THE CARBON ECONOMY

Navigating a decade when nothing is enough, but much is essential

The core question of the coming decade, and indeed the coming century, is obvious: *How will we transition from our dependence on petroleum and coal to other sources of energy that are more economically viable and less damaging to the interlocking biological, geological, and meteorological systems that sustain our human communities?*

This will be a decade of frustration as we realize that there are no silver bullets. No combination of alternative energy sources will meet the demands of the decade for low-cost energy. No tenable policies for conservation will compensate for the decline in conventional resources. No global carbon market will emerge as the regulating mechanism necessary to keep the planet's temperature from rising by more than 2°C.

And yet we will need to act posthaste to develop energy alternatives, to set new standards of energy efficiency, and to limit carbon emissions. How we manage this turbulent carbon economy over the next decade, will signal how well we, as humans, can use all the tools at our disposal to lay the tracks for a lightweight human civilization.

POST-PEAK INNOVATION: A COLLISION WITH COSTS

Many technologists and economists are betting on new alternative energy sources as a way to solve the triad of problems raised by declining oil reserves, environmental impacts of carbon emissions, and a collapsing global economy. Yet the critical question is whether these new technologies can meet the demand—and meet it at a reasonable cost. Two recent studies deliver grim reports.

The first, from SRI International's Ripudaman Malhotra, comes from an assessment of global energy production demand and capacity, and the assertion that, as demand is expected to triple by 2050, we cannot build out our alternative energy sources fast enough. The situation is exacerbated by a second study, from David Murphy of *The Oil Drum,* that suggests that the decline in post-peak oil production (and post-peak production for other conventional energy sources) will be much steeper than originally forecast due to the energy cost of energy production—that is, the energy it takes to produce energy. Murphy's forecast shows steep declines in production as early as 2015.

ENERGY EFFICIENCY: THRIVING WITH CONSTRAINT

What about the flip side of the coin? What about efficiency? Arthur Rosenfeld is a former particle physicist, the head of the California Energy Commission, and teacher of current Secretary of Energy, Steven Chu. He offers a promising projection:

Worldwide, human civilization has steadily improved its energy efficiency since the beginning of the industrial age in 1845 at a rate of about 1% per year. In times of extreme constraint (such as the 1970s oil embargo), energy efficiency has improved by as much as 4–6%. It is possible to sustain a 2% improvement in efficiency worldwide indefinitely. If we did that, we would be able to support the projected 10 billion people at the end of this century at a European quality of life while cutting current energy consumption in half.

Unfortunately, this long-term view doesn't address the disruptions of the next decade or two. In the short term, even heroic energy-efficiency efforts will not bring demand into balance with production—and perhaps more importantly, with the need to reverse the trend of growing carbon emissions.

CARBON MANAGEMENT: FROM MITIGATION TO ADAPTATION

Even as governments debate the essential details of a carbon market, many scientists, economists, and policymakers argue that taxes, not quotas, will be necessary to t ransition from a carbon economy and reduce carbon emissions on a scale deemed necessary. Yale University economist William Nordhaus points out that the stakes are too high to use an untested mechanism like cap-and-trade: "To bet the world's climate system and global environment on an untested approach with such clear structural flaws would appear a reckless gamble."

Still, a system of carbon quotas and credits could create a dynamic new financial market. A report by Point Carbon suggests that even if the nations of the world can't agree on targets, an aggressive US/EU trading exchange could "be an unstoppable force almost independently of any global climate framework" by 2020. But will such a mechanism actually reduce carbon emissions at the rate necessary to avoid the climate tipping point of >2°C—or even enough to avoid major climate impacts?

Given the combination of insurmountable demand, insufficient conservation, and ineffective carbon management, the next decade is likely to see a rapid shift of attention from carbon mitigation to rapid adaptation to extreme environments—both natural and economic.

SUPERSTRUCTING THE CARBON ECONOMY:
How will you live this forecast?

The **Superstruct Strategies** emerged from IFTF's 2008 massively multiplayer forecasting game, Superstruct. They suggest innovative ways to respond to this forecast.

EVOLVABLITY:
Nurture genomic diversity and generational differences

EXTREME SCALE:
Layer micro and massive scales for rapid adaptation

AMBIENT COLLABORATION:
Leverage stigmergy with environmental feedback

REVERSE SCARCITY:
Use renewable and diverse resources as rewards

AMPLIFIED OPTIMISM:
Link amplified individuals at massive scales

ADAPTIVE EMOTIONS:
Confer evolutionary advantage with awe, appreciation, and wonder

PLAYTESTS:
Challenge everything and everyone in fun, fierce bursts

EVOLVABILITY + EXTREME SCALE + AMBIENT COLLABORATION + PLAYTESTS

Invest in massively many globally local experiments in extreme carbon reduction. Set targets and devise strategies appropriate to the location. Set up competitions across the experiments with metrics that make sense for all of them. Design persuasive tools and monitoring devices to track performance at the community level. Connect to local citizen science networks to assess the impacts of new practices on the local environment. Do this at the company or community level.

EXTREME SCALE + REVERSE SCARCITY + PLAYTESTS

Work with alternative currency frameworks to translate personal carbon credits into tradeable currencies. Set up global or local personal carbon allocations. Create a bidding system to determine how much a particular adaptation—such as taking public transportation—is worth in carbon credits. Set up positive feedback cycles by exchanging carbon credits for energy efficiency in appliances: for example, give people 10% off an energy-efficient air conditioner in exchange for carbon credits. Set collective goals that pay dividends to everyone who participates in a particular challenge. Do this at the company level, the community level, or the level of global markets.

EXTREME SCALE + AMBIENT COLLABORATION + AMPLIFIED OPTIMISM + ADAPTIVE EMOTIONS

Create large system scoreboards that integrate daily personal carbon and energy statistics into visual simulations of impacts locally and globally. Leverage mobile devices that have deep penetration worldwide to connect people to daily "how-we're-doing-scores." Use visual tools and media that help participants make emotional connections between their efforts and awe-inspiring natural and social phenomena. Link these scoreboards and simulations to educational curricula for young children to increase their understanding of the interconnections among human and natural systems. Do this for systems at multiple scales and work to link the scoreboards together.

WHAT IT WILL TAKE TO FUEL HUMANITY

In the 1970s, Hugh Crane, of SRI International, developed the useful visual concept of "a cubic mile of oil (CMO)"—the total amount of annual worldwide oil consumption at the time. More recently, SRI's Ripudaman Malhotra has expanded the concept to include CMO equivalents for alternative technologies, allowing us to compare energy production and consumption across sources as different as oil and solar. Worldwide, we are currently consuming about 3 CMOs per year. Malhotra projects that by 2050, with the current demand growth rate, we will consume 9 CMOs annually—an increase of 6 CMOS. This would require heroic increases in alternative energy sources (Table 1).

Malhotra's calculations don't take into account the likely increases in the capacity of alternative energy technologies, particularly wind and solar. But his analysis makes clear the scale of the challenge we face and the need to move at our most aggressive pace to develop alternatives to carbon. We certainly can't afford to delay another decade in order to make the most of our diminishing carbon resources.

PEAK ENERGY FORECASTS

The challenge is further complicated by the fact that we're facing peak production scenarios in almost all these energy solutions. Peak production is the point in time after which the rate of production enters a terminal decline. While forecasts of peak production are widely debated, we have good models that suggest we have either reached or will soon reach peak production across our conventional energy sources (Figure 1). By 2020, even as demand is increasing, we will likely be facing a decline in production for the energy sources we currently rely on most heavily. Even if we could build out the alternative sources at the rate shown in Table 1, we would have to compensate for likely declines in oil, coal, and gas.

ENERGY RETURN ON ENERGY INVESTMENT (EROEI)

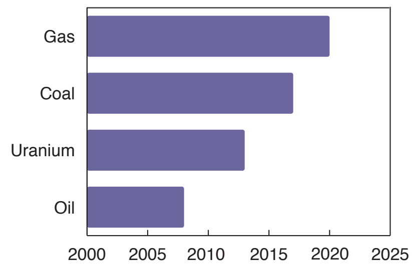
The story turns darker still when we consider the energy costs of energy production—or how much energy we have to spend to get more energy. While peak scenarios for oil and other energy sources generally assume that about half the usable reserves remain after the peak, the reality is that the higher energy costs to acquire these reserves mean that as much as 75% of the usable reserves have been acquired by the time we reach a peak. Likewise, many recent oil field discoveries are types of reserves that require proportionately more energy to extract. When we look at Hubbert's Peak for oil from this point of view, we see that the drop-off in petroleum production is actually much steeper than Hubbert predicted (Figure 2). With this scenario, current production drops by 50% by 2020, and bottoms out shortly after 2030. Peak scenarios for coal and gas are likely to follow similar post-peak trajectories.

TABLE 1 Necessary increases in alternate energy sources to produce one cubic mile of oil (CMO) per year by 2050.

Hydro	Build one new dam every quarter for the next 50 years
Nuclear	Build one plant a week for the next 50 years
Wind Turbine	Install 1200 per week for the next 50 years
Solar Roofs	Install a quarter million roofs a day for the next 50 years
Solar Power Plants	Build 150 a year for the next 50 years

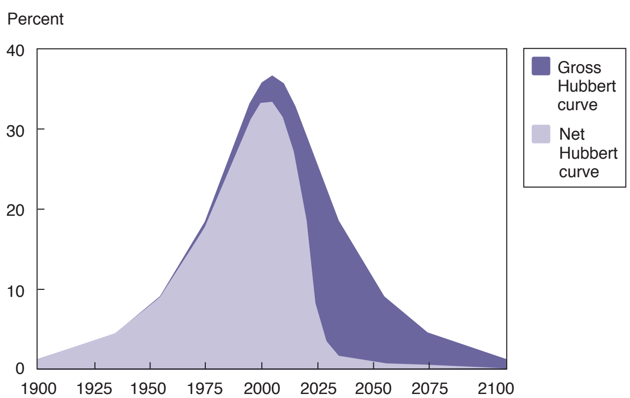
Source: IFTF from data presented in Ripudaman Malhotra, Ph.D., "Meeting Global Energy Demand," SRI International, November 2008.

FIGURE 1 Worst-case peak production dates for conventional energy sources show appoaching crises.



Source: IFTF from: International Energy Agency, 2008; Michael Dittmar, 2009; R.W. W. Zittel and J. Schindler, Bentley, 2002.

FIGURE 2 Net oil production, taking into account EROEI, drops precipitously in this decade.



Source: David Murphy, *The Oil Drum,* June 2009; http://netenergy.theoildrum.com/node/5500

THE EFFICIENCY GAP

Arthur Rosenfeld's prescription for energy and carbon management is inspirational—sustain a 2% improvement for the century and we can actually support 10 billion people without destroying the planet. This is, of course, a long-term scenario. Energy efficiency depends on many technological innovations and retrofits that take time to ramp up. New technologies must be designed to make appliances and electronics more energy efficient. Buildings, which consume the largest portion of energy today, take decades to be retrofitted or replaced. Even aggressive energy-efficiency policies require progressive implementation with goals that are modest in the short term (Figure 3).

All these barriers point to a gap, and with it, the high probability of crises within the coming decade as post-peak energy resources begin to collapse more rapidly than anticipated while renewables and energy efficiency are just beginning to ramp up. At the same time, these crises may actually hasten energy efficiency: in times of crisis, households and businesses make rapid cut-backs in energy use—the kind of lifestyle and structural changes that are tough to legislate or motivate with market incentives. Often, when the crisis is past, these changes persist.

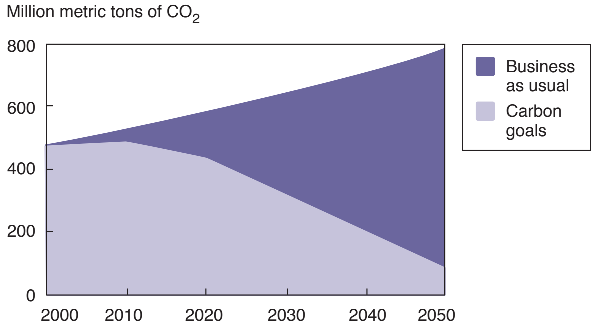
For the United States, the National Academy of Sciences estimates that an optimistic energy-efficiency scenario could actually reduce US demand, compaared with a business-as-usual scenario, by as much as 20% by 2020 and 31% by 2030 (Figure 4).

EFFICIENCY ON A GLOBAL SCALE

Of course, efficiency will look different in different countries, shaped by structural factors such as climate and type of economy (agrarian, manufacturing, service); by access to technology; and by policy choices. So, just as we need a global measure for energy demand, we need a measure for comparing energy efficiency across such diverse conditions.

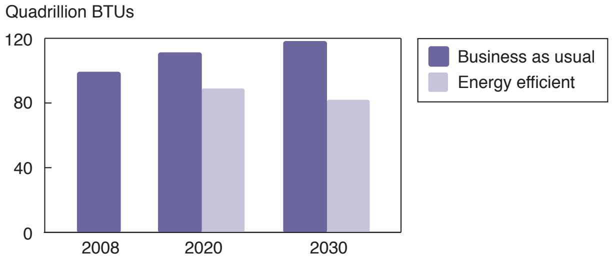
Energy intensity is what it costs a country to convert energy into GDP, and it's measured as a ratio of units of energy to a unit of GDP—for example, BTUs per dollar. Conversely, the economic energy efficiency of a country is GDP per BTUs. This measure allows us to visualize the relative challenges that countries around the world face as they try to grow their economies while increasing energy efficiency. The United States, for example, needs to increase its energy efficiency without losing productivity, while countries like China, India, and Brazil need to increase their productivity while keeping their energy efficiency from going down. Russia needs to become both more productive and more energy efficient. These different demands suggest different policies and strategies to achieve meaningful and equitable efficiency across the globe. But the basic framework of Energy Efficiency vs. Per Capita GDP helps us develop "globally local" strategies for managing energy demand and carbon emissions (Figure 5).

FIGURE 3 California's energy efficiency goals have their biggest impact after 2020, revealing the gap that must be filled.



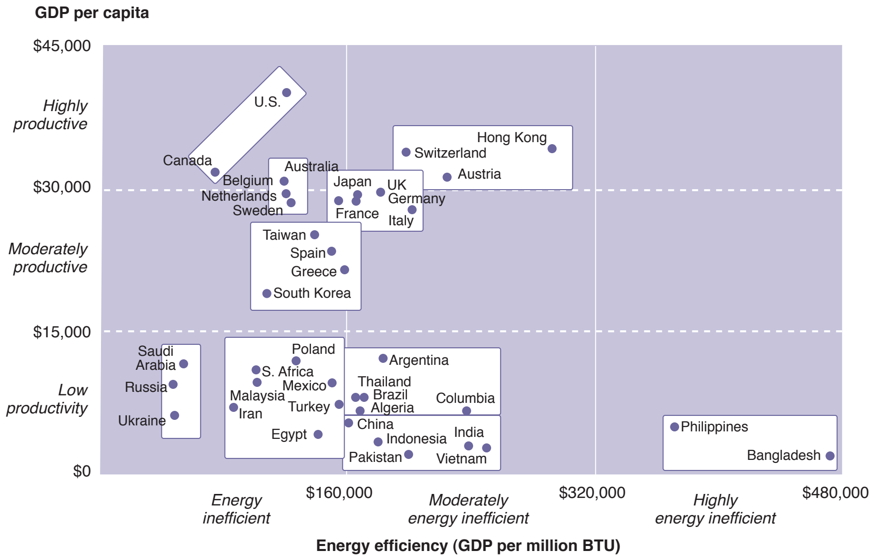
Source: IFTF from data presented in Arthur H. Rosenfeld, "Energy Efficiency as a Resource," ACEEE's 4th National Conference, Berkeley, 2007.

FIGURE 4 The US could use one-fifth less energy in the next decade with full deployment of cost-effective, energy-efficient technologies.



Source: IFTF from data reported in National Academy of Sciences, Real Prospects for Energy Efficiency in the United States, 2009.

FIGURE 5 Every country faces the challenge of attaining an ideal productivity-to-energy-efficiency ratio.



Source: Wikipedia Commons, based on 2004 data; http://en.wikipedia.org/wiki/File:Gdp-energy-efficiency.jpg

UNFORGIVING TARGETS, UNDENIABLE INEQUITIES

To avoid the most catastrophic effects of climate change, we need to limit global warming to a 2°C increase. To do that, we need to reduce global carbon emissions to zero by 2050. If we continue with business as usual, we will not only fail to meet this target; we will nearly triple today's emissions (Figure 6).

But, as nations, we are not uniformly responsible for emissions, so the burden of change is disproportionate. If every person were allotted the same carbon footprint, the United States would bear a much greater burden than China, for example, because the average person in the United States has a much larger footprint today, while China has many more people. In fact, China could actually continue to grow its emissions for the next decade before starting a fairly aggressive decline. The United States, however, would face an immediate and precipitous decline in this decade (Figure 7).

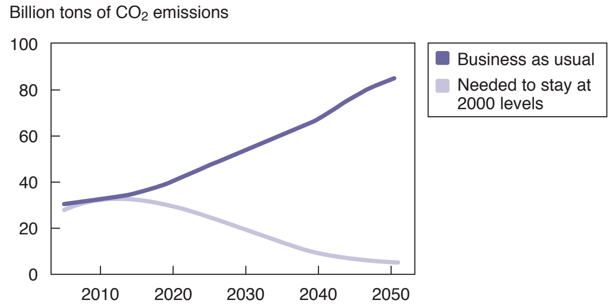
THEORETICAL OPPORTUNITIES, PRACTICAL BARRIERS

The primary mechanism that the world is currently pursuing to manage carbon emissions—and the inequities of carbon reduction—is the cap-and-trade carbon market. The markets, claim proponents, will not only target emissions but will also provide an effective means of investing in sustainable development, especially in the Global South. With constraints on emissions (carbon quotas or targets), carbon emissions become an internal cost of doing business, visible on the balance sheet, and subject to trading like any other liability (such as raw materials). The opportunity for carbon finance—that is, investing in projects that generate carbon credits or directly in credits themselves—drives companies (as well as nations) to reduce their carbon emissions as a means of generating value. Theoretically.

There are, however, numerous barriers to a profitable marketplace that also creates new wealth in the Global South (Figure 8). The biggest barrier is perhaps the lack of targets or quotas that compel serious reductions and thus drive up the value of carbon credits. (Witness the almost 9% drop in carbon prices on the London Climate Exchange at the conclusion of the Copenhagen talks in 2009.) An equally challenging problem is the lack of transparency (and metrics) to ensure that carbon savings are real: for example, the World Wildlife Fund argues that up to 20% of clean development mechanism (CDM) projects in 2007 were not providing actual carbon reductions.

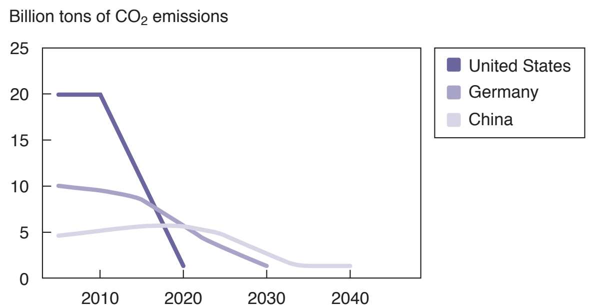
The market is also extremely prone to disruptions from natural and political events. For example, fires and drought could severely reduce the carbon reduction credits (CRCs) afforded by protected stands of forest. Similarly, Russia, having de-industrialized after the fall of the Soviet Union, is sitting on one of the world's largest stocks of carbon credits; if the country decided to sell a very large block of these credits, it could topple the market. The market is also ripe for speculation (derivative markets for carbon credits already exist). With the complexity of the system, the lack of real validation of CDMs and CRCs, and distributed oversight agencies, the chances for scams, abuse, bubbles, and collapse are substantial.

FIGURE 6 Carbon emissions under business-as-usual far exceed cuts necessary to avoid 2°C+ climate change.



Source: IFTF from data presented in http://www.newscientist.com/article/mg20327266.500-fair-carbon-means-no-carbon-for-rich-countries.html

FIGURE 7 The US, Germany, and China would have to make drastic cuts to achieve a world of equal carbon footprints.



Source: IFTF from data presented in http://www.newscientist.com/article/mg20327266.500-fair-carbon-means-no-carbon-for-rich-countries.html

FIGURE 8 Investments in credit-building projects in developing countries are still a small part of carbon markets.

Source: IFTF from data presented in http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTCARBONFINANCE/0,,contentMDK:21842339~menuPK:5213558~pagePK:64168445~piPK:64168309~theSitePK:4125853,00.html

MAKING THE CONNECTIONS

In a complex world, forecasts intersect. These are key intersections between The Carbon Economy and other 2010 forecasts.

CARBON + WATER:
The Water Costs of Energy Production

Water is emerging as a critical resource for the coming century. Just as we consider the energy costs of energy production, we must also consider the water costs of energy production. Traditional petroleum extraction, forecast to decline dramatically, is the least water-intensive fuel. All the replacements will increase demands on water: nuclear by a factor of nearly 100 or 10,000 depending on the process; enhanced oil recovery by a factor of 700; and soy-based biodiesel by a factor of 2.7 million (Table 2). These costs further exacerbate the scarcities of conventional fuel and may stymie our ability to implement alternative energy sources.

CARBON + WATER + POWER:
Black Carbon and the Himalayan Glacial Melt

Recent NASA research suggests that black carbon—a component of soot and dust—is accelerating the melting of the Himalayan glaciers five times faster than greenhouse gases (Figure 9). Sometimes referred to as the "Third Pole" because of the vast amount of water trapped in ice, the Himalayan glaciers provide water to about one third of the world's population. The NASA research points out that some global warming patterns are local and demand local solutions. But it also shifts the burden of responsibility for global warming from large northern polluters to southern nations that tend to rely more heavily on biofuels, which produce more black carbon than other sources. In the power games that will increasingly surround climate strategies, this finding will cloud the debates.

CARBON + POWER:
Energy Risk for Competing Nations

Each nation has its own configuration of opportunities and risks in the carbon economy, based on its natural resources and its existing infrastructure (Figure 10). As energy becomes increasingly volatile and as climate strategy becomes a potential "weapon" in national arsenals, these energy profiles point to the kinds of strategies that nations are likely to pursue in order to gain advantage from their strengths and minimize their weaknesses.

FOR FURTHER READING

Ripudaman Malhotra, "Meeting Global Energy Demand," SRI International Presentation at Greentech Innovations; November, 2008.

David Murphy, The Net Hubbert Curve: What Does It Mean? *The Oil Drum*, June 22, 2009; http://netenergy.theoildrum.com/node/5500

A.H.Rosenfeld, T. M. Kaarsberg, J. J. Romm, "Efficiency of Energy Use," in *The Macmillan Encyclopedia of Energy*, John Zumerchik, editor-in-chief, Macmillan Reference USA, 2001.

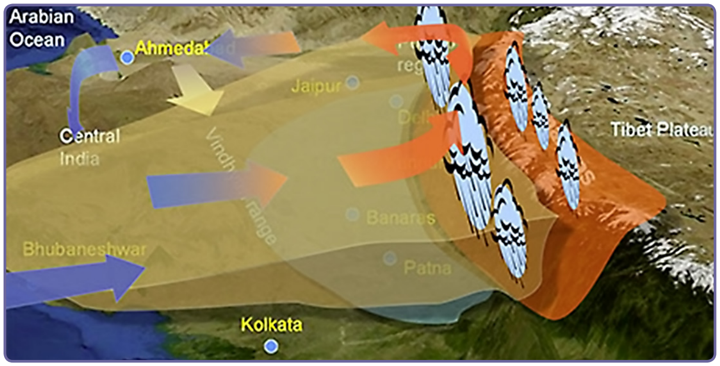
Endre Tvinnereim, The Global Carbon Market in 2020, www.worldcommercereview.com/publications/article_pdf/109w

TABLE 2 Water requirements for energy production (liters per megawatt hour) vary by fuel.

Process	L/MWh
Petroleum extraction	10–40
Oil refining	80–150
Oil shale surface retort	170–681
NGCC power plant, closed loop cooling	230–30,300
Coal IGCC	~900
Nuclear power plant, closed loop cooling	~950
Geothermal power plant, closed loop tower	1900–4200
Enhanced oil recovery	~7600
NGCC, open loop cooling	28,400–75,700
Nuclear power plant, open loop cooling	94,600–227,100
Corn ethanol irrigation	2,270,000–8,670,000
Soybean biodiesel irrigation	12,900,000–27,900,000

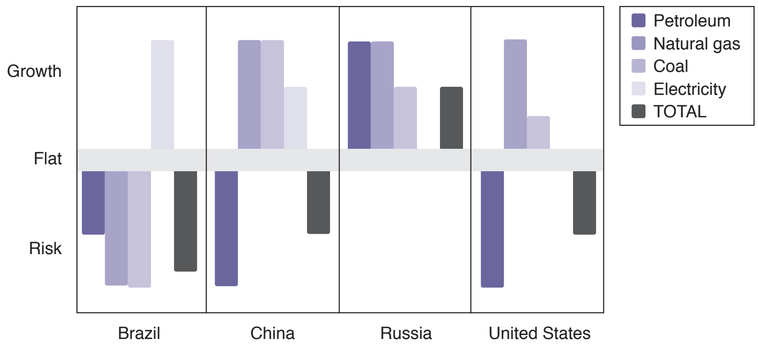
Source: IFTF from data presented in R. Dominguez-Faus, Susan E. Powers, Joel G. Burken, Pedro J. Alvarez, "The Water Footprint of Biofuels: A Drink or Drive Issue?" *Environmental Science and Technology*, 2009, 43 (9), pp 3005–3010, May 1, 2009.

FIGURE 9 Black carbon aerosols from India and Nepal appear to play a larger part in the melting of the Himalayan glaciers than greenhouse gases.



Source: NASA: http://www.nasa.gov/topics/earth/features/himalayan-warming.html

FIGURE 10 Vulnerabilities and possible energy power plays of Brazil, China, Russia, and the United States.



Source: Chris Arkenberg, IFTF, 2010, based on Department of Energy data.

GROWTH

Patchwork Infrastructures

As the world rushes to substitute alternative energy sources for post-peak carbon fuels, energy innovation stokes economic growth—without much attention to redefining lifestyles. Across the globe, innovation takes diverse paths, as each country tries to maximize its return on existing resources and infrastructures while transitioning to the new. Like the battles between computer operating systems or media format standards, the battles between energy solutions drive both market volatility and policy stalemates. By the end of the decade, global infrastructures have fragmented. Electric transport faces off against biofuels; natural gas competes with cheap closed-box nuclear reactors to fuel electrical grids. Meanwhile replacement materials boom as the dwindling petroleum supply drives up the prices of plastics, building materials, and agricultural fertilizers, among other petroleum-based products.

- In the Global North, a big push to build out electric vehicles (EV) draws dollars away from the investment required to convert the current petroleum fuel infrastructure to biofuels, creating a hybrid petroleum–EV infrastructure. China, short on petroleum and rich in coal, builds out its EV infrastructure faster than anyone. Electrical charging systems are installed by a host of surprising new players such as fast food chains and others who have a big stake in the mobile society.

- In the Global South, where the electrical infrastructure is not as robust, local bio-fuel production provides rapid relief from high petroleum prices, but climate-challenged crops are erratic, creating instability in developing nations. Brazil, losing its biofuels market in Europe, develops its ethanol automobile imports in the Global South and comes to the aid of drought-stricken southern nations by providing biofuels when local crops fail.

- In the Global North, the United States, Canada, and Russia leverage their large natural gas reserves (along with a slow but steadily growing wind turbine industry) to fuel the northern electric power grid—with considerable profit until the approaching natural gas production peak drives initial price spikes at the end of the decade.

- In the Global South, closed-box nuclear reactors, manufactured primarily in the United States, China, and Israel, outpace other energy innovations to power their small-scale local electric grids. These reactors begin to use alternatives to uranium, such as americium 242 and thorium. In India, the reactors power an electric vehicle boom.

- With government incentives, a renewed interest in energy solutions that leverage wind, solar, waste conversion, and hydrogen, stimulates the market. But with a shotgun approach to innovation and no clear indicators of winning technologies, the market signals for investing (by the financial community) and adoption (by consumers) are weak. The result is patchwork innovation without critical scale.

- New service models emerge for electrical vehicle charging. Card-based membership networks or car clubs help build out not just the physical infrastructure but also a new financial infrastructure.

- Renewable replacements for petroleum-based polymers boom, but investors, manufacturers, and consumers all take a roller-coaster ride as the replacements compete for base materials with biofuels and food. Result? Periods of scarcity, lots of ups and downs in the market, and price instability across many segments of the wholesale and retail markets.

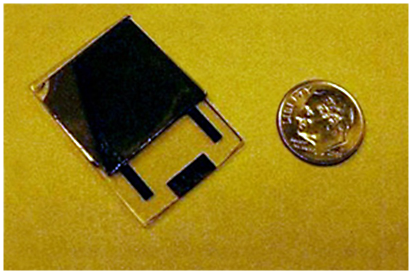
- Lacking a strong system of carbon quotas, global carbon market performance is disappointing—both financially and environmentally. As nations try to take advantage of their remaining carbon-based fuels, the gains from alternative energy innovation just aren't big enough to drive a significant decline in carbon emissions.

SIGNALS OF GROWTH
IN THE CARBON ECONOMY

NUCLEAR BATTERIES—LARGE AND SMALL

Batteries have been undergoing a slow and mostly quiet revolution over the past 10 years, but they are about to transform the way that we use energy. Nuclear batteries the size of a penny are designed to power tiny sensors, actuators, and labs on a chip, and should shrink in size to a hair's breadth in the coming decade. But on a much larger scale, closed-box nuclear reactors are beginning to power electrical grids: self-contained, with no moving parts and no human operator, they eliminate many of the problems of conventional nuclear power plants.

Researchers Jae Kwon and M. David Robertson at the University of Missouri scale nuclear batteries down to the size of a penny.



Source: http://www.boingboing.net/2009/10/07/tiny-nuclear-battery.html

The Hyperion Hydride Reactor can be hooked up to a steam turbine to power 25,000 homes for five years.

Source: http://thefutureofthings.com/news/1079/hyperion-nuclear-batteries.html

---

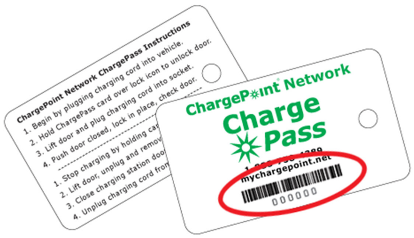
ELECTRIC VEHICLE CHARGING NETWORKS

In almost every scenario, electric vehicle charging stations will grow over the next decade, but in the growth scenario, this infrastructure becomes a competitive platform for new growth ($6.5 billion by 2015 according to Pike Research) and new business models. Coulomb Technologies' ChargePoint networks provide early signals of what these models might look like, with smartcard subscription services and partnerships with retailers that leverage mobility—for instance, McDonald's. While the US will see a large share of this growth, China will be the world leader.

McDonald's has begun to install ChargePoint charging stations in its "green" outlets.

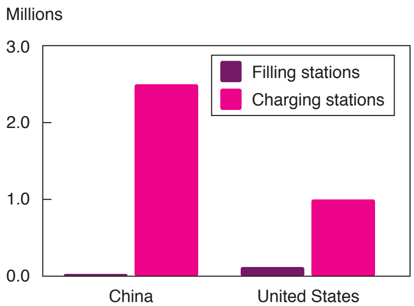
Source: http://www.engadget.com/2009/07/06/mcdonalds-to-offer-chargepoint-electric-vehicle-charging-statio/

Based in Silicon Valley, Coulomb Technologies offers a smartcard network subscription system for its worldwide network of ChargePoint charging stations.



Source: http://www.coulombtech.com/subscribers/activate.php

With its larger investment in filling stations, the United States will be slower than China to build out electric vehicle charging stations.



Source: IFTF from Pike Research data (http://www.greencarcongress.com/2009/07/pike-20090708.html)

CONSTRAINT

Carbon Efficiency

In a world where policy and public opinion align to drive a "war on carbon emissions," society re-orients itself around energy efficiency and "good carbon citizenship." Economic incentives for changing behaviors abound—from high prices of declining petroleum reserves to carbon trading to tax breaks for retrofitting buildings and equipment. Local and regional constraints on personal, corporate, and community carbon footprints drive a boom in carbon accounting tools and services, but even all this good citizenship isn't enough to avoid localized climate devastation in the short term. It turns out that the war on carbon is a war like any other—and the casualties include personal privacy, abundant consumption, and rapid development of the Global South.

- In spite of lackluster attempts to redeem the Copenhagen talks and create the durable agreements necessary for a global carbon trading exchange, the real growth in carbon trading is regional, or even local in some cases, with exchanges emerging across both the north and the south. These exchanges are robust enough to drive new carbon mitigation behaviors—from new agricultural practices that sequester more carbon to investment in new carbon-neutral technologies.

- Without a strong global carbon trading market, the incentives to invest in Clean Development Mechanisms (CDMs) in the global south are weak, and a general slow-down of economic growth leaves many developing nations with reduced expectations.

- Lifecycle assessment (LCA) replaces simple energy efficiency measures as a guiding metric for driving improvements in buildings, vehicles, appliances, and electronics. Tax breaks accelerate both innovation and adoption of higher-efficiency systems.

- Cradle-to-cradle design emerges as the hot new competence, with a Masters of Business Design—MBD—trumping a traditional MBA.

- Personal carbon quotas become a fact of daily life, whether voluntary or mandatory, with communities, corporations, and sometimes nations imposing limits—and sometimes taxing or fining excessive carbon footprints.

- Corporations likewise have extensive carbon accounting practices, with the growth of reporting demands, the elevated role of the triple bottom line (TBL), targeted carbon taxes and fines, and carbon-neutral branding campaigns.

- Monitoring tools proliferate at every level, from smart electric meters to personal mobile devices to sensor networks and environmental monitoring satellites maintained by multiple nations.

- Bottom-up monitoring networks span the globe, with citizen monitors reporting on everything from local food production to carbon levels measured by mobile sensing devices.

- Scientific frameworks for lifecycle analysis and carbon sequestration emerge to support standard metrics that underlie footprinting and credit allowances. Just as people recognize that the value of carbon credits varies with market demand, they come to expect refinements in science and metrics to influence carbon targets and the value of credits.

- Along with both voluntary and involuntary monitoring of energy consumption and carbon footprints come strident debates about privacy. As in any society with a strong consensus on values, a carbon-constrained society achieves its goals at least partially through peer pressure and even intimidation.

- To compensate for a pronounced decline in material consumption, society turns to interactive and virtual entertainment, continuing to escalate the growth of the games industry. Many of these games are designed to turn compliance with energy policy into play—with opportunities to cash in on compliance or, alternatively, to learn how to game the system.

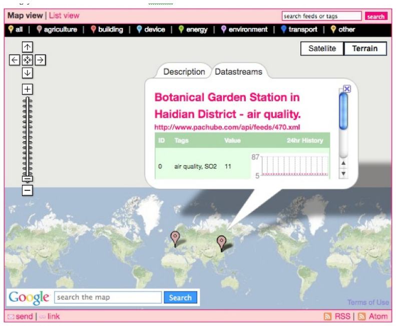
- Happiness indexes seek to replace economic measures of well-being as populations adjust to new material expectations.

SIGNALS OF CONSTRAINT
IN THE CARBON ECONOMY

BOTTOM-UP SYSTEMS MONITORING

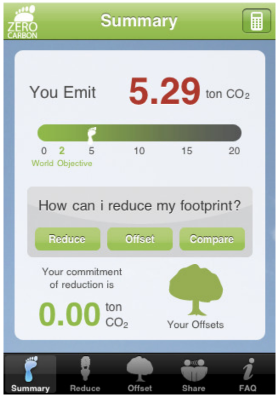
Networks and platforms for distributed monitoring of our natural and human-made environment are proliferating, with everything from citizen science networks for tracking the impacts of climate change on interlocking lifecycles in the environment (National Phenological Network) to global sharing of environmental sensor data from diverse sources (such as Pachube). At the individual level, devices for tracking one's personal energy and carbon footprint proliferate.

Embedded in web pages, Pachube data helps people "blog" sensor data, sharing real-time environmental readings from sensors that are connected to the internet.



Source: http://www.pachube.com/

Mobile devices, like the iPhone, become calculators for personal carbon footprints, with custom applications like this one from ZeroCarbon.



Source: http://search.appcraver.com/zerocarbon-iphone-95204/app

---

MEASURING CARBON WEALTH

One of the challenges of realizing wealth from carbon trading and environmental stewardship in the Global South is the lack of a system for measuring, monitoring, and managing carbon in a different kinds of landscapes. A number of projects are emerging to address this problem, including the Carbon Benefits Project that is currently working to create tools to measure and model the value of carbon management programs in Western Kenya, Western China, Niger, and Nigeria.

Source: http://www.greeneconomyinitiative.com/print.php?a=1480

The Carbon Benefits Project hopes to help farmers, foresters, and conservationists from the developing world tap what they hope will be multi-billion dollar markets for carbon trading.

CARBON GAMES

In a world where the gaming industry is outpacing every other entertainment sector, games become a key tool in achieving social goals. Already a number of games have emerged to teach people about carbon emissions, carbon trading, and personal carbon footprints. An example is Carbon Game, funded by the EU to teach students to use carbon trading mechanisms to solve the world's climate problems.

Source: http://www.carbongame.org/

In the Carbon Game, teams of students from across Europe play the role of carbon traders, buying carbon in an online market.

COLLAPSE

Lost Opportunity

A reluctance to impose significant limits on carbon emissions plus an under-investment in alternative energy sources and energy efficiency leads to an accelerating global carbon debt without any of the potential for generating new forms of wealth from carbon management. Petroleum production plummets, driving up the prices of fuel, food, and materials. Episodic climate disruptions are increasingly severe, and the long-term impacts of wetter weather in some places and drier weather in others come into focus. At the same time, adaptive strategies begin to emerge, hinting at a possible transformation of the future landscape.

- In the Global North, continuing financial weakness undermines investment in alternative energy. But the combination of greater and more diverse carbon energy resources plus strong infrastructures and several decades of material abundance temper the impacts of collapse, making it difficult to mobilize broad support for strong interventions, such as carbon taxation or international food treaties.

- In the Global South, famine is widespread. Waves of suicide in India, violent protests in Southeast Asia, and ethnic warfare and coastal piracy in Africa are all responses of impoverished farmers and fishermen to degrading conditions of the food landscape.

- In China, a flight from the cities collides with severe drought in the countryside, leaving millions with neither manufacturing jobs nor farming options. The result is a growth in violent protest.

- Brazil struggles as the perfect storm of rising incomes and expectations drive more high-value food consumption (especially meat) at the same time as agricultural productivity declines. The result is continued deforestation of the critical Amazonian rainforest.

- The United States, European Union, Canada, India, Brazil, and Thailand continue to subsidize biofuels, taking the lead in global production.

- Carbon trading markets collapse as the value of carbon credits and the value of investments in clean development fall to zero. Once again, the Global South is left with partially implemented infrastructure projects and unrecoverable debt.

- Worldwide, both driving and flying decline overall, resulting in a drop in carbon emissions but also undermining all the industries that depend on mobility, from retailers to mobile device manufacturers to tourism.

- Plantations designed to sequester carbon fail to store the carbon of the original forests they often replace, displacing traditional farmers and disrupting local communities that could provide some resilience to the poorest populations.

- The African land acquisitions of China, Japan, South Korea, India, Malaysia, Kuwait, Qatar, Jordan, and Saudi Arabia collide with climate impacts on arable land to further disrupt traditional communities and cultures, creating cross-regional conflicts that threaten global cooperation to confront the escalating threats of poor carbon management.

- Adaptive responses include permaculture in the desert areas of Africa, the Middle East and Australia; regional knowledge networks for blending global scientific models of climate change with local traditional knowledge of climates and horticulture; and an intense focus on creating adaptive crops that can thrive in increasingly challenging landscapes—through both genetic engineering and traditional breeding.

SIGNALS OF COLLAPSE
IN THE CARBON ECONOMY

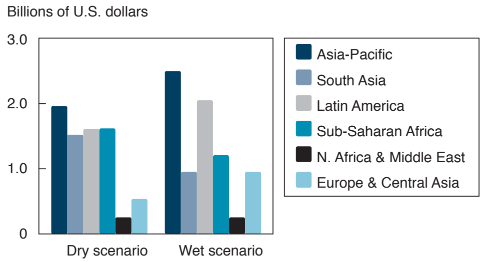
VULNERABILITY IN THE GLOBAL SOUTH

In a collapse scenario, the Global North enjoys a sort of perverse resilience while the Global South, with less capacity to respond, is the most vulnerable to extreme climate change events, food shortages, and famines, conflict and migration. The costs of climate adaptation are greatest in the Asia-Pacific region, where entire countries anticipate inundation, followed by Latin America and either China or Sub-Saharan Africa, depending on whether the scenarios play out wetter or drier.

These countries share the highest overall human vulnerability—based on population, exposure, and capacity to respond.

Source: IFTF, based on Charles Ehrhart, Andrew Thow, Mark de Bois, and Alyson Warhurst, "Humanitarian Implications of Climate Change, 2008; http://www.reliefweb.int/rw/lib.nsf/db900sid/PANA-7JXCDW/$file/ocha_aug2008.pdf?openelement

A World Bank study estimates climate adaptation costs by region, in billions of US dollars, under alternative climate scenarios, assuming that temperature rises by 2°C over the next four decades.

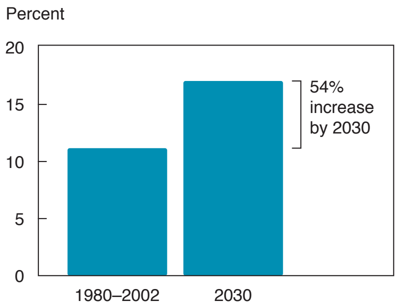


Source: http://www.earthtimes.org/articles/show/287879,climate-change-adaptation-to-cost-75-90-billion-dollars--summary.html

ADAPTATION IN AFRICA

Africa is considered the continent most vulnerable to the direct and indirect impacts of climate change. A joint study by the University of California, Berkeley, Stanford, New York University, and Harvard University projects a 55% increase in civil conflict between now and 2030. Given this scenario, Africa is working to create new networks that can help build its capacity to respond. An example is the Africa Adapt network. Among its projects is one designed to integrate indigenous knowledge into scientific climate forecasts at the local level—hopefully improving both the forecasts and the readiness of traditional farmers to respond.

African Civil Wars are projected to increase by over 50% as a result of climate change.



Source: http://berkeley.edu/news/media/releases/2009/11/23_africa_climate_change.shtml

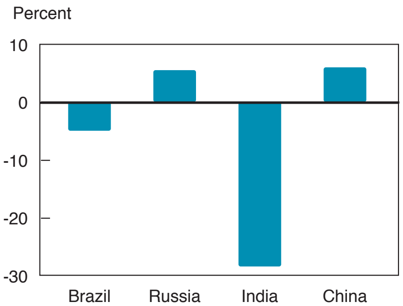
The Africa Adapt knowledge sharing network supports a range of projects to improve the resilience of Africa in the face of climate change.

Source: http://www.africa-adapt.net/AA/ProjectOverview.aspx?PID=wOrGUSXnVTs%3d

FOOD IMPACTS

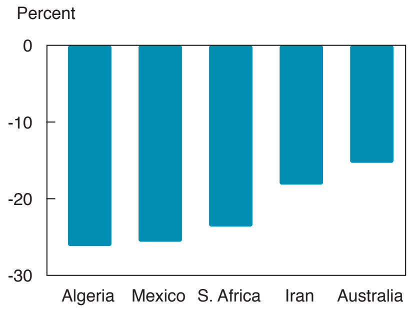
Climate change will have both near- and long-term impacts on food production. Already in India, severe drought is causing crop failure, leading to a wave of suicides among traditional farmers. In the longer term, models suggest that India will continue to be among the hardest-hit nations. One of the challenges is developing crops that can adapt to new growing conditions. The Global Crop Diversity Trust, which runs the Seed Vault, is providing $300,000 of funding this year for researchers in 21 agricultural institutions in 15 countries across the developing world to develop new seed strains, using primarily traditional breeding methods.

Even with beneficial atmospheric carbon fertilization, India's agriculture is projected to suffer the most among BRIC nations.



Source: IFTF, based on William R. Cline, Global Warming and Agriculture: Impact Estimates by Country, Center for Global Development, 2007.

The nations hardest hit in agriculture by climate change by 2080 span the continents.



Source: IFTF, based on William R. Cline, Global Warming and Agriculture: Impact Estimates by Country, Center for Global Development, 2007.

TRANSFORMATION

Carbon Down-Scaling

Lightweight innovation—with rapid low-cost prototyping that leverages networks of DIY innovators—quickly advances very small-scale technology to achieve energy efficiencies at a new scale while reducing carbon impacts. From molecular waste conversion to nano-fabrication, from micro-algae fuel production to molecular gastronomy, we change the texture of our daily lives by changing the scale at which we manipulate carbon. New production technologies start to weaken the globalized production and distribution model, with two big impacts: first, the carbon footprint of manufacturing and trade begins to shrink dramatically, and second, national economies based on cheap labor begin to collapse.

- Across the globe, the familiar institutional patterns of innovation, product development, manufacturing, and distribution are undermined by a set of disruptive technologies that include cloud computing, open hardware, combinatorial manufacturing, agile development frameworks, and desktop biotechnology. These technologies define a new "lightweight innovation" in which complex tasks are unbundled and distributed across actors with diverse skills around the world.

- Micro-fabbing emerges as a viable alternative to traditional production, siphoning the value out of a wide variety of large-scale manufacturing operations. Debates about how to slow or control the spread of these disruptive production technologies become globally divisive. China, slow to give up its manufacturing economy, is teetering at the end of the decade between resistance to and rapid adoption of a post-production economy.

- In the Global South, the lightweight tools invigorate nations with strong civil societies, such as Brazil, South Africa, and India. These countries embrace the new tools, along with strong open-source policies, as a way to accelerate development. In places with weaker civil societies, such as Nigeria and Iran, the results are more chaotic.

- Innovations in material science and biomimetic design deliver vast improvements in the energy efficiency of everything from cars and planes to household appliances. Ironically, these improvements offset the rising costs of carbon-based fuels and thus slow the switch to alternatives.

- Innovations in waste recovery drive a "zero-waste economy." While remaking happens at every scale, the most disruptive innovations are those that refocus technology—and daily life—on the scale of microbes, molecules, and atoms.

- The rush to convert by-products—otherwise known as waste—to usable materials engages widespread networks of corporations, communities, and individuals who are working together to match up waste producers with those who can use specific waste products to create new energy-efficient materials. A small boom in landfill mining also creates new jobs and new wealth.

- Waste-to-energy production has changed the scale of electrical power production in many communities, with neighborhoods, industrial parks, and even households producing some or all of their electrical energy from waste conversion processes that produce hydrogen, methane, and other usable gases as well as heat.

- Meanwhile, micro-algae fuel technologies are beginning to ramp up. From large open-field plants operated by power companies, production has begun to shift to tubes and tanks that reduce the demand for land and water and can be productive at smaller scales—including households.

- Molecular food is more than just a buzz: inexpensive micro-algae-based ink-jet printers are beginning to diffuse into households, replacing fuel-intensive stoves and hinting at a dramatic change in the food production and distribution landscape. A three-way struggle emerges among food naturalists, industrial food producers, and the new lightweight molecular gastronomes.

- A new literacy of molecular biology, combined with new desktop tools for manipulating molecules, is driving DIY biology projects. Distributed networks track microbes the same way they track environmental pollutants and toxins, creating unexpected new opportunities to understand epidemiology and disease.

- Meanwhile, people increasingly manage their health and well-being by managing the molecular processes in their own bodies, customizing foods, drugs, and supplements to have specific impacts that they track with personal diagnostic tools that can read the body's molecular state from saliva or blood samples.

- Just as economists today compare the GDP of nations to that of corporations, they begin to track the GDP of platforms such as Facebook, Google Wave, Groundcrew, and others that accomplish work and create value through brokering social connections.

SIGNALS OF TRANSFORMATION
IN THE CARBON ECONOMY

DO-IT-YOURSELF BIOLOGY

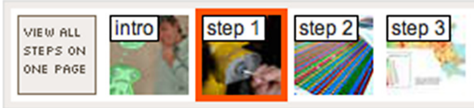
Using do-it-yourself networks and low-investment tools and processes, citizen scientists, amateur biologists, and DIY biological engineers are creating open platforms for sharing their knowledge and skills, building communities of experts, and developing safety and ethics codes necessary to conduct biological research and innovation outside traditional professional settings. While these networks seek to "democratize" the practice of biology and biological engineering, perhaps the most important result of their efforts will be to engage the public in understanding and interacting with organic systems at the molecular level.

DIYbio.org has members around the world working on projects such as the BioWeatherMap that is building a large-scale distributed network of amateurs and enthusiasts to map microbial communities in multiple large cities.

DIYbio

Source: http://diybio.org/local/

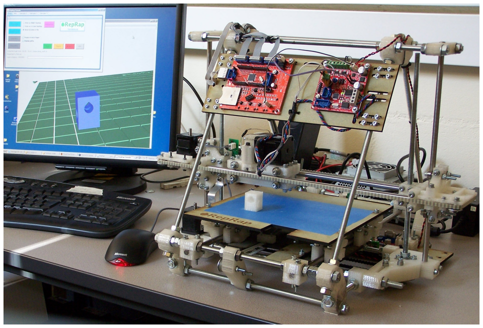
The materials and instructions for participating in the BioWeatherMap are available at Instructables, another DIY platform.



Source: http://www.instructables.com/id/Mapping_Microbes/step1/Collect-a-Specimen/

OPEN FAB

The open fabbing movement seeks to change the scale, the economics, and the politics of manufacturing. Using 3D printers with synthetic or organic materials, and espousing a philosophy of democratization of manufacturing, open fabbing is beginning to take shape as a user-driven movement, with platforms like fab@home and RepRap building networks of experimenters worldwide.



Source: http://objects.reprap.org/wiki/RepRap_Version_II_Mendel

RepRap is an early-stage DIY fabbing machine that is designed to be able to build most of its own parts, so a RepRapper can build and share additional machines.

MOLECULAR GASTRONOMY

Meanwhile, the potential for molecular manufacturing to change our daily lives is driven home by the vision of Homaro Cantu, a celebrity chef at Chicago's Moto restaurant: Cantu wants to replace all of today's familiar kitchen equipment with 3D printers and restock our pantries with microalgae as a way to reduce energy demand and carbon emissions while meeting global demand for tasty food. (Cantu may also change publishing—he recently began creating flavored inserts for magazines!)

Source: http://www.wired.com/wiredscience/2008/12/whatisfood/

Homaru Cantu at Moto Cuisine is defining the new industry of molecular gastronomics with foods printed on paper or using microalgae as a super-nourishing substrate for designer flavors.