Policy Forum Online 10-010: February 5th, 2010

-"Transformative Technology for a Sustainable Future"

By Peter Hayes

CONTENTS

I. Introduction

Every so often in history a technological innovation emerges that has a transformative effect on human civilization. As the world ponders how to avoid the catastrophic effects of climate change, Nautilus Institute Director Peter Hayes looks at some of the possible technological breakthroughs that could pave the way to a sustainable future.

The views expressed in this article are those of the author and do not necessarily reflect the official policy or position of the Nautilus Institute. Readers should note that Nautilus seeks a diversity of views and opinions on contentious topics in order to identify common ground.

II. Article by Peter Hayes

-"Transformative Technology for a Sustainable Future"
By Peter Hayes

The prospects for achieving global sustainability dimmed considerably after the debacle at the December 2009 Copenhagen climate conference, at least for the next few years.

This is bad news indeed, not only for the ultimate sustainability problem, climate change, but for other pressing issues — biodiversity, waste disposal, ventilation, water supply and many other essential environmental services. These too are all at risk due to human activity.

Without strong political leadership on climate issues, a global framework for market-based solutions to sustainability is unlikely to emerge. Nor does it look likely that governments will invest sufficiently in overcoming poverty to relieve pressure on critical environmental resources in the southern hemisphere. This leadership deficit is likely to persist, and underscores the need for a response one layer down at the level of cities and civil society. Although such a bottom-up response is important, it too will likely fall short of what is needed.

What other resources exist that can give rise to hope rather than gloom in the wake of the Copenhagen charade?

Technology is one source of optimism. Although technology may either undermine sustainability or contribute to it, the problem is that it often changes slowly, with incremental innovation. But every now and then, technologies emerge with little or no warning that disrupt existing market players (who often try to suppress the newcomer) or are so potent and universally applicable that they are transformative and rapidly displace old technology.1 Much of the technology needed to respond to climate change is the same as that needed to solve other sustainability problems.

Transformative technologies, sometime called platform technologies — the most recent example is the Internet — serve as springboards for technological change in many sectors at once. The steam engine, machine gun and genetic crop modification led to pervasive and massive impacts on the world economy, warfare and agriculture, respectively. Transformative technologies occur rarely, perhaps once or twice in a generation, and are inherently hard to foresee or recognize as they emerge.

Such transformative technologies are not born in vacuo, however. Usually, they draw on multiple strands of pre-existing technology recombined in ways that were previously unthinkable. Also, these technologies prove unstoppable because they respond much better to multiple needs simultaneously in ways that old, disparate technologies could not, either individually or in combination. Thus, there is a demand as well as a supply side to the timing of transformative technologies.

GRAPHIC 1 THE TECHNOLOGY REVOLUTION: TREND PATHS, META-TRENDS, AND "TICKETS"

Source: *The Global Technology Revolution, Bio/Nano/Materials Trends and Their Synergies with Information Technology by 2015*, RAND. See Note 2.

Past Technology	Present Technology	Future Technology
Then	Now	Soon
Trend Paths		
Metals & traditional ceramics	Composites & polymers	Smart materials
Engineering & biology separate	Biomaterials	Bio/genetic engineering
Selective breeding	Genetic insertion	Genetic engineering
Small-scale integration	Very-large-scale integration	Ultra/giga-scale integration
Micron plus lithography	Sub-micron lithography	Nano-assembly
Main frame	Personal computer	Micro-appliances
Stand-alone computers	Internet-connected machines	Appliance & assistant networks
Meta-Trends		
Single disciplinary	Dual/hierarchically disciplinary	Multi-disciplinary
Local	Regional	Global
Physical	Information	Knowledge
Trade schools	Highly specialized training	Multidisciplinary training
'Tickets' to the Technology Revolution		
General college	Specialized degree	Multidisciplinary degree(s)
Locally resourced products	Locally resourced components	Products tailored to local resources
Capital ($)	Increased capital ($$)	Mixed

As one might expect, the US military is especially interested in maintaining its technological edge against upstart technologies. It spends considerable effort anticipating how the convergence of dramatic technological innovation might present game-changing challenges. As a RAND Corporation report states (see Graphic 1) : "Beyond individual technology effects, the simultaneous progress of multiple technologies and applications could result in additive or even synergistic effects … Some advances will introduce capabilities that could be used to aid other advances and hence accentuate their effect beyond what would be achievable if the effects were independent and merely additive."2

The convergence of multiple transformative technologies may prove to be one of the missing links between our unsustainable past and a green, sustainable future.

Eruptions of transformative technologies resist prediction, not least because they are often produced first on a small scale and in tiny organizations without government or corporate backing. A good way to track these technologies is to follow venture capital. Even in the midst of the global financial crisis, investors have been sinking billions of dollars into new information, nano- and bio- technologies, the success of any one of which could have momentous implications for sustainability.3 Should these rapidly evolving technologies converge, the resulting fusion could have a truly transformative global impact.

Sustainability and Information Technology One emerging technology that could become transformative is the smart power grid, which uses information technology to radically change the way electricity is delivered. Smart grids monitor the flow of electricity to and from generators and consumers, use transmission lines to reduce power loss and accommodate intermittent and renewable power generators, enhance multi-layered network resilience and facilitate demand side management.4

In 2009, about $69 billion was spent globally on smart grids, of which about $21 billion was for “Unified Smart Grid” implementation in the United States. Europe is developing a “SuperSmart” grid, Australia committed to a “Smart City, Smart Grid” in 20095 and China has announced plans to create its own hybrid “Strengthened Smart Grid” by 2020.6 Dozens of technological innovations in hardware and software are needed to achieve this shift from a unidirectional, centralized grid system to an omni-directional, decentralized, polycentric, and locally controlled grid.

In general, smart grid technology can be grouped into five key areas — integrated communications, sensing and measurement, advanced components, advanced control and improved interfaces and decision support.7 But most technologies enabling the smart grid are off-the-shelf. As envisioned, smart grids will develop incrementally using these technologies and will not be discontinuous and transformational. In China, the initial emphasis on very high-voltage transmission lines — and the decision to delay the integration of renewable energy generation to a later stage — reinforces the traditional electric utility culture, dominated by engineering values.

To become transformative, smart grids need to couple with new technologies for urban redesign, transportation systems and new modes of power generation, distribution and end use — all of which are driven by sustainability imperatives. Of these, the vision of electric and hybrid cars serving as generators when not in use or re-charging is a possible combination that makes the smart grid and hyper-car, considered together in a fusion, truly transformative.8

For this to occur, hyper-cars need to move from concept to sales lot in large numbers, and smart grids will need to accommodate millions of new, small auto-generators feeding electrons back into the grid.9 The hyper-car entails shifting from fossil fuels or a centralized power supply stored in batteries to industrially produced bio-fuels, as well as genetically enhanced plants with high efficiency photosynthetic conversion of sunlight to biomass. Another concept is to convert underground coal or natural gas in situ into hydrogen, storing the carbon dioxide underground, and using the hydrogen in fuel cell-powered hyper-vehicles.

Such a shift from centralized generation, whether fossil fuels or renewable sources such as wind, to millions of small-scale generators that are also consuming machines, would turn the smart grid upside-down and inside-out — and reap huge gains in energy efficiency, avoid billions of tons of greenhouse gas emissions, increase network resilience in the face of climate impacts on the power system, and yield massive economic savings.

To work, such a system would need high bandwidth wireless monitoring and decision-support systems that could support tens of millions of parked auto-generators, and the development of automatic power dispatch algorithms that reflect the interaction of driving patterns with power generation capacity. The fusion of the smart grid with hydrogen and bio-fueled hyper-cars is a possible transformative technology that could become the platform for a sustainable civilization.

Of course, no one can predict exactly how such a transformative technological fusion will emerge. But let us assume that something along these lines happens over the coming generation. What else is on the sustainability horizon that might complement the IT-enabled smart grid combined with the hypercar?

Sustainability and Nano-Technology

Manufacturing at the nano, or molecular, level is already big business. Two sustainability applications have immense potential to increase the efficiency of energy use and production.

The first is the use of specialized coatings to achieve a cooling effect on buildings and pavements. Most of these man-made surfaces are produced with little regard to their impact on a technical measurement called albedo, which is the amount of light that is reflected rather than absorbed by a surface. Roofs, for example, could use materials that provide a high near-infrared radiation reflectance basecoat, and a cool topcoat (tens of microns) with weak near-infrared radiation absorption. Doing so, according to a recent technical analysis, would increase their albedo by about 10 percent, and result in cooler surfaces.10

If implemented globally to cool roofs, this relatively simple measure could avoid huge amounts of local cooling requirements and offset as much as 24 billion tons of carbon dioxide emissions per year, at low cost. The same principle applies to pavements (equivalent to another 20 gigatonnes of emissions), and indeed, to any human object that is exposed to the sun and requires cooling. Acrylic, elastic polymers and cement coatings and plastic membranes are already available for roofs and to a lesser extent for pavements. However, widespread use would likely generate new nano-tech based coatings that would interact with intelligent building materials and structures in ways that would anticipate and adapt to the operational needs of the smart grid — and a stock of decentralized generators based on the hyper-vehicle fleet.

Another nano-tech innovation with transformative potential is the development of nano-rods that serve as nano-scale photovoltaic cells. In less than a year, the Helios Project Team at the US Lawrence Berkeley National Laboratory demonstrated the feasibility of creating a forest of vertically aligned nano-rods decorated with catalysts at the top and bottom that match the solar flux to generate electricity.

Membranes of nano-photovoltaic cells developed into a commercial product could lead to completely unconventional pathways to power production on coatings applied to objects and buildings. Just as today's electric hybrids prefigure hyper-cars, today's clunky and expensive solar cell panels presage this vision of nano-photovoltaic power generation. The current approach is constrained by cost and complexity of operation whereas nano-photovoltaics could be integrated seamlessly into building and object design, materials, construction and operation.

Is Convergence Enough?

Many transformative technologies emerge largely independent of organizational scale, location or funding. Does this mean that we can simply do nothing and wait for technological panaceas to save us?

Of course not. To do so would not only exhibit technological hubris, it would also ignore the history of such breakthroughs. Like any tipping point, the enabling conditions for system-level change must be in place for the shift to occur. A petri dish requires a suitable medium before bacteria can be cultured after seeding. Many incremental and divergent changes in individual, institutional and governmental behaviors are critical to create the conditions for transformative technological change to be welcome. Each of these changes requires careful, continuous and constructive efforts by governments, markets, and civil society to cultivate our receptivity to the radical technical changes needed to achieve sustainability.

Being in the right place at the right time is less a matter of luck and more a matter of concentrating on the forces that bring about luck. Put another way, we don't know which technological butterfly will result in a hurricane of change. Thus, the convergence of transformative technologies described above is one of a myriad of possible combinations of technological potential. Nonetheless, we know how to create and maintain butterfly habitats that ensure there are millions of butterflies fluttering, a few of which are likely to generate super-hurricanes of positive change.

For this reason, despite the failure at Copenhagen, we can be realistically optimistic about the prospects for humanity achieving a transition to sustainability.

Read the rest of the article at: http://www.nautilus.org/fora/security/10010Hayes.pdf

III. Notes

1) National Intelligence Council, "Disruptive Civil Technologies, Six Technologies with Potential Impacts on US Interests out to 2025," Conference Report, April 2008, http://www.dni.gov/nic/confreports_disruptive_tech.html

2) P. Anton, R. Silberglitt, J. Schneider, The Global Technology Revolution, Bio/Nano/Materials Trends and Their Synergies with Information Technology by 2015 (RAND, MR-1307-NIC), p.41, http://www.rand.org/pubs/monograph_reports/MR1307

3) The choice of these three is somewhat arbitrary, although guided here by venture capital flows. A different list of six disruptive technologies — biogerontechnology, energy storage materials, biofuels and bio-based chemicals, clean coal technologies, service robotics, and the Internet of things, is identified in “Disruptive Civil Technologies” (See note 1)

4) National Energy Technology Laboratory, A Vision For The Modern Grid, March 2007, http://www.netl.doe.gov/moderngrid/docs/ A%20 Vision%20for%20the %20Modern%20Grid_Final_v1_0.pdf, and Mason Willrich, “Electricity Transmission Policy for America: Enabling a Smart Grid, End-to-End,” MIT-IPC energy innovation working paper 09-003, July 2009, http://web.mit.edu/ipc/research/energy/pdf/EIP_09-003.pdf

5) “Australia’s Rudd Government Invites Industry Bids To Transform Its Energy Grid Through Smart Grid, Smart City Initiative,” Clean Technology Business Review, October29, 2009, http://www.cleantechnology-business-review.com/news/australias_rudd_government_invites_industry_bids_to_transform_its_energy_ grid_through_smart_grid_smart_city_initiative_091029

6) J. Li, Jerry, “From Strong to Smart: the Chinese Smart Grid and its relation with the Globe,” AEPN, Article No. 0018602, Asia Energy Platform, 2009, http://www.aepfm.org/ufiles/pdf/Smart%20Grid%20-%20AEPN%20Sept.pdf

7) National Energy Technology Laboratory, A Compendium of Smart Grid Technologies, July 2009, http://www.netl.doe.gov/moderngrid/referenceshelf/whitepapers/Compendium_of_Technologies_APPROVED_2009_08_18.pdf

8) A. Lovins, Hypercars, Hydrogen, and Distributed Utilities: Disruptive Technologies and Gas-Industry Strategy, Rocky Mountain Institute, 2000, http://www.rmi.org/rmi/Library/ E00-25_HypercarsHydrogenDistributedUtilities

9) See www.hypercars.com and A. Lovins, D. Cramer, “Hypercars, Hydrogen, and the Automotive Transition,” International Journal of Vehicle Design, Vol. 35, Nos. 1/2, 2004, pp.50-85.

10) H. Akbari, S. Menon and A. Rosenfeld, “Global Cooling: Increasing World-Wide Urban Albedos To Offset CO_2,” Climatic Change, 94, 2009, pp.275-296.

IV. Nautilus invites your responses

The Northeast Asia Peace and Security Network invites your responses to this essay. Please send responses to: bscott@nautilus.org. Responses will be considered for redistribution to the network only if they include the author's name, affiliation, and explicit consent.