A SUSTAINABLE FUTURE






The Role of Basic Computing Research

As the world's population grows, so do the demands of society upon environments, natural resources, and aging energy and transportation infrastructures. Researchers in many different fields of science and engineering are developing new approaches for facilitating a sustainable ecosystem, one in which future generations can enjoy the high qualities of life prevalent today. With information technology so ubiqutous, computing research is critical for putting the world on such a path toward sustainability. | **Summer 2011**

What is the Role of Computing in Sustainability?

Computing research has led to transformative developments and discoveries that are focused on meeting the demands of the environment, economy and society for present and future generations.

What are the Goals for Sustainability?

- Decrease overall energy consumption
- Increase use of renewable energy sources
- Improve transportation to minimize energy usage and environmental impact
- Protect the environment through preservation of existing ecoystems
- Eliminate waste by designing products for full reuse
- Move toward zero loss of non-renewable resources

What are the Computational Tools for Achieving These Goals?

Optimization

Many complex systems require optimizing variables to achieve the most sustainable outcomes, such as optimal vehicle routing to minimize congestion or optimal placement of wind farms to maximize energy generation and minimize environmental impact.

Human-Centered Computing

Humans are constantly interacting with complex energy, transportation, and environment systems. Information technologies must facilitate improved human-computer interactions, enabling better response to human needs and greater incentivization of changes in human behavior.

Intelligent Systems

Data analytics approaches can infer patterns from large data sets to improve our decision making. They can also contribute to intelligent control systems that optimize system behavior in real time.

Large Scale Intelligent Data Management

Data about our natural environments as well as physical and cyber infrastructures are constantly being generated. They are often heterogenous, noisy, and incomplete. We need ways to assimilate these data – often from many different locations around the world – and assess our confidence in them for future analyses.

Modeling and Simulation

Programs can represent, simulate, and predict human and environmental behaviors and outcomes.

ENGINEERING A SMART ENERGY GRID

Advanced information technologies are connecting together millions of computers, controls, power lines, renewable energy sources and devices to enable greater efficiency and reliability of the energy system, all the while reducing the overall environmental impact. This new "smart grid" infrastructure, which requires enhanced communication, new intelligent systems, sensor networks, improved visualizations and advanced optimization approaches, is much more able to adapt in real time, providing personalized services to end users and yielding reduced costs.

Innovation for Energy

Scientists today are using advanced sensors, digital data streams and analytics approaches to:

- Continually improve energy efficiency and reliability
- Determine the resource usage of individual appliances
- Eliminate the need for users to manually set configurations
- Reduce negative environmental impact
- Detect and restore failures in energy sensors or networks
- Automate energy distribution and energy consumption
- Integrate large-scale renewable energy sources
- Increase awareness about electricity use and the environment

Managing Energy Consumption

Utility companies are implementing smart meters or advanced sensor systems in buildings and homes to manage energy usage. These systems can complement human interaction, learn human behavior and continuously monitor regular usage to provide an optimal level of price, comfort, and convenience for occupants.

Preventing Outages

Intelligent systems and sensor networks monitor and identify corrupt or at-risk areas of the energy distribution system. If a failing component is identified, the system will isolate or reconfigure itself through intelligent self-healing control technology to prevent power failure and maintain energy distribution while that component is fixed.

Did You Know?

- It is estimated that smart grid enhancements will ease congestion and increase utilization (of full capacity), sending 50 to 300 percent more electricity through existing power lines. [1]
- Renewable energy consumption increased by about 8 percent between 2008 and 2009, contributing about 8 percent of total energy demand and 10 percent of total electricity generation in the U.S. in 2009. [2]
- Renewable-generated electricity will account for 17 percent of total U.S. electricity generation in 2035, up from 9 percent in 2008. [3]
- Wind-generated electricity increased by 61 percent between 2007 and 2008 and by 28 percent between 2008 and 2009, more than any other renewable source of generation in both years. [4]

CLEARING THE WAY FOR ENERGY EFFICIENT AND SAFE TRAVEL

Advanced information technologies – such as highway and roadside sensors, communication tools, and data analytics approaches – are making the U.S. transportation system safer, more reliable and less congested, leading to an "intelligent transportation system." For example, computing researchers are examining traffic flows to improve urban design. They are also developing new tools that provide personalized travel information and real-time driver assistance, improve hybrid vehicle efficiency, and enable more effective scheduling of mass transit systems.

Did You Know?

- Transportation uses approximately 22 percent of all U.S. energy and is responsible for roughly the same proportion of CO_2 emissions. [5]
- Hybrid electric vehicles can reduce air emissions of smog-forming pollutants by up to 90 percent and cut carbon dioxide emissions in half. [6]
- "Smart" transportation technology can reduce congestion and accident rates by 10-15 percent. [7]

Innovation for Transportation

Computing researchers use real-time sensors, predictive modeling and intelligent control systems to:

- Advance new construction and infrastructure for urban design
- Track the position and speed of all vehicles to avoid congestion
- Provide price, time and personalized travel options directly to travelers' smart phones
- Increase safety through automatic detection of oncoming vehicles
- Monitor road, bridge and highway conditions
- Develop electric hybrid vehicles as well as new transportation fuels
- Help traffic controllers and emergency response teams detect and respond to accidents
- Reduce air traffic congestion and accidents with advanced GPS technology

Open Communications

Computing researchers are developing automobiles and transportation infrastructures that can talk with one another. For example, sensors embedded in roads, bridges and traffic lights can communicate with a car and/or driver, providing information on weather and road conditions, collision avoidance and traffic jams to increase safety and reduce fatalities.

Fuel Efficiency

The development of gas-electric hybrids, plug-in hybrids and all-electric vehicles is dependent on advanced computing technologies. For example, computer scientists and engineers use computer-aided design and dynamic digital testing, along with IT-enabled passive safety restraints (e.g., air bags) and electronic stability control systems, to develop lighter and more fuel-efficient vehicles.

REDUCING ENVIRONMENTAL IMPACT THROUGH INFORMATION TECHNOLOGY

Concerns regarding environmental protection – e.g., habitat preservation, water supply and treatment, etc. – are motivating computing researchers to develop new technologies that are capable of monitoring natural and built systems as well as providing advance warnings when conditions warrant. For example, such systems can detect pollutants in the air or water that are likely to harm an ecosystem in the short or long terms.

Innovation for the Environment

Computing researchers, together with environmental scientists, are using sensors, data mining techniques, and predictive modeling to:

- Study weather trends to improve early warning
- Detect negative patterns within specific ecosystems
- Achieve improvements in water treatment and overall supply
- Measure the impact of negative fuel emissions
- Monitor characteristics of energy use and distribution
- Establish renewable energy sources in prime locations

Connecting to the Sea Floor

Computing researchers and environmental scientists are collaborating to study our climate by extending the Internet to ocean floors. Communications and monitoring systems will allow thousands of chemical, physical and biological sensors to stream enormous volumes of data back to scientists who can use this information to better understand the impact of climate variation on ocean, land and planet-wide ecosystems.

Wind Farm Optimization

Computing researchers are working to optimize the placement of new wind farms for sustainable and renewable energy. Key considerations are to maximize the energy harvested, all the while minimizing adverse impacts of wind farms upon existing habitats and ecosystems.

Did You Know?

- Smarter and reduced electricity use, and the subsequent reduction in electricity generation at power plants, could cut total carbon emissions from U.S. utilities by as much as 12 percent by the year 2030. [8]
- If clean water technologies and a new infrastructure are not developed by 2050, more than 1 billion urbanites could be living on less than 26 gallons of water a day per person. The average U.S. resident uses 2-5 times that much. [9]

Facilitating Growth through Agency Investment

Achieving a sustainable future requires a long-term Federal investment in interdisciplinary research spanning computer science, social science, electrical engineering, transportation systems engineering, and environmental science, among other disciplines.

National Science Foundation (NSF)

- The NSF recently established the Science, Engineering, and Education for Sustainability (SEES) initiative, seeking to address challenges in climate and energy through support of fundamental research projects. By including all of the NSF directorates, SEES can foster an interdisciplinary, systems-based approach to understanding, predicting and reacting to change in the natural, social and built environments. However, it is imperative that NSF solicitations make it possible for computing researchers to be integrally involved in these interdisciplinary teams – not just as partners but rather as equal partners.

Federal Investment Must Support:

- Fundamental research, to include computer science, that advances sustainability
- Highly collaborative, multi-disciplinary groups of researchers
- Data, code and model sharing through incentive-based funding opportunities
- Communication and community-building through workshops and conferences
- Strong programs for education and outreach on sustainability, to support building a next-generation workforce

Department of Energy

- The DoE should continue to commit funds for the research and development of a smart grid that is capable of reducing energy consumption and improving the utilization of renewable energy sources. Next-generation power systems must enable sensing and mining of large quantities of data to make energy generation, transmission and delivery much more efficient. And they must convey the right information to the right stakeholders at the right time – using enhanced graphics and visualization techniques – to facilitate informed decisions and incentivize behavior change. This effort should be forged by teams of computer scientists and electrical engineers.

National Institute of Standards and Technology

- NIST must continue to define smart building integration technology standards in consultation with computer scientists who are developing improved energy distribution and consumption technologies.

Department of Transportation

- The DoT should create numerous surface-transportation research centers at universities across the country to study the U.S. transportation infrastructure. These centers should be based on a competitive solicitation and each should be funded for at least five years.

The Need for Computing Research

Computing research has led to breakthrough technologies that have solved some of the world's biggest challenges. Most of the revolutionary technological advances of the last 50 years were pioneered at U.S. universities through Federal research grants. We have a unique opportunity to address grand societal challenges through additional Federal support in key areas of basic networking and information technology research.

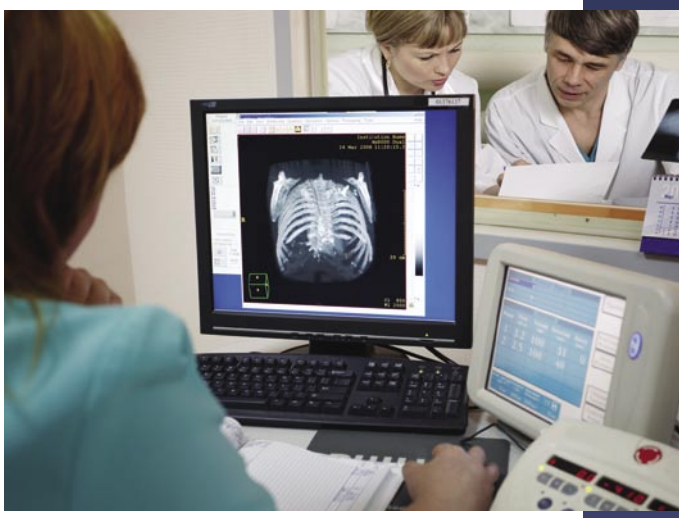
Economic Development – Every billion-dollar sub-sector of the IT industry bears the stamp of Federal support for basic research. U.S. preeminence in science and technology has long been the engine of job creation and the source of global economic leadership.

Scientific Advancement – Innovations in networking and information technologies have led researchers to develop new tools that expand the breadth of many scientific disciplines – ranging from the mapping of the human brain to studying issues of climate change to analyzing massive amounts of astronomical data to better understand our universe.

Improve Daily Life – Computing research is improving areas as diverse as healthcare, transportation, energy and education. The development and distribution of these technologies will allow people to live safer lives, conserve natural resources, receive personalized education and beyond.

Technologies Developed from Government-Funded Computing Research

- The Internet
- Google
- Global Positioning Systems (GPS)
- Smart Phones
- Home Security Systems
- Doppler Weather Radar
- Health Monitoring Devices



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FOR MORE INFORMATION

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