



**Long-Term Technology Pathways to Stabilization of Greenhouse Gas Concentrations**  
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**Co-chairs**

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**Overview:**

This interdisciplinary session of the Aspen Global Change Institute will focus on long-term energy technologies and associated pathways that can contribute to the stabilization of radiative forcing resulting from human activity. The session will be organized around three themes with an emphasis on technologies and the quantitative contributions they each can make in significantly altering the last two terms of the Kaya Identity – where carbon dioxide emissions are expressed as the product of population, per capita gross domestic product, primary energy intensity, and carbon intensity.

**Theme I: Closing the Loop on Carbon & Other GHGs**

**Theme II: Increasing Reliance on Efficiency, Renewables, Nuclear, and Bio Energy**

**Theme III: Beyond the Standard Suite**

The meeting will have approximately 45 to 55 participants, all contributing to daily discussions and the week-long work of the working groups and their findings. 24 invitees will be asked to prepare presentations on topics within the 3 themes with an equal number of invited respondents offering prepared rebuttals or supplementary information.

Quantitative analysis of specific technologies and energy systems designs will be presented that will include nuclear fission & fusion, space and terrestrial based renewables, bio-energy, carbon management/fossil energy, and efficiency. Related topics will also be discussed including energy carriers/storage, conversion technologies, and other greenhouse gases. Quantities will be expressed in common currencies such as TW saved or produced (terrawatt =  $10^{12}$  W), or GtC-equivalent emissions avoided, so as to enhance comparison of potential paths and their contribution at the global scale.

A technical proceedings will include a chart with the areal energy density, total resource available, maximum penetration possible by 2050, 2100, key technical hurdles, and environmental/societal issues associated with each technology pathway. Attempts will be made to identify technologies and approaches that can be deployed on the massive scale needed to support robust economic growth while stabilizing radiative forcing.

*For a successful technology, reality must take precedence over public relations, for nature cannot be fooled* –Richard P. Feynman

## **Background**

One of the greatest challenges of the 21<sup>st</sup> century is to find environmentally acceptable ways of promoting sustainable economic growth and development, both in industrialized and developing countries. From an energy perspective, this means finding ways to improve the economic utility of the energy we consume and finding ways to produce energy that will greatly reduce the risk of adverse environmental consequences.

Our present development trajectory risks generating severe global climate change, a wave of extinctions leading to reduced biodiversity, and other serious environmental problems. Many of these potential problems are of concern primarily on the timescale of decades to centuries and involve protection of a global commons. In contrast, market forces respond most strongly to short-term private interests. Hence, there is a role for government investment in developing and improving ways of producing and using power that can be commercialized and brought to market by the private sector. If we are successful, this investment can lead to an era of sustained economic growth and development that is cognizant of and consistent with our finite world.

There is a need to identify promising technologies that can facilitate sustained environmentally acceptable economic growth. Even among experts, there is no consensus regarding which technologies and approaches are most promising. Each technology or approach has its own set of barriers to widespread adoption. These barriers may include technological hurdles, physical limitations, economic, social or political factors, national security concerns, and so on. We will consider these limitations and barriers, and assess candidate technologies for their ability to contribute to the development of a vigorous and just global economy operating in a healthy global environment. Furthermore, the session will be designed to identify critical research and development issues including a rationale for the sequencing of technology development, demonstration and deployment that must be addressed to assess or facilitate the viability of these options.

Human civilization has reached the point where we no longer play a minor role in the natural cycles that govern our planet. We must move beyond thinking in terms of trade-offs between our economy and the natural world — there is one physical world encompassing both of these things, impinging on us at every instant. We have the opportunity to try to make this physical world as good as it can be for the long haul — this is our opportunity and our challenge. It is our good fortune to be able to address these most important problems at this turning point in the history of human civilization, and our responsibility to find solutions that work.

## **Rationale**

The goal of the proposed meeting is to identify promising energy technologies and strategies that can help reduce greenhouse gas emissions, physical limitations and barriers to development for each technology, and most important next steps – a sequencing of research and development initiatives – that would help lead each technology towards testing in the marketplace.

The proposed meeting will address these issues primarily from a physical sciences and engineering perspective. However, we recognize that engineering solutions are tools for society, and thus must be consistent with a plausible development path that take into consideration economic, social, political, and national security concerns. Furthermore, whereas the proposed meeting will involve primarily the discussion of technologies and focus on addressing global climate change, these discussions must include the participation of environmental scientists who may be able to foresee some of the as-yet unanticipated consequences of widespread adoption of a new energy strategy.

The meeting would have as its product a written document identifying promising energy technologies and strategies, and the sequencing of critical next steps in research and development.

## **Participants**

This meeting will include a diverse range of intelligent and creative participants; primarily physical scientists and engineers, along with a several economists, representatives from NGOs, policy analysts, etc. and will include several international invitees.

Creative experts with divergent opinions will be sought out on the following topics (some invitees will have expertise in more than one area; some areas will have more than one expert). Categories involving physical scientists and engineers will be most heavily populated.

## **Preliminary Segment topics:**

### **Day 1**

Introduction, Session Premise & Overview

Climate Sensitivity & Stabilization Primer

Emission Scenarios Primer

DOE Draft Technological Stabilization Pathways

### **Theme I: Closing the Loop on Carbon & Other GHGs (Approach and Quantification)**

Point Source Sequestration

Device, Behavior, and Systems Efficiency

Non-Point Source Sequestration – Terrestrial & Oceans

Other Fossil Strategies – gas & liquids

### **Day 2**

Integrated Visions Part I

**Theme I Closing the Loop (continued)**

Terrestrial Renewables and Conventional Bio-Fuels

Other Greenhouse Gases

New Generation Nuclear Fission

Coal-Based Systems

**Theme II: Increasing Reliance on Efficiency, Renewables, Nuclear, and Bio Energy (Approach & Quantification)**

Advanced Bio-Technology

Predictability of Technological Change

W.O. Roberts Public Lecture: Energy & Nanotechnology

**Day 3**

Integrated Visions Part II

**Theme II: Increasing Reliance on Efficiency, Renewables, Nuclear, and Bio Energy (Continued)**

Dramatic Expansion of Renewables

Electricity and Hydrogen as Major Carriers

**Theme III: Beyond the Standard Suite (Approach and Quantification)**

Fusion: Pipe Dream or Panacea

Space Based Solar Power

Advanced Nuclear Fuel Cycles

Sectoral, Structural & Behavioral Change; Innovation & Surprise

Working Groups Meetings

WGI: Quantitative mix to achieve climate stabilization, common currency

WGII: Sequencing of technological options & paths, overcoming barriers

WGIII: Describing a rational R&D program, grand challenges

**Day 4**

Integrated Visions Part III

**Theme III: Beyond the Standard Suite (continued)**

Global Grid and/or Massive Decentralization

Major Shifts in Composition of Economic Output to Non-Consumptive Pattern

Future Lessons from the Past – Innovation and Intensity

Air to Chemical Capture of CO<sub>2</sub>

Working Group Meetings

**Day 5**

Integrated Visions Part IV

Working Group I Report:

Quantitative mix to achieve climate stabilization; common currency

Working Group II Report:

Sequencing of technological options & paths; overcoming barriers

### Working Group III Report:

Describing a rational R&D program; grand challenges

Synthesis Discussion (Working Group Leaders)

Outcomes: Report, journal paper, wrap-up discussion

### **Design comments:**

Each presentation of approximately 30 minutes will have 1 or 2 pre-selected respondents allowed 5 to 10 minutes for rebuttal. Since some speakers will respond to other presentations, a meeting size of 45 to 54 is anticipated. In addition there will be ample group discussion interspersed throughout each work day. All participants will have the opportunity to contribute to the working group work and reports or contribute to the poster session.

As a running theme, a large “energy/technology matrix” will be posted with rows listing technologies, and columns for energy density, total resource available, maximum penetration possible by 2050 & 2100, key technical hurdles, etc. Rectangles in this matrix will be large enough to include multiple answers. Throughout the meeting, participation in the matrix will be solicited whereby experts post their ideas. The matrix will serve the “putting it all together” talks on the last morning and provide useful input into the post-session synthesis process and final report. In addition to the energy/technology matrix developed over the course of the meeting, there will opportunities for poster presentations.

### **Session Proceedings:**

The report will consist of a session overview and key findings by the session chairs, the set of approximately 24 invited technical papers and rebuttals addressing the full range of topics, working group reports, the energy/technology matrix chart, and a set of research and development recommendations. The grant monies will provide enough funds to print 500 perfect bound reports of approximately 250 pages each. One copy will be provided each participant with the remainder for use by the supporting agencies. Additional hardcopies will be printed via a print-on-demand service and available for cost directly from AGCI or its assigned distributor. Pdf files of the entire publication or selected parts will be posted on the internet and freely available for downloading.