Emerging Energy S&T: Understanding Issues with Potential Security Impacts

Presentation Summary

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Advances in science and technology are needed to meet the challenges brought on by the convergence of energy, economies and global futures, especially with increasing global energy use commensurate with economic development. In this context, Dr. Cantwell discusses two considerations. The first is the need for transformational discoveries and disruptive technologies to mitigate climate change, decrease all dependencies on nonrenewable fossil fuels, create localized resource capacities for increased resiliency and manage/understand the increasing complexities of global energy. The second consideration is Dr. Cantwell's belief that leaders in innovation will drive the technology that defines the 21st century. In this respect, she emphasizes that policymakers must stay engaged with global innovations. One of the pressing issues that both these communities need to address is to improve understanding of the impacts of new technologies on global energy and resource 'systems.'

Discussing in more detail her view on global energy resource systems, Dr. Cantwell raises the issue of resource wars. She identifies two systemic features that frame the debate around the possibility of future resource wars. The first is the existence of **interdependencies**. In this early 21st century, access to energy sources depends on:

- global markets;
- the incapacity of most countries to be self-sufficient;
- cross-border pipelines and other strategic transport channels;
- closely-linked financial and energy markets;
- the interdependence between energy, water and land use; and
- existing risks including major supply disruption through political conflict or war, technical system failures, accidents, sabotage, extreme weather or financial market turmoil.

The second feature addresses the vital **networks** of complex energy systems to include:

- supply from upstream to downstream;
- vast infrastructure of offshore platforms, pipelines, tankers, refineries, storage, generation capacity, and transmission and distribution systems; and

- the revolutionary transition of power grids worldwide into so-called 'smart grids' that exploit renewable energy sources; as such, distributed power generation requires networked control, making future power systems more exposed to cyberattacks.

Global energy resource systems also contain various energy opportunities. Dr. Cantwell argues that all these opportunities contain both positive and negative aspects (table 1) as well as scientific and technological challenges (table 2), and it is too early to pick winners.

Opportunity	Advantages	Disadvantages
Nuclear power	Carbon-free electricity	Large water requirement, used nuclear fuel, proliferation risk
Biofuels	Low net carbon fuels	Competes with food crops for land and water
Electric vehicles	Reduced point-of-use emissions	Requires electricity, grid, infrastructure
Net-zero-energy buildings	Reduced energy consumption	Prescriptive standards may limit innovation, cost benefit
Carbon sequestration	Reduced net emissions	Significant efficiency penalty, indemnification
Solar and wind power	Zero net carbon generation	Large footprint for generation at scale, grid integration, cost benefit

TABLE 1 Energy Opportunities: Positive and Negative Aspects

Technology	Requirements
Nuclear fission	Reduced water consumption and (maybe) economical fuel reprocessing
Nuclear fusion	Major breakthroughs in several fields
Biofuels	Efficient conversion of cellulosic materials, distribution
Electric vehicles	Improved vehicle-scale energy storage, VII
Demand-side management	"Smart grid" and smart appliances
"Clean coal"	Efficient carbon capture and sequestration
Wind/solar	Utility-scale energy storage
Utility-scale solar	New nanostructured materials

TABLE 2 Energy Opportunities: Scientific and Technological Challenges

Dr. Cantwell then proceeds to discuss her list of energy science and technology (S&T) to watch, including the potential security issues they present to security practitioners and policy-makers alike (table 3).

- **Advanced fossil fuel options**
- **Nuclear Power**
- **Wind**
- **Hydrogen**
- **Bioenergy**
- **Energy storage**
- **Energy efficiency**
- **Buildings**
- **Distribution and Transmission**
- **Vehicle electrification**

Potential security issues?
- **Nuclear materials proliferation**
- **Development in materials science**
- **System interconnects & issues**
- **Resource wars – concurrent competition for water, raw materials, land use**
- **Cybersecurity**
- **Sensing & observing environmental & climate impacts**
- **Global definitions of sustainability – influence on economies**
- **Soft power options for defense engagements**

TABLE 3 Energy Science and Technology to Watch

Among her list of potential security threats, Dr. Cantwell believes that the "top four" security challenges arising from future energy S&T developments are:

- nuclear materials proliferation – advancing the use of nuclear energy will require that the back end of the fuel cycle be intelligently handled, and that both the fissile resources and waste streams be properly managed (examples of new challenges include small modular reactors that will place nuclear material in far more locations);
- development in materials science – supercomputing capabilities have been shown to greatly expand our options for "materials by design" to solve problems in nuclear, solar and energy efficiency. These computers know little to nothing about where the molecules they design can/will be sourced in real world manufacturing;
- system interconnects – as the global energy system becomes more interdependent and far more networked, how to understand (predict), manage and control – to the extent possible – the propagation of "problems" (this may be one of the best ways to mitigate resource wars); and
- cybersecurity – the future grid will be in many senses global and will be a smart grid with automated power delivery, networked to ensure a two-way flow of electricity and information between a few thousand conventional generators and hundreds of thousands of distributed and variable renewable resource generators delivering energy services to hundreds of millions of interactive and smart loads.

Dr. Cantwell concludes her presentation by proposing some options for collaboration:

- soft power options for defense engagements;
- joint scenario planning with very advanced modeling capabilities that cross all resources and are interdependent with energy/climate issues can enhance communication and collaboration on the analysis of secure, low-carbon pathways (there is no 'silver bullet' for any nation or region);
- joint efforts to analyze and examine the effects of energy S&T on newly emerging carbon markets (although this is not a subject of this presentation, it is a critical issue in promoting global transition to lower carbon economies);
- developing a structure that enhances our likelihood for ad hoc interactions around technologies and their effects; and
- joint technology investments in clean energy technologies, and more importantly, pilot studies on energy systems.