Climate Technology Challenges: Low-Carbon Coal Case Study

Joe Chaisson
Clean Air Task Force
WWW.CATF.US

CATF

- Our Mission:
  - Reduce the impact of human activity on the Earth's atmosphere – with emphasis on climate change
- Dual focus:
  - Reducing air pollution through public policy advocacy – with emphasis on air pollutants impacting climate.
  - Get cleaner technology to market faster through business-to-business strategy and business collaboration.
- What makes us different:
  - Science informs our priorities and strategies; we do not view science as a tool of advocacy for a pre-determined agenda.
  - We have been working on climate technology development and deployment for the past decade.
  - We have been deeply involved in nearly all aspects of coal technology with carbon capture and geologic sequestration
  - We have worked closely with a wide range of companies – ranging from small technology innovators to large power generators and traditional advanced coal technology vendors.
  - We are now working with research teams at MIT, LLNL and elsewhere to fill some key low-carbon coal technology RD&D gaps.

Introduction

- Meeting greenhouse gas reduction targets may be a substantially larger challenge than most recognize.
- At a simple level, the depth of the necessary reductions and their increasing urgency frame the enormous physical and economic challenge.
- Political, institutional and cultural issues will also constrain developing and deploying GHG emissions reductions – adding further layers of complexity to this enormous challenge.

Some Key Dimensions of the Challenge

- The ***amount and speed*** of desired GHG emissions reduction is daunting.
- Most reductions will require rapid and potentially radical transition of very large embedded energy systems – ***which have enormous inertia***.
- Much “breakthrough” technology development will likely be needed to afford the target emissions reductions – ***this is not “business as usual”***.

Challenge Dimensions (2)

- Developing countries will need to grow their economies to afford target reductions and will not likely accept a lower standard of living than has been achieved in developed countries – ***economic development may be a big part of the solution and not just the problem*****.**
- Effective policy intervention to facilitate target reductions must address a very wide range of situations that will typically require unique intervention solutions – ***rather than just simple generic policies, like "cap and trade".***
- Significant alteration of the private sector climate technology "value chain" may be essential.

Challenge Dimensions (3)

- Reduction economics are daunting –
  - Structural economic barriers may constrain development of key technology
  - The ***recent very large energy project capital cost increases are unprecedented*** and are clearly slowing down needed technology deployment

- Recent science suggest that the climate action emissions reduction technology "portfolio" needs to be expanded – by addressing several non-CO2 air pollutants.

Challenge Dimensions (4)

- Technology forecasting is difficult to impossible in some key areas like low-carbon mobility systems or CO2 capture from power plant flue gases or directly form the atmosphere.
  - Which could constrain radical and costly energy system transition
  - Which argues for a diverse technology development

- Breakthrough climate technology technology may result from non-traditional areas of science – ***for example genomic biotechnology*** – that have poor to non-existent linkages to energy technology development.

Low-carbon Coal Case Study

- CATF has collected our observations about action needed to develop and deploy the advanced coal and carbon capture and sequestration technology that will be essential to meeting current and evolving climate targets.

- These observations are presented in the following case study to provide one example of the complex suite of action likely to be needed to rapidly develop and deploy a needed climate technology. We hope that this specific example may be helpful as the broader topic of addressing the climate technology challenge is explored.

- This case study assumes that serious carbon management policies driving significant carbon allowance prices will be in place in major Western nations – including the US - within the near future.

Caveats

- CATF’s observations are clearly incomplete and the structure we have used to organize our observations is preliminary and could well be improved upon.
- CATF is active pretty much across the entire spectrum of coal/CCS technology development and deployment action, however our geographic coverage is not universal – so we may be missing some key activities.

Low Carbon Coal – Observed Deployment Challenges

- Conducting core enabling science and engineering research.

- Producing key information needed to support early and widespread coal/CCS deployment, to include for examples: national/regional assessments of CO2 storage capacity and conducting large-scale geologic sequestration demonstration projects that include appropriate science.

- Moving currently “stuck” or “sluggish” existing technology into the market

- Adapting technology developed for another application – *for example applying molten metal bath and blast furnace technology to gasify coal.*

Observed Deployment Challenges (2)

- Developing technology that does not yet exist.
- Improving existing commercial technology
- *Much faster* deployment of commercial and pre-commercial technology
  - Innovative deployment of existing technology
  - Early and very expensive demonstration of fully integrated, commercial scale power plants with CCS.
  - Support for large scale and very expensive commercial deployment before such projects are fully economic.
- Rapidly expanding critical human resources.

Low-carbon Coal Case Study - 1

Category	Situation	Potential Interventions	Notes
Conduct core enabling science.	Included in concept in the US coal/CCS R&D program, but being scaled down.	Expand, adequately fund and effectively manage an advanced concepts R&D program addressing core science.	
Develop core engineering tools	Powerful engineering-economic simulation tools are needed for analysis and refinement of complex, integrated coal/CCS systems.	Include in public R&D and adequately fund. Potential for private sector support in this area (Shell/MIT example?)	MIT coal study identified this R&D gap
Production of critical information needed to plan the deployment of coal/CCS systems. A key example is preparing broad national/regional assessments of CO2 injection potential – both volumes and rates.	Australia has conducted a national assessment – setting an example for other counties/regions.	Public support for developing national/regional assessments.	A US national assessment was authorized in the 2007 Energy Bill, but the prospects for Congressional funding are not yet clear. Australia is funding and participating in a national assessment in China. Australia is now conducting detailed CO2 storage capacity and injectivity assessments in key regions.

Low-carbon Coal Case Study - 2

Category	Situation	Potential Interventions	Notes
Existing Pre-commercial Technology Much potentially important technology exists today that is either "stuck" or moving very slowly into the market.	Several advanced coal gasification technologies are in various stages of development but are typically either "stuck" or moving only slowly into the market. Several related technologies that are important components of coal/CCS systems are in similar situations – one example is innovative compression technology.	"Company grooming" by experienced energy "operatives". Public process demonstration support.	Several of these technologies are adapted from other applications. At least one technology was initially developed (by Exxon) with DOE R&D support in the 1970's – but dropped when oil prices collapsed.
	Companies "stuck" at first commercial project stage, or constrained to sub-economic scale for initial commercial project(s)	Establish private sector "First Project Fund" (Google is considering supporting organization of such a fund). Government program to surgically address specific financial risks of first commercial projects; Consider shifting commercial deployment to China	Intervention could *significantly accelerate* technology deployment. Some companies are shifting technology deployment to China (SES) to expedite commercialization.
	Very limited capability to deliver technology – for example, **underground coal gasification**	"Company grooming" by experienced private sector energy "operatives". Establish professional UCG engineers organization. Expand academic output of needed engineers and scientists.	Could be ***the*** critical technology for China and India. Company "grooming" has been quite successful in facilitating capability expansion. Potential to scale up rapidly in China (Xinao)

Low-carbon Coal Case Study - 3

Category	**Situation**	**Potential Interventions**	**Notes**
Incremental Improvement to Existing Commercial Technology	Focus of most US R&D	May not be needed, beyond expanded funding.	Not likely to lead to cost/performance "breakthroughs"
Innovative applications of existing technology	Innovative applications appear feasible that could substantially lower costs and have other operational benefits – for example standard design for prefabrication. Sinopec may be developing this concept. Another example might be development of coal to substitute natural gas (SNG) projects, with carbon sequestration (cheap) combined with natural gas CC power plants – which appears to be economic today in the US.	Identifying companies (like Sinopec) that have the capability (both technical and "mind set") to develop innovative applications of coal gasification/CCS systems. "Business to business" facilitation may be sufficient to connect relevant companies. Better engaging the appropriate portions of the chemical/ petrochemical industry in coal/CCS R&D planning and coal/CCS power technology/project development.	Current commercial coal gasification technology was developed for refinery applications. Current vendors do not appear to have transitioned to a power systems "mind set". Small ***project*** developers appear to be more adaptable than large companies . The chemical/petrochemical industry has knowledge that could probably be applied beneficially to coal/CCS power system development – but this industry is not typically engaged in coal/CCS power project development or coal/CCS RD&D.

Low-carbon Coal Case Study - 4

Category	Situation	Potential Interventions	Notes
Inventing New Technology	A needed application is identified and either some processes have been identified in concept or no processes to meet the need have yet been identified. **Examples include "break through" post-combustion CO2 capture and geo-chemical CO2 sequestration.** Cross-science applications may be important (applying genomic bio-technology to coal/CCS applications). For example, genomic biotechnology may eventually produce knowledge that could enable breakthrough technology development, but linkages between energy systems and this area of science are weak and this field may need to evolve well beyond it's current "medieval watch-maker" before it can be effectively integrated into energy systems applications.	Expand private sector value chain to establish a role for early technology development company/project financing (the pharmaceuticals industry value chain may offer some insight)? Fill key R&D gaps - innovative post-combustion CO2 capture is ***not*** being addressed by existing public coal/CCS R&D? More effectively conduct public R&D. Establishing a "DARPA-Energy" is one proposal for doing so. Improve cross science/technology linkages (how?).	CATF is supporting development of RD&D road maps addressing several gaps in current coal/CCS R&D support – including innovative/"breakthrough" post-combustion CO2 capture technology. Some private sector coal/CCS technology developers will not participate in public R&D programs. While some promising private sector activity is addressing innovative coal/CCS concepts (Accelergy), such work is typically limited to concepts that could be commercially deployed with a few years time – the extent of today's private sector energy technology value chain.

Low-carbon Coal Case Study - 5

Category	Situation	Potential Interventions	Notes
Demonstrate "risky"/currently uneconomic applications of existing technology – **power plants.**	Full commercial-scale coal power plants with carbon capture and sequestration needs to be demonstrated. While this technology is commercially available – initial applications will be scaled up and integrated beyond current applications and will thus be financially and technically risky and will further not be fully economic before carbon management is implemented.	Public financial support. "Early-adopter" incentives for developers that can move at least some aspects of the need demonstration without public financial incentives.	Support for such projects today could well require up top ***several billion dollars per plant.*** Several such plants across a range of technology types and coal ranks are needed. US FutureGen, a sub-commercial scale project has collapsed due to recent very large technology cost increases. This need is under discussion in the US and EU – but the necessary financial commitments have not yet been made.

Low-carbon Coal Case Study - 6

Category	Situation	Potential Interventions	Notes
Demonstrate "risky"/currently uneconomic applications of existing technology – **large scale geologic carbon sequestration projects.**	Several large-scale demonstrations of geologic carbon sequestration need to be conducted globally in appropriate geologic settings and must include the necessary science package to produce the knowledge needed to develop operational project siting, operation, monitoring and closure procedures. ,	Public financial support, as these projects will be totally or largely uneconomic without such support. Authorization for several large-scale US GCS demonstration projects was included in the 2007 Energy Bill. Funding of these provisions is pending Congressional action. DOE's capability to manage these projects has been questioned. If such concerns are valid, an alternative management mechanism may need to be established.	These demonstrations are probably necessary before widespread deployment of CCS can be implemented and are thus potentially the most time-critical coal/CCS technology development/deployment need. These demonstrations would have no economic value before carbon management is implemented. The global GCS development and deployment "road map" was developed in the MIT coal study. Large scale GCS demonstration projects were identified as a critical step in this road map.
Early commercial deployment of demonstrated technology before it is fully economic	Plausible US GHG cap and trade system implementation will not have sufficiently high GHG prices in the early years to drive early deployment of new coal power plants with CCS.	Government financial incentives for early, large scale deployment. Deployment would likely allocate support to all three major coal ranks and to both above-ground plants and UCG. This could require as much as $40-$80 billion.	Both major bills in the US Senate include financial incentive provisions for large scale coal/CCS early commercialization support. Financial incentives are funded by direct allocation of GHG allowances or by GHG allowance auction revenues.

Low-carbon Coal Case Study – 7

Category	**Situation**	**Potential Interventions**	**Notes**
Early commercial deployment of physical infrastructure needed to support rapid deployment of coal/CCS.	The US has an existing CO2 pipeline system established to conduct enhanced oil recovery.	Public financial support for broad national/regional assessments of CO2 injection potential – both volumes and rates. Public financial support for: early-stage expansion of the existing US CO2 pipeline system, public-private planning for long-term CO2 pipelines systems needs and possible financial support for full pipeline system development.	Modest financial incentives may be sufficient to facilitate rapid initial expansion of the existing US CO2 pipeline system. Establishing early. Adequate CO2 pipelines systems may be more challenging in other areas – for example, in the EU.
Rapidly expanding the pool of critical human resources.	Engineers and scientists in key areas needed to support rapid development and deployment of coal/CCS technology do not exist.	Public/private sector assessment of needed human resources skills. Public financial support for relevant science and engineering training. Stressing the need for such skills to help attract capable students.	China may be able to provide a significant portion of the needed engineering skills.

Some Summary Observations

- Action needed to rapidly develop and deploy low carbon coal/CCS technology must address a very wide range of situations – many of which will require relatively unique action and some of which will be enormously expensive.

- Institutional capability and inertia and public program politics will be important constraining factors.

- Much progress is being made (although far from enough) – typically through innovative private sector action or national or bilateral government action (as for example the Australia/China "clean coal" initiative).

- Enhanced private sector performance appears feasible and has tended to be overlooked as part of "the solution". Examples include –
  - Shifting technology development, demonstration and initial commercial deployment to China.
  - Expanding non-VC "stuck" company "grooming" capability.
  - Facilitating much greater and more effective "business to business" interactions between Western, China and India companies.

Summary Observations (2)

- Current coal/CCS technology RD&D in the US (and perhaps elsewhere) has:
  - Focused largely on incremental improvement to existing commercial activity;
  - Been politically “captive” of a core group of large companies and trade associations.
- Most recent RD&D “road map” development addressing key coal/CCS areas not included in current major public RD&D programs has been or is being developed outside of government. Examples include the MIT coal study (particularly the ground-breaking GCS road map) and work commissioned by CATF and financially supported by the Duke Foundation.
- More focus on and public financial support for core enabling science and early applications exploration is needed.

Supplemental Material

Size and Nature of the Challenge

Summary of Challenges

1. Sheer size
2. Need for speed
3. Limit of current tech platforms
4. Energy system inertia
5. Energy system risk aversion
6. Difficulty of forecasting
7. Structural barriers
8. Global cost explosion
9. RD and D silos

Challenge #1: Sheer Size

- Need 50+% reduction from current CO2 by 2050 to limit atmospheric CO2 in 2100 to 500 ppm.
  - Given CO2 longevity, must further reduce CO2 emissions after 2100 to near-zero to stabilize climate.
- All this when the world economy today is “re-carbonizing,” energy intensity is static or growing, and world energy demand is set to grow 2-3X by 2050.
- At a minimum, this means re-building the world energy system, twice over by 2050, with zero carbon emissions technology.

Challenge #2: Need for Speed

- Many scientists believe we may face such irreversible climate “tipping points” as extreme Arctic sea ice melt within the next several decades.

- Avoiding these will likely require:
  - Much more emphasis on near-term action to constrain warming and ice/snow melt
  - Radically reducing short term non-CO2 climate forcing (methane, black carbon, ozone, carbon monoxide)
  - Reducing atmospheric CO2 to 350 ppm CO2, thus:
    - Focus on CO2 removal from atmosphere
    - Geo-engineering?

- Adding geo-engineering to the serious research agenda.

Challenge #3: Much current technology unlikely to work at scale

- Current energy efficiency: doesn’t come close to displacing projected underlying 10X electricity demand growth in LDCs

- Biofuels: severe constraints on arable land, a problem for cellulosic ethanol and other advanced biofuel conversion processes.

- Conventional wind: land constraints

- ***THEREFORE, BREAKTHOUGH TECHNOLOGY WILL BE NEEDED IN MANY AREAS***

Breakthrough Technology Examples/ Challenges (2)

- Post-combustion CO2 capture technology:
  - Does not appear economic today, certainly for developing countries,
  - Thus no plausible technology is available to reduce GHG emissions from existing fossil power plants until they are replaced 60-100(?) years from now

- Low/no carbon mobility systems
  - May require synthetic fuels produced using CO2 captured form the atmosphere and hydrogen produced from several potential large zero-carbon sources (nuclear power, large scale wind and coal with carbon capture and sequestration).

- Little support appears to exist today for breakthrough technology development.

- Structural economic barriers may exist to developing some such technologies.

Challenge #4: Energy System Inertia

- Significant changes to very large scale energy systems - for example, a possible shift to hydrogen mobility fuel - will be very costly and may not be possible even by mid-century
  - Institutional inertia and sunk costs
  - Enormous amounts of capital will be required to make such a transition

- Compare innovation in low unit cost, short lifetime technology that “plug into” existing infrastructure - like advanced lighting technology or more efficient light vehicles – that require much less capital investment and time to develop and deploy.

Challenge #5: Risk Aversion

- The energy system is highly risk averse to developing and deploying new technology:
  - Grid reliability premium
  - Finance community doesn’t like “big bets” (e.g. first project for new power system platforms)
  - Most venture capital investment is in climate/energy technology that can pay back in three years.
  - No energy sector analogue exists today to the extended pharmaceuticals industry value chain that recognizes new drugs may have a twenty-plus year development cycle
- To make matters worse, we are currently in global frenzy of risk-shedding

Challenge #6: Difficulty Forecasting

- Poor (to non-existent) energy technology forecasting capability presents a further constraint to significant large energy system transition, as even the basic direction of change may not be possible to predict today, particularly in areas of little or no experience to date, for example –
  - post-combustion capture of CO2 from large point sources, or
  - CO2 capture from the atmosphere
- Some technology breakthroughs could undercut large system changes that might be underway –
  - For example, a breakthrough in CO2 air capture combined with synthetic fuels production using zero-carbon hydrogen sources would likely rapidly undermine a transition to hydrogen mobility fuel infrastructure that might be underway

Challenge #7: Structural Economic Barriers

- Reducing GHG emissions will typically require technology that has only GHG reduction value – *and will not otherwise provide improved products or services.*
  - *Imagine the IT revolution occurring if there had been no intrinsic consumer value in increasing computing speed or lowering costs, etc*
- Barriers exist to high development cost, low implementation cost technologies
  - For example, government *promises* of high future GHG allowance prices are unlikely to "kept" if technology is developed at a high development cost that has a low marginal abatement cost – which raises questions about technology development cost recovery.

Challenge #8: Costs

- Existing technology is probably capable of reducing power system GHG emissions to near zero by mid-century, but at a slow scale up and a *substantial* cost.
  - US CCS rapid scale up could cost $80 Billion
- Recent and dramatic energy project capital costs increases are unprecedented and are clearly slowing down needed technology deployment.
  - US power project costs up 2X since 2005,
  - Cancellation of many commercial projects (both in the US and in the Gulf), including critical climate technology projects like FutureGen.
  - Future cost trajectory of such projects is unclear – will the current pace of cost inflation continue? Will costs plateau, but not decline for the foreseeable future? Will costs plateau and then decline to more traditional levels?
  - CATF is aware of no climate action plans or analyses that adequately incorporate current technology costs.

Challenge #9: RD and D “Silos”

- Breakthrough climate technology may result from non-traditional areas of science – *for example genomic biotechnology* – that have poor to non-existent linkages to energy technology development.

Some Themes and “Bins” That Might Move Us Forward On the Larger Design Issues

Theme #1: Sub-divide the Problem

- Climate technology development and deployment covers vast terrain
- A similarly vast array of actions will likely be needed to develop and deploy needed technology
- ***Facilitating climate technology development and deployment is inherently "granular" and must be addressed by disaggregated and flexible actions***

Examples of Several “Bins” To Think About

A. Technology that is “good enough” or nearly “good enough”

B. More substantial innovation

C. Creating innovation infrastructure

Bin A – "Good enough" or nearly "good enough" technology

- Commercializing technology that already exists - at the conceptual, "bench" or process demonstration unit stage – *which may require non-conventional (i.e., non-VC) company "grooming", new "first commercial project" financing mechanisms, etc.*
- Incremental improvements to existing technology – *e.g. the primary focus of current DOE/EPRI low-carbon coal research, but needs more $$.*

Bin B - Substantial Innovation

- Adapting technology developed for another application – *for example applying molten metal bath and blast furnace technology to gasify coal.*

- Inventing new processes - *for example, a process for economic and practical CO2 capture from the air.*

- Cross-technology connections - *for example, General Compression's innovative wind power system that uses an air compressor instead of a wind turbine generator.*

- Cross-science applications – *for example, applying genomic biotechnology to CO2 air or flue gas capture.*

- Commercially demonstrating very expensive, financially risky and currently uneconomic existing technology – *for example, full scale commercial new coal power plants with carbon capture and storage at perhaps $5 billion each.*

Bin C - Creating Innovation Infrastructure

- Producing/accessing the necessary scientists and engineers to develop and deploy needed technology

- Significantly altering the education of certain professions to capture the full potential of buildings and energy systems design – *as for example commercial architects and mechanical engineers.*

Theme #2: Emphasis on Private Sector Action?

- Anecdotal evidence suggests that considerable technology innovation is occurring that is not moving easily into the market and that private sector “solutions” may be more effective in moving such technologies than would government policy or programs.

- Private sector climate technology development and deployment activity can flexibly partner and cross international borders and thus may be more effective than public interventions.

Theme #3: The Value of “Skunk Works” and Small Players

- Technology innovation appears to be more prevalent in small companies and independent project energy project developers than in large companies like GE or traditional power generators (like Duke or AEP).
  - This may suggest a disconnect between where much innovation is occurring and the private sector players with sufficient resources to rapidly develop and deploy innovative technology

- RD and D efforts should tap into innovative centers and not be limited to politically sophisticated incumbents

Theme #4: Expand/refine the Climate Emissions Reduction Portfolio

- Several short-lived non-CO2 air pollutants are driving significant Arctic warming and ice melt (their impact is roughly equal to CO2) as well as global warming:
    - Methane
    - Tropospheric ozone
    - Carbon monoxide
    - Black carbon

- Reducing these air pollutants will have ***relatively immediate climate benefits*** – as opposed to reducing CO2 – which has a long atmospheric lifetime.

- Reducing these air pollutants may be the only practical opportunity to constrain Arctic warming and ice melt within the next several decades

- Thus, actions to reduce emissions of these air pollutants (or their precursors) and the necessary associated technology to do so must be added to our climate action portfolio.

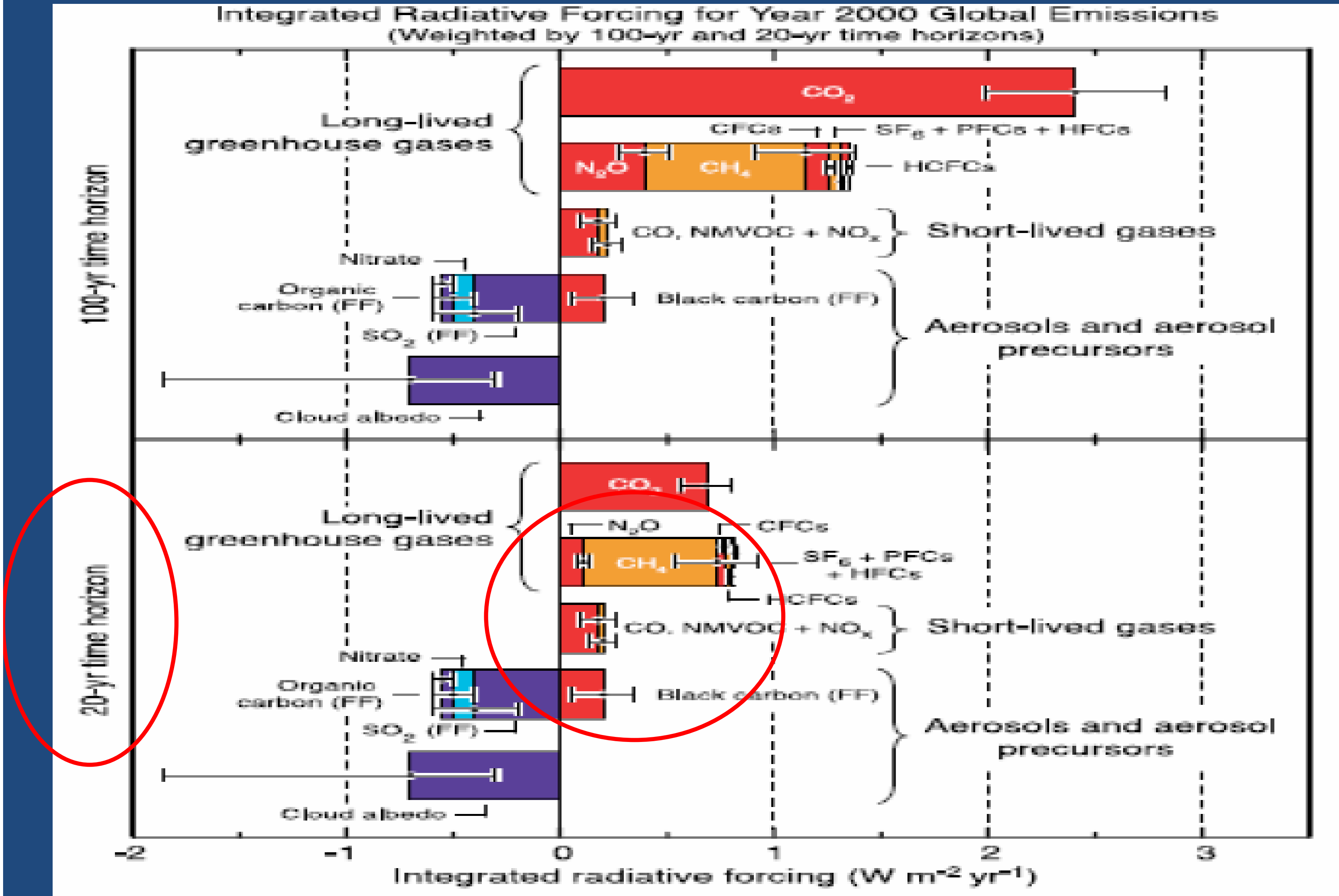

Figure 2.22. *Integrated RF of year 2000 emissions over two time horizons (20 and 100 years). The figure gives an indication of the future climate impact of current emissions. The values for aerosols and aerosol precursors are essentially equal for the two time horizons. It should be noted that the RFs of short-lived gases and aerosol depend critically on both when and where they are emitted; the values given in the figure apply only to total global annual emissions. For organic carbon and BC, both fossil fuel (FF) and biomass burning emissions are included. The uncertainty estimates are based on the uncertainties in emission sources, lifetime and radiative efficiency estimates.*

Theme #5: Connect Disconnected Science/Engineering

- Potential: knowledge gained in an area of science like genomic biotechnology may produce climate technology breakthroughs.

- Such emerging areas of science will typically be “disconnected” from the energy technology industry.

- In some cases like genomic biotechnology, today’s status may be considered at the “medieval watchmaker” stage, but may be far advanced within the next decade or two.

- The necessary connections with climate technology needs essentially do not yet exist and the potential roles of such technology cannot be predicted and could be nearly unimaginable today.