Applying Nanotechnology
To the Challenges of Global Poverty: Strategies for Accessible Abundance

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1ST CONFERENCE ON ADVANCED NANOTECHNOLOGY:
RESEARCH, APPLICATIONS, AND POLICY
OCTOBER 21-24, 2004 WASHINGTON, D.C.

PRECONFERENCE DRAFT

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Abstract: Billions of people around the world still suffer from inadequate access to clean water, energy, information, shelter, healthcare and other basic needs. Despite positive trends, poverty is likely to persist for decades, especially compared to the prosperity currently enjoyed in wealthy countries. Advanced nanotechnologies could help poor people improve their lives, if developed in ways that are appropriate and accessible. Examples of potential molecular manufacturing applications for water, energy, information, health, and materials illustrate future opportunities and strategies for applying nanotechnology to reduce global poverty and promote sustainable prosperity.

Research and development of appropriate applications could increase the availability of benefits from advanced nanotechnology. Point-of-use water filtration could purify water for those without clean and reliable water supplies. Solar cells integrated into roofing panels could yield safe, sustainable, and inexpensive energy. Continuing drastic reductions in the cost of information technologies, enabled by nanotechnology, would facilitate universal access to computing and communications. Packaging of integrated systems applying advanced nanotechnology for diagnostic testing, custom compounding of medication, and targeted delivery of treatments, could deliver medical care where doctors and hospitals are scarce. Materials formulated with molecular precision could provide better shelter and tools. Molecular manufacturing could enable clean production and environmental clean-up, enabling global abundance to be both feasible and sustainable. Actual applications of nanotechnology will depend on a range of factors, including the evolution of related technologies such as

biotechnology and information technology, economic systems and institutions regulating intellectual property. Illustrative examples of possible applications, such as those discussed above, may be useful for planning scenarios, identifying objectives for research and development, and developing strategies to improve access to the benefits of advanced nanotechnology.

A range of strategies could expand access. Decentralized technologies could overcome some of the limitations of centralized systems. Appropriate design could pro-actively adapt technological solutions to sustainably serve needs. Open standards and innovative software could facilitate universal access. Suitable design of intellectual property arrangements could share access to useful knowledge. Guidelines, templates, and procedures for safe design and operation could reduce risks of abuse and promote affordable international access to the benefits of advanced nanotechnology.

Application of advanced nanotechnology is likely to be profoundly disruptive, posing challenges of socioeconomic transition. Useful lessons can be learned from earlier transitions from agricultural to industrial to service economies, and from command to market economies. Molecular manufacturing could not only help to alleviate material deprivation, and illness, but also expand opportunities for experience, personal growth, exploration, and participation in larger endeavors. Suitable policies and programs could facilitate individual and social adjustment to expanding opportunities. Availability of advanced nanotechnology could help provide not just a safety net to cushion socioeconomic transition but a foundation for global prosperity for all.

Global Poverty

At present, over a billion people live on less than one dollar per day, while some three billion people, nearly half the world's population, live on less than two dollars per day. Over a billion people lack access to improved water sources. Over two billion are not connected to electricity. These are only a few of the stark statistics of global deprivation and denial of opportunities. During the twentieth century, huge growth occurred in global production and notable progress was made in reducing the proportion of those living in poverty around the world. The Millennium Development Goals of the United Nations set ambitious goals to halve the number of people of in poverty by 2015. It is far from certain that the goals will be achieved. However, even if they are achieved, large numbers of people will still live in poverty.

Advanced nanotechnology could offer an awesome range of possibilities to provide pure water, sustainable energy, global communications, accessible healthcare, advanced materials and a clean environment. However, the question is whether the benefits of these new technologies will be available for everyone, including poor people in poor countries, or, will the benefits be restricted to those who are already wealthy in global terms?

This essay looks at some of the ways in which advanced nanotechnology, also termed molecular manufacturing, could be applied to improve the lives of those living in poverty. Benefits depend not just on technical innovation but the institutions that influence who has access to technologies. The following sections use a range of potential applications to look not just at technical potentials, but also at strategies expanding access to the benefits of advanced nanotechnology: decentralizing technologies, adapting designs, opening access, sharing knowledge, verifying safety, recycling resources, and facilitating socioeconomic transitions.

Decentralizing Technology for Pure Water

Precision engineering at the level of individual atoms and molecules means the capability to build extremely effective filters to remove all impurities from water. While the timetable for such advanced nanotechnology is uncertain, it is likely that even decades from now many people around the world will still lack access to pure water supplies.

On the other hand, technologies for safe and affordable urban water supplies have been available since the nineteenth century. Even for rural areas, many technical options are already available for protecting sources and, where necessary, filtering and treating water. Current international critiques of water management emphasizes the extent to which lack of clean water is not simply a matter of technology, but a "crisis of governance," the failure of the institutions, including national and local governments, to ensure basic utility services are available not just to the wealthy but to the poor. One strategy now being pursued in many countries is to improve the institutional framework within which water supply services are provided, reforming water governance.

Institutional solutions can yield progress, but take time to shift entrenched bureaucracies. The natural monopoly character of centralized water systems poses major challenges for reforms. Some options, particularly privatization of service delivery, are subject to intense debate and opposition. The independent regulatory agencies and courts needed to oversee more accountable service providers are often absent. In the meantime, billions of people lack access to improved water supplies such as piped water systems and covered wells, and so must rely on riskier sources. Even where improved supplies are available, they are still susceptible to contamination, or may be neglected in favor of more convenient sources. In these circumstances, point-of-use solutions can make a difference and are the subject of increasing interest. Point-of-use solutions are not a replacement for centralized piped water systems, but can complement them, where services are not yet available or where the quality and reliability of piped networks cannot be assured.

Advanced nanotechnology could remove not just the bacteria and solids extracted by current treatment technologies, but also remove even trace levels of toxins (such as arsenic) and biologically active molecules (such as synthetic hormones). The capacity for nanotechnology to deliver molecular level filtration and extreme purity is an illustration of how development of decentralized technology can offer services to poor people to serve their basic needs. The proliferation of bottled water use, in both poor countries and rich countries, illustrates the large demand for pure water that advanced nanotechnology might serve.

Adapting Designs for a Solar Economy

Photovoltaic systems offer a sustainable source of energy. Solar energy could overcome the resource limitations and pollution problems of fossil fuels, making productive use of the vast amounts of energy that the earth already receives each day from the sun.

At present, the delivered cost of current solar energy systems is not yet competitive, still much higher than the prices charged for conventionally generated electricity (although those charges omit significant environmental costs). Installation of photovoltaic systems is further complicated by the need for storage, and for conversion to the convenient voltages.

Basic nanotechnology, processing materials at the nanoscale of billionths of a meter, already offers the prospect of substantially reducing costs and increasing the flexibility of photovoltaic systems. Advanced molecular manufacturing could be a key to further raising the efficiency of photovoltaic systems. However, in addition to the technical requirements of greater efficiency, further design challenges would need to be overcome, to supply power when needed and in ways that are easy to install and operate. Design of photovoltaic systems needs to be integrated with storage or other sources to provide power when it is needed, not just when the sun is shining. Operation in conjunction with fuel cells is one way to resolve storage problems, since the fuel cells can be "run backwards" to split water into hydrogen and oxygen, when surplus power is available. Systems connected to an electric grid may also be able to send surplus power back into the grid.

Deployment in rural villages and sprawling megacities of developing countries brings additional requirements for simple installation and use. In developing countries, roofing materials made from materials such as fiberglass and plastic already compete with traditional products such as tile and galvanized metal. An obvious solution would be to incorporate photovoltaics into panels that can be used for roofing and siding on homes and other buildings. Thus, a significant challenge, and a strategy for making the benefits of advanced nanotechnology widely accessible, comes not just in developing the basic technology, but in designing appropriate ways to deploy the technology so that it is easy to adopt.

Opening Access to Communications and Computing

Nanotechnology opens the path the keep reducing the cost and increasing the power of computers and information technologies by further orders of magnitude. Huge amounts of money are already being invested in ways to further shrink electronic components. Low cost technology compatible with open standards could allow universal access to communications and computing.

The expansion of computers and the internet brought increasing concerns about a "digital divide," the risk that those in poorer countries would be left behind and disadvantaged in access to information, communications, and international competitiveness. Many developing countries suffer from shortages of skilled teachers and educational facilities, with budgets inadequate to invest in educating future generations. Various initiatives have been undertaken to develop low cost computers for developing countries. The need is not only for hardware, but for software and for systems that actually assist learning.

Rapid advance in information technologies has brought opportunities to "leapfrog" by applying advanced technologies. Wireless telecommunications are helping to overcome the "last mile" problem in communications links. Satellite-based internet services offers further ways to expand access. The "inter" in internet comes from the open standards that allow interconnection between different computers and communication systems. The open standards of the internet and the world wide web are often taken for granted. However, maintaining open standards may be crucial to further extending access to computers and communications.

The basic justification for public funding of education lies in the wider social benefits that accrue to society from having skilled and knowledgeable citizens. Furthermore, students and their parents often lack the means to adequately finance education, even when the future benefits may be quite large. The same argument can be used to justify global support for educations, as an investment with large payoffs, which does not receive enough resources.

Neil Stephenson's novel of advanced nanotechnology, *The Diamond Age*, described a "universal primer," mass produced cheaply and quickly using nanotechnology, with an interactive educational curriculum for self-learning. More recently, after the successful flight of SpaceShip One, the X-Prize consortium is proposing to offer a new set of prizes for innovative technologies. One of the possible candidates would be a nanotechnology molecular assembler. Another would be "Education: Demonstration of a self-sufficient education facility able to operate independently and educate villagers anywhere on the planet." Progressive miniaturization, lowering costs and power requirements, while increasing capacity would be a key to making such technology possible, especially for a device that could operate independently.

Sharing Knowledge for Healing

Diagnostic tests are likely to be among the early applications of nanotechnology. Medical tests ultimately depend on detecting changes at the scale of cells and their constituents. Precise manipulation of small samples can enhance accuracy, and allow simultaneous processing of an array of samples and tests. Nanotechnology can also contribute to more sensitive sensors for nondisruptive external and internal monitoring. Vastly smaller and more powerful electronics can further enhance the capabilities of sensors, and of the systems that analyze their information to support diagnosis and prescription. As capacity for molecular manufacturing develops, pharmaceuticals may be one of the early high value applications. Precision formulation can avoid contamination, and ensure that only the exact molecules needed are produced, avoiding waste and unwanted side effects. Nanotechnology can help to deliver medications to precisely where they are needed in the body, offering enormous gains in efficiency and effectiveness compared to the crude delivery mechanisms of current pills and injections.

However, the question is whether access to advanced medicine will be available to all, or only to a wealthy minority. High prices and intellectual property rules can make medicines unaffordable. Poorer countries have come under increasing pressure to comply with intellectual property rules, in ways which may restrict access to medical treatment and also make it harder for local companies to comply with intellectual property rules and compete effectively. Lack of buying power on the part of poor people also impedes investment in developing treatments for diseases that afflict only those in poor countries. The AIDS crisis has heightened attention to the way in which pricing policies can block access, and the huge potential benefits of reducing barriers to access.

Adjustments in intellectual property rules and pricing policies have now begun to expand access to AIDS treatments, lowering prices and allowing production and export from low cost suppliers. The anthrax crisis showed the willingness of even the U.S. government to impose changes in pricing or compulsory licensing. There is also now increasing recognition in the United States that public support for scientific research ought to be matched by broader access to the results of such research. In short, intellectual property rules are subject to reconsideration and revision.

Even within the context of current intellectual property rules, various means are available to share knowledge. The open processes of scientific research and publication put vast amounts of knowledge into the public domain. Recent initiatives to expand access to scientific journals, in general and specifically in poor countries, help to make this knowledge more accessible. Licensing, usually with payment of royalties, is a well-established way to allow access to patented knowledge. Recognition of the problems of orphan diseases, for which the number of patients is too small, or the patients too poor, to be commercially attractive for developing vaccines or treatments, has brought more attention to the role that can be played by public and private subsidies for research, including prizes or bounties for particularly important targets, such as malaria vaccine.

Measures such as these could be combined to share the knowledge needed to diagnose and treat disease. A special purpose nanofactory, able to compound medications on the spot could provide flexibility, avoiding the need to maintain large stocks of different medications. Regulations on dispensing medicines could be implemented by only allowing operation by authorized personnel. The same kind of requirements for authentication could also help prevent use for formulating other dangerous substances.

Thus it is conceivable that relevant medical knowledge can be shared and delivered to those who need it, with suitable packaging of both technology and intellectual property. It would require overcoming the challenges of both designing suitable equipment and bundling public domain, open source and licensed intellectual property. This would obviously not eliminate danger, but would put it within a controlled context, subject to regulation and enforcement, that could be designed to be at least as safe, and probably much safer, than the current regulatory framework applied to pharmaceuticals and toxic chemicals.

Verifying Safety in Manufacturing

The ultimate achievement of molecular manufacturing would be a general-purpose nanofactory, capable of fabricating almost anything. A box the size of a microwave oven might offer a large menu of choices. If such a nanofactory could be used to produce all its own components, then exponential growth would help to make such capabilities available very rapidly for the whole world.

Appreciation of the productive potential of molecular manufacturing has been accompanied by fears, first of runaway replicators proliferating out of control and second of the dangers of weapons using nanotechnology. More recently concerns have been expressed about health risks of nanoscale materials, including those already being used in commercial products such as cosmetics and those being studied by researchers, such as carbon nanotubes.

Earlier conceptions of nanomanufacturing brought concerns about run-away replicators and other abuses. It is now clearer that there is no need to build a nanofactory that can extract its own raw materials from the environment, move around on its own, reproduce its components and itself without external command or authorization, or be able to evolve and build new products independently. Designing and building nanofactories that use externally provided materials, depending on outside transport, working only when given properly authorized commands, and only producing approved products would be much easier and more efficient technically, as well as safer. Effectively implementing guidelines and designs for safe manufacturing would be a key to developing advanced nanofactories that could be safely spread around the world. Restriction and verification of the capabilities, product designs, and outputs of nanofactories would also contribute to reducing the dangers of equipment being abused to produce dangerous weapons.

More specialized production equipment would be likely to precede a general purpose nanofactory. The capability of molecular engineering could produce materials far stronger and lighter than those currently available. In the same way that plastic pipe makes it much easier to deliver water to rural villages and to homes, new building materials could offer properties such as strength, insulation, and easy construction. Such materials could be both very light and extremely strong. If most of the interior space consists of air (or vacuum) then they would provide high quality insulation against heat or cold. Fabrication on site would help to further reduce costs. For simplicity, one can think of assembling prefabricated blocks. However, in practice, construction might be more like pouring formwork or spraypainting in 3D.

Providing a menu of verified designs for the products of nanofactories would also provide a process through which safety can also be protected in terms of avoiding release of hazardous materials, including relevant regulatory review. If production requires authorization and verification, for example through encrypted communications, then further levels of control would be possible. An open source approach to providing templates for materials and equipment to be produced in nanofactories could further expand access to benefits of advanced nanotechnology. One can think of having a large catalogue of tested designs, freely reproducible without royalties.

At another level, an open source approach could be applied to various levels of nanofactory systems. Open standards for interconnection between different components would facilitate technological development, helping to avoid monopoly traps of exploitation, exclusion or abandonment. An open architecture could still allow specific modules using proprietary commercial software. In this connection, it may be worth noting that open source software, such as BSD Unix or Linux, typically runs on microchips subject to a host of patents. Applying an open source approach at one level need not mean that every other level or component must be open source. Developing a verifiably safe open source architecture for nanosystems could be an extremely powerful way to promote innovation in general, and accessibility for poor people in particular.

Recycling Resources to Sustain Abundance

Nanotechnology offers the prospect of enormous increases in productive capacity. However, if this creates increased demand for scarce resources and generates pollution, then growth would be unsustainable. Much current rhetoric about international development, economic growth and globalization points to "overconsumption" in wealthy countries as a source of global environmental degradation. The threat is that further economic growth could worsen global warming and other problems.

Pollution is a problem not just in wealthy countries, which have made huge gains in cleaning up their environment, but even more so in the villages and megacities of the developing world. The cost of treating waste, scarcity of resources, and abundance of competing priorities, in an environment with little effective monitoring and weak regulatory enforcement, often leads to wastes being disposed without treatment.

Molecularly precise assembly would enable extremely efficient production, with little waste and pollution, if suitably designed. As with water purification, the capability for atomically precise manipulation would also facilitate recycling, decomposing wastes to recover useful materials for further production, "closing the loop" in an industrial ecology. Advanced nanotechnology could thus both help reduce the amount of pollution produced, and help in cleaning up the environment.

Perhaps even more important at the conceptual level, is the way in which nanotechnology offers the potential for environmentally sustainable prosperity. Much thinking about international development is still influenced by ideas about limits to growth, resource scarcity, pollution (including global warming), and overconsumption. By enabling closed cycles of material use, and environmental clean-up, nanoremediation, nanotechnology suggests the feasibility of a green path to wealth for all.

Facilitating Socioeconomic Transitions

Advances nanotechnology offers a cornucopia of possibilities, which may make abundant many things which are now scarce. Salt and pepper were once high value trade goods, and watches were once precious high tech gadgets. Salt is now one of the cheapest products sold in shops. Wristwatches can be bought for a few dollars. Wall clocks are so cheap and reliable that they fade into the background.

Nanotechnology promises to be a profoundly disruptive technology that, especially in combination with changes in information technology and biotechnology, ushers in social and economic transformations as great or greater than in previous transitions from hunting and gathering to agriculture, and from agriculture to industrial society. However, rather than change spread across generations, transformations may be even more accelerated than those accompanying the spread of computers and telecommunications in last two decades of the twentieth century. As happened in Russia and other former command economies, a rapid economic transition could render many industries obsolete and uncompetitive, and put masses of people out of work. There is a threat of drastic economic crisis, on a scale of the Great Depression of the 1930s or worse. On an even more fundamental level, many people derive not just their income, but the identity and community from their work. Loss of work thus brings the threat is the loss of meaning, the disruption of the livelihoods and relationships that people rely on to understand and orient their lives.

Contemporary definitions of poverty look not just at income, expenditures or nutrition, but also examine a range of factors that influence quality of life and ability to pursue livelihoods. Thus overcoming poverty is not just a matter of fulfilling basic needs for water, food, and shelter, but also of being included in a system of rights and relationships that helps cope with natural disasters and other shocks, secures access to resources, and supports social, political and economic cooperation. So it is important to think not just about how nanotechnology might support material abundance, but how it might affect other aspects of people's livelihoods and lives.

Societies are not helpless in the face of economic crisis. The emergence of an advanced nanotechnology could require the equivalent of a global early retirement program. It is useful to review some of the short and medium term tactics already used in the United States and elsewhere to maintain stability and provide social safety nets:

- Unemployment benefits provide some continuing income while searching for new employment.
- Education helps people learn new skills and pursue interests and personal growth. It also acts to buffer the impact of unemployment (as occurred with the GI Bill in the United States after World War II)
- Entitlement programs can help provide a "safety net" of access to food, and other basic needs, (as done with Food Stamps and other means-tested benefits)
- Jobs can be created by government, (as for example occurred with the Civilian Conservation Corps and Works Progress Administration during the Great Depression)
- Pensions assure income to those who have retired or want to retire (equivalent to the U.S. Social Security system)
- Health care can be publicly provided (Medicare and Medicaid in the U.S.)
- Macroeconomic policies can help maintain demand and stimulate the economy

There is of course plenty of room for debate about specific programs and about larger issues concerning the relative roles of governments and individuals in responding to economic changes. Nevertheless, it is clear that governments are far from helpless. Many measures are available to respond to the disruptions that may occur, even from rapid technological and socioeconomic change.

Programs such as these will be relevant not just for wealthy countries that already have extensive programs for public assistance, but could also be developed in poorer countries to help mitigate the effects of technological unemployment and economic crises. The World Bank, International Monetary Fund (IMF) and other international financial institutions were established to promote economic recovery after World War II. They subsequently took on an increasing role in coping with economic crises and promoting international development. To the extent that technological change produces unemployment, financial crises and other problems, international financial institutions could continue to play an important role.

Expanding access to the benefits of nanotechnology also means finding ways to facilitate transitions to lifestyles that offer quality of life, not just in terms of material satisfaction but also in terms of meaningful activities and participation. There is a need to develop clearer ideas about how people will live and work in a society where nanotechnology is widely applied. Clearer visions of what may be possible can help to plan ways to respond to the opportunities and threats that accompany major socioeconomic transformation.

One way of describing this is in terms of the development of an "experience economy" oriented not towards the production of goods or services, but of meaningful experiences. For many people, leisure pursuits, such as hobbies and sports, may offer a focus for interests. Some may be content with more passive entertainment, or interaction in the virtual realities of computer games and simulated environments. The opportunity for continuing education may be important for many, both for personal growth and in order to become more capable of responding to a changing world. Some forms of experience go beyond just pleasurable entertainment to become more a matter of personal transformation, whether psychological self-improvement or spiritual quests. Large social projects might also offer a framework for meaning for many, whether environmental restoration, space exploration or participation in various kinds of communities pursuing common interests such as art, reenactment of historic events and lifestyles, or the creation of new communities. Various kinds of education may play a crucial role in helping people to orient themselves amid the choices facing them.

Many critics of globalization and contemporary capitalist development seek alternatives that would empower local communities to pursue sustainable, self-reliant lifestyles based on their own values. In the face of wrenching change, many people do want to be able to preserve their values and live with those who share similar culture and aspirations. Arrangements for allowing greater autonomy to various communities may be one way of enabling people to make a smoother transition that takes advantage of the potentials enabled by advanced nanotechnology and other changes.

Strategies for Accessible Abundance

Advanced nanotechnology could be applied to overcome many of the problems of poverty. Impurities could be filtered to deliver clean water. Appropriately designed roofing panels could capture solar energy to provide sustainable energy. Continued miniaturization in electronic components would enable computing and communication capacity to become universally available. Nanoscale sensors could provide the information for diagnosis, medications could be compounded on the spot, and then precisely delivered where they are needed. Nanofactories could produce advanced construction materials, equipment and other products. Clean production and the ability to decompose wastes would enable sustainable abundance. Advanced nanotechnology could provide not just material goods and improved health care, but abundance of time and opportunities for people to pursue their interests and participate in larger endeavors.

A range of strategies could be used to help make the benefits of advanced nanotechnology available to the poor. Development of decentralized technologies such as point-of-use water filtration can provide new options to those not adequately served by centralized systems. Innovative design could adapt solar panels and other products for convenient installation and use in homes. Open standards for information technologies could help to ensure that the benefits of education and easily accessible information are universally available. Integrated packaging of technologies and accessible intellectual property for medical diagnosis and treatment could help deliver health services even in rural areas and for those who are unable to afford expensive hospital-based medical care. Implementing guidelines for verifiably safe molecular manufacturing equipment could help avoid unnecessary restrictions and allow widespread distribution of nanofactories. Improved understanding of the potential for clean manufacturing and environmental cleanup using advanced nanotechnology would help overcome fears about resource scarcity and pollution, showing that global prosperity is feasible and sustainable. Policies to facilitate socioeconomic transition can strengthen social safety nets and help individuals and communities to take advantage of new opportunities.

Nanotechnology is not a panacea, and will certainly not bring an end to problems. Instead, it offers further challenges, both transitional ones of how to expand access to benefits and reduce risks, and more fundamental choices about how people want to live their lives, pursuing their interests and visions

Notes

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Advanced nanotechnology capabilities. The discussion here generally follows the types of molecular manufacturing capabilities first outlined in Eric Drexler's *Engines of Creation* and then further described by Drexler et al. (1991) in *Unbounding the Future*. For a further discussion of some of the potentials of advanced nanotechnology, see Robert Bradbury's (1999) essay "Sapphire Mansions." For an example of critical discussion, see the etc Group's 2003 report *The Big Down: From Genomes to Atoms*.
Global poverty. The World Bank is the main source for estimates of global poverty. The one and two dollar a day poverty lines are relatively arbitrary, and measurement of global poverty can get quite complicated. For a presentation from the World Bank point of view see Dollar 2004. For an introduction to some of the issues of international inequality see More or Less Equal?" in *The Economist* (Mar 11th 2004) and the essay by Deaton (2003) cited there. For a recent assessment of global access to improved water supplies in the context of the Millennium Development Goals, see WHO/UNICEF (2004).
Water filtration. For a contemporary discussion of one point-of-use filtration technology see Roberts (2003). An international network was established in 2003 to promote household water treatment and storage (WHO 2003).
Photovoltaics. For a recent discussion including "basic" nanotechnology, i.e. nanoscale materials without precise manipulation at the atomic scale, see Fairley (2004). For a

discussion of a hydrogen economy with decentralized technology, emphasizing natural gas and fuel cells, see Lovins (2003).
Nanofactories. Phoenix and Drexler (2004) present arguments for the advantages of a factory-style approach to advanced nanotechnology, which would make autonomously self-replicating nanobots inefficient, unnecessary and deserving to be prohibited.
Transitions. Pine and Gilmore (1999) describe the development of an *Experience Economy*. Frederick Turner (2002) offers an interesting exploration of implications of global wealth in his essay “Make Everybody Rich.”

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