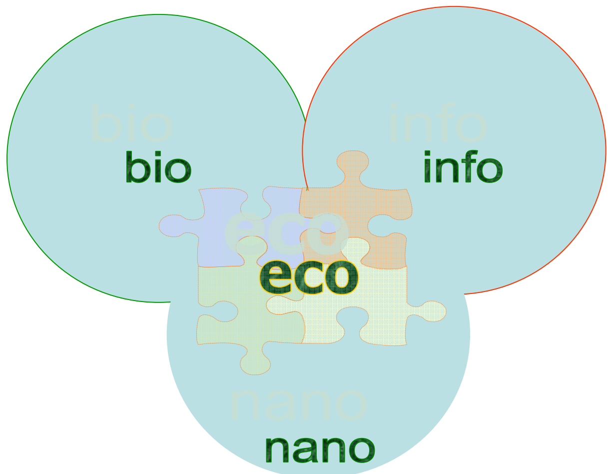
Convergence of Global Public Goods as a Catalyst for Sustainable Economic Growth

" O " What's Next ?



Shoumen Datta
Massachusetts Institute of Technology

Disclaimer : Comments in this document are by no means comprehensive for any national growth strategy. These suggestions are indicative of minor segments in any economic plan, albeit incomplete and inadequate. Important issues such as, infrastructure (land, sea, air) and energy are not discussed, yet, but are vital for growth. The topics (bio, info, nano, eco) mentioned here are generic sketches, not a roadmap of their true potential or future scope. Eco (energy) issues pertaining to hydrogen is discussed as a strategic vision statement. The purpose of this article is to suggest some of the exciting possibilities. None of the original ideas are that of the author. This may serve as a provocative guide for future initiatives, at best. The opinions and comments in this article are solely due to the author. The views expressed in this article do not express the opinion of Massachusetts Institute of Technology, as an institution. Please visit http://supplychain.mit.edu/innovation/shoumen.htm or send email to shoumen@mit.edu.

The physicist Leo Szilard once announced to his friend Hans Bethe that he was thinking of keeping a diary: "I don't intend to publish. I am merely going to record the facts for the information of God." "Don't you think God knows the facts?" Bethe asked. "Yes," said Szilard. "He knows the facts, but He does not know this version of the facts."

Hans Christian von Baeyer in *Taming the Atom*

Why ask why, if you can ask, why not?

Biotechnology (bi**O**) and information (inf**O**) communication technology are rewarding directions for growth (basic & applied) and industry, but traditional approaches are over-subscribed. However, it appears that nan'**O**' science and technology is not yet a core in the traditional vein nor is the concept of ec'**O'**, according to the author, which targets to eliminate non-renewable fossil fuel in favour of using hydrogen as a fuel. Profound economic benefits for poor nations and political changes for the affluent nations may result from the hydrogen economy. The impact from nano may be significant for nation's that may be aligned to take advantage of this progression from engineering to nano-engineering. Wilson's Double Core tennis balls use nano-composite clay to keep them bouncing 2 to 4 times longer. They appeared at the 2002 Davis Cup and are now the official balls of this championship event. Babolat has introduced super-strong carbon nanotubes in tennis rackets for improved torsion and flex resistance. Nanotube enhanced golf clubs may be arriving soon. Drug delivery by nano-encapsulation is nearing human trials.

Creating an 'innovation' society within a 'knowledge economy' demands workforce creation that must promote a national policy of gender-blind encouragement in secondary and post-secondary systems for pursuit of science and mathematics, as key pillars for sustainable economic growth leading toward quality of life improvements. However, traditional educational curriculum that promotes learning of facts and regurgitation in tests are incapable and insufficient to address the needs of an 'innovation' society. Structured inclusion of experimentation from pre-teen years is essential to foster creativity. The latter demands teachers who have had exposure to basic research in core scientific principles. Policies to attract and retain teachers with some research experience to teach in secondary schools are essential for long-term sustainability of any 'innovation' society. It is also necessary to create programs that allow cross-pollination between secondary school and university faculty as well as secondary school student project activities that may be supervised by university students or faculty involved in research. It is imperative that nations do not replicate the gross mistakes of the US public K-12 education system as revealed in a seminal 1996 report from the Carnegie Foundation that suggested reasons for declining effectiveness of US basic education. The report reveals that 51% of mathematics teachers in US public schools (K-12) never took math as a part of their college curriculum. A third of the science teachers never took science as a major in college. A national survey of US high school physics found 18% of physics teachers had degrees in physics while 11% had *some* degree in physics education but not in core physics while 27% teachers had neither a degree nor experience in physics.

Building an 'innovation society' demands different measures. Innovation germinates when there is a confluence of education, respect, discipline and tolerance. However, the classical definition of education, respect, discipline and tolerance is not sufficient to gel the confluence which may shape imagination and pave the road for innovation (Albert Schweitzer in *The Decay and Restoration of Civilization*). In *Aims of Education*, the mathematician-philosopher Alfred North Whitehead observes, "the University of Cambridge which had done best at teaching mathematics is the one from amongst whose graduates have come more of the English poets, while Oxford which has specialized in the humanities, has tended to turn out writers who have attained, on the whole, a high level of mediocrity. I suppose that by the time one has discussed literature with a witty and learned professor, you know what has been achieved and how good it is. You become respectful and begin to wonder who am I to do better?'' The element of leadership, thus, is complex and most difficult to cultivate but it should be a key national goal.

In 1830, Ferdinand de Lesseps, a French diplomat in Cairo, dreamed of linking Europe and Asia (Mediterranean and Red Seas) by cutting a canal through 118 miles of arid land at a cost of FFR 200 million. In November 1869, the Suez Canal opened and fewer than 500 ships passed through in 1870, far below the projection (ROI or return on investment). Dividends failed to materialize on "shares of passion" and Egyptians, desperate for cash, sold the shares to Great Britain for GBP 4 million. In 2002, 15000 ships passed through the Suez Canal generating US$ 2 billion in revenues for Egypt (*Parting the Desert: The Creation of the Suez Canal* by Zachary Karabell). In 1880, Ferdinand de Lesseps formed a company to replicate his feat in Panama. This travail was undone both by weather and tropical diseases (yellow fever, cholera, malaria) that killed 22,000 labourers. In 1904, through the urging of US President Theodore Roosevelt, the US Army Corps of Engineers re-started the work, which would cost US$352 million and 5609 lives. In 1918, after four years in operation, less than 5 ships passed through the Panama Canal daily. Since 1970, more than 15,000 ships pass each day (*The Path Between the Seas: The Creation of the Panama Canal* by David McCullough).

In the 20th century, the 31 mile tunnel linking England to the Continent got started in 1987 fueled by GBP 5 billion from banks and 112,000 British investors. In its first 3 years since May 1994, The Chunnel saw fire and operating expenses around GBP 2 billion. In 1997, the original investors suffered losses when the banks seized shares in exchange for restructuring the crushing debt. By 2001, the winds changed, more than 16 million passengers and nearly 2.5 million tons of freight passed through the tubes (*The Chunnel: The Amazing Story of the Undersea Crossing of the English Channel* by Drew Fetherston).

Big ideas offer big dividends but have stormy beginnings. Even worse is when people cannot visualise the future because their imagination is bent out of focus by short-term ROI or resistance to change *status quo* in politics.

Creating analytical reports are essential but analysis should also bolster the need to change. Sometimes the latter is under-emphasized and may be reflective of authors who may be inclined to believe in core operating principles that 'should' remain unshaken and the continuity of the environment in which they operate (*Built to Last* by Jim Collins). In fact, that very environment is under constant change and they may be unable or too late to recognize the need for change integration. This issue of "continuity" in the context of a future vision may be simply wrong (*Creative Destruction* by Richard Foster and Sarah Kaplan). Economy is not a continuous process but rather a series of flash or strategic inflection points when the operative procedures may change suddenly and without warning (Andrew Grove in Financial Times, 20 August 2003). In this respect, economics draws from the study of evolution. Stephen Jay Gould, the famed Harvard evolutionary biologist and prolific author who influenced his field for decades, is perhaps best known for his idea of "punctuated equilibria" in which he argued that evolution consisted of relatively rapid spurts of species evolution rather than gradual, continuous transformations. A nation must continually take actions to reinvent itself to keep up with the competition and gain advantage. The economy must show resilience through a continuum of implementation, anticipation and adaptation to the future before the 'writing on the wall' becomes visible (Gary Hamel and Lisa Valikangas in *The Quest for Resilience* Harvard Business Review, September 2003). These and other similar ideas need to percolate within most world governments.

It is vital to ensure systemic integration of basic education with workforce creation to stimulate economic growth and create jobs suitable for the knowledge economy's 'innovation' society which could demand a standard of living improvement at least 2-10 fold higher than the current per capita income. Although creating policy is a preface to implementation as well as a legislative necessity for appropriations, true progress often demands 'out-of-the-box' leadership. Policy is like music, silent unless performed. Thus, implement systemic models that are economically sustainable and then, replicate programs for dissemination and adoption, to enhance global competitive measures.

Systemic vision requires individuals who can visualize future issues with a dynamic and analytical convergence lens which balances the odds of probabilistic decision making in a generally uncertain world. It is such 'inclusive' thinking that is less common because institutions still offer prizes for depth of expertise, almost exclusively. However, many erudite individuals such as Murray Gell-Mann and Nicholas Negroponte, continue to comment on the need for individuals with 'horizontal' understanding. But, academic *status quo* and paucity of such enlightened views are discouraging individuals to pursue a broad spectrum of 'horizontal' understanding. In "Darwin's Middle Road" that Gould wrote for his monthly column in the Natural History magazine, Gould once said, "if genius has any common denominator, I would propose breadth of interest and the ability to construct fruitful analogies between fields."

In 1910, General Billy Mitchell proposed that airplanes might sink battleships by dropping bombs on them. The US Secretary of War, Newton Baker, remarked, "That idea is so damned nonsensical and impossible that I am willing to stand on the bridge of a battleship while that nitwit tries to hit it from the air." The editor of the prestigious Scientific American wrote, "to affirm that the aeroplane is going to 'revolutionize' naval warfare of the future is to be guilty of the wildest exaggeration."

Global Leadership: Friend or Foe of Sustainable Economic Growth?

Biotechnology is currently, almost, synonymous with biopharmaceuticals. In other words, establishing corporate-academic liaison to generate basic research that can be scaled for applications and production of drugs. As of 2001, funding for six key (pioneer/leader) US biopharmaceuticals is an estimated US$6 billion (Exelixis, HGS, Lexicon, Millennium, Tularik and Vertex). In this "supply chain" where do you want to play? The "design" phase harbours the intellectual property and long term potential for premium jobs. Specialized technical employment (>5 fold per capita income) demands a pipeline of expertise that segues to concerns for mathematics and science foundation from pre-elementary to post-secondary education. Biotechnology initiatives may soon require new direction (nano-bio) and coordination for workforce development competent enough to attract investment.

Country	R&D personnel per million people	R&D Spending	GDP in 2002 Billions USD	Patents per million people	Population In 2015
Ireland	2,132	1.5 %	111	106	4.4 million
Israel	1,570	3.7 %	125	74	7.7 million
Singapore	2,182	1.1 %	93	8	4.8 million
UK	2,678	1.8 %	1,404	82	60 million
US	4,103	2.5 %	9,612	289	321 million
Japan	4,960	2.8 %	3,394	994	127 million

Table 1: Favourable R&D statistics?

It appears that nations are keen on the post-genomic era despite the complexity of genomic-proteomic approach that requires cross-functional multi-disciplinary programs to act in *synchrony*. Strategists are aware that screening 10,000 potential compounds may reveal only one which may find approval as a prescription drug. The process may take about 15 years and costs on average US$1 billion to develop. In 2001, worldwide pharmaceutical R&D topped US$50 billion. Where do you wish to position your nation on the biotechnology spectrum? Where do you stand on apomixic agri-biotech, RNAi (Alnylam) or nano-biomedicine? Following the US model may not be sufficient for leadership. Perhaps one reason is the extent of basic research funding in US (for 2001, nearly US$50 billion) that also trickles down to pre-college education. In 2002, US Congress appropriated about $23 billion for the National Institutes of Health and US biotech companies invested more than $25 billion for R&D. By 2050, 25% of the US population will be over 65 years and currently US healthcare costs about 14% of GDP or $1.3 trillion (2002).

Think different ?

Can biotechnology enhance sustainable economic growth through creating markets? It may be prudent for the few developed economies to venture beyond their solipsistic bliss and begin to weigh the saturation of Western markets, fierce competition in the far-East versus the potential of the Third World as emerging economies with increasing need and buying power. Today, number of people living on less than $2 a day is about 3 billion or nearly half of the world population. While biotech offers great promise (see below), it is equally important to remind ourselves of the 'mundane' measures that still begs attention. There are still at least 48 countries where more than half of the population cannot afford to use iodized salt. More than 40 million infants in the developing world are unprotected from iodine deficiency, which is the most common cause of preventable mental retardation in young children.

What is perhaps alarming is the unregulated global public deception carried out in the name of biotech to promote public hysteria by groups with 'earth friendly' names. They invent data to paint Frankenstein-esque images to provoke deliberate media sensationalism and force governments to enact policies that produce death by starvation or malnutrition. For politicians to act based on reports from such advocacy groups, is akin to saying that the Pope is unbiased on contraception. Advocacy is essential to extract truth and keep us honest but it is detrimental when advocacy groups are unreasonably biased against reason. In *The March of Unreason* by Dick Taverne, Lord Taverne provides the example of Golden Rice Project. It was demonized by environmentalists while researchers concluded that consumption of 200g of Golden Rice a day prevents blindness and measles in 14 million children under 5 years old. The scientific world hailed it as a breakthrough in genetic engineering of rice to create strains that produce additional Vitamin A in the body. 80% of the world's population needs and deserves the benefits from advances in science for society. The political illiteracy of most scientists and scientific illiteracy of politicians coupled with a commercial media focused on selling sound bytes enables the unbounded irrational clamour of a few to drown out the voices of reason in abject disregard for the plight of the hungry.

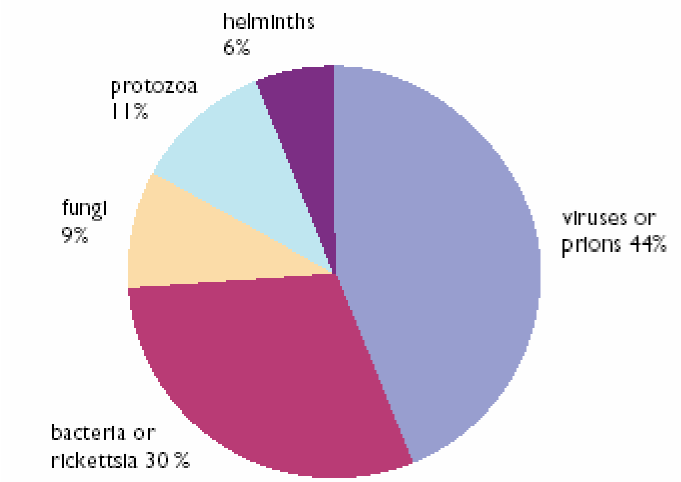
Country	GDP Growth 1975-2000	GDP Growth 1990-2000	Per capita 1973	Per capita 2002	Health Expense % of GDP	Health Expense per capita	TB reported per 100,000
Ireland	4 %	6.5 %	$ 7,023	$ 28,662	7 **	$ 1,234 **	
Eq Guinea *	10.4 %	18.9 %		$ 2,087			
China	8.1 %	9.2 %	$ 1,186	$ 4,671			
Thailand	5.5 %	3.3 %	$ 1,750	$ 6,575	6.1	$ 112	
Botswana	5.1 %	2.3 %		$ 7,792	4.2	$ 219	303
Vietnam	4.8 %	6 %		$ 2,072			
Sri Lanka	3.2 %	3.9 %		$ 3,202	3.4	$ 99	
Mozambique	1.5 %	3.9 %		$ 892	5.8	$ 50	104
Ghana	0.1 %	1.8 %	$ 1,260	$ 1,946			

* Equatorial Guinea ** 1998

Table 2: Economic Growth Comparisons and Health (WHO)

In the global health vein, it does not require much training to grasp that the number of people affected by cancer, diabetes, hypertension, neural dysfunction and cardiovascular disease is far less than the mortality and morbidity from malaria (parasite), TB (bacteria), meningitis (bacteria and virus), to name a few. The economic loss is simply staggering. Many of the major etiological agents of infectious diseases identified in the past 30 years either originated or severely affected sub-Saharan Africa and are either viruses or prions (see Chart 1, below).

Chart 1: Distribution of Emerging Disease Agents (WHO)



Year	Agent-Disease	Year	Agent-Disease
1972	Small round structured viruses Diarrhoea	1989	Hepatitis C virus (non-A, non-B hepatitis)
1973	Rotaviruses Infantile Diarrhoea	1990	Human herpesvirus-7 Exanthema subitum
1975	Astroviruses Diarrhoea	1990	Hepatitis E virus Enteric non-A, non-B hepatitis
1975	Parvovirus B19 Aplastic haemolytic anaemia	1991	Hepatitis F virus Severe non-A, non-B hepatitis
1976	*Cryptosporidium parvum* Acute enterocolitis	1992	*Vibrio cholerae* O139:H7 epidemic cholera
1977	Ebola virus Ebola haemorrhagic fever	1992	*Bartonella henselae* bacillary angiomatosis
1977	*Legionella pneumophila* Legionnaires' disease	1993	Hanta virus pulmonary syndrome
1977	Hantaan virus Haemorrhagic fever	1993	Hepatitis G virus Non A-C hepatitis
1977	*Campylobacter spp.* Diarrhoea	1994	Sabia virus Brazilian haemorrhagic fever
1980	(HTLV-1) Adult T-cell leukaemia/myelopathy	1994	Human herpesvirus-8 Kaposi's sarcoma
1982	HTLV-2 Hairy T-cell leukaemia	1995	Hendra virus Castleman's disease
1982	*Borrelia burgdorferi* Lyme disease	1996	Prion (BSE) Meningitis, encephalitis
1983	HIV-1, HIV-2 AIDS	1997	Influenza A virus New variant Creutzfeldt-Jakob
1983	*Escherichia coli* O157:H7 Haemorrhagic colitis	1997	Transfusion-transmitted virus
1983	*Helicobacter pylori* Gastritis, gastric ulcers	1997	Enterovirus 71 Epidemic encephalitis
1988	Human herpesvirus-6 Exanthema subitum	1998	Nipah virus Meningitis, encephalitis
1989	*Ehrlichia spp*. Human ehrlichiosis	1999	Influenza A virus Influenza (Hong Kong)
		1999	West Nile-like virus Encephalitis (New York)

Table 3: Disease Agents Identified (1972-1999, WHO)

Table 4: Morbidity and Mortality Facts about Malaria and Tuberculosis

Tuberculosis	• TB kills approximately 2 million people each year • Between 2002 and 2020, nearly 1 billion people will be newly infected • 150 million people will get sick and 36 million will die of TB • Someone in the world is newly infected with TB every second • Nearly 1% of the world's population is newly infected with TB each year • One third of the world's population is currently infected with the TB bacillus • More than 8 million people become sick with TB each year • About 2 million TB cases per year occur in sub-Saharan Africa • Around 3 million TB cases per year occur in south-east Asia • Over a quarter of a million TB cases per year occur in Eastern Europe • HIV and TB is a lethal combination, each speeding the other's progress
Malaria	• Malaria kills an African child every 30 seconds • Malaria kills 1 million people each year (90% in sub-Saharan Africa) • Malaria causes more than 300 million acute illnesses • 20% of the global population is at risk of contracting malaria • Malaria cost Africa more than US$ 12 billion in annual GDP • Constitutes 10% of Africa's overall disease burden • Key challenge is drug resistance (chloroquine, sulfadoxine-pyrimethamine)

Can post-genomic biotechnology offer pharmaceutical solutions to ameliorate the affliction caused by infectious diseases? The example of Novartis in combating leprosy is a prime example. Yet, in 2001, about 20% of US global pharmaceutical R&D supported efforts for cancer drugs and an equal amount was devoted for neural disorders. Less than 10% was spent for infectious diseases, of which, the major share went for HIV/AIDS drugs.

Leadership is necessary to develop world health solutions from biotechnology and nano-biotech through genomic-proteomic emphasis. Can biotech investments create a legacy through innovation in utilizing the modern biotech tools to produce therapeutics that shall improve the plight of millions, those who are downtrodden and forgotten? Rather than mimicking the US model, the theory of global club goods may be applied in a 'center of excellence' modus operandi to spawn global collaboration, for example, to create a novel designer mosquito that cannot carry *Plasmodium falciparum*, the principal malaria parasite. Map of the malaria genome and bioinformatics can be instrumental in creating drugs to treat resistant strains. A global distributed technology focus may hold the key.

The critics and pharmaceutical industry may point toward financial losses from the drug for river blindness, that most African countries could not afford. Recent disputes with HIV/AIDS drugs are perhaps even better known. But the economics of "lack-of-profit" based opposition from pharamaceutical behemoths may be inherently flawed when it comes to "disruptive" models stemming from agile, nimble companies using collaborative investments and taking advantage of innovation partnerships. The lesson (see below) from disruptive technologies may support this perspective (*Innovator's Dilemma* by Clayton Christensen).

Apple Computer's early entry into the hand-held computer or PDA market, later popularized by 'Palm' Pilot, offers a definitive example of large companies in small markets (from *Innovator's Dilemma* by Clayton Christensen). In 1976, Apple Computer sold 200 units of Apple I for about $600 each. In 1977, Apple II was introduced and 43,000 units were sold within two years. Based on this success, Apple Computer went public and its 1980 IPO was an industry triumph. By 1987, Apple Computer had grown into a $5 billion company and sought large chunks of annual revenue to preserve its shareholder value. In 1990, the PDA market was emerging and Apple Computers invested millions to develop the "Newton" PDA which sold 140,000 units in 1993-1994. It amounted to only 1% of Apple Computer's revenue and hardly made a dent in Apple Computer's need for new growth. While selling 43,000 units was viewed as an IPO-qualifying triumph in the smaller Apple Computer of 1979, selling 140,000 "Newtons" was viewed as a failure in the giant Apple Computer of 1994.

Thus, the principle is based on observations that small markets (profits) fails to support the financial growth needs (excitement) of large companies. As a consequence, the larger an organization becomes (Merck, Amgen, Abbott, Pfizer and the US ethos, in general), the weaker the argument that emerging growth opportunities (markets) can be useful engines for financial growth. The math is simple: a $40 ($4000) million company can grow profitably at 20% with an additional $8 ($800) million revenue in the first year, followed by $9.6 ($960) million the second year. Pharmaceutical companies posting annual revenues of $10 billion, then, require $2 billion in additional revenues to grow at 20%. Disruptive models facilitate the emergence of new markets but there aren't any $2 billion emerging markets or even $800 million emerging markets! It is precisely when emerging markets are small and the least attractive to large companies that entry into them is critical. This issue may be worth more consideration and reflection for distributed technology policy and investment by institutions such as the World Bank, IMF and Asian Development Bank as well as organizations such as Third World Academy of Sciences (TWAS) or the Inter Academy Council (IAC).

The criterion of civic responsibility is divorced from analysis of markets that don't exist. In formulating (and more importantly, implementing) policy in biotech mediated growth, nations may wish to seek the zeal to innovate to alleviate suffering and provide a moral example to be judged by history based on actions, amidst the fervour of globalization and its discontents. The 'south' nations are struggling to achieve such capabilities and deserve help.

Bill Gates opens a window on Africa

Nicholas D. Kristof nicholas@nytimes.com for International Herald Tribune (25 September 2003)

Here's a titillating scoop: Bill Gates has an assignation on Wednesday with Botswana prostitutes, not just one of them but a whole team. Wait, it gets kinkier: He's bringing his wife, Melinda. The encounter between the world's richest man and some of the world's poorest prostitutes is part of Gates' new passion: doing to AIDS and malaria what he did to Netscape. I'm tagging along with the couple during their tour of Mozambique, South Africa and Botswana, and frankly, one of the best things to happen to Africa is their fervor to alleviate Third World fevers.

The buzz among African aid workers is that Gates will be remembered more for his work fighting disease than for Windows. Certainly the wealth of the Bill and Melinda Gates Foundation (nearly $100 billion) is improving the prospect that vaccines will be found for malaria and AIDS. The foundation's most banal work is with vaccines, but those programs have already given out vaccines that will save 300,000 lives.

AIDS, malaria and tuberculosis are all worsening in the Third World and now kill 6 million people per year. This slaughter is one of the central moral challenges we face today, yet Western governments have abdicated responsibility and Western medical science is uninterested in diseases that kill only poor people. Many times more money addresses erectile dysfunction than malaria.

Info

The revolution in use of information technology may have been the viral spread of the internet using the medium of the world wide web which witnessed 0 to 25 million websites in 2 decades (1980-2000). An inaudible evolution of the 25 year old web began more than a decade ago (1994) with the proposal to create the semantic web by Tim Berners-Lee, the innovator who synthesized the world wide web by creating software to allow electronic documents to link to each other. The semantic web, similarly, is a vast open source area where both start-ups and behemoths can play critical roles. The impact of the semantic web will be briefly described in specific scenarios, elsewhere.

High tech start-ups and small firms in US, launching innovative disruptive IT products, logged about $62 billion in revenues (1976-1994) but those who followed after the market was established had revenues of only $3.3 billion, a *twenty fold* difference! Investment in ICT as an economic growth area must shift from repetitive manufacturing to "intelligent" products and services. Some nations may no longer remain interested in making "boxes" for Dell but wish to further academic-industry partnerships to create disruptive products and services for new markets. But,

- are there qualified primary and secondary school teachers to foster innovative math-science education?
- how robust are the systemic endeavours to nurture the talent required for economic growth?
- are their tolerant "incubators" for "out of box" thinkers and their non-conformist blue-sky ideas?

US colleges awarded 24,405 bachelor degrees in computer science in 1996, 50% ***less*** than 1986 [30,963 in 1989]. Engineering graduates dropped from 66,947 in 1989 to 63,066 in 1996. With globalization of technology, 60% of all new jobs created require IT related skills but only a fifth of workers possess such skills. Utilizing ICT services as an economic engine for the ambitious youth will require different thinking where (business) systems related virtual products and services can be offered globally. Services today are not about ISP or web hosting. A surfeit of ISP companies or websites do not indicate progress (Ukraine has more internet service providers that any other non-English speaking country; in Germany, for every 1000 people there are 85 websites) just as being able to buy Gucci handbags in Moscow is not an indication that the country is a market economy.

Businesses in US generate >1 terabyte of data per second. With the deployment of auto identification technologies, the US retail industry alone may be faced with >1000 terabytes of static data storage each year. Imagine the sheer data volume for all global industries and businesses, taken together. The current internet holds a billion pages with 10 petabytes of data. The internet as we know today will be dwarfed. The future demands radically different (nano) mechanism of data handling and software, to make sense of data (semantic web) to extract useful information and shunt intelligence to improve processes. The economics of data-rich societies create other issues of which the problem of unemployment is key. It will affect those with basic skills (check-out clerks in retail industry, warehouse labourers) since track and trace automation technologies (for example, radio frequency identification of objects) are likely to drastically reduce the requirement for low skill labourers. This wave of pervasive automation will further shift the yardstick of "skills" and current estimates are likely to be flawed. The ability to automatically identify objects (eg: consumer goods) using radio frequency id tags must be implemented by some suppliers by 2005 if they wish to work with Wal*Mart. But is that a model for the world to follow? About two-thirds of the nearly 1 million employees, in 3000 Wal*Mart stores in US, are item checkers. Can automation of object identification potentially eliminate millions of jobs? The cost savings for Wal*Mart ($8.35 billion; Fortune 17 Nov 2003) or businesses, will not be ignored by shareholders. Imagine the cumulative effect on workforce with the unstoppable adoption of automated object identification technologies? Yet, the understanding of the benefits are still flawed. The real value of disconnected data may be profoundly influenced by evolving developments of the semantic web.

Quarter century ago, robotics created a divide between Japanese and US automobile industry that drove Chrysler to bankruptcy. Detroit witnessed riots as UAW (United Auto Workers) unions fought lay-offs and job terminations from automation. The economic cycles have shifted and now major grocery store chains in California are feeling a significant financial impact from the ongoing strike and lockout of 70,000 United Food and Commercial Workers Union members (14 October 2003). UFCW in California may be concerned about elimination of jobs since all three major chains are also involved in pilot studies to explore future operational cost savings from use of RFID tags. This bandwagon is not fueled by systemic improvements but only short sighted *ad hoc* processes (eg: Wal*Mart).

The unfathomable volume of data will cause data handlers to declare war on the *status quo* software and pamper an irreverent group of thinkers who may innovate software to handle gargantuan tasks without traditional "lines of code" programming fraught with error (100 to 200 errors per 1000 lines). Charles Simonyi (WYSIWYG) and Mitch Kapor (Lotus-1-2-3) are pioneering these fields and Steve White is hot on the trail of self-healing autonomic software by exploiting the nexus of artificial intelligence and artificial biology. Nowhere more will the lack of strength in elementary and secondary education, if unattended, will become painfully obvious. Lack of academic rigour in pre-college education will erode the "supply chain" of talent and exclude the economy and youth from contributing in this field. As a consequence, businesses must start as followers once the fields are established. If the talent is available but the vision, will and infrastructure to nurture "out of the box" thought is in short supply, then the exodus of talent may not be unreasonable.

The impact of "bad" software in current use is fueling innovation to create programs without programming or software that "senses" what tools the user needs (just-in-time programming, tangible user interfaces). In 2000, a quarter of all commercial software projects in the US were terminated due to poor quality of software, at a loss of about US$67 billion. Bad data caused estimated losses of another US$61 billion. New models for data, databases and data movement are promising fields for intellectual leadership and intelligent services that include use of Agent based models embedded in the semantic web. The ability to innovate (small scale innovation) and extract intelligence from data is also required to meet the emerging applications of sensor networks and ultrawideband (UWB) applications. Sensors, by themselves are an important component of ICT vision (hardware) and the field will soon be transformed by nanotechnology. *Ad hoc* sensors networks (see below) communicate via multi-hop broadcast protocol (802.15.4) which can transform telecommunications, particularly where telco infrastructure is lacking (Third World). Sensor data from security installations may find value in non-obvious relationship analysis (NORA). Bio-sensors are increasingly important in healthcare as well as military. The abundance of data may make current database architectures quite impotent and the field requires new thinking (streaming database, adaptive data flow) that can segue to next generation products. Innovative liaison and research funding must be bolstered to speed the present and propel the future ***convergence*** of bleeding-edge research (behaviour-based millibot) with frequency agnostic interrogators (software defined radio) for analytical data mining through the semantic web.

Wireless sensor networks are a prime example of pervasive computing that ranges from blood pressure sensors in arteries transmitting data to monitoring devices or sensors suggesting trends in warehouse shelf occupancy or a plethora of security applications. Sensors are self-powered and can form wireless *ad hoc* networks that upload through nodes connected to databases or internet. Each sensor has certain analytical and in-network processing abilities. Such networks can transmit analyses of the data (not raw bits) in order to provide "answers" rather than only 'numbers' to a system. Emerging need for sensors in transportation logistics makes it an attractive pragmatic focus for funding consideration. The concept of sensors is bio-inspired. Living organisms are a network of sensors (smell, taste, sight, sound, touch). In the 19th century, Humphrey Davy developed a miner's lamp that sensed the presence of methane in coal mines. Today we have sensors already embedded in our lives but nanotechnology will soon make a whole new class of ultra-sensitive sensors possible as well as feasible for pervasive deployment.

• Africa	35 countries in sub-Saharan Africa have less than one telephone per 100 people
• Kenya	80% of the population have no phones
• Ethiopia	Internet account costs US$600 per year (one-third of a physician's annual salary)

Wireless Health-Care

by Leander Kahney www.wired.com/news/wireless/0,1382,58296,00.html (01 April 2003)

A Boston nonprofit (founded by Nobel Laureate Bernard Lown) has ambitious plans to build a nationwide, wireless computing network for Uganda's impoverished health-care system. The project will be built "on the cheap" using the country's existing cell-phone network, Palm handhelds and new battery-powered, wireless Linux servers.

Satellife, a nonprofit organization specializing in medical technology, hopes the network will be based on 3,000 to 5,000 Palm handhelds given to doctors and health-care workers in the field. The handhelds will be used for routine health administration, ordering and tracking medical supplies, delivering new treatment guidelines and, of course, communication. In the field, the handhelds will connect to inexpensive, battery-powered Linux servers set up across the country. Built by WideRay, a San Francisco startup, the Jack servers have built-in GPRS radios, which afford them an always-on connection to Uganda's near-ubiquitous cell-phone network. About the size of a thick hardback book, the Jack servers act as "caching" servers, storing content sent to them over the cell network from the administration's computers in Kampala. In turn, reports and e-mail received from handhelds are relayed wirelessly back to the capital. The servers communicate with handhelds using an infrared link. The servers are powered by industrial-grade batteries and a single charge lasts up to a year. "It's all you need to provide connectivity in remote locations," said Saul Kato, WideRay's founder and CEO. "The big issue is connectivity. There are no landlines. The only real infrastructure is cellular. Some of the facilities are literally huts, but you don't need any other hardware on site." WideRay makes versions that are equipped with infrared as well as Bluetooth and Wi-Fi wireless technologies. "It's an incredible project," said Kato. "There's no other way to deploy this kind of thing. It's a moneymaker for us, but its also serving a critical need. It's good every way you look at it."

Nano

The first nanotechnologists may have been the glass workers in medieval forges who may have made the Lycurgus Cup (Roman Empire), now in the British Museum. The process of nano-fabrication, in particular the making of gold nanodots or quantum dots, is old. The colour in stained glass windows found in medieval and Victorian churches depend on the fact that nano-scale properties are quite different from microscale properties. At the nanoscale, the yellow colour of macroscale gold, gives way to orange, purple, red or greenish, depending on the size of nanodots and their density per unit area (which makes the colour visible to the naked eye). Nano gold does not act like bulk gold. The different coloured gold nanodots will look yellow again if they are pushed back and allowed to join. If enough (number) of the nanodots are close to each other but not close enough to combine, then, we can see, with the unaided eye, different colours, red, for example, in red stained glass (glass contains 40 parts / million of gold).

According to NSF, 1nm (1 billionth of a meter) is a magical point on the dimension scale. Nanostructures are at the confluence of the smallest human-made devices and the largest molecules of living things. Nanoscience is the study of molecules and structures roughly between 1 and 100 nm. A human hair measures 50,000 nm across and the smallest features etched on commercial microchips are approximately 130 nm (2002). By 2010, almost all the principles involved in making microprocessors (chips) must be re-thought. The industry must shift from micro- to nano-chips. CMOS chip fabrication will change, for good. Integrated circuits (IC) depend on the science described by Ohm's Law. In the nanoscale regime, Ohm's Law may not work. The fundamentals of charge motion are then described by quantum mechanics. It is, thus, not surprising that microchips claiming to etch at the 90 nm level are two years behind in production schedule due to problems with current leakage. Assembling nano-devices into logic structures and architectures is a tantalizing challenge that offers great opportunity for research.

In the next decade, we may witness the emergence of chemically assembled electronic nanocomputers (CAEN) that uses molecules (rotaxanes) to switch the current passing through a molecular wire from a high to low current state. This switching is the basis for an entire integrated architecture (switches placed in an array of logic gates that can actually perform computation). The basic research on CAEN work was published nearly a decade ago in *Science* by Stanley Williams from HP Labs. Today, we are at the dawn of the pre-nano era, comparable to the pre-silicon era of 1950s when TV was black and white, small and limited, unreliable and fuzzy.

Nano is not an isolated field. It is highly multi-disciplinary and a fundamental principle. Nano will influence every facet of science, technology and business to transform life in a manner that will have visible and economic impact ranging from use of suntan lotions to the future of space travel on an elevator (lift). For any aspiring nation to under-emphasize the importance of nano may be analogous to making vacuum tubes or vinyl records, today.

Unlike information technology, where almost anyone can train to be a technician (eg: Cisco Networking Academy in US high schools) and become productive in a matter of months, nanoscience research and business stemming from nanotechnology, will, in most cases, require in-depth scientific knowledge and a PhD training. Therefore, the estimates of PhD's required to become an 'innovation' society may require re-evaluation. Short sighted estimates are troubling given that such reports are still being published half a century after the founding speech of nanotechnology (Richard Feynman, 1960) and even after nano made the cover of *Forbes* and *Science* magazine in 2001, ten years after the discovery of carbon nanotubes (1991), for which several Nobel Prizes have been awarded.

Nanoscience and nanotechnology require us to imagine, make, measure, use, design and innovate at the nano-scale. Because the nanoscale is unimaginably small (one nanometer is one billionth of a meter), it is clearly difficult to do the imagining! In the short term, globally, there will be a shortage of talent. It is an opportunity to lead or succumb to brain drain. Researchers in universities may be offered significant compensation if they move to private sector or start-ups. Unlike the bursting of "dot com bubble" where an asset-less dot com (eg: eBay) command a market value several times more than a business with goods (eg: Sotheby's), the "nano dot" boon may offer actual goods and products. Nano skin creams and suntan lotions are marketed by Sol Gel Technologies, a start-up from Hebrew University, Israel, now co-occupy travel handbags with nano-coated stain resistant khakis from Dockers!

Nano is big business and priority for HP, NEC, IBM, Merck, Dow, 3M, Boeing. In US, spending on nano research in 2002 is estimated at US$1 billion. The US National Science Foundation predicts that nano-related goods could be $1 trillion market by 2015. It is likely that nano may become a bigger economic force than the combined US economy from software, cosmetics, drugs and automobiles (*Nanotechnology* by Mark Ratner and Daniel Ratner). However, a percentage of economic growth emerging from nano will remain within existing markets, for example, use of nanopore structures (Zeolites) by Mobil Corporation for directed catalysis or its use for domestic water softeners. Zeolites represent the first broad scale profitable application of nanotech (saves 400 million barrels pa or $12 billion) but cryptic under the petroleum or water industry. Nanostructures for nanofiltration are being pursued by Air Products and Dow Chemical. Efficient ways for drinking water purification (Generale de Eaux) is certainly good business and friendly for the environment (nano-catalysts for hydrogen economy). Nanostructures for separation will aid dialysis patients (the blood need not be pumped out/in for dialysis to occur). Toyota uses steel produced by NKK Japan that incorporates nano-particulate carbon during the rolling process, thus offering fuel efficiency through weight savings without compromising structural integrity.

Nano Materials

This is probably the area with most aggressive reach (milk cartons to ship building) and business-wise in the short term (nano-catalysts). Current examples of homogeneous nanomaterials include:

[a] Refractive polymers – tints glass to adjust to sun light or laminates to block UV
[b] Self-healing automobile tires – polymer forms a bridge over punctured surface
[c] Corrosion prevention – lowers bridge and railroad maintenance
[d] Automobile windshields that do not get wet – ice cannot form, rain does not impair visibility
[e] Bathroom tiles and hospital sheets – self-cleaning, biocidal (Nanogate Technologies)
[f] Flexible display technology – digital paper (Ntera, Ireland; E-Ink, Xerox-PARC)

Heterogeneous nanostructures or nanocomposites, may evolutionize construction, aerospace and ship building industries. The basic building block, reinforced concrete (concrete poured over a framework of metal rods), may soon find stiff cost competition from plastic being poured over framework of strong, firm, rigid carbon nanotubes, which are 60 times stronger than steel (tensile strength). A carbon nanotube that is narrower than human hair can suspend a semi-trailer (lorry or cargo truck with 18 wheels). A single nanotube could stretch from earth to the stratosphere and be able to support its own weight. This fact spurred NASA in 1999 to review ideas proposed by Konstantin Tsiolkovsky (1895) a Russian visionary and Arthur C. Clarke in *The Fountains of Paradise* (1978). The idea is to build an elevator (lift) that will travel 60,000 miles from the earth's surface into space carrying cargo and humans. It is predicted that the 'space elevator' will lower the cost of positioning a satellite in space from $10,000 to $100 per pound. NASA provided $570,000 to Bradley Edwards to provide details. Bradley Edwards' proposal calls for a single nanotube about 75 cm wide and thinner than a piece of paper that will stretch 60,000 miles from the surface of the earth or the ocean floor (*The Space Elevator* by Bradley Edwards, 2002).

A 3-day NASA conference in Santa Fe, New Mexico (September 2003) drew 60 scientists and engineers working on the concept. The outcome of the meeting: "it is plausible." (Gentry Lee, Chief Engineer, JPL, Cal Tech). The 'space elevator' apparatus would lift up to 13 tons of cargo in a week to reach the geosynchronous orbit (22,300 miles). The necessary underlying technologies exist except the carbon nanotube material (ribbon). The estimated cost to build the first space elevator may be $6 to $12 billion. Subsequent elevators may cost $2 billion. The estimated cost of building and operating the international Space Station is expected to exceed $100 billion. Those who are teenagers today, may wish to plan to take an elevator to space to celebrate their 50th marriage anniversary!

Self-healing nanocomposites will prevent Titanic-esque tragedies from a mere gash and may allow an aircraft to recover from the sort of fuel tank damage that downed Air France's Concorde flight 4590 or even the space shuttle Challenger. The future of clothing (Nano-Dry from Nano-Tex) and combat wear for the US military promises to combine nano-composites with (bio)sensors to offer a host of monitoring as well as protective features (Institute for Soldier Nanotechnology, Center for Material Science, MIT). Can the US and EU re-invent shipbuilding with nano-composites? Cheap, disciplined labour and Taylor-esque efficiencies catapulted Hyundai Heavy Industries, Daewoo Shipbuilding and Samsung Heavy Industries to emerge as the main beneficiaries of the South Korean shipbuilding boom. The West may have relinquished leadership as traditional shipbuilders (Newcastle, UK) but nanomaterials may offer a come back strategy for the industry, if leaders are not afraid of risks that innovation demands. Korean (and Taiwanese) shipbuilding operations are booked through 2006 (International Herald Tribune, 25 September 2003). Every 35 days three ships go out and three get started at Hyundai's Ulsan shipyard. Ships sell for about $67 million for a 300,000 ton crude oil carrier and $200 million for carriers capable of transporting liquid natural gas. Last year, South Korea produced ships totaling 12.4 million gross tons (up 40% from 2001) with a backlog of 27.5 million gross tons (up 36% from 2001). In contrast, the numbers for Japanese shipbuilders are 11.5 and 24 million, respectively. EU shipbuilders ranked 3rd with 4 million gross tons and China is 4th with 1.6 million gross tons but is a rising competitor banking on disruptive technologies.

Nano opto-magneto electronics lies at the confluence of nanoscience and information technology (ICT). The present state of electronics may be near the end of its ability to continue to improve based on lithographic techniques. Nanotechnology offers solutions and even allows for computation in clothing, wallpaper, paint (Bill Butera, PhD Thesis, 2003; MIT) or anywhere else. Nothing need to be without processing power and nothing need be left unlinked. Pervasive computing is within grasp and the fruits (of nanofabrication) may be within the reach of Third World nations. The macroscale radio frequency identification (RFID, UWB) tags of today may be replaced with tiny frequency agnostic nano-tags that can identify jewelry, books, ammunition and zoological specimens. The $40 billion annual memory disk business is bound to grow with penetration of pervasive computing. Chris Murray (IBM) has shown that bits can be stored as magnetic nanodots and the size can be reduced up to the super paramagnetic limit. Using dip-pen nanolithography, it is possible to reduce individual features down to a few nanometers. If each nanodot contained one bit of information (0 or 1) and if they were spaced at distances equal to 10 times their own size, then, on a piece of paper 8.5x11 inches (US standard letter size), one could store 200,000 sets of the *Encyclopedia Britannica*. Nanotechnology also holds promise for artificial photosynthesis, thus, converting light into energy. The current annual energy consumption of US is about 100 quads or $1x10^{17}$ BTU (1 quad = $1x10^{15}$ BTU). The energy contained in the sunlight that shines each year on the 48 contiguous states is ≈ 45,000 quads.

Nanoscale Sensors and Nanobio Medicine

This area lies at the confluence of nano science and biotechnology. However, the "success" of this confluence in terms of applications must wait for diffusion of the semantic web within IT and software infrastructures. For the time being, bio-medicine may reap the early harvest from nanoscale sensors. In designing the provisions necessary for a national economy to benefit from nanoscale sensor business, it is imperative to think confluence and convergence. Sensors are sterile unless data are used for decisions to improve process or aid diagnosis. The focus on opportunities in healthcare may yield rapid results but the real value from data may still remain disconnected unless the industry invests and reaps the benefits from the development of the semantic web to connect the dots.

Type I diabetes results from disequilibrium of blood glucose levels due to improper regulation by insulin. Diabetics currently use a host of methods to detect blood glucose levels but it lacks an automated continuous monitoring tool. Nanoscale sensors may be an answer (see below). The ability to reliably detect DNA or RNA based disease agents (anthrax, TB, AIDS) or medical risks (breast cancer, Tay-Sach's disease) may offer benefits. Current techniques (micro-array, DNA sequencing) are expensive in developed nations and are prohibitive in the Third World nations.

Robert Letsinger and Chad Mirkin of Northwestern University founded Nanosphere and developed the quickest and most accurate test for anthrax. Tests for AIDS are next. Integrating bio-sensors with "lab-on-a-chip" technology (system-on-a-chip or SOC) from micro-array developments (such as Affymetrix) will offer POC (point of contact) tests that can perform parallel tests for several diseases at one time, instead of individuals tests for TB, AIDS, Hepatitis, for example. These integrated BSOC (bio-system-on-a-chip) systems are expected to be far cheaper and will be feasible even for the under-developed nations (with the highest disease burdens) to take the first step forward through affordable diagnostics. Nanotechnology holds the potential to turn this vision into reality and nations prepared to invest in the ground work may reap the collective economic benefits plus the boon of a healthy workforce (lower national healthcare cost). Investment in nano-biotech as an economic growth engine need not be stirred by altruism. In many developed nations, there are enough medical reasons to justify serious focus on nano-scale bio-sensors for screening and diagnostics. Developments will be accompanied by debates ranging from privacy, insurance and legal methods to prevent Third World immigrants or visitors from entering a nation by determining infection profiles at ports of entry (TB, malaria, AIDS) or genetic risks.

Research and advances in nanoscale diagnostics can save millions of women from the morbidity caused by breast cancer and linked mortality. Two genes, BRCA1 and BRCA2, identified nearly a decade ago, appear to be closely linked with familial early-onset breast cancer that constitutes about 5% of all cases. In addition to BRCA1 and BRCA2, at least eight other genes have been identified as contributors to breast cancer either directly or indirectly [AKT2, BWSCR1A, CDH1, ESR1, FKHR, PAX7, PIK3CA, ST8]. BRCA1 and BRCA2 are also linked to ovarian cancer and rhabdomyosarcoma (cell types are significantly different from mammary epithelium). Among the familial early onset group of women with breast cancer, 40% of them have mutations in BRCA1 and BRCA2. About 120 different type of mutations have been identified in these two genes and twice as many are actually thought to exist in the 10,000 base pairs of A, T, G, C that make up these two genes. Any attempt at patient care management for this subset of afflicted women will be incomplete [or even wrong] without an understanding of the nature of changes [which one of the hundreds of possible mutations] that caused the carcinoma in the first place. The situation is analogous to repairing a leak in a water pipe that is a mile long. If you cannot identify the site of the leak, what are the chances of repairing the pipe? If you do not know 'where' or 'how' to look, what are the chances of identifying the site of the leak? (Hence, the semantic web). The parallel processing that may be possible with nano-molecular recognition of DNA profiles may produce a breakthrough in diagnosing the specific mutations in BRCA1 and/or BRCA2 in a patient with breast cancer. The price for traditional diagnostic is $1000 per patient (Myriad Genetics, OncorMed). About 40 million women in the US alone are at risk, including some close relations of women diagnosed with breast or ovarian cancer.

Biotech and pharmaceutical firms can confirm that the most difficult problems in therapeutics are bio-availability and variable efficacy. It is estimated that $65 billion of current pharmaceuticals suffer from poor bio-availability. For example, if chemotherapeutic agents can be delivered to a tumour site prior to metastasis then the prognosis of the patient's quality of life improves. Nano-bio-medicine may have answers for improving bio-availability through advances in nano-encapsulation, magnetic nanoparticles and photodynamic therapy. Variations in efficacy are linked with understanding the genetic profile in the same way that screening identifies mutations in breast cancer or neurofibromatosis. The ability of some nano-particles to cross the cellular and nuclear membranes is an area that deserves attention to prevent undesirable side-effects.

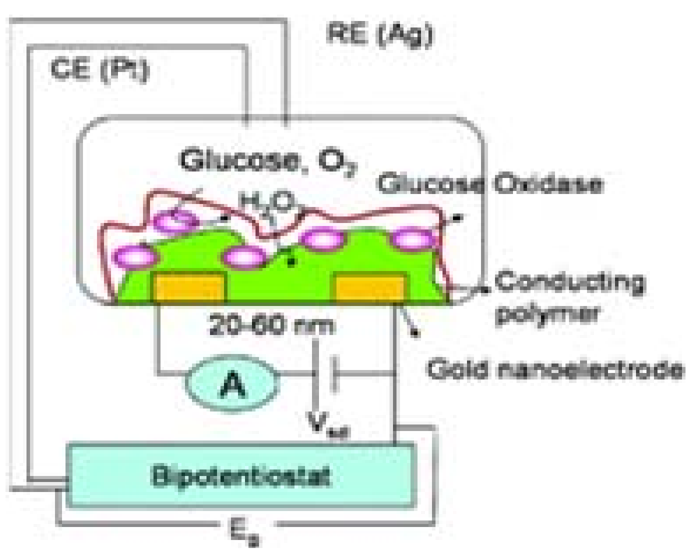
Consider that Bayer's Aspirin may not work with my headache but Aleve works. Why? The answer may lie in the heterogeneity of single nucleotide polymorphisms (SNP). SNPs may hold the key to our "individual differences" and the contribution of coding (cSNP) or non-coding (ncSNP) SNPs occurs once every 1000 base pairs along the string of 3 billion base pairs of our genomic DNA. Nine out of ten drugs fail, mostly due to unexplained metabolite side effects. Overall, the efficacy rates, even for drugs that proceed through the FDA trials, are reduced. About 40% of the pharmaceutical industry budget is spent on pre-clinical and clinical phases. If the industry can obtain rapid, low-cost, genotyping of prospective patients, it can stratify trials based on metabolites with adverse reactions in individual with certain genotypes.

Around 1998, micro-array was used to stratify patient populations with AML (acute myeloid leukemia). Cytarabine produced remission in 78% of patients (even after a five-year period) in patients selected by genotype profile [pharmacogenomics, toxicogenomics]. In parallel studies with other AML patients, who were genotypically grouped and predicted to be less responsive, Cytarabine showed remission rates of only 21%. In the pre-genomic era when genotypic stratification was not available, this drug could have produced a widely variable remission rate depending on the mix of patients and may not have received FDA approval. Stratification is not yet the norm due to high cost but nano diagnostics may make it routine. Stratification is a segue toward materializing the 'designer drug' concept that aims to treat patients with genotypically matched drugs to maximize efficacy. Such advances may impact FDA drug approval or rejection policies and introduce an efficacy index. Nano-genotyping technologies will influence the ROI, hence revenues, of the bio-pharmaceutical industry, justifying major research investment.

The example above demonstrates the need for ontologies and translational mapping *between* ontologies to enable semantic web users (in medicine) to make necessary connections from vast resources of decentralized information. Research data on AML, clinical data on AML, pharmaceutical data on chemotherapy, epidemiological data, patient demographics, research advances (RNAi), FDA policy, human trial rules, safety compliance, trial related resource availability and other important data are not and will not be organized in any one search space, in any one nation, in any one format or in any one specific ontological schema. Creating global consensus to pursue ontological mapping in the biomedical domain may enable the future use of the semantic web to resolve as simple a problem as a single mother in Accra learning from the village kiosk to add iodized salt to her baby's diet to prevent mental retardation. The semantic web of the future may also reveal to a medical resident that the seemingly intractable pain from an apparent cervical spondylitis may not be an orthopedic case. The resident may uncover that such pain sensation can be triggered by local inflammation reflecting autoimmune reaction with roots in the patient's teen-age years when she had a strep throat (*S. aureus*) but did not complete the full course of the prescribed antibiotics. Epitopes presented by *S. aureus* are also present on human leukocyte antigens (HLA-B2) in this tale of bio-mimicry. The resulting pain is caused by inflammation. Connected thinking from distributed and decentralized information sources, thus, offers application guidance at the point of contact (POC) to help the medical resident consider shifting the focus from conventional thinking that relates spinal pain to osteopathy or neurology to immunology. Based on this improved understanding, facilitated through the medium of semantic web integrated application at the point of contact, the medical resident offers accurate diagnosis and prescribes therapy to sufficiently relieve the discomfort and augment the patient's quality of life.

CONFLUENCE OF BIO–NANO-INFO: *Can glucose nano-sensors stem the onset of diabetic retinopathies?*

Vertical depth of research and researchers are crucial to successful progression of knowledge but some real world applications require horizontal thought experiments that can create converges of vertical depths to design solutions. The illustration below shows a glucose nano-sensor [NanoLetters (2004) 4 1785-1788], which is a convergence of bio and nano. Info from such sensors, through the use of the semantic web, may improve diagnosis and prognosis. Is there a need to catalyse such convergence, as one example, to spawn efficient healthcare management?



Let us explore a simple healthcare scenario where a local hospital in US zip code 08544 is the first point of contact for seniors aged 65 and above. About 200 patients are identified to have some form of diabetes (type I and late onset). It is necessary for these individuals to have a monthly check-up and when the blood glucose is elevated, the physician may prescribe a short period of insulin therapy. Family history data reveals that some patients may have parents or grandparents who had glaucoma, suggestive of diabetes-dependent glaucoma. Today, the 200 diabetic patients will travel to the local hospital for monthly tests in the outpatient clinic. Perhaps most will have normal blood glucose levels (120 mg/dl) or levels within tolerable limits or that which may be controlled by slight modification of carbohydrate intake. However, a few patients (assume 5) with a family history of glaucoma, require more careful monitoring yet only monthly visits are covered by the insurance. If this check-up happens to reveal elevated blood glucose in this 'risk' group, then, the outpatient clinic may schedule a physician appointment for check-up and intravenous insulin administration.

Process analysis of this scenario will easily reflect the costs associated with screening and monitoring the patients, who may be otherwise normal. The "supply chain" perspective will reveal volatility of inventory of insulin with a short half-life and other supplier-dependent (location of Genentech on the west coast of US) factors that makes it necessary to stock enough insulin (inventory carrying cost) and risk expiry. The quality of life analysis may reveal that 195 patients with diabetes but without known family history of glaucoma are perfectly fine but the less than optimum screening for the 5 at risk patients may have reduced their quality of life as well as increased their risk of glaucoma. In effect, poor exception management in the preventive phase may eventually precipitate glaucoma in one or more of these five at risk patients. Poor vision or lack of vision creates far greater needs on the system (insurance, social fabric) and vastly reduces the patient's quality of life.

Glucose nano-sensors may alter the outcome. Patients with sub-cutaneous (implanted) glucose nano-sensors will monitor blood glucose levels in real-time (not merely one reading at one specific monthly event). The data may be updated to a domestic node (in-home WiFi 802.11b) and transmitted through web-based service (via 802.16a or WiMax MAN) to a monitoring portal at the local hospital. Hospital policy kernels and patient authorizations will be linked to patient-specific data. The data is analysed in applications with rules or Agent impregnated monitoring systems which, if necessary, alerts nurse practitioners or doctors should any aberrant blood glucose fluctuation is detected in the 'otherwise normal' or 'at risk' patients. The frequency of necessary insulin administration in the 'at risk' group will be synchronized with events in near real-time rather than monthly. The latter has the potential to appreciably decrease the onset of glaucoma or perhaps keep the patient glaucoma-free for life. The ability to record, monitor and analyse the variation of blood glucose levels over 24 hour period in real-time in the 'otherwise normal' group may uncover subgroups with patterns of glucose utilization that may offer clues with respect to variations in glucose-insulin interactions or other anomalies (insulinoma, autoimmune, insulin receptor dysfunction).

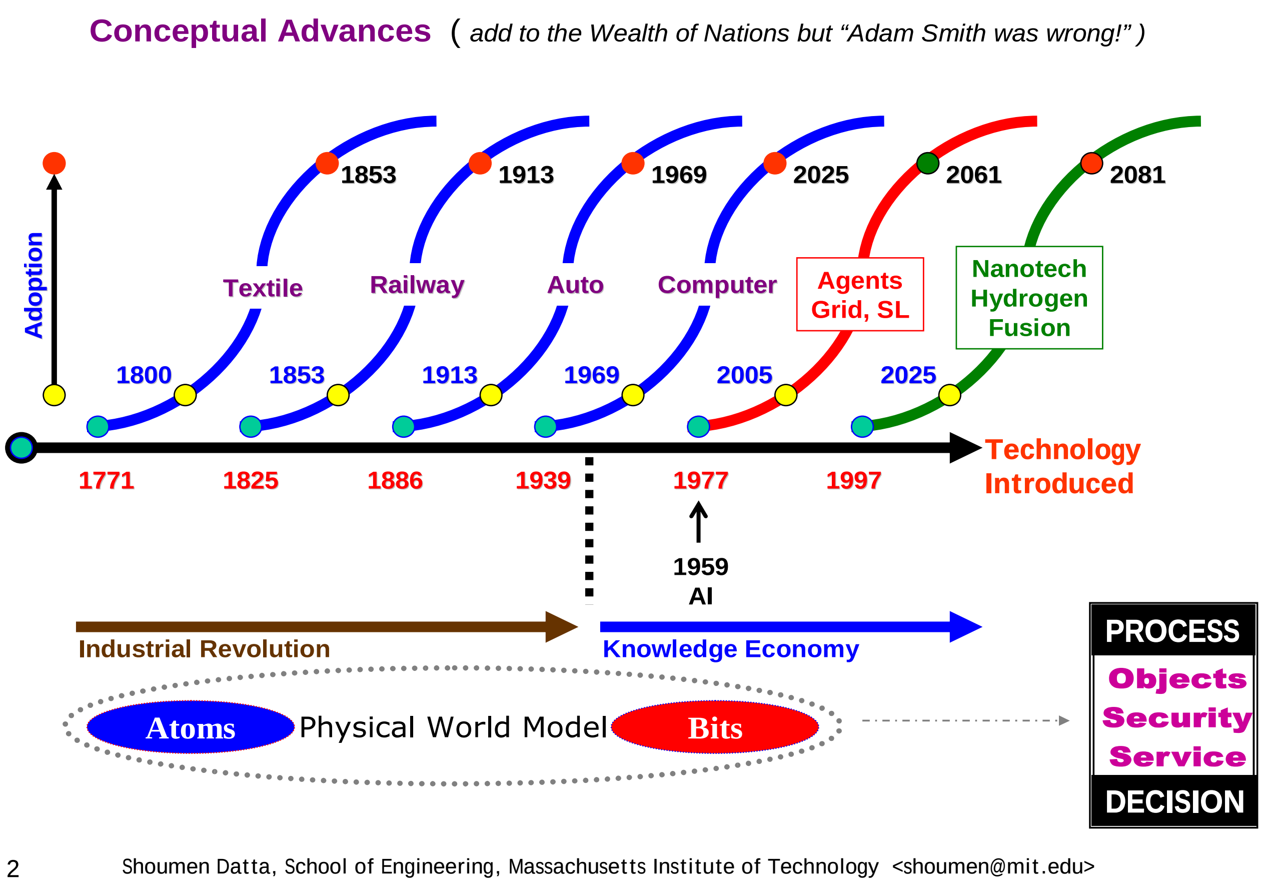
The petabytes of real-time data, if appropriately available through medical semantic web (semantic metrics), may reveal population genetic traits, which could guide future healthcare policy and funding for biomedical research based on the need of the population or self-service communities (independent living for Alzheimer's patients). For low birth rate nations with ageing population and healthcare costs around 10-15% GDP, the ability to ask right questions may help convert the acquired real-time data into revealing valuable information. Mining patterns for insulin consumption may help hospital procurement managers adapt the 'supply chain' of insulin and diminish inventory carrying cost and stem wastage without decreasing service level (quality of service). Elimination of the need for monthly blood glucose test will decrease costs and improve resource utilization. Taken together, over a number of services and expensive drugs, real-time connected data may offer risk pooling of services and products by geography to reduce costs for managed healthcare and national health services (eg: the NHS scheme in UK).

Nano bio-sensors for blood glucose, cartilage degeneration, blood pressure and others are already available or will soon become available. Wireless data transmission protocols are in existence along with the ubiquitous internet. All the tools necessary to reduce costs, now, are at hand, as is, profuse skepticism. If innovative leadership is allowed to function, the scenario above may be implemented, in a few short months. For the next phase, this data may be expected to help with better, improved and accurate diagnosis-prognosis through connected thinking via medical semantic web. The latter is an important emerging confluence and a task for creative organizations that may be modeled on Doug Lenat's Cycorp. The diffusion and incorporation of the semantic web is still a slow process but it is gaining momentum almost in proportion to the increasing honours being bestowed on its founder and his penchant for open source idealism. This infectious idealism has crossed traditional software borders and now is the GOSPL (generalized open source programmable logic) that could revolutionize the semiconductor industry.

Adoption

Norman Poire, an economist with Merrill Lynch, observed (illustration below) that it takes a quarter of a century for a technology to gain social acceptance. Then it fuels a period of growth lasting an additional half a century. After a century since 'invention' or introduction, it may become a commodity and grows in line with fluctuations in macroeconomic forces (textile, railway, automobiles, computers). Agents, based on distributed artificial intelligence (in principle) may follow a similar trend (increasing adoption beginning about 2005). Supporting evidence for the latter is accumulating. Using the same criteria, it seems that nanotech growth may accelerate in 20 years. NSF suggests that by 2015 nano-business may reach $1 trillion, perhaps based on the year 1991 milestone (discovery of carbon nanotubes). As discussed below, the use of hydrogen as a fuel may follow a parallel trajectory. Various confluences will emerge along similar lines. Bio-nano convergence has already created at least ten startups (Albion, BioForce Nanosciences, Biophiltre, Cambrios, Chimerix, Dendritic NanoTechnologies, eMembrane, Metabolix, Nanomix, ZettaCore).

Economic History from Norman Poire



Curbing the Fossil Fuel Dependency

Confluence of Agri-biotech, Nanotechnology & Nuclear Fusion as a Bridge to the Hydrogen Supply Chain

Dr Shoumen Palit Austin Datta

Research Scientist, Engineering Systems Division

Department of Civil and Environmental Engineering

Co-Founder and Research Director

MIT Forum for Supply Chain Innovation

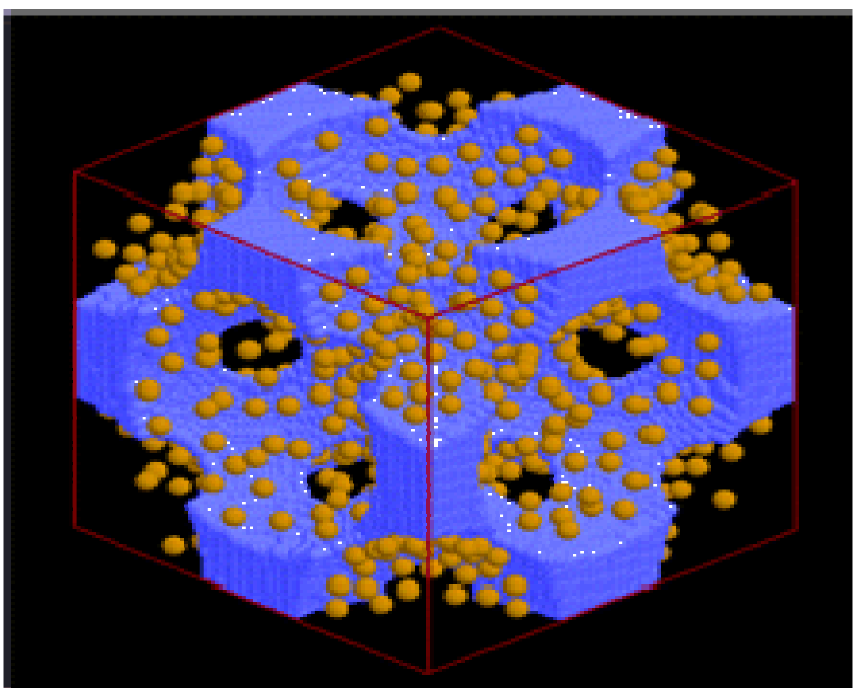
School of Engineering

Massachusetts Institute of Technology

Cambridge, Massachusetts 02139

shoumen@mit.edu

Molecular Simulation of Novel Carbonaceous Materials for Hydrogen Storage



Snapshot of hydrogen molecules adsorbed in the GCIO porous material. Carbonaceous material in blue and yellow spheres represent Hydrogen.

http://pubs.acs.org/cgi-bin/article.cgi/nalefd/2004/4/i08/pdf/nl0491475.pdf

1.0 Energy Economy

In 2003, when General Motors (GM) demonstrated HydroGen3 at the Tokyo auto show, the $1M price tag for the minivan may have evoked nostalgia in those old enough to remember that DEC priced its desktop computer, PDP-1 at $120,000 in 1960. Michael Ramage, former Executive VP of ExxonMobil Research and Engineering commented that, “we face a chicken and egg problem that will be difficult to overcome.” Bernard Bulkin, former Chief Scientist at BP echoes the ‘chicken and egg problem’ as the “need for a massive new hydrogen infrastructure to deliver the goods.”

In other words, the pipe dream about filling stations and fueling services – the bread and butter (with jam) for the global petro merchants. Perhaps the latter may explain, in part, the tone from US National Academy of Science (NAS) and American Physical Society (APS) reports that the hydrogen economy challenges are enormous and “the transition to a hydrogen economy, if it comes at all, will not happen soon.” Predictions are difficult to make, especially about the future, but the recent report (chaired by Michael Ramage of ExxonMobil) from NAS, an august society of thinkers, stopped short of declaring it is impossible. The facts may be genuine but one must wonder about the quality of vision of the leadership that is bound to retard the progress toward the economic prospects and environmental benefits from use of hydrogen as a fuel, albeit, in the future that one may not map with accuracy.

Today, the world uses about 13 terawatts of power, of which, approximately 80% is derived from carbon dioxide emitting fossil fuel. To keep the Earth’s average temperature low enough to prevent eventual sea level increases (projected to be from 8 metres to 35 metres) and sustain 3% annual economic growth, we will need between 10 and 30 terawatts of new carbon-free power by 2050.[1]

For fossil fuel enthusiasts, the Middle East spells doom not only because it fails to contain its metaphysical zeal but also because it cannot sustain the global demand for oil even if peace was offered a fighting chance in between its many wars. A decade ago economists were confident that demand for oil was stagnating at 70 million barrels per day (bpd). Our current global consumption of about 85 million bpd (US uses 21 million bpd) vastly exceeds such estimates. It is now clear that global growth, especially in India and China, will push demand for oil over the 120 million bpd mark by 2030, according to the International Energy Agency (IEA). For such demand to be met, one assumes “boundless Middle East oil” output to grow by more than 30 million bpd. Saudi Arabia’s comforting “trust me” statements about its oil reserves (jumped to 280 billion barrels in 1988 from 110 billion barrels in 1978) and production capacity (expects to sustain 10-15 million bpd for at least another half century) are highly suspect since these numbers have never been subject to any third party audit or any report on how the reserves stack up on a field-by-field basis. In 2000, 90% of Saudi Aramco’s oil was produced from 6 fields. The three most important fields producing 80% of Saudi oil (total production is about 10 million bpd) were discovered in 1940, 1948 and 1951 (Matthew Simmons). In the next 25 years, additional supply of oil may grow at a rate less than the estimated increase in demand (20 million bpd). In other words, oil output of about 100 million bpd may result in oil shortages of about 20% or more by 2030.

---

[1] Jim Hansen, Goddard Institute for Space Studies, NASA in MIT Technology Review (07-08/2006)

Discovery teams in search for new resources are accelerating their missions but success is rather scarce and expensive. A bit of hope comes from the oil sands (tar sands) of Fort McMurray (Alberta, Canada) that cover an area of 58,000 square miles. It is expected to yield 174 billion barrels of oil (active through 2025). At the current rate of consumption of oil by the US (21 million barrels per day of which 60% is imported and represents 25% of global demand), the Canadian reserves will be depleted in about 22 years even if Canada chooses to sell every drop of oil from tar sands to its neighbour but none to China.

The discovery of “Tahiti” deep sea oil field by Chevron in the Gulf of Mexico may add about 500 million barrels[2] or a 3 week supply for USA. The Minerals Management Service of the US Government estimates about 44 billion barrels of oil (~5 year supply for US) remain to be discovered in the Gulf of Mexico.

Emergency oil stores are most certainly inconsequential. Rokkasho, an oil-storage site in Honshu holds 30 million barrels of oil. It is barely enough to supply one week’s worth of Japanese demand. Rokkasho is also dominated by giant wind-turbines but Rokkasho’s fresh sea breeze can operate the turbines 20% of the time and may not produce enough power to make up for the energy consumed in their construction. Japan was keen to invest in yet another hydrogen venture – that of nuclear fusion reactor – in Rokkasho. However, the project (ITER) is now slated to be housed in Grenoble, France. The industrial world is vulnerable to oil supply disruptions in the Middle East. The economic progress in developing countries will be retarded by energy crisis and it will jeopardize the already dubious UN Millennium Development Goals (MDG) to reduce global poverty by half by 2015. The promise of oil from the Middle East and UN’s plight to reduce poverty may be utopian dreams unless the vision of hydrogen as a fuel is a part of the answer to global demand for energy.

A report published in 2001 by Sir David King, Chief Scientific Adviser to British PM Tony Blair advocated a fast track for fusion development. Fusion “should not be a place to play short-sighted international politics” says veteran nuclear researcher Tomabechi of Japan and expects “fusion-generated electricity will be sent to the grid within the next 35 years” but admits it will be expensive.

One proposed fusion reactor uses Hydrogen and Boron-11 as fuel. Hydrogen is obtained by electrolysis of water and Boron deposits are plentiful (140 million tons in California, 500 million tons in Turkey). A 100 mega-watt plant would burn 200 grams of Boron a day, as opposed to 700 tons of coal[3] to power a similarly sized coal-burning plant.

---

[2] Chevron claims that it could cost $3.5 billion to develop the “Tahiti” oil field that may yield 500 million barrels of crude petroleum. The exploratory vessel, *Deep Seas*, leased from Transocean, costs $250,000 per day (including team of 170 it is $500,000 / day).

[3] The annual amount of carbon dioxide released from burning fossil fuel is projected to increase from 24 billion metric tons in 2002 to 33 billion metric tons in less than 10 years (by 2015). Coal presents the world’s single largest opportunity for carbon dioxide mitigation. Coal generates 37% of the global fossil-fuel related emissions, in second place, after oil (42% from oil). In the US, coal contributes 51% of electricity but 81% of carbon dioxide related to power generation. Overall, 40% of global electricity is generated from coal-burning plants that spews twice as much as carbon compared to natural gas (kilowatt for kilowatt). World Coal Institute estimates there are 164 years worth of coal in the ground compared to 40 years store of oil (through 2050). According to the Natural Resources Defense Council, the enthusiastic coal mining countries are US, India and China. More than fourteen hundred 500-megawatt coal powered plants are planned worldwide by 2020, of which 140 are in the US. (Source: MIT Tech Review 07-08/2006)

Better yet, this type of fusion reactor emits no radiation. In addition, because the reactor is safe and clean, it is possible to build small neighborhood power plants or even have a portable domestic fusion reactor right in your back yard, eliminating wasteful long distance electricity transport.

The investment necessary to transform this vision into reality is not quite there, even though evidence suggests billions of dollars worth of government investment in hydrogen fuel projects in US, EU and Japan. A bit of this was spent on perfecting procedures to break down natural gas into hydrogen and carbon dioxide with substantial wastage as heat (~15% of energy). According to Pete Devlin of the US DoE (Department of Energy), it costs $5 to produce the amount of hydrogen that releases as much energy as a gallon of gasoline (assume a modest $2 per gallon but crude is creeping toward the ominous $100 per barrel with continuing Middle East uncertainties). Today, it is increasingly attractive to consider dumpster size conversion equipment costing about $375,000 according to Sandy Thomas of Alexandria (VA, USA) based H2Gen Innovations, manufacturers of hydrogen generators (2004).

Dr Joseph Romm, former Acting Assistant Secretary for Renewable Energy at US Department of Energy (DoE) may have sounded like the doomsday prophet when he told the US Congress (House Science Committee) in March 2004 that, "if we fail to do so because we have bought into the hype about hydrogen's near-term prospects – we will be making an unforgivable national blunder." Perhaps Dr Romm had the best intentions of promoting hybrids or alternative fuels such as biomass usage (carbon sequestration) and ethanol. Unfortunately, despite its great potential, we have not yet made any significant strides with ethanol (US annual production is just about 2 billion gallons, mainly from corn) and the same holds for biodiesel and hybrids. JoAnn Miliken, who currently heads the hydrogen storage research for US DoE agrees that hybrids, "can't solve the problem."

The gobal hydrogen endeavour is lacking direction and leadership. It is necessary to articulate an unambiguous goal unencumbered by the imminent geo-political ramifications that surround any such profound economic change. Much to the chagrin of the wealthiest industrial nations and energy industry behemoths, hydrogen may be that elusive bridge between the 'haves and have nots' which was once conceived to be built bit by bit with information technology. The industrial revolution and the information age provided some incremental quality of life benefits to the developing world but the energy economy increasingly yet silently drains resources and dampens productivity gains. The energy genie is still in the bottle and it has hydrogen written all over it.

1.1 Electrolysis

A simple process that can catapult the hydrogen economy to the forefront of global progress comes from the same man who invented the electric motor, nearly two centuries ago. Michael Faraday, born on 22 September 1791 in Newington, Surrey (England), invented the dynamo in 1831 which led to the invention of the electric motor and the profitable revolution[4] that followed. In 1832, he started work on electrochemistry that led to the discovery of the principle of electrolysis. He lived to see the first isolation of Lithium by electrolysis by his mentor, Humphrey Davy and later in 1855 by Bunsen and Mattiessen. Michael Faraday died on 25 August 1867 in Hampton Court and is buried in the Highgate Cemetery in London. What we should not bury is the idea of generating hydrogen from electrolysis of water, in every garage!

---

[4] Paul A. David and Gavin Wright (2003) *The Economic Future in Historical Perspective* (Oxford University Press)

It may have intrigued Faraday to see his discovery of electrolysis being practiced safely and successfully since 1875 to remove unwanted hair. Charles Eugene Michel (1833-1913), an ophthalmologist in St. Louis, (Missouri, USA), helped pioneer a technique for removing wild eyelash hairs (cilia) by means of electrolysis. It is the only process that is universally and medically approved, documented and accepted by the US Food and Drug Administration, as a means for permanent hair removal. It is perhaps time to add another universally accepted process to the credit of electrolysis: portable hydrogen generation[5] from water to replenish solid hydrogen storage in automobiles.

Electrolysis of water in your garage to generate hydrogen to replenish hydrogen storage tank in your automobile (“gas tank”) could eliminate the trillion dollar investment necessary to re-tool the infrastructure for generation and delivery of hydrogen fuel. If electrolysis is successful and portable hydrogen generators are in every garage, there may not be an “oil industry” or behemoths to reap the financial largesse from the petroleum pool. These behemoths exercise global clout and exert pressure on organizations (governments) that plan and promote the pathways to hydrogen economy. Few, if any, nations of the world have leaders who are willing to lead at the expense of their personal popularity at home and abroad. John F Kennedy, threatened by the Sputnik progress of the then USSR, challenged the nation (USA) to put a ‘man on the moon’ within a few years. It did happen, soon enough. We lack leaders who can articulate such unambiguous universal agenda to challenge the global research community to concentrate their focus on developing efficient commercial portable electrolyzer compatible with solid hydrogen storage systems for automobiles. If automobile usage, alone, could become independent of fossil fuel, imagine the impact on the global economy, decreasing oil prices and the potential economic boom for the developing nations.

It is often said that we humans are our own worst enemies. The economic revolution possible through the use of hydrogen fuel for automobiles harbours the potential to trigger resistance from the uneducated and uninformed about the source of energy for electrolysis. Renewable energy (solar, wind) systems may supplement a part of the energy required for electrolysis but for commercial uses (car rental agencies, fleet operators) the use of nuclear energy (nuclear fusion?) to run the electrolyzers may be inevitable unless the ethanol economy starts working wonders hitherto unexplored. Some nations (for example, Ireland) have banned the use of nuclear (fission) energy!

Chernobyl has been sensationalized by the media yet the incident-free accidental nuclear (fission) plant meltdown at Three Mile Island (USA) is virtually unknown. Chernobyl did not use the recommended safety precautions but the operation at Three Mile Island nuclear power plant was monitored according to the highest safety standards. Safe nuclear (fission) energy has been a reality for several decades yet the ignorance of the public is still carefully cultivated only to worsen global warming (*The March of Unreason* by Dick Taverne).

UK obtains one fifth of its electricity from nuclear plants and all but one (Sizewell, UK) will be decommissioned by 2023. Sir David King and Mr Tony Blair may no longer stand up for the “green” mirage with North Sea oil reserves declining and greenhouse gas emissions on the rise. Even politicians know that politics may temporarily derail long term vision but long term needs can annihilate political frameworks and fail to protect disingenuous individuals from social wrath.

---

[5] Richard Bourgeois and his team at GE Global Research (Niskayuna, NY) has built a low-cost mass-manufacturable electrolyzer using a GE plastic (Noryl) resistant to corrosive electrolytes. The prototype produces hydrogen via electrolysis for $3 per kilogram (functionally equivalent to a gallon of gasoline) which is substantially lower than current estimate of $8 per kilogram.

Cheaper and safer nuclear fusion energy is on its way, too, as discussed earlier and perhaps sooner than expected (*Colliding Beam Fusion Reactor* by N. Rostoker, M. Binderbauer, H. Monkhorst in Science (1997) 278 1419). Are there any national leaders who can promote science literacy to enable the public to evaluate the risk to reward ratio of safe use of nuclear energy (fission and fusion) as one mechanism to declare independence from fossil fuel? The simplest way to usher in the hydrogen economy is not a 'chicken and egg' problem, it is a political problem.

1.2 Scientific Hurdles

Simple ideas are often complex problems and this is not an exception. Several questions need answers through focused research. By using energy (solar, wind, nuclear, hydroelectric, geothermal) we can convert water to yield hydrogen in an electrolyzer and reverse the process in a fuel cell to obtain electrical energy from hydrogen. Energy required to produce hydrogen by electrolysis is 32.9 kWhr/kg. For 1 mole (2g) of hydrogen the energy is (approx) 0.0660 kWhr/mole. For commercial electrolysis systems that operate at 1 A/cm^2, 1.75 volts is required, which translates to 46.8 kWhr/kg and an energy efficiency of 70%. Lowering the voltage for electrolysis, will increase the energy efficiency of the process and is one important area for research. R. P. Viswanath and his team at the Indian Institute of Technology in Madras, claims to split water into hydrogen and oxygen at a lower potential (0.9V) by using a compartmentalized electrolytic cell. Current efficiency works out to 135% (a key advance, if reproducible).

In an ideal case, fuel energy from hydrogen is converted to electrical energy at an efficiency of 80% or more. This is greater than the ideal efficiency of a generating facility which burns hydrogen and uses heat to power generator. Fuel cells currently may not approach >80% efficiency but are still more efficient than electric power plants which burns a fuel. In comparing the fuel cell process to its reverse reaction (electrolysis of water) it is useful to treat the enthalpy change as the overall energy change. Gibbs free energy is necessary to drive the reaction. In electrolysis and fuel cell pair, 237 kJ energy is required to drive electrolysis and the heat from the environment will contribute 48.7 kJ. In the fuel cell, 237 kJ is regained as electrical energy (48.7 kJ escapes as heat but part may be recaptured for use). The benefits from catalysis and search for nano-materials (nano-catalysts with greater surface to volume ratio) that can improve efficiencies in the electrolysis/fuel cell paradigm are key areas for research.

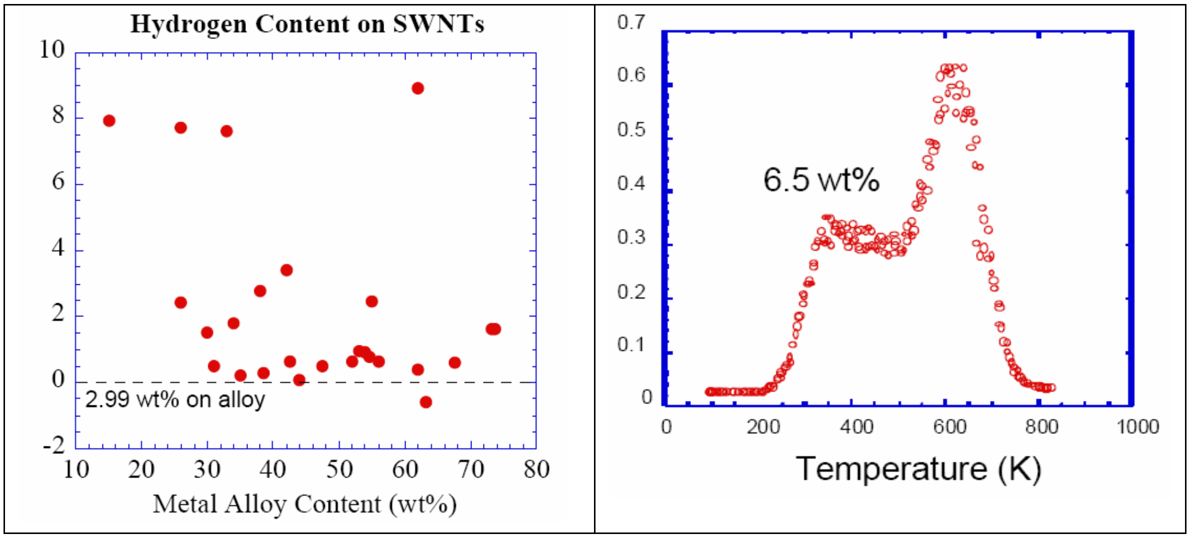
Can we use bio-catalysts for hydrogen generation? John Peters and Lance Seefeldt of Utah described the structure of an enzyme found in the soil microorganism *Clostridium pasteurianum*. CpI is a hydrogenase, which uses iron atoms to catalyze hydrogen (waste) production from protons and electrons. The enzyme active site, tethered to a substrate, may improve hydrogen production efficiencies. Non-platinum catalysts are also of increasing importance (G.W. Huber, J.W. Shabaker and J.A. Dumesic. 2003. Raney Ni-Sn Catalyst for H_2 Production from Biomass-derived Hydrocarbons. *Science* **300** 2075–2077).

Safe, non-toxic, cost-effective on-board solid hydrogen storage solutions are emerging from traditional materials (sodium borohydride) as well as nano-materials (nanotubes). Catalysts (doped nanotubes) that can improve storage capacities above the US DoE recommended 6.5% (storage by weight) will be a boon to this fuel system. Solid sodium borohydride currently can store 10.5% hydrogen[6] by weight.

---

[6] One kg of solid $NaBH_4$ reacted with 950gm of water yields 213.5g of hydrogen gas or 24,230 BTU = 7.1 kWh = 25,560 kJ (1 kg of hydrogen = 119,600 kJ which is a close equivalent to 1 gallon of gasoline = 121,300 kJ).

Carbon single-wall nanotubes (SWNT) and other nano-structure materials exhibit hydrogen storage capacities at room temperatures. Capacity for adsorption of hydrogen by SWNT is about 8% by weight. A method for growing SWNTs by vapor deposition from methane holds promise when scaled-up, to produce SWNTs for $1 per kilogram.



HYDROGEN STORAGE IN CARBON SINGLE-WALL NANOTUBES

Proceedings of the 2002 US DoE Hydrogen Program Review

A.C. Dillon, K.E.H. Gilbert, P.A. Parilla, J.L. Alleman, G.L. Hornyak, K.M. Jones, and M.J. Heben

1.3 The Road Ahead

Except for Iceland with its vast geothermal resources, Hydrogen is the global Holy Grail. Standardization of form for fuel cells and mechanism to replenish with hydrogen from portable electrolyzers may be as simple as inserting a tube to feed hydrogen to adsorbent in the on-board storage tank or solid material that can be stored in the hollow frame of an automobile. When the domestic electrolyzer is not available (while on vacation), electrolyzer outlets may be ubiquitous in stores, grocery chains, restaurants or charged fuel cells can be exchanged just as cooking gas is available in tanks in most corner stores. GPS-RFID-UWB linked hydrogen sensor tagged fuel cells can help track and trace customer issues, inventory, billing operations, as well as monitor fill-status and safety considerations.

Perhaps this discussion about hydrogen as a renewable fuel for the near future focuses disproportionately on fuel consumption as a function of automobiles and transportation. In most industrialized nations, energy consumption in this sector is about 20-25% of total energy. Successful implementation of hydrogen as a fuel reduces need for fossil fuel by the same amount. However, residential and commercial use is another 20-25% while industrial uses claim almost half of the energy output. Fusion reactors are a definitive answer but are still a few decades away. The 'south' nations cannot continue to wade through squalor while scientists develop ways for mass deployment of fusion reactors still decades away (2025-2050). One doesn't need the brilliance of Jeffrey Sachs to grasp that energy is the key that may change the tide for sustainable growth in 'south' nations and lend credibility to Mary Robinson's penchant to pursue ethical globalization. However, politically unpalatable it may be, the 'fast food' model of energy is in demand but of course not in disproportion to global hunger that affects more than a billion, each day.

There may be a "STAR" solution, albeit a partial solution. Sealed, transportable, autonomous reactors (STAR) can generate power from nuclear fission without refueling or maintenance. It is a choice that is available now and those who will keep it out of the hands of those who need it the most may wish to consider the odds. By the time you finish reading the rest of this article, several children will have perished from malaria. In Africa, a child dies every 30 seconds from malaria, alone. Improvements in sewer and sanitation can eliminate this morbid mortality statistic. Lack of energy is the gatekeeper in the 'south' nations who are reliant on the proactive benevolence of the 'north' even for their very basic survival. Disposable nuclear fission reactors may be an interim answer to this agony.

STAR can meet the immediate energy demands of under-developed and developing countries without the risk of malicious use by disenfranchised individuals to use the by-products for weaponry. Taking a lesson from modern submarines, STAR was developed by the Lawrence Livermore National Laboratory in California, to be transported to a site and generate power for decades (current estimate is 30 years). When the fuel is spent, it can be retrieved from the site and disposed under proper supervision since there is no option in a sealed STAR for recharging the fuel rods depleted of fissile isotopes (usually commercial operators replace fuel rods every few years). The latter coupled with a tamper-proof casket eliminates the risk of extracting fissile material. An even better reason to use STAR in 'south' nations is the ability to produce versions capable of generating 100 or 10 megawatts of electricity compared to the conventional nuclear stations that produce about one gigawatt. Without an extensive electricity grid, the output from a conventional nuclear station is wasted or unused due to lack of distribution infrastructure. STAR units producing 100 megawatts may be 15 metres tall, 3 meters in diameter and weigh 500 metric tons. A lighter, 200 metric ton version may produce 10 megawatts of electricity. Nuclear fuel, liquid lead coolant and a steam generator is sealed in the housing along with steam pipes ready to hook up to an external generator turbine.

In the 5th century BC, Herodotus noted in his *History* that every Babylonian was an amateur physician, because the sick were laid out in the street so that any passerby might offer advice for a cure. Nearly 2500 years later, we are all environmentalists offering advice, apostles of platitude without power, uniformly impotent, to cure the energy sickness. Yet the 'penicillin' from the mold in Dr. Florey's coat was gifted as the cure for the energy-addicted world, over half a century ago by Lise Meitner, Otto Hahn and Frederic Joliot-Curie, among other notables.

1.4 One Shoe Fits All ?

Safe use of nuclear fission for energy *cannot* become the 'one shoe fits all' solution for the impoverished nations to climb out of their poverty capsules. It is a solution at hand and one that will empower the 'south' nations to see some light at the end of the tunnel. It is important that national policies commit to concomitant exploration of other renewable energy sources that can stem the tide of global warming, even if the validity and reliability of such warming trends are often steeped in scientific controversy and subject to incessant political spin through the media.

Encouraging advances include one by UK-based Intelligent Energy and its product – a motorcycle - that runs on hydrogen fuel cells, attains speeds of upto 50 mph and travels for 100 miles before refueling is necessary. Tokyo Gas launched (2005) a residential fuel cell project where a home-owner can lease an unit that extracts hydrogen from natural gas and uses it to generate enough electricity to meet about 60% of the demand for a four-person household. Each unit may reduce a home's annual greenhouse gas emissions by 40%. A 10 year lease costs JPY 1 million (<$10,000) but the savings from reduced energy usage, today, may not cover the cost of the lease. The annual shortfall is estimated to be about JPY 40,000 (<$400) per home (MIT Technology Review, March 2005).

Developments from super-conductivity research are helping to produce better fuel cells. New thin film solid oxide fuel cells (SOFC) offers catalyst-independent operating temperatures of less than 500^0 C. At less than 1 micron thin and an output of about 1 volt, a stack of SOFC equivalent to two soda cans may produce more than 5 kilowatts (enough to power one or more typical households). Connected to a homeowner's natural gas line, this stack operates at an efficiency of about 65%, a two-fold increase in efficiency over conventional power plants.

Plankton fuel cells, energy from spinach, biodiesel, carbon sequestration (Craig Venter Institute) and natural forces (air, water, solar) to generate energy are all likely to be more or less viable in specific use cases and environments. The latter is demonstrated in part by Costa Rica which claims to derive 92% of its energy from renewable sources. It is vital to pursue these and other emerging 'green' sources of energy while we continue to boldly support options available at hand to immediately provide energy for the emerging economies that are politically responsible. The sooner the impoverished countries are economically mature, the sooner they can contribute to invest in the global plight for alternative 'green' energy to reduce fossil fuel dependency and reduce carbon emissions.

1.5 Manufacturing Energy: Biofuels

With 40% of operating automobiles **not** running on petroleum, Brazil has demonstrated that it is the global leader in the use of ethanol without government subsidies. Alcool (ethanol) as an alternate fuel for cars, buses and other motor vehicles is in use because 75% of all vehicles sold in Brazil are flex fuel vehicles that can run on ethanol or gasoline or a mix. Commencing with ideas and idealism that sprouted during 1970-1975, Brazil now boasts of ***manufacturing energy*** from 5 billion gallons of ethanol per year. Brazil is manufacturing energy from sugar (sugarcane) and pays for plant operation using energy obtained from burning the fiber from sugarcane (biomass). This is a remarkable paradigm shift because till recently energy was traditionally associated with discovery and mining (oil, coal, natural gas). While "sugar farmers" in the EU are sparring over the size of "hand outs" (subsidies), sugar is effectively used as an energy cash-crop in a novel entrepreneurial zeal just a few thousand miles, south.

The necessary detour to use ethanol and others biofuels remain low on the strategic agenda for many nations despite the projections that gallon for gallon ethanol is competitive with gasoline in terms of fuel efficiency even if crude prices drop to $40 per barrel. One wonders why national energy policy wonks are yet to grasp that production of biofuels can be tuned by manufacturing at a cost comparable to or lower than that of gasoline. Agriculture and farming can reinvent its financial lustre from corn, sugarcane, sorghum and the oil-weed, *Jatropha curcas*, to name a few common agricultural raw materials that can be chemically processed (fermentation) to yield energy. Although ethanol does not significantly reduce carbon emissions, if viewed in the narrow sense of emissions alone, it adds little to the *total* carbon in the atmosphere. The carbon dioxide given off while burning a gallon of ethanol is roughly equal to the amount absorbed by the plants to produce the next gallon but biodiesel scores higher on the "green" scale. Biofuels may thus be an interim beacon of hope to wean away the war on peace by reducing our dependency.

Commercially, biofuels may be lucrative. Small, industrially advanced and truly innovative knowledge economies (nations) may now manufacture energy (biofuels). Hence, these countries may sell biofuels plus its associated knowledge services to the fuel-guzzling Dragon (China) and the Elephant (India). It is as simple as manufacturing and selling skyr or pizza or tikka masala or wonton soup!

The commercial chemical appeal cryptic in ethanol may be further stimulated by the understanding that ethanol can be obtained from *any* cellulose source because basic sugars are the key building blocks of cellulose. In practical terms, cellulose is present in all plant materials – wheat and rice straw, switchgrass, paper pulp, agricultural waste, leaves. This fact doubles the potential to squeeze twice as much as fuel from the same unit area of land without decreasing food crop for animal and human consumption. The latter is false perception currently peddled by some.

The convergence of energy scientists with chemists and biologists are likely to unveil new vistas only limited by our imagination. Hydrocarbon chemists are hopeful that the methanol economy (George Olah, USC) may chime in before the ethanol economy gathers steam. For now, the biologists contribution to biofuels and the ethanol economy seems to lead the way. Biologically speaking, converting cellulose to ethanol is a two-step process. First, the long chains of cellulose must be broken down to basic units (glucose, fructose or other sugars) and second, fermenting those sugars into ethanol. In nature, fungi and bacteria secrete enzymes (cellulase) that hydrolyzes cellulose to "free" the sugars. Yeasts ferment the sugars to produce alcohol. With tools available from biochemistry, molecular genetics, recombinant DNA and bio-engineering, it is possible to improve the efficacy of the microorganisms for production of cellulosic ethanol. Genetic engineering to yield strains of yeast (*Saccharomyces cerevisiae*) that tolerate higher concentrations of ethanol[7] in a fermentation reactor and can survive on cellulose alone[8] may be a "disruptive technology" in the ethanol energy economy. The strides made by genomics and proteomics may make it possible to engineer an existing microorganism[9] with an artificial chromosome to harbour genes for the enzymes necessary to direct a high yield manufacturing process to produce ethanol from cellulose by enzyme catalysis.

Manufacturing energy may lend itself to the practices of near-shoring, off-shoring and outsourcing, classical strategies used in global supply chain management. For example, recently Singapore leased an island for 999 years from Indonesia to set up a chemical processing facility. Leasing a few islands from Indonesia may not be an absurd idea given that it is the world's largest archipelago with 13,667 islands nestled between Asia and Australia, spanning 3200 miles along the Equator from east to west (almost the expanse of US) and 1100 miles from north to south. In addition to an abundance of plant (cellulose), these tropical islands are suitable for Jatropha, sugarcane or sorghum. The entrepreneurial and industrialised nations of the world, for example, may off-shore biofuel manufacturing in Indonesia (or partner in India with Bihar, the arid state with vast wastelands) in the true spirit of confluence of globalization and innovation. The potential for significant profits from such investments in biochemical-energy may be only limited by politics and the inefficiencies that often plague the knowledge network of information arbitrage.

[7] Greg Stephanopoulos of MIT has developed a yeast strain that claims to tolerate 50% more ethanol.

[8] Lee Lund of Mascoma, a start-up in Cambridge, Massachusetts, has engineered a thermophilic bacteria to optimise the kinetics of cellulase and whose only fermentation product is ethanol.

[9] Synthetic Genomics, a start-up in Rockville (Maryland, USA), founded by Craig Venter, is exploring *Mycoplasma genitalium*, a microbe which dwells in the human urinary tract and has the smallest genome (517 genes) of known life form (except viruses), to produce task-specific genetic pathways (for example, the two steps or tasks necessary to breakdown cellulose to produce ethanol) in much the same way that software is loaded on to a computer's operating system. Instructions from the software could be used to create spread sheets or word processing. Similarly, the "biological software" introduced in the genome of *Mycoplasma genitalium* would instruct the microbe (the cell) to break down cellulose to produce ethanol.

Value Chain: Example of Demand (India)[10]

	Sorghum bicolor (Sweet Sorghum)	*Saccharum officinarum* (Sugarcane)	Corn	Annual Demand India (2004)
Growth Cycle	4-5 months	12-16 months		
Crops / year	2	1		
Water / crop	4,000 m^3	36,000 m^3		
Biomass	70 tons / hectare	90 tons / hectare (TPH)	1.4 – 6.5 TPH	
Ethanol	40 litres / ton	70 litres / ton (LPT)	400 LPT	
Yield / crop	2800 litres / hectare	6300 litres / hectare (LPH)	560-2600 LPH	
Annual Yield	5600 litres / hectare	6300 litres / hectare (LPH)	560-2600 LPH	
Production Cost	USD 0.30 / litre	USD 0.29 / litre	USD 0.37 / litre	
Cost / US Gallon	$1.14 per 3.785 L	$1.10 per 3.785 L	$1.40 per 3.785L	
90EBG*				1 billion litres
95EBD**				3 billion litres
Other				1 billion litres
Production				2 billion litres
Import Potential				3 billion litres
3 billion Litres	1.1 million hectare	0.83 million hectare		

90EBG* = 90% gasoline plus 10% ethanol and 95EBD** = 95% diesel plus 5% ethanol

[10] If my theory of relativity is proven successful, Germany will claim me as a German and France will declare that I am a citizen of the world. Should my theory prove untrue, France will say that I am a German and Germany will declare that I am a Jew.
(ALBERT EINSTEIN, Address at the Sorbonne, 1936)

Illustration 1 – ELECTROLYSIS OF WATER

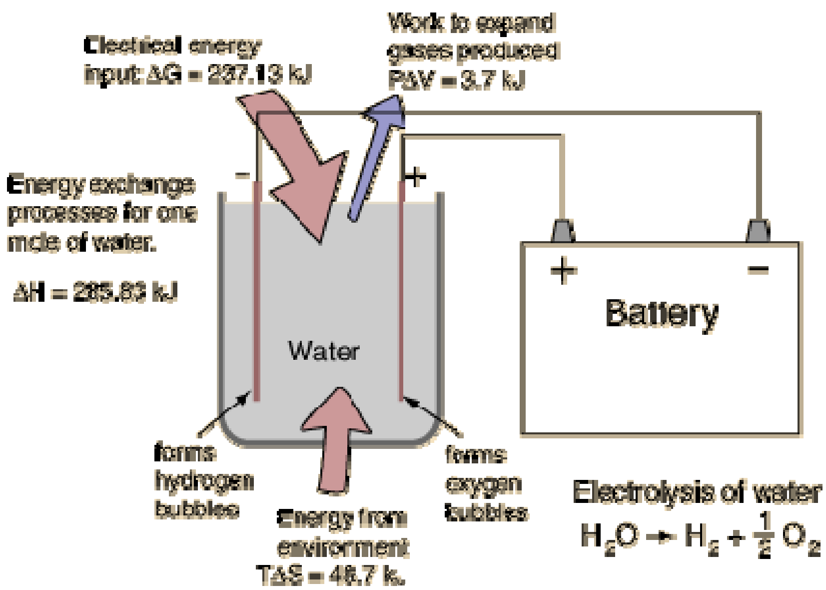
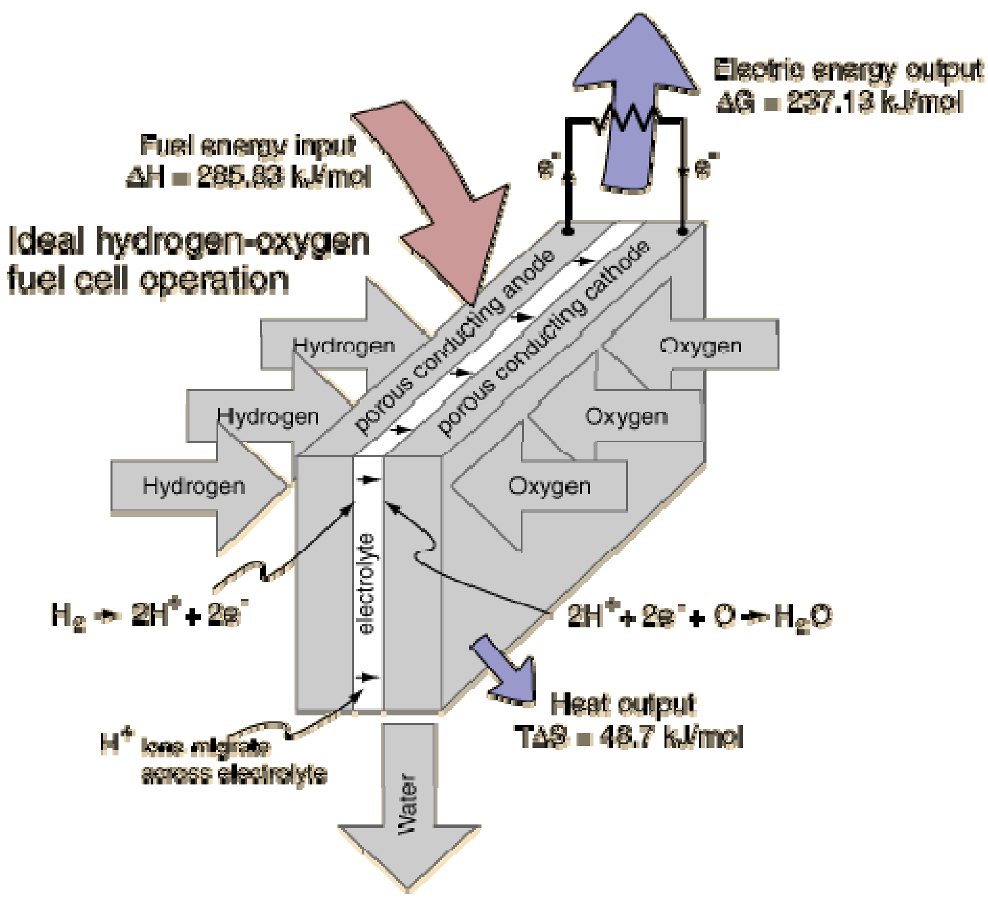


Illustration 2 – REVERSE OF ELECTROLYSIS OF WATER: HYDROGEN FUEL CELL



GM Corn, Sugarcane, Sorghum, *Jatropha curcas*

USA
>21 million barrels per day or ~8 billion barrels per day (petroleum)
(60% imported) >25% world consumption
Ethanol production ~2 billion gallons

Canada
~170 billion barrels in Fort McMurray (Alberta) active ~25 years (2025)
(<20 years supply for US at current rate of consumption – unrealistic)

Brazil
Ethanol >40% of transportation fuel (current production ~3 billion gallons)

China
Ethanol export negotiations with Brazil
Fort McMurray to Vancouver pipeline negotiations
25% of Russian gas reserves : pipeline negotiated

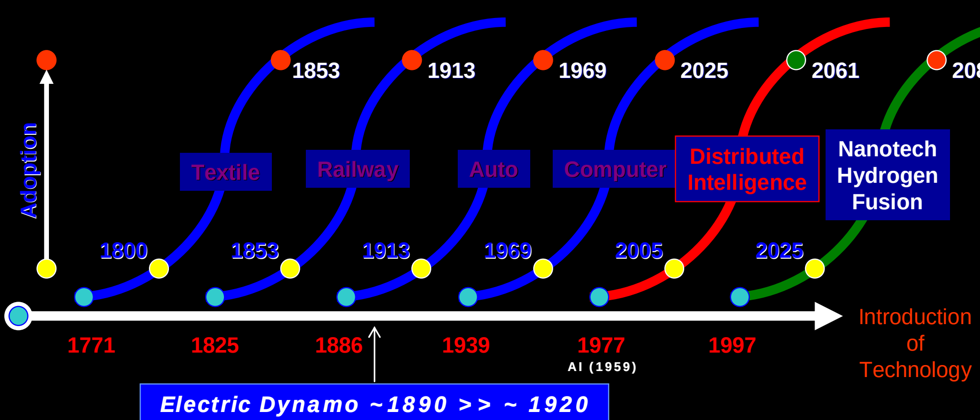
- ***Irrigation & Agriculture***
- ***Production & Distribution***
- ***Automobile Engine Compatibility***

Convergence

Energy Crisis Mitigation Strategy: Saccharomyces cerevisiae?

Economic History from Norman Poire and
Francis T. Evans in *Roads, Railways, and Canals: Technical Choices in 19th century Britain*

Conceptual Advances add to the Wealth of Nations >>> GPT



UK was the first to adopt one standard time. William Hyde Wollaston (1766-1828) suggested the idea and popularized by Abraham Follett Osler (1808-1903). The first railway to adopt London time was the Great Western Railway in November **1840**. On 22 September 1847, Railway Clearing House, recommended GMT at all stations. By 1855 majority of public clocks in UK were set to GMT. Final switch to GMT took effect through the Royal Assent on 2 August **1880** (Statutes Act – Definition of Time). Standard time instituted in US and Canada by the railroads on 18 November **1883**. Detroit kept local time until 1900. Central time adopted by Detroit in 1905, by vote. Standard time zones established in US by the Standard Time Act of 19 March **1918**.

Biofuels: Demand

for

Ethanol and Biodiesel

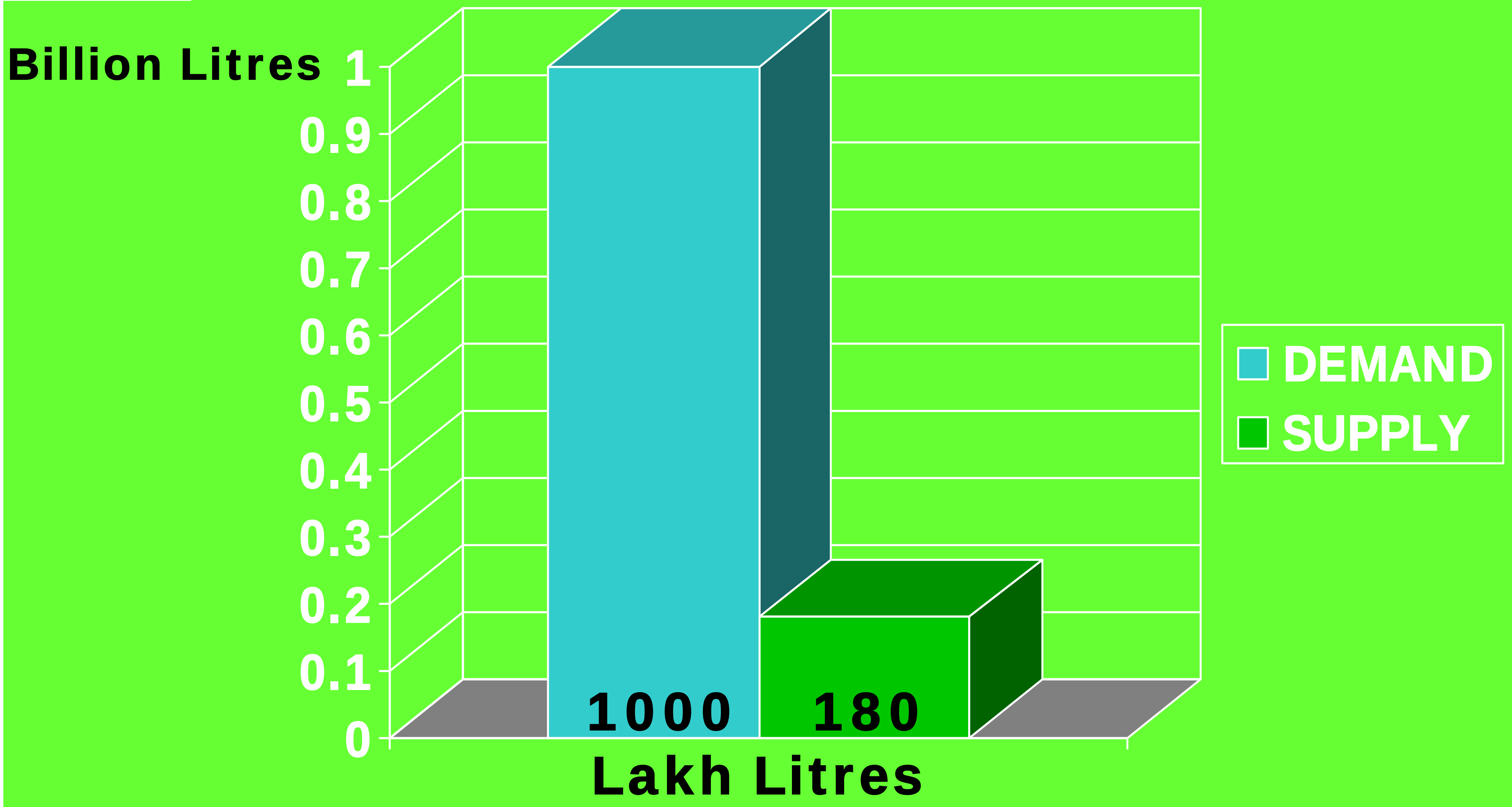
Example: India

Compiled by
Dr Shoumen Palit Austin Datta
School of Engineering
Massachusetts Institute of Technology

Biofuel Sources

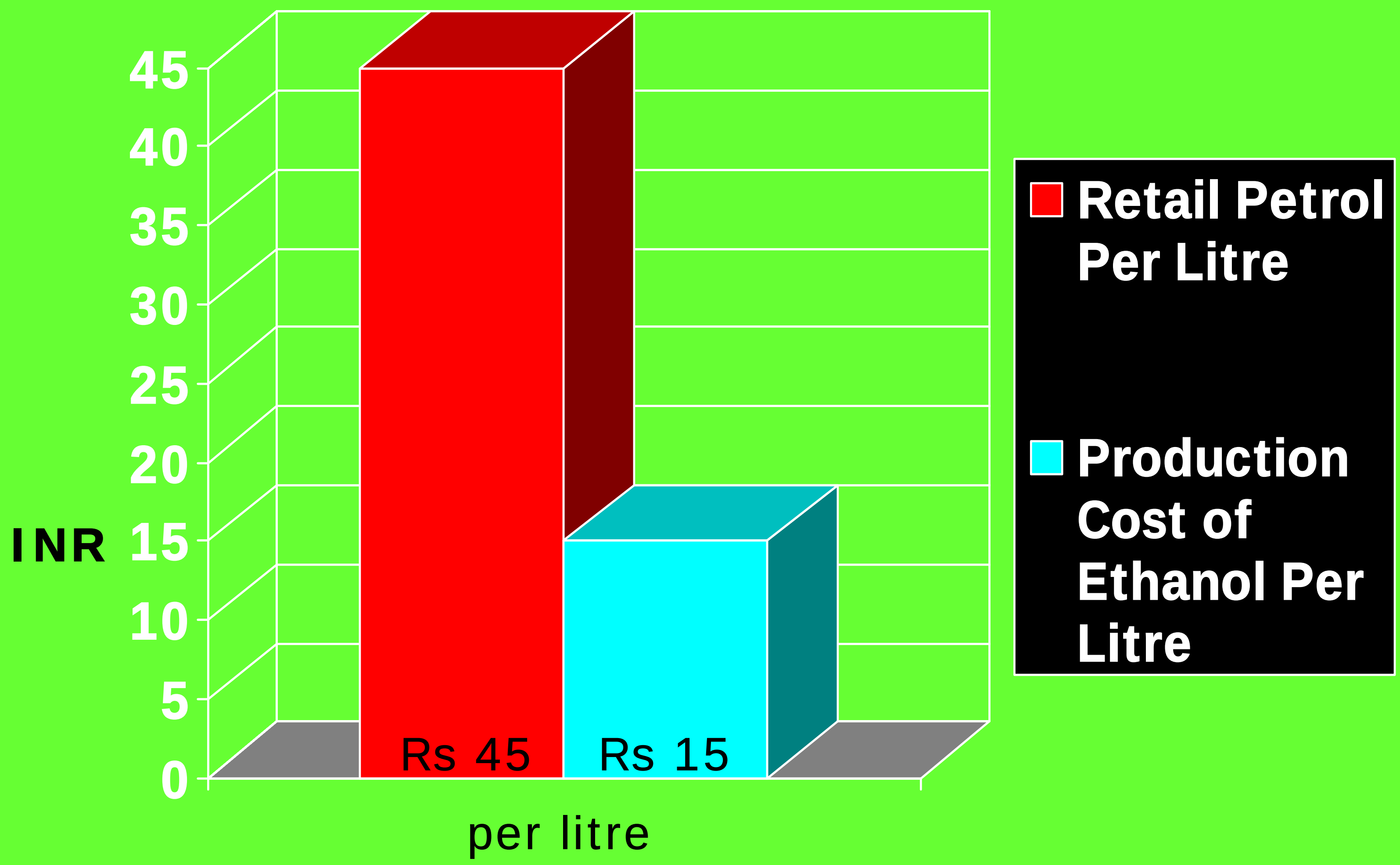
- **Ethanol**
  - **molasses, beet, sweet sorghum, sugarcane**
  - **cellulosic (wood, grass, biomass residue)**
- **Vegetable oils (non-edible)**
  - **Jatropha curcas**
  - **Karanjia**

Ethanol Demand vs Supply



Data per Government of India. According to the US Department of Commerce, the current demand for ethanol in India is 3.6 billion litres or 3,600 lakh litres.

Price of Petrol vs Cost of Ethanol



Biofuels: Bridge to Hydrogen Economy

Number of automobiles 2005 (60% 2-wheelers)	> 60 million
New vehicles registered (50% 2-wheelers)	~ 10,000 per day
Actual Petrol consumed by automobiles	10 billion litres per annum
Total Petroleum consumption in 2006	>130 million tons of crude
Diesel consumption	40 million tons
Imported petroleum	80%
2035: Fuel consumption by on-road automobiles *	60 billion litres
2035: Demand for Ethanol @ 10% (90EBG)	6 billion litres
Biomass residue (cellulose from crops & plantations)	> 500 million tons per year
Potential for Cellulosic Ethanol (200 litres per ton)	> 200 billion litres per year
Potential for power generation from biomass	> 50000 MegaWatts per year

* Projected by the Asian Development Bank

Ethanol Use in India

- IOC R&D undertaken detailed studies using ethanol blended gasoline (EBG) including 5% (95EGB) and 10% (90EBG) for commercial use.
- Ethanol blended gasoline mandatory in many states and 90EBG approved on 1 October 2003
- Adequate supply of ethanol is not available
- Cellulosic ethanol preferred over grain ethanol

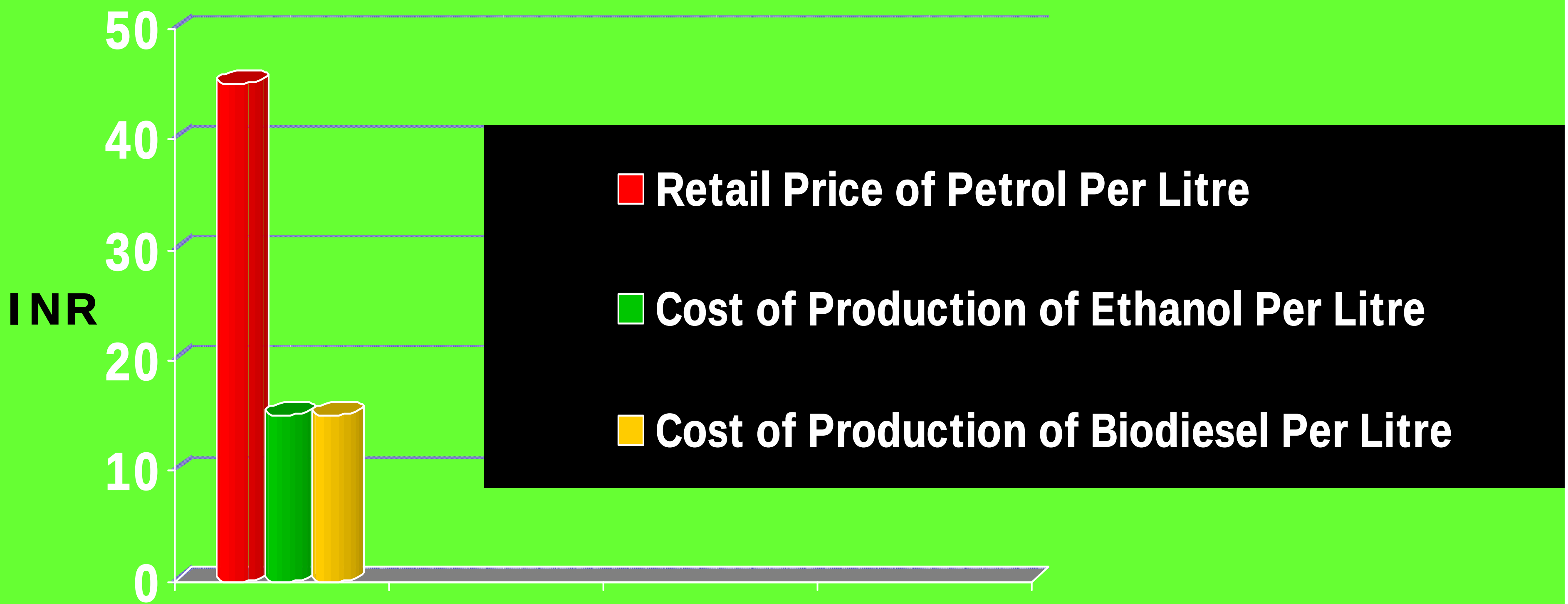
Ethanol Use in Brazil

- 360 million tons sugarcane from 5 million hectares producing 500,000 jobs on plantations and 500,000 jobs in production
- 25,000 petrol pumps dispensing Gasoline, EBG and Ethanol (Alcool)
- VW and GM flex-fuel vehicles (FFV) can run on any fuel or any blended fuel (mixtures)
- Brazil-India cooperation MOU signed in 2001

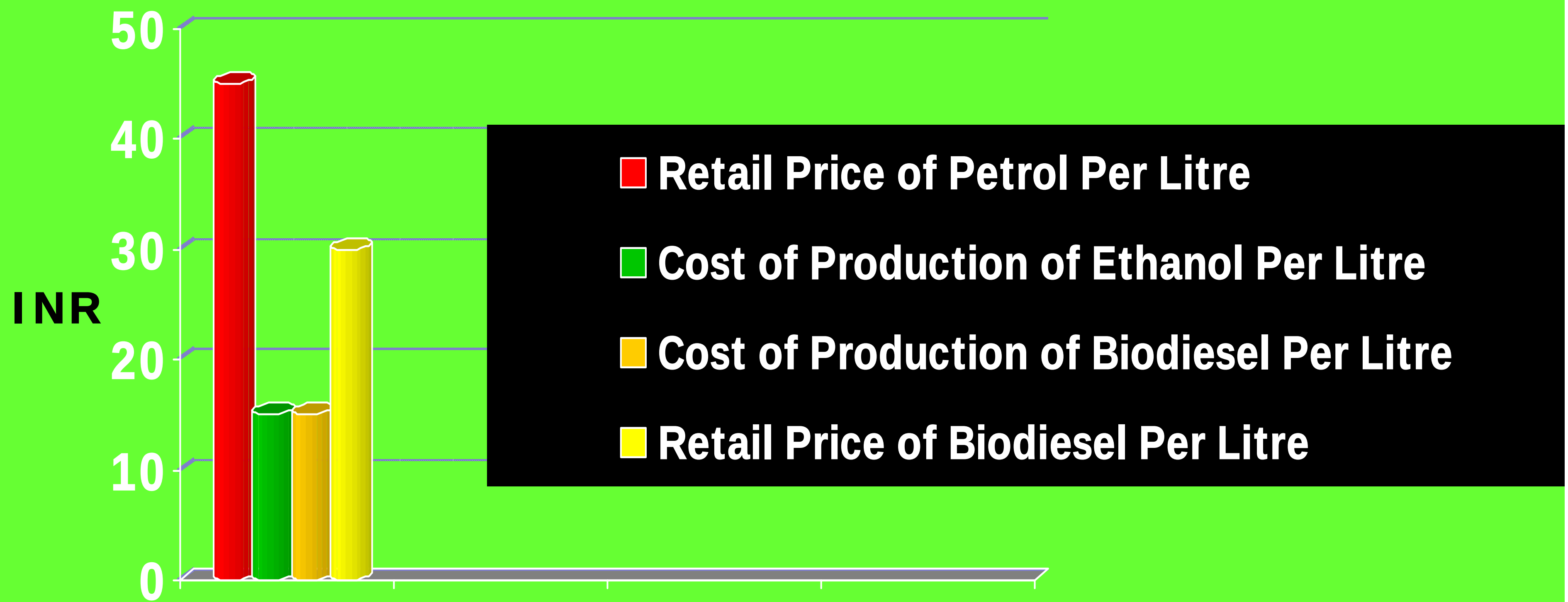
Biodiesel

- Renewable, non-toxic, biodegradable, non-edible vegetable oil
- Lower emissions compared to diesel (zero sulphur, 78% reduction of CO_2 and 50% reduction of CO)
- Better fuel properties (cetane number, lubricity, flash point)
- Daimler Chrysler India successfully tested cars running on 100% biofuel extracted from Jatropha curcas
- 11 million hectares of wasteland suitable for Jatropha cultivation
- 126,000 hectares adjacent to railway tracks owned by Indian Rail

Price of Petrol vs Cost of Biofuels



Rs 30/L **Biodiesel: Profit / Hectare ~ Rs 25,000**



Biodiesel: Profit & Jobs

Lifecycle of plant	50 years
Oil content of seed	35%
Oil yield / kg of seed	250 ml
Plants / hectare	2,500
Job creation / hectare	0.25 FTE
Cost of maintenance / hectare / year	INR 20,000
Seed yield / hectare / year	7 tons
Oil yield / hectare / year	1750 litres
Cost of oil production / litre	INR 15
Cost of oil transport to Europe / litre	INR 5
Cost of oil production / hectare	INR 26,250
Pressed seedcake / hectare	4.5 tons
Selling price of seedcake / ton	INR 4,000
Cost of oil production & maintenance / hectare	INR 46,250
Sales of oil @ INR 30/L and seedcake / hectare	INR 70,500
Gross earnings from biodiesel / hectare	INR 24,250
Area adjacent to railway tracks (hectare)	126,000
Earnings from biodiesel from 126,000 hectares	INR 30 CRORES
New job creation from use of 126,000 hectares	30,000
Wasteland	10 million hectares
Earnings from biodiesel per million hectare	INR 2,425 CRORES
New job creation per million hectare	250,000
Potential for new job creation from Wasteland	25 LAKHS **

** 1 LAKH = 100,000

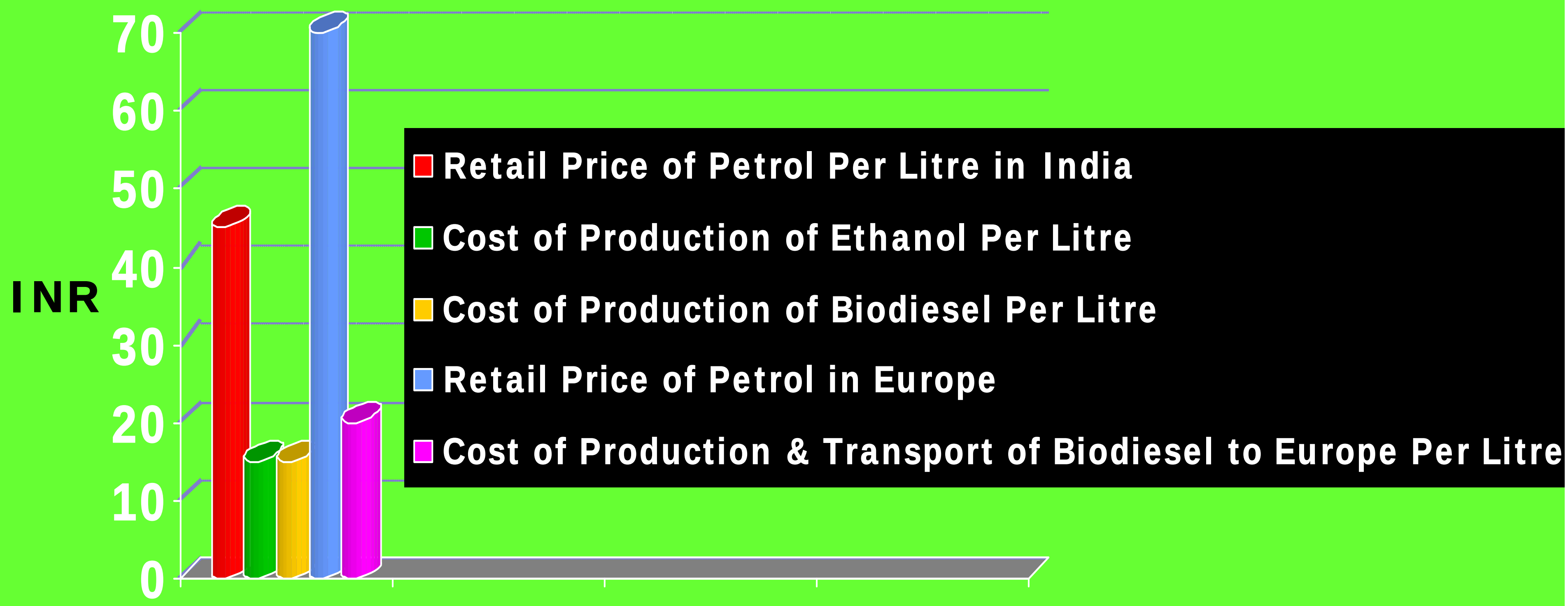
IOC, Indian Railways, Tata & Other Initiatives

- Trans-esterification, process optimization and commercialization
- Testing of locomotive engines with biodiesel (B100) and blends
- Vehicle performance and emission studies (Escorts, Tata, M&M)
- Field trials with buses in Gujarat
- Jatropha plantation on 70 hectares adjacent to rail tracks
- Studies on 16 cylinder engine (3100 hp) with B5, B10 and B20
- Shatabdi & Jan Shatabadi Train trial runs
- Trains through Lucknow using bio-diesel (B10) from June 2006
- Evaluation of B20 for 4 passenger cars and 2 commercial vehicles
- Tata Motors employee buses using B10 in Pune
- Haryana Roadways converts entire (Gurgaon) bus depot to use B5

Biodiesel Purchase Policy (9 October 2005)

- **Biodiesel policy involves PRIs for Jatropha plantations and oil extractions by establishing Rural Business Hubs**
- **OMC purchase price INR 25 per litre.**
- **Assistance for Jatropha plantation and oil extraction.**
- **IOC R&D to increase biodiesel content from 5% to 20%**

Profit from Export of Biodiesel



February 2006:
BP invests $9.4 million in India for Jatropha biodiesel.

China: Biofuel Boom

- 13 million hectares for Jatropha plantation
- 200,000 tons of biodiesel by 2010
- 1 billion litres of Ethanol produced in 2006
- Production cost for cellulosic ethanol $0.25 / L

Biofuels in India: Potentially Profitable

- **Significant profit from ethanol and biodiesel**
- **Export potential for higher profitability**
- **Ethanol-resistant yeast to improve yield**
- **Enzyme-catalysis for cellulosic ethanol**
- **Creates new jobs even in wastelands**
- **Implementable with minimal time**
- **Foreigners ready to grab market**

Strengths	Increasing Demand ROI 15% of Capital INR 20000 / ton capacity Robust supply chain Distribution Channels Job creation in wasteland No new carbon addition	Decrease fossil fuel use Reduce carbon emissions Oil crisis mitigation Government regulation European distribution Worldwide awareness	**Opportunities**
Weaknesses	Does not eliminate carbon emissions completely In the very long run may be more expensive than hydrogen via electrolysis Existing engine conversion	US / EU investors Slow pace of bureaucracy MNCs land lease venture Failure to use new tools Lethargic approach Paralysis from analysis	**Threats**

Power in Every Garage

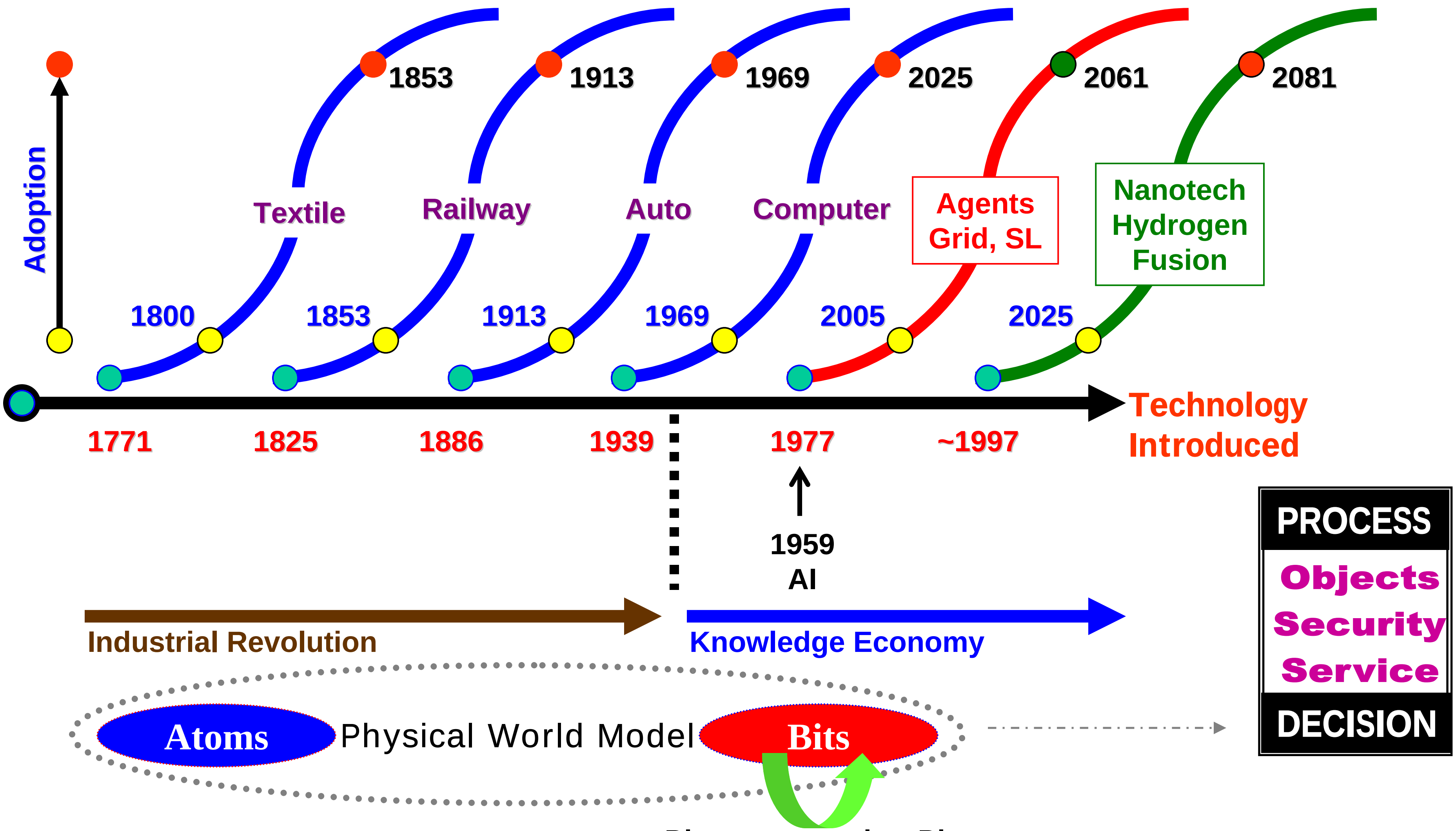
pH ●→ The Power of Hydrogen

A chicken in every pot and a car in every garage!

Herbert Hoover 1928 (1929-1933) 31st POTUS

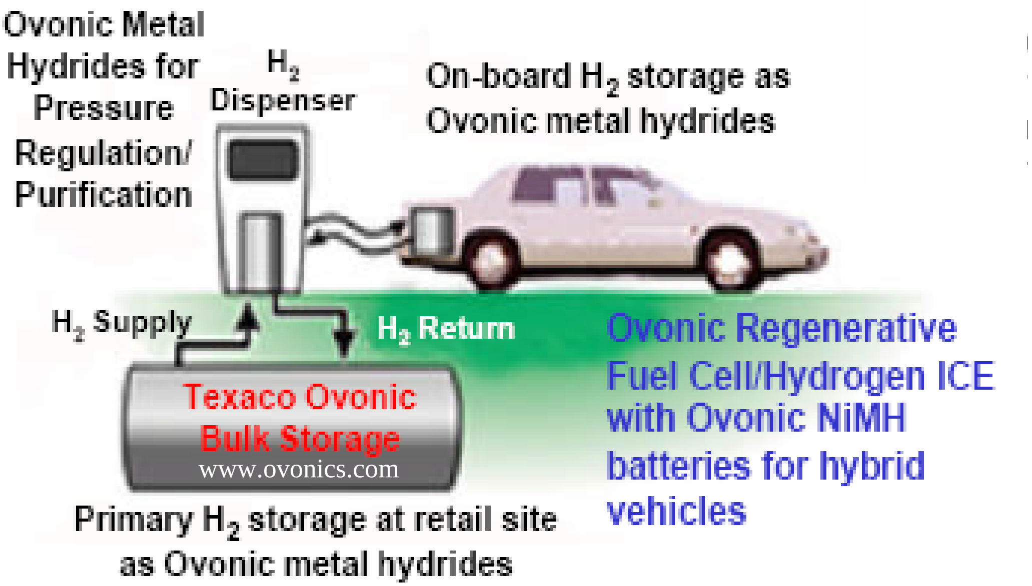
Shoumen Datta, School of Engineering, Massachusetts Institute of Technology <shoumen@mit.edu>

Conceptual Advances (*add to the Wealth of Nations but "Adam Smith was wrong!"*)



Shoumen Datta, School of Engineering, Massachusetts Institute of Technology <shoumen@mit.edu>

Pipe Dreams ?



173,000 petrol pumps in US
Motorists stopped a total of 11 billion times in 2002
Station refuels 175 cars/day

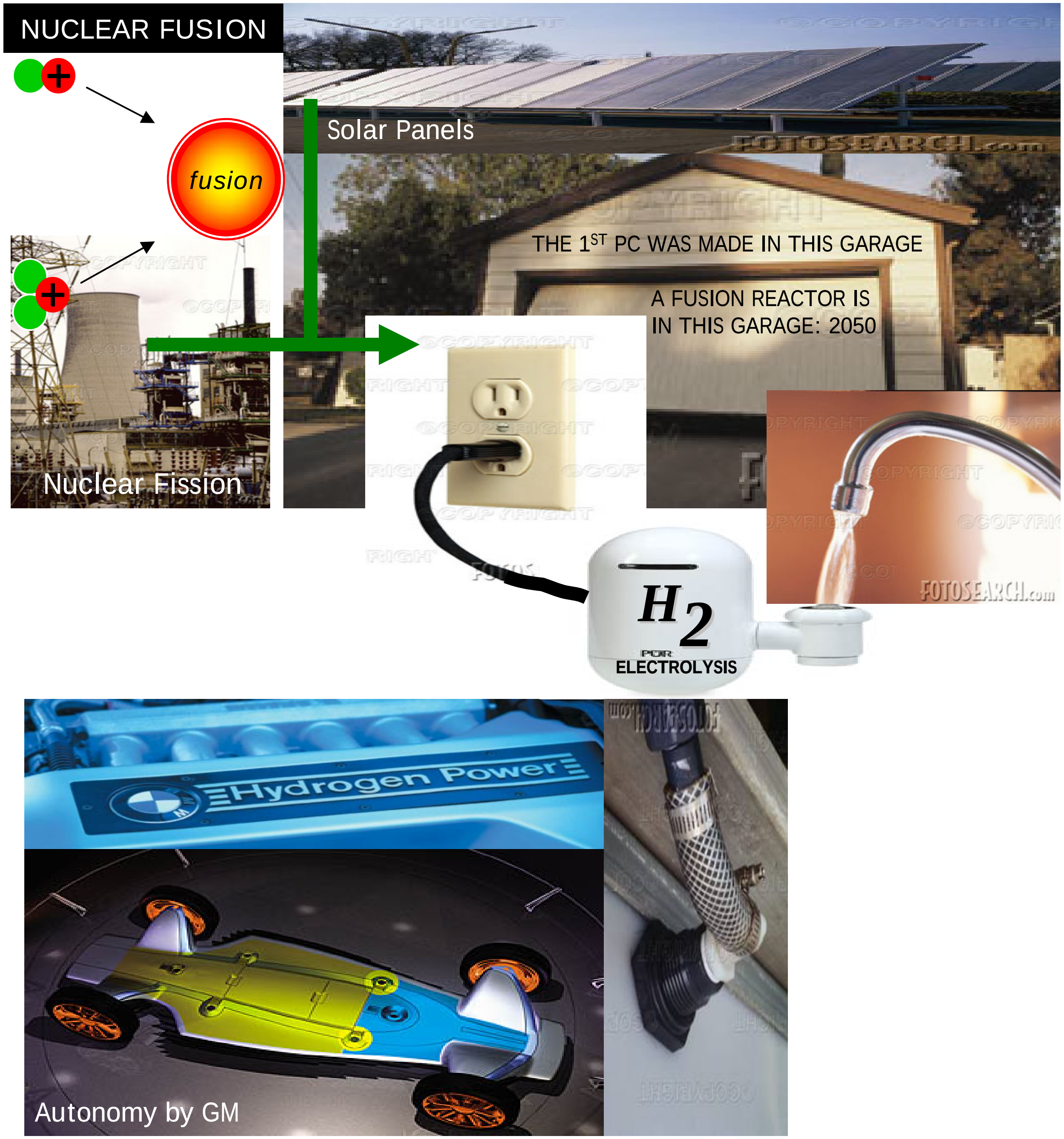
Source: www.auto.com/industry/hfuel5_20030305.htm

www.auto.com/industry/hfuel5_20030305.htm

US$ 400 Billion

Re-tool pump infrastructure and pipeline in US

Shoumen Datta, School of Engineering, Massachusetts Institute of Technology <shoumen@mit.edu>



pH: Power of Hydrogen

Power in your Garage

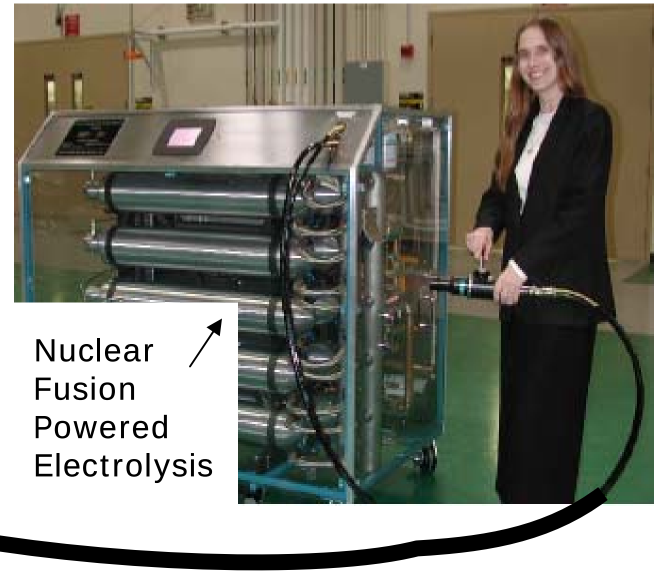
Future

2025 - 2050

Museum of Fossil Fuel

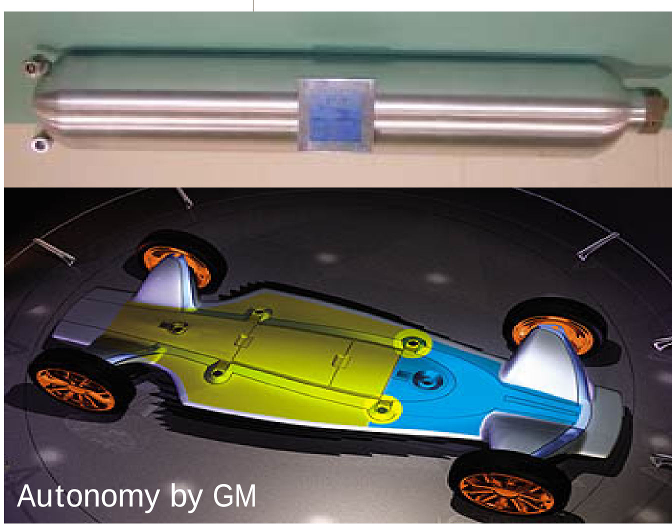
Shoumen Datta, School of Engineering, Massachusetts Institute of Technology <shoumen@mit.edu>

pH: Power of Hydrogen



Power in your Garage

Cartoons: Ovonics



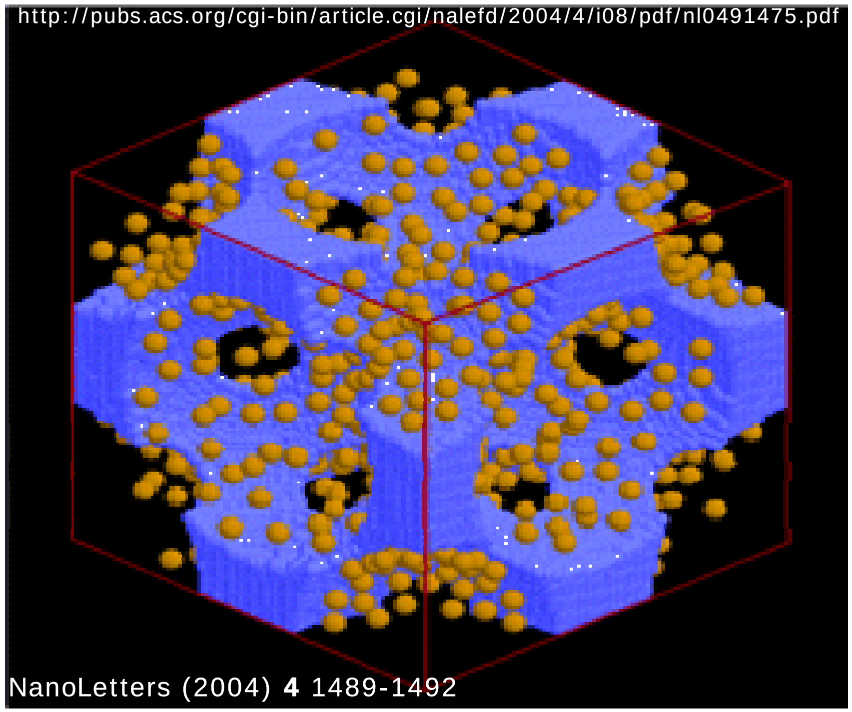
Ubiquitous Hydrogen on Demand

GPS-UWB linked hydrogen sensor tagged Hydrogen Power Cells for sale in restaurants and grocery stores to replenish fuel, anytime.

Create that, not which is acceptable, but what will become accepted.

Molecular Simulation of Novel Carbonaceous Materials for Hydrogen Storage

Snapshot of hydrogen molecules adsorbed in the GCIO porous material. Carbonaceous material indicated in blue and yellow spheres represent Hydrogen.



 Shoumen Datta, School of Engineering, Massachusetts Institute of Technology <shoumen@mit.edu>

pH is Unstoppable for Sustainable Economic Growth

	1960	2005	2025	2050
VCR*	$ 50,000	$ 50		Portable Domestic Fusion Reactor
PC*	$ 120,000	$ 500	$ 50	
pH		$ 375,000*	$ 2000	

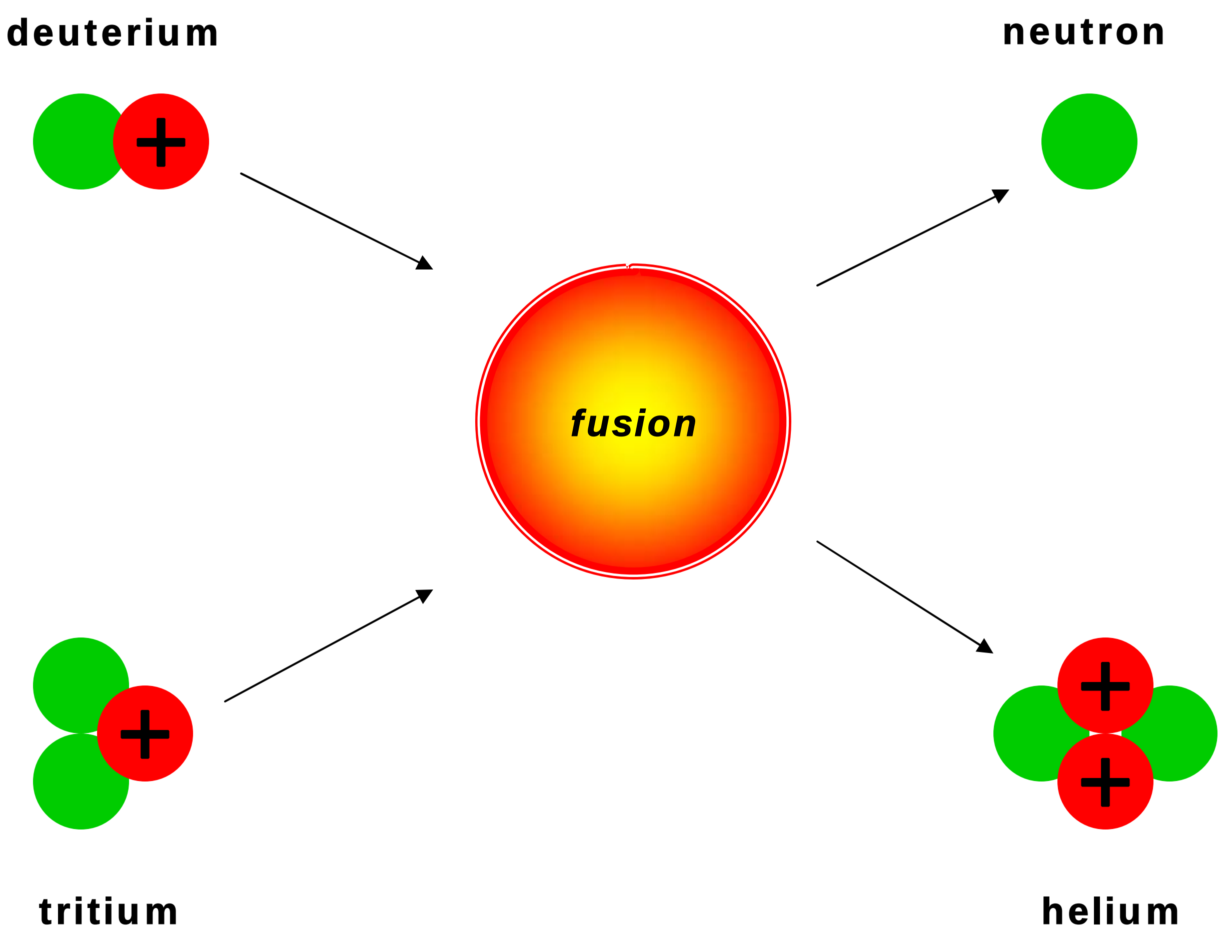
Energy Plant in Every House

* Cost of semi-portable Hydrogen generator from natural gas (www.auto.com/industry/hfuel5_20030305.htm)

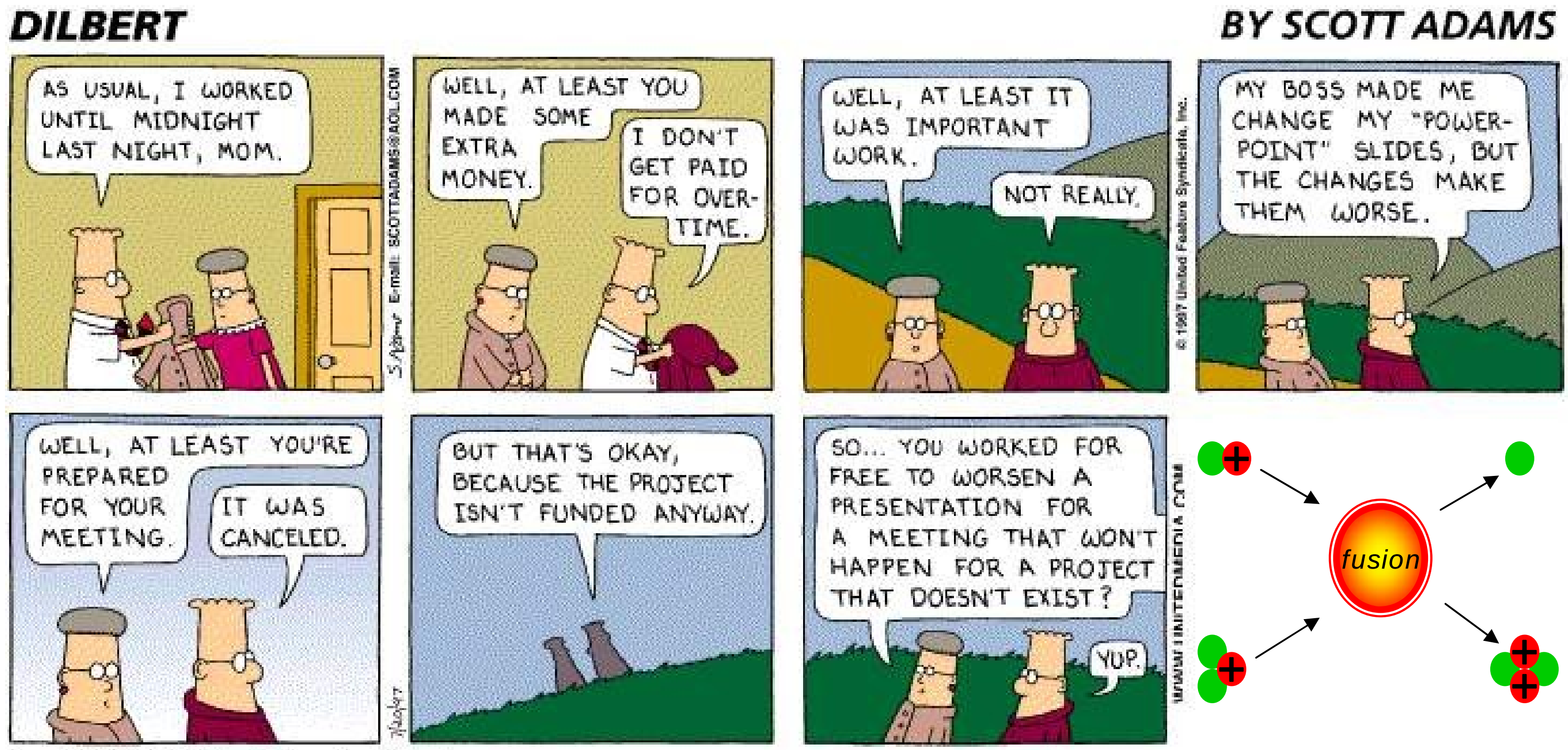
* VCR manufactured by AMPEX Corporation; * Desktop PC model PDP-1 manufactured by DEC

FUSION REACTION

Heavy Hydrogen in one can of sea water provides about as much energy as one tanker truck of gasoline (petrol).



Shoumen Datta, School of Engineering, Massachusetts Institute of Technology <shoumen@mit.edu>



Copyright © 1997 United Feature Syndicate, Inc.
Redistribution in whole or in part prohibited.