks later he'll FedEx you the physical object. Lewis launched eMachineShop a year and a half ago, and customers are using his service to create engine-block parts for hot rods, gears for home-brew robots, telescope mounts—even special soles for tap dance shoes.[121]

Assessment. Franz Nahrada, of the Global Village movement, has criticized Factor e Farm in terms of its relationship to a larger, surrounding networked economy. However, he downplayed the importance of autarky compared to that of cross-linking between OSE and the rest of the resilient community movement.

> I really think we enter a period of densification and intensive cross-linking between various projects. I would like to consider Factor_E_Farm the flagship project for the Global Village community even though I am not blind to some shortcomings. I talked to many people and they find and constantly bring up some points that are easy to critisize [sic]. But I want to make clear: I also see these points and they all can be dealt with and are IMHO of minor importance.
>
> * the site itself seems not really being locally embedded in regional development initiatives, but rather a "spaceship from Mars" for the surrounding population. The same occured to me in Tamera 10 years ago when I stayed at a neighboring farmhouse with a very benevolent Portuguese lady who spoke perfect German (because she was the widow of a German diplomat). She was helpful im [sic] mediating, but still I saw the community through the "lenses of outsiders" and I saw how much damage too much cultural isolation can do to a village building effort and how many opportunities are missed that way. We must

118 Bauwens, "The Emergence of Open Design and Open Manufacturing," *We Magazine*, vol. 2 <http://www.we-magazine.net/we-volume-02/the-emergence-of-open-design-and-open-manufacturing/>.
119 <http://www.bigbluesaw.com/saw/>.
120 <http://www.emachineshop.com/> (see also <www.barebonespcb.com/!BB1.asp>).
121 Clive Thompson, "The Dream Factory," *Wired*, September 2005 <http://www.wired.com/wired/archive/13.09/fablab_pr.html>.

> consider the local and the regional as equally important as the global, in fact the global activates the local and regional potential. It makes us refocus on our neighbors because we bring in a lot of interesting stuff for them - and they might do the same for us....
>
> * the overall OSE project is radically geared towards local autonomy—something which sometimes seemingly cuts deeply into efficiency and especially life quality. I think that in many respects the Factor e Farm zeal, the backbreaking heroism of labor, the choice of the hard bottom-up approach, is more a symbolic statement—and the end result will differ a lot. In the end, we might have regional cooperatives, sophisticated regional division of labor and a size of operations that might still be comparable to small factories; especially when it comes to metal parts, standard parts of all kinds, modules of the toolkit etc. But the statement "we can do it ourselves" is an important antidote to todays absolutely distorted system of technology and competences.
>
> We cannot really figure out what is the threshold where this demonstration effort becomes unmanageable; I think that it is important to start with certain aspects of autarky, with the idea of partial autarky and self-reliance, but not with the idea of total self-sufficiency. This demonstration of aspectual autarky is important in itself and gives a strong message: we can build our own tractor. we can produce our own buidling materials. we can even build most of our own houses.[122]

So OSE is performing a valuable service in showing the outer boundaries of what can be done within a resilient, self-sufficient community. In a total systemic collapse, without (for example) any microchip foundries, the CNC tools in the Fab Lab will—obviously—be unsustainable on a long-term basis. But assuming that such resilient communities are part of a larger network with some of Nahrada's "regional division of labor" and "small factories" (including, perhaps, a decentralized, recycling-based rubber industry), OSE's toolkit will result in drastic increases in the *degree* of local independence and the length of periods it can weather on its own resources.

100kGarages and OSE may be converging toward a common goal from radically different starting points. That is, 100kGarages maybe complementary to OSE in terms of Nahrada's criticism. And OSE is complementary to 100kGarages in terms of Eric Hunting's criticisms of the distributed manufacturing movement which we saw above (Jeff Vail also raised similar criticisms of distributed manufacturing, questioning whether it could move beyond its apparent fixation on trinkets[123]). Open Source Ecology's package of designs are about as serious and purposeful as it's possible to imagine; and every time another product is prototyped and its CAD files made public, it becomes available for the taking for anyone who wants to order it from a shop in the Ponoko or 100kGarages network.

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122 "Strategic Support for Factor e Farm and Open Source Ecology," *P2P Foundation Blog*, June 19, 2009 <http://blog.p2pfoundation.net/strategic-support-for-factor-e-farm-and-open-source-ecology/2009/06/19>.

123 Jeff Vail, "Distributed Manufacturing Beyond Trinkets," *JeffVail.Net*, September 28, 2009 <http://www.jeffvail.net/2009/09/distributed-manufacturing-beyond.html>.