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Computing Research for Sustainability

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Content

I. Roles and Opportunities for information technology in meeting sustainability challenges

II. Elements of a computer science research. Agenda for sustainability

III. Programmatic and Institutional Opportunities to enhance computer science research for sustainability

SUMMARY

Applications of IT

Built infrastructure and systems

Ecosystems and the environment

Sociotechnical systems

Examples:

- smarter and more sustainable ways of providing electricity
- agriculture productivity
- development of sustainable and resilient infrastructures

The Value Of The Computer Science Approach To Problem Solving

Systems: challenges of architecture, scale, heterogeneity, interconnection, optimization and human interaction with systems

Iteration: fast-moving iterative, incrementally evolving approaches to problem solving in computer science, which were critical to building the Internet and web search engines, will be useful in solving sustainability challenges.

CS Research areas: although current technologies can and should be put to immediate use, CS research and IT innovation will be critical to meeting sustainability challenges. Effectively realizing the potential of CS to address sustainability challenges will require sustained and appropriately structured and tailored investments in CS research.

Efforts:

- Measurement and instrumentation;
- Information-intensive systems;
- Modeling, simulation, and optimization; and
- Human-centered systems.

Strategy and pragmatic approaches

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- Emphasize Bottom-Up Approaches and Concreteness
- Use Appropriate Evaluation Criteria for Proposals and Results
- Apply CS Philosophy and Approach
- Foster Sustainability Research Through Funding Initiatives
- Foster Needed Multidisciplinary Approaches
- Blend Sustainability and Education

Roles and Opportunities For Information Technology In meeting Sustainability Challenges

Preword

Computing underlies and enables systems that affect our lives every day—from financial and health systems to manufacturing, transportation, and energy infrastructures.

One ***important consequence*** is that advances in computing are critical enablers of change for addressing the growing sustainability challenges.

A ***key finding*** of the book is that information technology (IT)1 will play a vital role in achieving a more sustainable future and that research and innovation in computing, information, and communications technologies are consequently critical to addressing the broad range of sustainability challenges

Green IT and its place

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- The greening of IT, through efforts such as reducing data-center energy consumption and electronic waste, should be and is an important goal of the computing community and IT industry.

  (The 2010 OECD report “Greener and Smarter: ICTs, the Environment and Climate Change” (in OECD, OECD Information Technology Outlook 2010, OECD Publishing)

- Information technology can serve as a bridge between technical and social solutions by enabling improved communication transparency for fostering the necessary economic, political and cultural adjustments.

  (4E. Ostrom. A general framework for analyzing sustainability of social-ecological systems, Science 325:419-422 (2009)

Systems where opportunities of achieving sustainability objectives exists:

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1) *Built infrastructure and Systems*
   Built infrastructure and systems include buildings (residential and commercial), transportation systems (personal, public, and commercial), and consumed goods (commodities, utilities, and foodstuffs).
   - Smart logistics use IT for more effective supply chains
   - Computing innovation to achieve better management of consumed resources
   - Reductions in different areas: e.g. smart water consumption, regional planning etc.

1) *Ecosystems and the Environment*
   Assessing, understanding, and positively affecting (or not affecting) the environment and particular ecosystems are crosscutting challenges for many sustainability efforts.

1) *Sociotechnical Systems*
   Designed to aid in behavioral assistance and reinforcement and to provide information about progress are a critical element for global sustainability efforts.

Examples in IT & Sustainability

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- The smart grid
  the grid is clearly part of built infrastructure, but it also has the potential to affect regional ecosystems dramatically as new sources of renewable energy are brought online (for example, solar facilities deployed in deserts will affect the desert ecosystem).

- Food systems
  encompasses built environments (including the transportation system), the environment, and ecosystems (in various aspects from macro effects on watersheds to strategies for precision agriculture)

- Development of sustainable and resilient infrastructures
  crosscutting sustainability challenges, especially when considering a broad view of sustainability that encompasses economic and social issues.

Toward a Smarter Electric Grid

Challenges for the Modern Electric Grid

- Increased electricity consumption and corresponding growth of the grid;
- The current model of load-following supply, in which capacity is dispatched on the basis of real-time power demand, with coarse predictive analytics deployed to ensure that enough will be available;
- The difficulty in implementing a supply-following model, in which demand is managed to better match the available supply;
- Appropriate accounting for currently externalized costs.

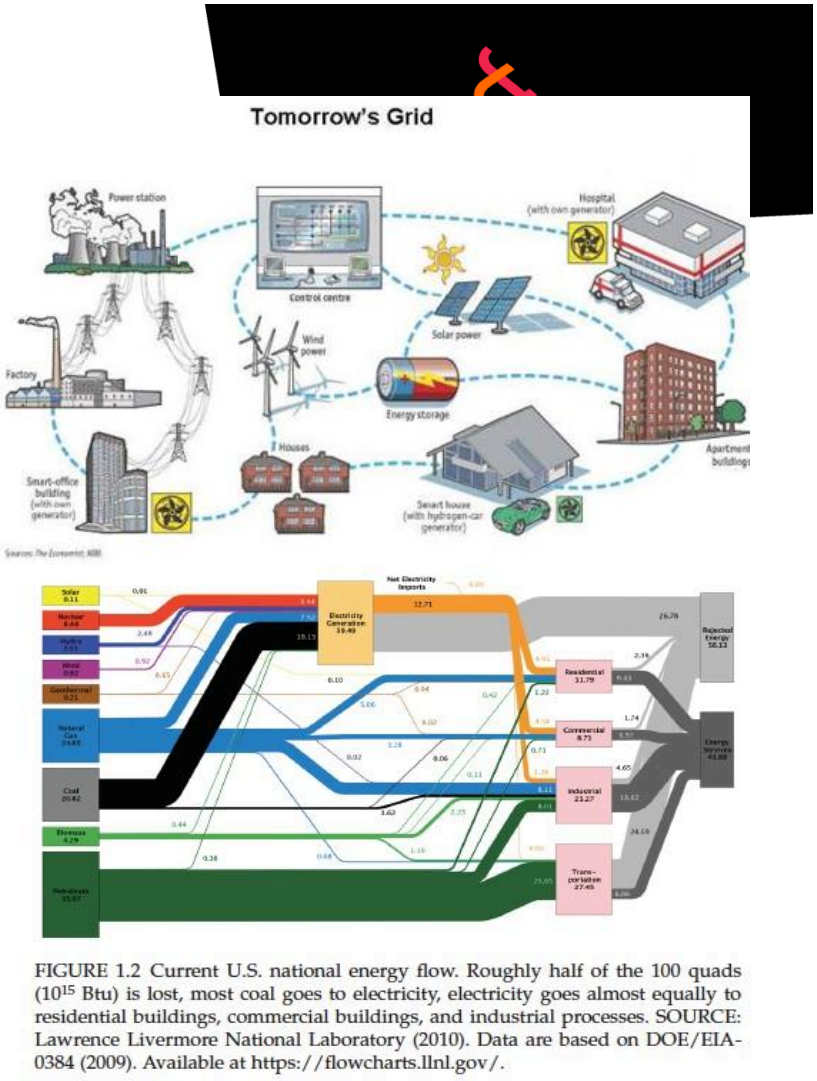

FIGURE 1.2 Current U.S. national energy flow. Roughly half of the 100 quads (10^{15} Btu) is lost, most coal goes to electricity, electricity goes almost equally to residential buildings, commercial buildings, and industrial processes. SOURCE: Lawrence Livermore National Laboratory (2010). Data are based on DOE/EIA-0384 (2009). Available at https://flowcharts.llnl.gov/.

Approaches needed

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(1) sculpt demand to match the supply of renewable power more closely; when abundant renewable power is available, use it for shiftable power needs (such as ice makers, hot water, dishwashers, electric car charging);

(2) sculpt demand to smooth out spikes so that less high-speed dispatchable supply is needed;

(3) reduce total demand by improved efficiency in transmission and use;

(4) apply instrumentation and modeling to measure carbon emissions as part of carbon pricing and capping policies.

Toward sustainable food systems

Challenges to Developing a Sustainable Food System

Increasing Demand

Population increase -> causes increasing demand

Environmental Impacts

Agriculture is a contributor to greenhouse gas (primarily methane and nitrous oxide) emissions through various soilmanagement activities and livestock operations.

Public Health Impacts

Air and water pollution

Approaches needed

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Taking a Systems View Overall

there is a need to take a systems view of agriculture (much like taking a systems view in other areas of sustainability, such as the smart grid, described previously) in order to understand and analyze the total impact of agriculture on the environment, economy, and society.

Methodology for Measuring Costs, Benefits, and Impacts

there is a substantial need for the development of methods and tools to measure the total costs, benefits, and impacts of different agricultural systems.

Precision Agriculture

The use of information and computing technology in agriculture has greatly increased in the past 50 years.

Information for Informed Consumption

Increasing the information available to individuals regarding the nature of the food that they buy and how it was produced can assist them in making sustainable choices about food.

Social Networks for Local Food Sourcing

IT could be used to increase networking among individuals and organizations, encouraging locally and regionally sourced food consumption.

Toward sustainable and Resilient Infrastructures

Challenges to Developing More Sustainable and Resilient Infrastructures

- Cities are highly complex
- Threat of natural disasters
- Time lines

The Role of Information Technology in Developing Sustainable and Resilient Infrastructures

Modeling and Simulation
Communication IT
Performance
Managing Uncertainties
Citizen Participation
Indicators of Future Outcomes
IT Infrastructure Improvements

Thank you for attention!