CLIMATE CHANGE, SUSTAINABILITY & THE NEW TECHNOLOGY REVOLUTION

Forecasts for Climate Change Impacts on Florida and Emerging Sustainability Technologies

For

The Century Commission for a Sustainable Florida

By

The Institute for Alternative Futures

March 2007

Cover

The image on the cover, produced by the Environmental Studies Laboratory at the University of Arizona, shows the areas of Florida that will be inundated if sea level rises by one meter as a result of global warming. The Fourth Report of the Intergovernmental Panel on Climate Change (IPCC) published in February of 2007 estimates that between now and 2100 sea level could rise by up to 23 inches. The report acknowledges that this is a conservative forecast. Factors that cannot yet be reliably quantified, such as methane (a powerful greenhouse gas) being released by thawing tundra and the faster than expected melting of the Greenland ice sheet that is currently underway, were not considered in making this estimate. As a result, a one meter rise in sea level by 2100 is within the "zone of plausibility" if we fail to take strong action to minimize climate change.

http://www.geo.arizona.edu/dgesl/research/other/climate_change_and_sea_level/sea_level_rise/sea_level_rise_old.htm#images
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Climate Change, Sustainability & The Next Technology Revolution

Forecasts for Climate Change Impacts on Florida and Emerging Technologies to Reduce Greenhouse Gas Emissions

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INTRODUCTION

This report from the Institute for Alternative Futures to The Century Commission for a Sustainable Florida provides an overview of a set of emerging advanced technologies – what we call the Next Technology Revolution – that will be important for moving toward a sustainable future in Florida over the next 50 years. We set out to identify technologies that *hold the promise of being good for business and the economy, good for the environment, and good for the quality of life in Florida, all at the same time.* We gave special attention to technologies essential for addressing what is almost certainly the greatest long-term threat to Florida's sustainability, climate change. While focusing on the climate challenge, we also provide examples of how the technological advances underway today can contribute to progress in virtually every area of the Commission's concern.

Approach of this Report in Relation to the Commission's Approach

The Century Commission for a Sustainable Florida is charged to:

> *…envision a future of Florida; develop a shared image of our developed and natural areas; focus on essential state interests; serve as a repository for ideas; and, develop a report annually. The report is to make recommendations for addressing growth management, discuss the need for inter-governmental cooperation, balance environmental protection with future development, and make recommendations on issues, including dedicated resources for funding of infrastructure, environmental, and educational needs.*

In its first report, the Commission notes that one function of its work is to "force us to think about things we would rather not think about. It might involve some sacrifice and it might step on some toes." It has developed several operating principles, among which are commitments to:

> *1) think long-term and statewide without getting caught up in today's controversies, 2) focus on solutions, not blame, 3) make recommendations based on factual data, 4) gather existing knowledge where available, whether from people or completed studies, 5) explore fundamental changes*

In developing this report, the Institute for Alternative Futures has tried to adopt the same approach as the Commission, following the same operating principles, being willing to think about potentially distressing things, but ultimately working to envision a positive future for Florida. We set out to identify technologies that would be important for sustainability over the next 50 years in Florida. The technologies we have chosen to highlight are not only essential for minimizing global warming, but also *hold the promise of being good for business and the economy, and good for the quality of life in Florida.*

We believe that the fundamental scientific, technical and industrial know-how to solve the climate problem for the next 50 years either already exists or is within reach. Changes in behavior will play a part in meeting the climate challenge, but technological progress to use energy and other resources much more efficiently and to utilize new sources of energy is by far the biggest element of the climate solution. The technical changes needed to stabilize the climate are much larger than most people realize, but they are feasible and taken together are a major part of the Next Technological Revolution.

Florida obviously cannot stop climate change by its own actions. The State does have the opportunity, however, to join more actively with other states and cities to promote the technological progress that can slow and eventually reverse global warming. Given the extensive negative impacts climate change is likely to have on the state, Florida has every incentive to play a leadership role in moving forward into the Next Technology Revolution. The benefits of pursuing this path of development will far outweigh the costs.

Technology for a sustainable Florida

The Concept of Sustainability

Sustainability is at bottom an ethical concept, an ideal of "intergenerational equity." Sustainable development is development carefully designed to meet the needs of the present without compromising the ability of future generations to meet their own needs. Our children and grandchildren will not be able to meet their needs if severe environmental degradation undermines natural processes vital to human society and the functioning of the biosphere such as regulating the atmosphere and climate, cycling nutrients and water, providing pollination and biodiversity, controlling pests and disease, and assimilating and detoxifying society's wastes. But it is equally true that the future will not "work" for the generations ahead if there is economic failure, gross inequities or disruptive, unresolved social problems. The key to creating a sustainable future in Florida is to recognize that economic opportunity, ecological integrity, and social equity are interlocking links in the chain of well-being. The pursuit of one without the others or in opposition to the others will ultimately jeopardize our future progress. When understood properly, the idea of sustainable development leads toward a more sophisticated approach to governance based on policies designed to move *simultaneously* toward economic, environmental and social goals.

Technology and Sustainability

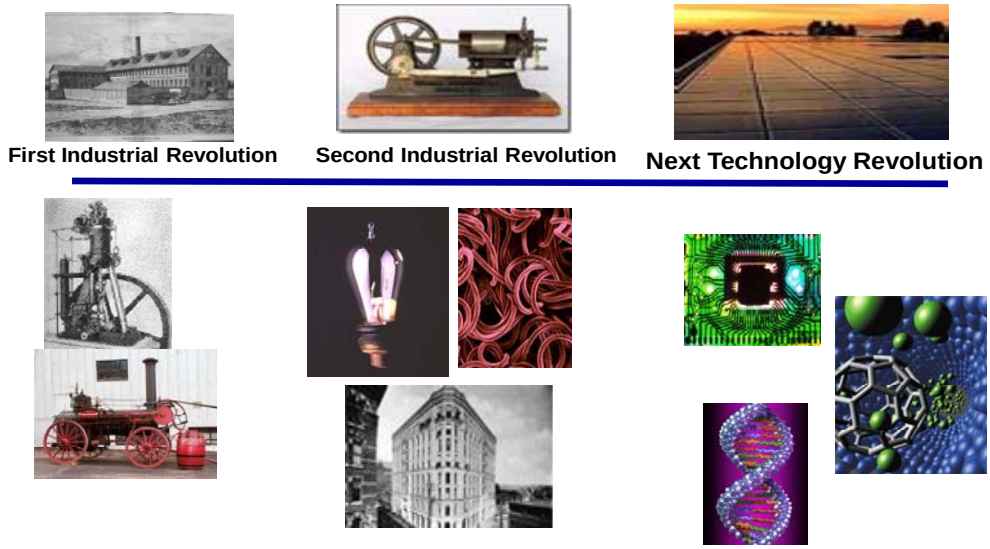
Moving toward a sustainable future for Florida will require changes in outlooks, priorities and behavior. But ultimately these changes must all support a broad shift to a new generation of more advanced technologies. Especially in the area of climate change, no solution is possible without a comprehensive shift away from fossil fuels to alternative sources of energy and technologies to use energy and other resources much more efficiently.

Seeing the possibilities ahead requires a shift of perspective away from the confusion that arose in the environmental debates of the 1970sand 1980s. During that time, many environmentalists became skeptical critics of advanced technology, which they saw as the source of growing environmental problems. At the same time, many technological optimists failed to understand the seriousness of those environmental problems.

In retrospect we can see that both of these polarized positions were wrong. Both assumed that the technologies of the time were advanced technologies. But in light of the progress that has occurred since then in information technology, nanotechnology and materials science, biotechnology and other areas, it is obvious that "advanced technology" is a moving target.

In fact, many observers believe we are in the midst of a technological revolution as important as the Industrial Revolution (coal, steam engines, machine tools, mass production) and what some historians call the Second Industrial Revolution (oil, internal combustion engines, steel, electrification, chemical products).

The technical changes needed to stabilize the climate are all part of the Next Technology Revolution that will take us to a far more advanced technology



By now there is a growing understanding that a sustainable future is possible precisely because rapid technological progress occurring in many areas can allow us to move away from fossil fuels and sharply reduce our consumption of energy and generation of pollution per unit of economic growth. A Toyota Prius, for example, has nearly the computer power of a Space Shuttle, and tomorrow's lightweight hybrids will use advanced alloys or carbon composites. Next-generation solar cells from companies like Konarka, Nanosys and Nanosolar will employ different forms of nanotechnology. Modern wind turbines are designed in supercomputers and use advanced alloys and control circuitry. New enzymes are being created through genetic engineering to process cellulosic plant material into biofuels. None of this is "going back" to simpler technologies. It is part of the unfolding of the Next Technological Revolution. Gus Speth, who was an environmental techno-critic in the 1970s when he helped found the Natural Resources Defense Council, sums up the change in perspective occurring in industry and among environmentalists:

> *"We must rapidly abandon the twentieth-century technologies that have contributed so abundantly to today's problems and replace them with more advanced twenty-first century technologies designed with environmental sustainability in mind."*

Climate Change:

Florida's Greatest Sustainability Challenge

There is no longer any serious doubt that global warming is occurring and is being driven largely by human activity. The Fourth Report of the Intergovernmental Panel on Climate Change (IPCC) published in February of 2007 represents the consensus view of hundreds of climate scientists around the world. The report concludes that the evidence for global warming is now "unequivocal," that the world is already committed to generations of warming, shifting weather patterns and rising seas, but that strong and prompt action can still blunt those impacts and prevent dangerous climate change. The uncertainties and debates now center on how severe the impacts will be, how rapidly they could unfold, and what to do to minimize them.

The IPCC estimates that between now and 2100 the Earth's average surface temperature will increase by 3.5 to 8 degrees F. and sea level will rise by from 7 to 23 inches[1]. The report acknowledges that these are conservative forecasts. The faster than expected melting of the Greenland ice sheet currently underway, methane being released by thawing tundra and other factors than cannot yet be reliably quantified could produce impacts that go well beyond these forecasts.

Even at the midrange of these estimates, climate change stands out as the most serious long-term threat to Florida's economic, environmental and social sustainability. Many changes consistent with early stages of climate change have already been observed in Florida, including erosion of shorelines, salt water intrusion into freshwater aquifers, increased forest fires, dying coral reefs, and warmer air and sea temperatures[2]. The potential range of impacts that climate change could ultimately have on Florida has been fairly well documented, but there are still uncertainties about their timing and magnitude.

No matter how severely the effects of global warming ultimately manifest themselves, Florida's latitude, low-lying geographic profile and peninsular geography with extensive coastlines insure that it will shoulder a highly disproportionate share of the climate-related costs imposed on the U.S. Understanding this creates an incentive for Florida to be a leader and model in the adoption of technologies that can dramatically reduce greenhouse gas emissions and minimize damages from climate change.

Impacts on Tourism

Tourism is likely to be hit harder by climate change than any other sector of Florida's economy. Over the century ahead, the state's famous beaches will be eroded by sea level rise and many ocean-front hotels and homes will be flooded. In the lowest areas, a thirty inch increase in sea level would translate into a horizontal movement of the

[1] United Nations Intergovernmental Panel on Climate Change, Fourth Assessment Report (AR4), *Summary for Policy Makers,* February 2007.
[2] Natural Resource Defense Council, *Feeling the Heat in Florida,* 2001

oceanfront by as much as 400 feet[3]. Roughly 30 percent of Florida's ocean beaches and two-thirds of its estuarine beaches would disappear[4].

Despite the small regional cooling currently taking place in the southeastern U.S., rising temperatures will make Florida more unpleasant for more of the year. The projected increase in the summer heat index of 8 to 15 degrees F. by the end of the century will be the highest in the nation[5].

Sea level rise and hotter temperatures will degrade all the coastal ecosystems that make Florida such a unique and appealing tourist destination. The lower Everglades could be completely inundated by 2100. Saltwater fishing and sport diving could nearly disappear as ocean warming causes Florida's coral reefs to die off.

Impacts on Urban Areas

With over 15 million of Florida's 16 million residents living and working within 35 miles of the coast[6], sea level rise impacts on urban areas are a key concern. Miami Beach, Pensacola, St. Petersburg, Tampa and other densely populated areas near the ocean will face enormous expenditures for elevating areas, building sea walls and other flood control structures, and encouraging relocation.

As sea level rises, storm surges from hurricanes and northeasters will cause more flooding because they will come in from a higher base of water. A FEMA report to Congress estimates that with a 1-foot rise in sea level, annual damages to existing development in the U.S. Coastal Zone would increase by 36-58 percent, and a 3-foot rise would cause up to a 200 percent increase in annual damages[7]. Climate change impacts are fast becoming a central concern within the insurance industry and areas subject to damages can expect sharply rising rates or even refusal of coverage[8].

Hurricanes

Warming of the ocean will increase tropical hurricane intensity. This could be very significant by later in the century, but over the next several decades the effects of climate change will be small compared to other cyclical weather patterns, which are likely to increase the frequency of hurricanes. Fortunately, global warming itself is not

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[3] S.P. Leatherman, K. Zhang, and B.C. Douglas, "Sea Level Rise Shown to Drive Coastal Erosion." in *EOS Transactions*, American Geophysical Union, 2000, 81: 55–57.

[4] The National Wildlife Federation & The Florida Wildlife Federation, *An Unfavorable Tide: Global Warming, Costal Habitats and Sportfishing in Florida.* Retrieved November 22 , 2006 from: http://www.nwf.org/nwfwebadmin/binaryVault/An_Unfavorable_Tide_Report.pdf

[5] The heat index measures the perceived temperature to the human body based on both air temperature and the amount of moisture in the air.

[6] U.S. Census Bureau, 2000. Retrieved November 30, 2006 from: http://quickfacts.census.gov/qfd/states/12000.html

[7] Environmental Protection Agency, "Costal Zones and Sea Level Rise." Retrieved November 20, 2006 from: http://www.epa.gov/climatechange/effects/coastal/index.html

[8] Joel Garreau, "A Dream Blown Away: Climate Change Already Has a Chilling Effect on Where Americans Can Build Their Homes." *The Washington Post*. December 2, 2006, C01.

expected to increase the number of hurricanes[9]. But over time warming ocean surface temperatures will tend to increase the strength of the hurricanes that do occur.

Impacts on Agriculture and Citrus Growing

The best current estimate is that over the coming century climate change will make it impossible for about half of the American land to sustain the types of plants now on that land[10]. In Florida, agriculture could actually benefit for several decades from increased carbon dioxide in the atmosphere and a modest amount of warming. Warming could also protect citrus crops from freezing. But if the average temperature increases beyond 3 to 4 degrees F., farmers and growers will face declining yields from that point on[11].

Beyond these general forecasts, climate change is likely to have many unanticipated impacts on particular crops in particular areas of the state. For example, an analysis of Florida agriculture impacts done in 2001 did not anticipate problems that some parts of Florida agriculture have already begun to experience. The relative cold in Florida in the early winter months is crucial for mangoes and litchis to produce flowers that grow into fruit later in the year. The warm weather thus far in 2007 is threatening those crops. And the balmy conditions have also brought tiny virus-transmitting pests that bedevil tomato and bean growers.[12] The key uncertainty is rainfall. Some climate models forecast reductions in precipitation which would limit crop growth by decreasing soil moisture and water availability, but other models predict increases in precipitation. Whether rainfall decreases or increases, it is expected to come increasingly in the form of more intense downpours followed by longer periods of drought[13].

Impacts on Water Resources

Heavy rains and extended periods of drought make it more difficult for water managers to provide reliable water supplies, control flooding, and protect natural areas. Shallow coastal aquifers will be increasingly at risk from salt water intrusion. For example, the Biscayne aquifer, a primary water source for all of South Florida, is recharged by the freshwater Everglades. As rising water levels submerge low-lying areas of the Everglades, growing areas of that aquifer will be infiltrated[14].

Impacts on Commercial Forests

Dominant tree species will change over time as the climate warms. Higher temperatures and more prolonged periods of drought will make forests more vulnerable to damage from wildfires. Indeed, there is statistical evidence of the beginnings of such an increase

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[9] R.A. Pielke, *et al*., "Hurricanes and Global Warming.".*Bulletin of the American Meteorological Society*, 2005.

[10] James Gustave Speth, "Creating a Sustainable Future: Are We Running out of Time?" in Robert Olson and David Rejeski, eds., *Environmentalism and the Technologies of Tomorrow: Shaping the Next Industrial Revolution*. Washington, DC: Island Press, 2005, pp.12-13.

[11] Natural Resource Defense Council, *Feeling the Heat in Florida*, 2001.

[12] Tere Figueras Negrete, "Warm weather gives Florida farmers chills." *The Miami Herald.* March 1, 2007, p. 12.

[13] Natural Resource Defense Council, *Feeling the Heat in Florida*, 2001.

[14] Environmental Protection Agency, "Coastal Zones and Sea Level Rise." Retrieved November 20, 2006 from: http://www.epa.gov/climatechange/effects/coastal/index.html

over the past few decades[15]. Warming may also increase the threat of invasive species and pests. In the long run, unchecked climate change would turn Florida into a treeless savanna.

Impacts on Commercial Fishing

Florida's coral reefs are the underpinning for the state's commercial fisheries. These reefs are already in decline as a result of disease and coral bleaching, a process directly tied to rising ocean temperatures[16]. Recently both Elkhorn and Staghorn Caribbean coral were added to the list of threatened species under the Endangered Species Act. Both species have declined by 97 percent since the late 1970s[17].

A recent survey commissioned by the Florida Wildlife and National Wildlife federations forecasts that if global warming continues, sea level rise and warming temperatures would dramatically alter the extent and composition of important coastal habitats and that fishing, as we know it, could disappear in a matter of decades. Among the species most at risk are Bonefish, Flounder, Gag grouper, Gray snapper, Permit, Pompano, Redfish, Snook, and Tarpon. Essential habitat would also be reduced for prey species such as shrimp, crabs and smaller fish[18].

Impacts on Health

The projected 8° to 15° F. increase in Florida's heat index over the next century will pose a growing health threat, especially to the elderly population most vulnerable to heat stroke and other heat-
related ailments. Warmer temperatures also contribute to higher ground level concentrations of harmful ozone and to smog formation[19]. As warming alters global disease patterns, both humans and wildlife in Florida will be exposed to more tropical strains.

Impacts on Natural Systems

Natural ecosystems are likely to fare worse than agriculture, commercial forestry and other intensively managed systems. Sea wall projects and other flood control structures to protect highly populated areas may actually increase damages to ecosystems in unprotected areas. Low lying areas and shallow water areas will be particularly affected by sea level rise. A 15 inch rise in sea level would inundate 50 percent of Florida's salt marshes and 84 percent of its tidal flats[20]. Current plans to restore the Everglades rest

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[15] Natural Resource Defense Council., *Feeling the Heat in Florida*. 2001.
[16] Rick Lyman, "Rising Ocean Temperatures Threaten Florida's Coral Reef." *The New York Times*. May 22, 2006
[17] Ibid.
[18] The National Wildlife Federation & The Florida Wildlife Federation, An *Unfavorable Tide: Global Warming, Coastal Habitats and Sportfishing in Florida.* 2006 Retrieved November 22, 2006 from: http://www.nwf.org/nwfwebadmin/binaryVault/An_Unfavorable_Tide_Report.pdf
[19] Natural Resource Defense Council, *Heat Advisory*, 2004.
[20] The National Wildlife Federation & The Florida Wildlife Federation., *An Unfavorable Tide*, 2006.

on the assumption that sea level will rise by no more than one foot by 2100, which may well be overly optimistic[21].

Emerging Technologies to Reduce Greenhouse Gas Emissions

ENERGY

Solar Photovoltaics

Of all the renewable energy technologies, Florida has by far the most potential for harnessing direct solar energy. Direct solar technologies, photovoltaic cells in particular, have begun to improve at a rate so accelerated that developers are calling it a "second silicon revolution," following the first silicon revolution of ever more powerful integrated circuit chips. In fact, a growing number of the Silicon Valley venture capitalists and entrepreneurs who led that first revolution are now investing in solar start-ups. In October 2006 Silicon Valley-based SunPower announced the development of a silicon cell with a record 22% efficiency in converting sunlight to electricity (solar cells in use today are generally about 12% efficient). Two months later, Boeing-Spectrolab achieved a world record conversion efficiency of 40.7% with a solar cell that uses an optical concentrator to increase the sunlight intensity falling on the cell. Other companies like Nanosys and Nanosolar in Palo Alto are developing a new kind of photovoltaic technology that incorporates nanotechnology and results in thin rolls of highly efficient light-collecting plastic that can be spread across rooftops, built into building materials, or even sprayed on to other materials or woven into clothing. A recent economic analysis of declining costs of electricity from solar cells estimates that solar-generated electricity will become cost competitive with grid electricity in Miami by 2016.

Biofuels

When biomass is used to create ethanol or other liquid fuels, the carbon dioxide released when the fuel is burned is roughly balanced by the carbon dioxide captured through photosynthesis as more fuel crops are grown. Biofuels, therefore, can be relatively "carbon neutral," as long as they can be produced efficiently without using too much fossil fuel. Secretary of Energy Samuel Bodman recently announced the goal of making ethanol a practical and cost-competitive alternative by 2012 (at $1.07/gal) and displacing 30% (60 billion gallons) of current gasoline consumption by 2030. If fuel efficiency can doubled or tripled over time (see the Hypercar description below), then most of the U.S. light vehicle fleet would be able to run on biofuels. Almost all the ethanol produced today is derived from corn grain, and it will remain the dominant feedstock for the next few years. But rapid progress is occurring in the production of "cellulosic" methanol derived from fibrous, generally inedible plant matter such as post-

[21] "Sea Change Coming for Everglades." *USA Today*. Interview with Everglades National Park chief Dan Kimball. May 31, 2006.

harvest corn stalks and other agricultural residues, switchgrass and poplar. A recent study at Oak Ridge National Laboratory concludes that Florida has a significant potential for producing various types of biomass. It estimates that at a price of $20/ dry ton Florida could produce 2,761,950 dry tons of biomass, and at a price of $50/ dry ton it could produce 9,533,398 tons.

Advanced Coal Technologies with Carbon Sequestration

Coal burning in Florida, primarily for generating electricity, releases over 68 million metric tons of carbon dioxide emissions per year into the atmosphere. Only ten other states have larger emissions from coal. Florida can continue to use this abundant energy source – if its environmental impacts can be sufficiently reduced. In the 1980s, amid concerns about acid rain and particulate emissions, a federal effort was undertaken to develop Clean Coal technologies. In recent years, concerns about carbon dioxide emissions and global warming have prompted a renewed effort. Integrated Gasification Combined Cycle (IGCC) and other advanced combustion technologies, combined with carbon capture and sequestration, could make coal a sustainable energy technology. Some industry analysts believe it may be possible to burn coal with zero emissions at competitive prices by 2020. If these more advanced coal technologies are not pursued, however, growing use of coal will become the main driver of climate change.

Fuel Cells – Hydrogen

Hydrogen fuel cells are just now starting to enter specific market niches. Microcells for powering portable electronic devices will enter the U.S. marketplace this year. Larger stationary fuel cells will soon be able to compete on cost to provide backup power for industrial, commercial and even residential applications. Large investments are being made by both business and government to improve performance and reduce costs enough to make fuel cells practical for running electric cars. If this proves possible, fuel cells will revolutionize the auto industry and its vast network of suppliers. The only emission from running fuel cells on hydrogen is water vapor, so shifting from oil to hydrogen could dramatically reduce carbon dioxide emissions from transportation as well as all other kinds of auto-related urban air pollution. But how clean hydrogen really is depends on how it is produced. Energy is required to produce hydrogen, and if that energy comes from fossil fuels there will still be carbon dioxide emissions. For many people involved in hydrogen development, the Holy Grail is a Solar Hydrogen Economy based on extracting hydrogen from water using solar energy.

Ocean Current Power and OTEC

Two forms of ocean current-based electricity generation may prove important for Florida's future. The first is the power achieved by capturing the energy contained in the moving water of tides. The kinetic energy of currents between ebbing and surging tides can be captured by turbines that work in the same way land-based windmills extract energy from wind.

This form of tidal current power is already being used in Scotland and other parts of the United Kingdom, and many coastal sites worldwide are being examined for their suitability. The other form of ocean current power is more speculative but would have a huge potential if it proves cost-effective. It involves placing large turbines offshore to harness energy from the Gulf Stream. This mighty ocean current flows at 1,000 times the rate of the Mississippi River and transports water at a rate of 30 million cubic meters per second through the Florida Straits. Harnessing only a tiny fraction of this kinetic energy could meet Florida's energy needs. Because the Gulf Stream is a warm current, it may also offer opportunities for Ocean Thermal Energy Conversion (OTEC) where electricity is generated using the temperature differences of seawater at different depths. The Gulf Stream transports about 1.4 petawatts of heat, equivalent to the output of a million power plants. Researchers at Florida Atlantic University have recently received a $5 million dollar grant to examine these possibilities.

TRANSPORTATION

The Hypercar

Florida has the third highest carbon dioxide emissions from transportation of all the states, exceeded only by California and Texas. Technology that can cut these emissions sharply through major improvements in fuel economy is evolving rapidly. Fuel-electric hybrids and advanced diesels can already allow mid-sized cars to achieve around 50 mpg in normal driving. Growing use of biofuels in the fuel mix will further reduce CO2 emissions. The next major jump of progress is likely to be "lightweighting" by making car bodies out of advanced alloys or carbon composites and substituting electronic components for bulky mechanical systems. Carbon composites five times stronger than steel by weight could make cars safer while cutting their weight in half. Eventually, it may prove feasible to power vehicles with zero-emission hydrogen fuel cells, which are twice as efficient as the best internal combustion engines. All of these possibilities have been brought together in the Hypercar concept originated at the Rocky Mountain Institute to demonstrate how the transportation aspect of the climate change challenge can be solved. Rigorous technical modeling suggests that the combination of hybrid-electric drive, ultralight construction, low-drag design, and efficient accessories can achieve a 3 to 5-fold improvement in fuel economy with equal or better performance, safety, amenity and affordability, compared to today's vehicles.

Smart Public Transit

Public transit is far more energy-efficient than travel in single-passenger automobiles, so greater transit use can reduce CO_2 emissions. Transit will play a larger role over time as higher energy prices and public policy converge to promote more clustered Smart Growth development patterns.

Light rail technology and the reintroduction of trams (trolleys) in urban cores are likely to expand. Demand-Responsive Transport systems that offer on-demand call-up door-to-door service from any origin to any destination in a service area will become more common and sophisticated as Intelligent Transportation Systems technologies come into widespread use. Emerging technologies are likely to blur the very concept of public transit. Cars coordinated by GPS and traffic monitoring sensor systems, for example, could function as 'personalized public transit' well before the actual functions of driving are automated. As virtual connectivity becomes ever more sophisticated, telecommuting will likely reach a tipping point, reducing the need for many types of physical travel. Flexible telecommuting combined with improved transit, more walkable neighborhoods, and higher energy prices could begin to reduce vehicle miles traveled.

HOUSING

Green Development

Buildings consume nearly a third of Florida's energy, much of it wasted by inefficient design. Real-estate development therefore offers major opportunities for using energy more efficiently and reducing greenhouse gas emissions. Well designed green buildings typically use from one-half to one-quarter of the energy used in conventional construction. Done well, green development involves analyzing interconnected issues like building site and design, resource efficient construction, energy and water efficiency, lighting and mechanical design, and the potential toxicity of building materials. Then it strives to optimize all these aspects in so far as possible in an integrated design. While this approach requires more knowledge than conventional development, it is not proving to be more costly. Features that have higher individual costs, like better windows, can actually reduce the whole building cost because other elements such as the heating and air conditioning system can be downsized. The U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) rating system is a tool to evaluate building performance from this kind of "whole-system" perspective. It provides the definitive standard of what constitutes a green building. The Council states that a LEED Silver-rated building should not cost more than a conventional building, while outperforming conventional construction by all of its measures. Over the past year or two, green development has passed a threshold where many developers are realizing that this approach is good business as well as good for the environment.

ECONOMIC DEVELOPMENT – INDUSTRY & AGRICULTURE

Green Manufacturing

Developments in pollution prevention, green chemistry, computer monitoring and control, recycling and other areas are coming together into a new image of the potential for 21st century manufacturing. Leading companies pioneering superefficient "green manufacturing" are already demonstrating fundamental changes in production design and technology that extract two, five or even ten times the work out of each unit of energy and materials used, minimizing the release of carbon dioxide and other pollutants. They are striving to avoid hazardous substances like toxic heavy metals and chlorinated hydrocarbons. Over the decades ahead, advanced green manufacturing will move toward closed-loop production systems, modeled on nature's designs that return every output harmlessly to the ecosystem or create valuable inputs for other manufacturing processes. Waste and pollution will come to be viewed as a design failure, not an inevitable product of industrial production.

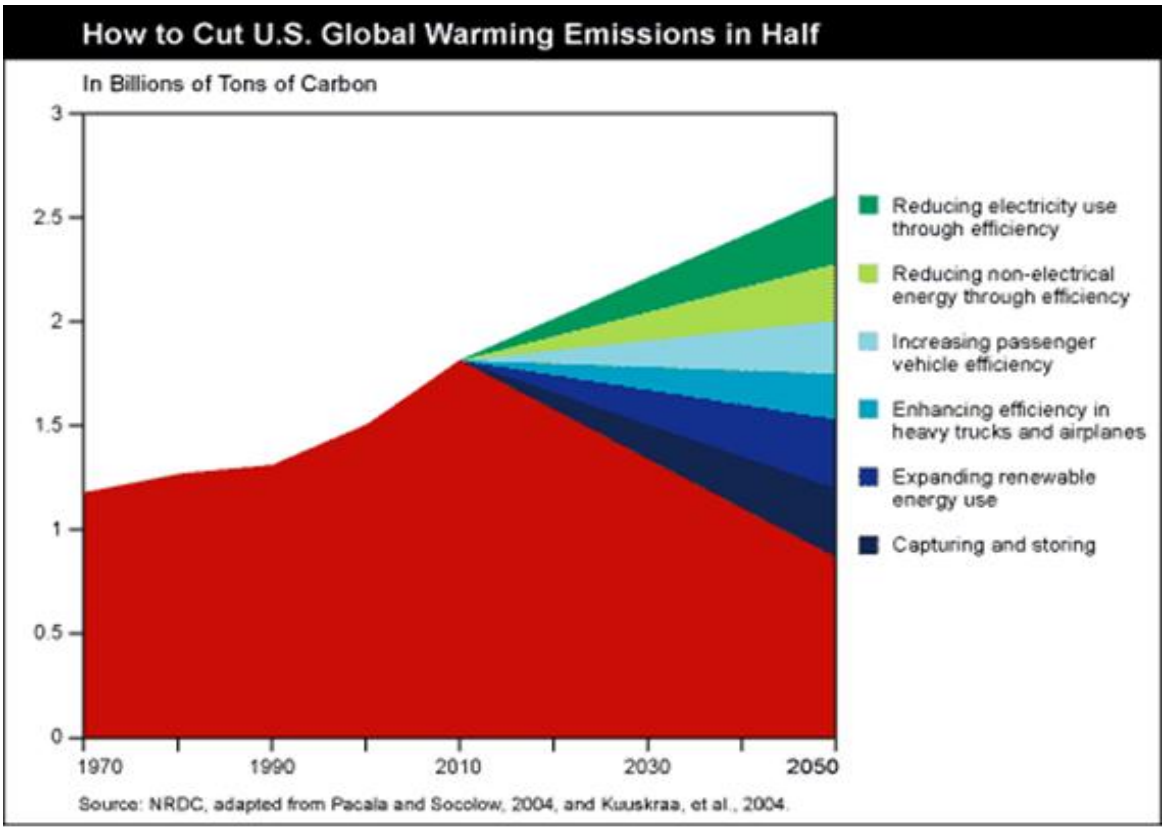
Precision Agriculture

Precision agriculture is the application of information technology to farming processes. It allows water, fertilizers, pest control agents and other inputs to be precisely applied, where needed and as needed, minimizing waste. For example, satellite information can be analyzed by computer programs designed to detect evidence of pest damage and the information relayed to farmers for corrective action. Drip irrigation systems linked to soil moisture sensors can provide water when and where needed, reducing water use while optimizing soil moisture.

Stabilization Wedges of CO2 Reduction

Princeton professors Robert Socolow and Stephen Pacala have developed an easy-to-understand approach to thinking about technology and behavior changes to reduce carbon emissions. Global stabilization of atmospheric carbon dioxide requires cutting carbon emissions from about 14 to 7 billion tons per year by 2055. Socolow and Pacala divide up this job into "wedges" of change that can each reduce emissions by 1 billion tons per year. It would therefore take 7 wedges to stabilize the climate. Socolow and Pacala give a score of examples of technologies that are already proven or are nearing commercial readiness which could provide a wedge if deployed on a large scale. They demonstrate that no one strategy is sufficient to do all the work, but there is a more than adequate portfolio of options available to meet the climate challenge. Applying this concept to the U.S., the image below provides one example of how CO_2 emissions could be cut in half by 2050 despite continuing economic growth.

Other strategies could be employed to create wedges, such as using even more coal (with carbon sequestration) or doubling the use of nuclear power. To choose wisely among the different ways to meet the climate challenge, what is needed are objective, comprehensive analyses to identify the “best buy” options that should be pursued first because they provide the most energy services and the fastest carbon reduction per dollar spent. As the image below suggests, it is important to fairly assess the contributions that can be made by using energy more efficiently. Technical progress to increase the efficiency of energy-using technologies so that they do more work and produce more GNP for every unit of energy used can make a far larger contribution than most people usually assume. Increasing energy efficiency has a similar economic impact to using more energy, but efficiency is often a better bargain in terms of cost, job creation and environmental impact.



Building these wedges over the next 50 years is an ambitious but clearly feasible challenge. All of the driving and flying in 2057 will be in vehicles that have not yet even been designed. Most of the buildings people will use in 2057 have not yet been built. The location of most of the communities that will be built between now and 2057 has not yet been decided upon. Utility owners are only now beginning to plan for the power plants that will serve those communities. Dramatic technological progress is clearly possible by 2057 – if it is set in motion by our generation.

The costs involved in this change-over are smaller than the costs of not doing it. The best global analysis to date of the costs of meeting the climate challenge is *The Stern Report*, produced by a team of UK researchers led by Sir Nicholas Stern, head of the Government Economic Service and former Chief Economist and Senior Vice President of the World Bank. The report warns that climate change threatens to be the greatest market failure in history, disrupting and shrinking the global economy 20 percent by the end of the century. Taking adequate action now to head off these disruptive impacts would cost just 1% of global gross domestic product. Shifting the world onto a low-carbon path would eventually benefit the economy by $2.5 trillion a year. By 2050, markets for low-carbon technologies could be worth well over $500 billion. The report concludes that responding to climate change will not hurt the economy – it will save it. Low-carbon technology will be the greatest economic development opportunity of the 21st century and a focus of global competitiveness.

Technology and Broader Aspects of Sustainability

The advances in *foundational technologies* that underlie the current revolution in technology and are making it possible to meet the climate challenge can help Florida meet other sustainability-related goals. The examples below are suggestive of the possibilities ahead. But needless to say, progress in virtually every area requires more than a simple "technological fix." New technologies can help, and may even be critical, but progress also requires changes in mindset, policies, priorities, and investments.

Health Care

Spending for health care in the US was 16.5% of the GNP in 2006 and is forecast to rise to 20% by 2015. Yet 45 million Americans are not insured and the results of the US health care system rank us at the bottom of developed nations. Clearly health care in the U.S. is the epitome of an unsustainable system. To create a sustainable health care system, we will need to give much more attention to the *major determinants of health*. "Health care" accounts for only a small fraction of what affects differences in health (about 10%), yet it is where we spend our money, usually after we are sick. But many diseases, such as type 2 diabetes, and a significant percentage of cancer and heart disease can be prevented from occurring in the first place. The major and sustainable changes for health care require behavior changes. For many people, particularly low income individuals and families, their options for healthy behaviors are limited by social and economic determinants. A sustainable approach to health will require focusing on those factors. Within this context of focusing more on affecting the determinants of health, emerging technologies in health care can make an increasing difference.

Non-invasive, low cost, easy to use biomonitoring will give us early warning of many diseases and support better treatment. Vaccines for many diseases are possible. Proof of effectiveness from many complementary and alternative approaches, like acupuncture, chiropractic, herbal remedies and their subsequent increased use can make a significant cost difference. Better deployment of health care providers, including greater use of nurse practitioners, physician assistants as well as use of virtual health care providers and health coaching with enhanced self care can reduce costs. Personalization of health care, based on our genes and current conditions, and our approach to learning can increase effectiveness (ultimately technology will make reading our genome inexpensive, though in the next decade it will remain costly). And information systems and data bases from biomonitoring of individuals along with their genetic data will develop. With appropriate privacy and security protections, learning from these databases will yield breakthroughs that will lead to better forecasting of disease and better treatment. As with energy, the "next technology revolution" offers potential solutions, but public policy, corporate strategy and consumer behavior are required to achieve sustainable results.

Low Cost Housing

Low cost housing will be revolutionized by advanced design and fabrication methods and innovative materials that allow high energy efficiency to be achieved at low costs. One technology that illustrates the possibilities ahead is Contour Crafting (CC). Developed at the University of Southern California, CC is a rapid production technology which uses robotic mechanisms to assemble building substructures much as robotics is used in car assembly today. As a result, total building times can be accelerated by an order of magnitude. The technology is already being considered as an option for emergency reconstruction and disaster relief. A wide range of inexpensive, energy-efficient construction materials are being developed for prefabricated housing, including Expanded PolyStyrene (EPS) wall and roof panels with cementitious coatings, ferrocements, calcium silicate products, wood-based composites, and a variety of recycled products.

Serious Games

The role and scope of computer games is rapidly expanding, driven in large part by the increasing capacities of the internet. A recent study at the University of Southern California found that 43% of participants in online role-playing feel as strongly about their virtual communities as they do about their physical ones. Within this context, serious games are increasingly being developed as learning tools and as a way to explore and prepare for real challenges and situations. The Woodrow Wilson Center for International Scholars in Washington, D.C. has created a Serious Games Initiative to help forge productive links between the electronic game industry and projects involving the use of games in education, training, health, the environment and public policy. In the future, these technologies will provide new educational strategies to use in Florida's schools and engaging tools for Florida policymakers and public servants to more fully explore the circumstances that they face.

Water Efficiency
The availability of sufficient water for agriculture, power generation and public use will be critical to the future of Florida. In the wake of increasing climate uncertainty and expanding populations, water efficiency technologies will be one key to maintaining water supplies at necessary levels. These technologies can be expected to shape both processes, as in precision agricultural practices detailed above, and products, including more advanced water-efficient appliances and toilets. For example, advances in technologies based on reusing grey-water could vastly improve water efficiency at the residential level. Additionally, nanotechnology offers the promise of more effective membranes for water filtration and potentially even for desalination.

Advanced Agriculture Based on Green Biotechnology
Green biotechnology is the application of biotechnology and ecological engineering to agricultural processes. It includes both the rapid and precise transfer of genetic traits into agriculturally useful organisms and more holistic approaches based on an understanding of natural nutrient cycles and ecological relationships. Relations between environmentalists and companies involved in biotechnology have at times been adversarial, and biotechnology is not without environmental risks. But used wisely, with greater understanding of plant physiology and the interactions between plants, microbes and soil, green biotechnology has the potential to dramatically reduce the environmental impacts of agriculture. It promises to make crop and forestry species more resistant to stresses such as heat, drought, freezing, poor soil, salinity, pests and disease. Further in the future, biotechnologists may be able to transfer nitrogen fixation from legumes to grains like wheat and corn, reducing the need for synthetic fertilizers, and increase the photosynthetic efficiency of crops, boosting the production of food per area of land.

Earth Systems Engineering and Management
Earth Systems Engineering and Management (ESEM) is an innovative, if extremely controversial, approach to environmental thinking based on analyzing, designing, engineering and managing complex environmental systems. The concept is essentially analogous to earth-bound terraforming and involves the conscious application of technology for the purpose of influencing the Earth's environmental properties. Within this conceptual framework, civilization may actively mitigate negative environmental impacts by actively intervening in environmental processes. Proponents of the approach point to the engineering of Florida's restoration of the Everglades as an early example of the idea's feasibility.

Conclusion

This report from the Institute for Alternative Futures to The Century Commission for a Sustainable Florida has considered climate change impacts on Florida as well as the technology horizon. There is a set of emerging advanced technologies – what we call the Next Technology Revolution – that will be important for moving toward a sustainable future in Florida over the next 50 years. The ones we have identified *hold the promise of being good for business and the economy, good for the environment, and good for the quality of life in Florida, all at the same time.* They can provide a basis for Florida's competitiveness as well as its social well-being.

We urge the Commission to consider these technology and development options as it formulates its recommendations for energy strategy and other issues areas such as transportation, housing, education and health care. Technological progress is indispensible for achieving a sustainable future, but it is not sufficient in itself. A sustainable future requires a commitment to sustainability in the fullest sense, including a commitment to building a fair and equitable society, along with the relevant public policy, business and consumer responses. As one of the highest state producers of greenhouse gases, Florida will need to become a leader, along with other states and nations, if the state is to avoid near-catastrophic impacts over the century ahead. The Commission is charged with providing foresight for the State. No other parts of State government are charged with taking the long 25 to 50 year view, and with considering the implications and options in that context. The "next technology revolution" provides important options as the Commission takes its long view.

Appendix: Technology Forecast Information Sources

In the initial environmental scan that served as the basis for choosing the technologies reviewed in this report we consulted the publications of the organizations and individuals below to identify which emerging technologies they thought would be most significant for shaping a sustainable future over the next 25 to 50 years:

- Battelle
- British Telecom
- Foresight Institute
- Future Survey/World Future Society
- GW (George Washington University) Forecasts
- Hudson Institute
- MIT's Media Lab
- MIT's Technology Review
- National Academy of Engineering
- National Renewable Energy Laboratory
- RAND Corporation
- Rocky Mountain Institute
- SRI International
- Woodrow Wilson International Center for Scholars
- World Business Council for Sustainable Development
- World Resources Institute.
- Forecasts of individual visionaries: Arthur C. Clarke, Paul Hawken, and Ray Kurzweil.