Reducing Greenhouse Gas Emissions: The Scale and Scope of the Technology Challenge

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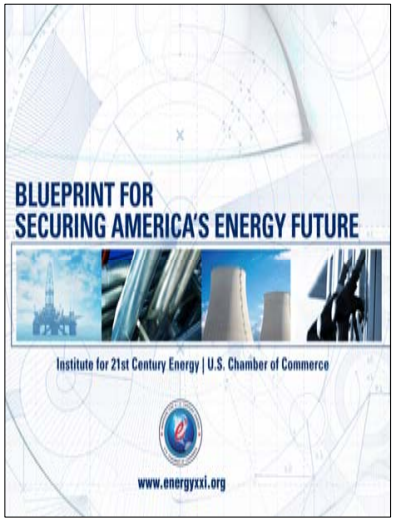
About the USCC Energy Institute

- Institute for 21st Century Energy was established as an affiliate of the U.S. Chamber of Commerce August 2007
- Leadership:
  - President and CEO—General James L. Jones, USMC (Ret.)
  - Executive Vice President and Managing Director—Karen Harbert
  - Vice President—Frederick C. Smith
- Purpose: Unify energy stakeholders and policymakers behind a common strategy
- Activities: Educate the public, engage thought leaders, mobilize grassroots activists
- Recent Activities:
  - "Open Letter" to 44th President and 111th Congress
  - Policy Blueprint
  - Transition Plan
- Web Address: http://www.energyxxi.org



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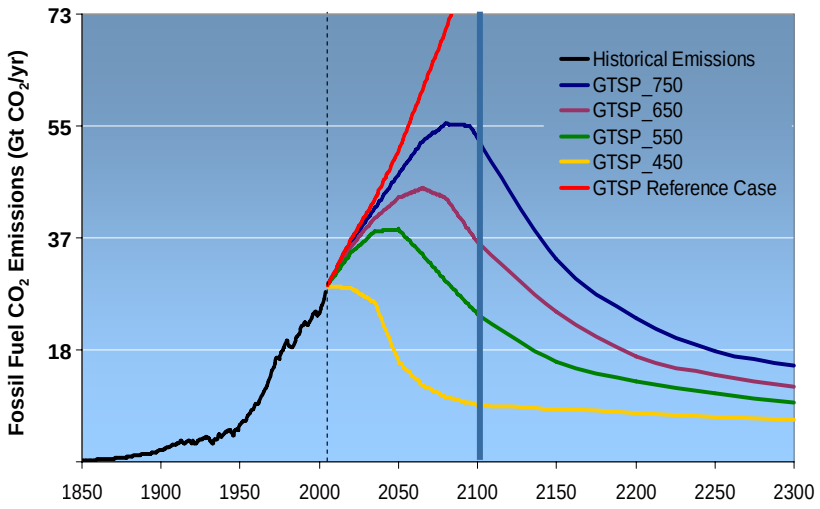
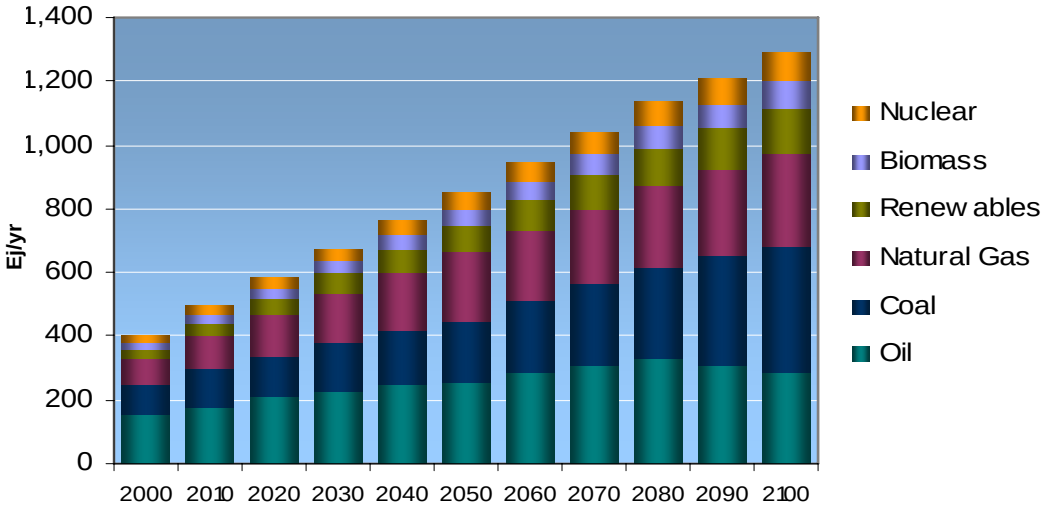
Climate Change Technology: Meeting the Long-Term Global Challenge

To provide the energy for continued economic growth and development while reducing greenhouse gas emissions, we will have to develop cost-effective technologies that transform the way we produce and use energy.

CO_2 Stabilization Curves



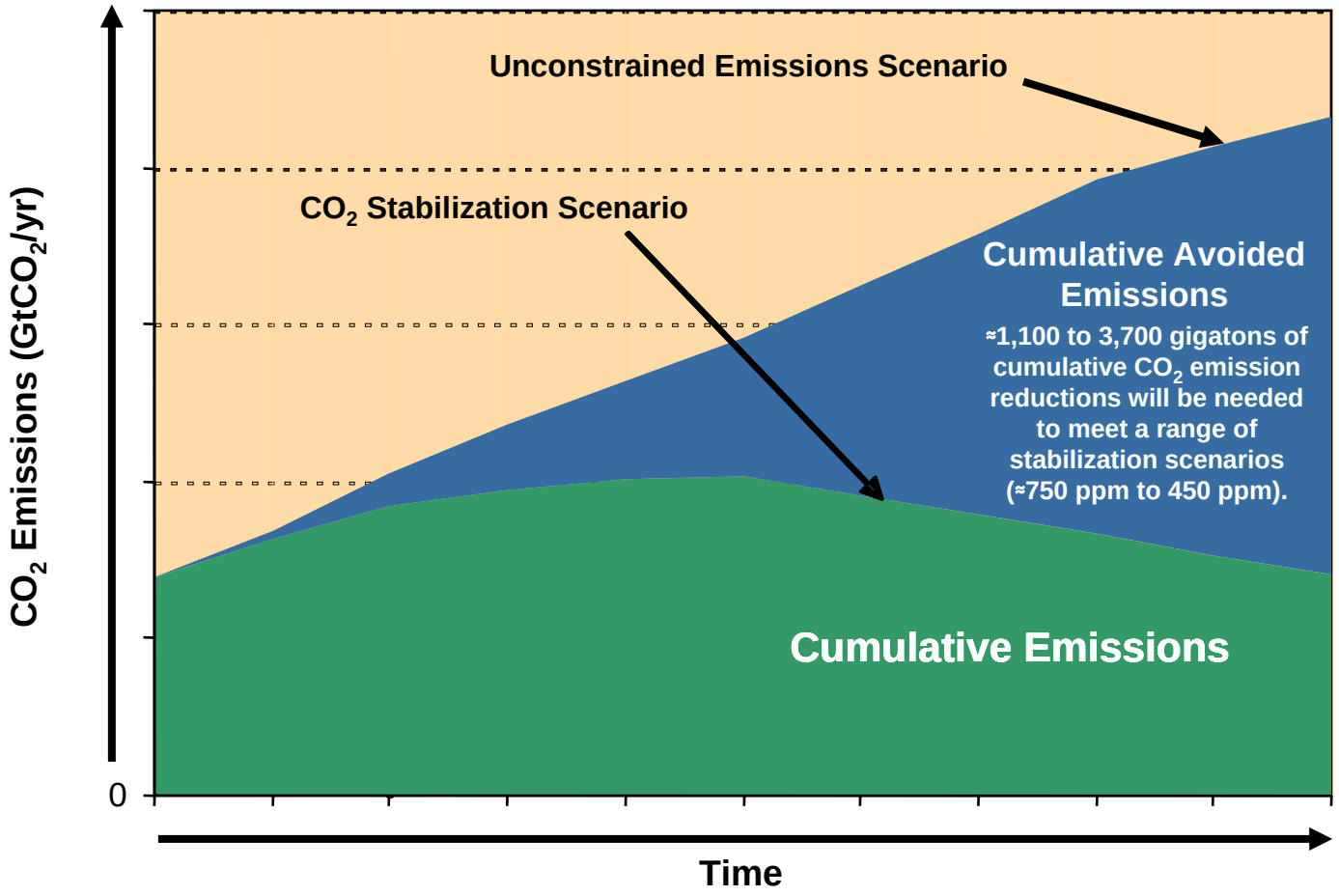
Projected World Primary Energy Demand, 1990-2095: A Reference Case Example



Sources: Battelle Global Energy Technology Strategy Project; Climate Change Science Program. 2007, *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations* (MINICAM Results).

Reductions in Global Emissions Needed to Meet Range of Possible Goals

Cumulative global emissions reductions ranging from about 1,100 to 3,700 gigatons of CO_2 equivalent would be need over the course of the century to meet a range of atmospheric concentration goals.



Source: Clarke, L. *et al.* 2006. *Climate Change Mitigation: An Analysis of Advanced Technology Scenarios*. Richland, WA: Pacific Northwest National Laboratory.

Global 100-Year GHG Mitigations ($GtCO_2$)

CCTP Strategic Goal	Very High Constraint (≈450 ppm CO_2)	High Constraint (≈550 ppm CO_2)	Medium Constraint (≈650 ppm CO_2)	Low Constraint (≈750 ppm CO_2)
Reduce Emissions from Energy End Use and Infrastructure	920 – 990	700 – 770	550 - 620	400 - 510
Reduce Emissions from Energy Supply	660 – 1,210	400 – 770	290 – 510	110 – 290
Capture and Sequester Carbon Dioxide	550 – 1,210	180 – 510	110 – 260	70 – 150
Reduce Emissions of Non-CO_2 GHGs	587 – 620	510 – 550	440 – 480	330 – 370

Estimated cumulative GHG emissions mitigation ($GtCO_2$) from accelerated adoption of advanced technologies over the 21st century across a range of hypothesized GHG emissions constraints.

Source: Clarke, L. *et al.* 2006. *Climate Change Mitigation: An Analysis of Advanced Technology Scenarios*. Richland, WA: Pacific Northwest National Laboratory.

When Would the First $GtCO_2$/yr of Global Mitigation be Due?

CCTP Strategic Goal	Very High Constraint (≈450 ppm CO_2)	High Constraint (≈550 ppm CO_2)	Medium Constraint (≈650 ppm CO_2)	Low Constraint (≈750 ppm CO_2)
Reduce Emissions from Energy End Use and Infrastructure	2000 - 2010	2010 - 2020	2010 – 2020	2020 - 2030
Reduce Emissions from Energy Supply	2000 - 2010	2010 – 2020	2015 – 2020	2035 – 2040
Capture and Sequester Carbon Dioxide	2010 - 2020	2010 – 2020	2015 – 2020	2030 - 2040
Reduce Emissions of Non-CO_2 GHGs	2010 - 2020	2020 - 2030	2030 – 2040	2040 - 2050

Estimated timing of advanced technology market penetrations, as indicated by the first $GtCO_2$-eq./year of incremental emissions mitigation across a range of hypothesized GHG emissions constraints.

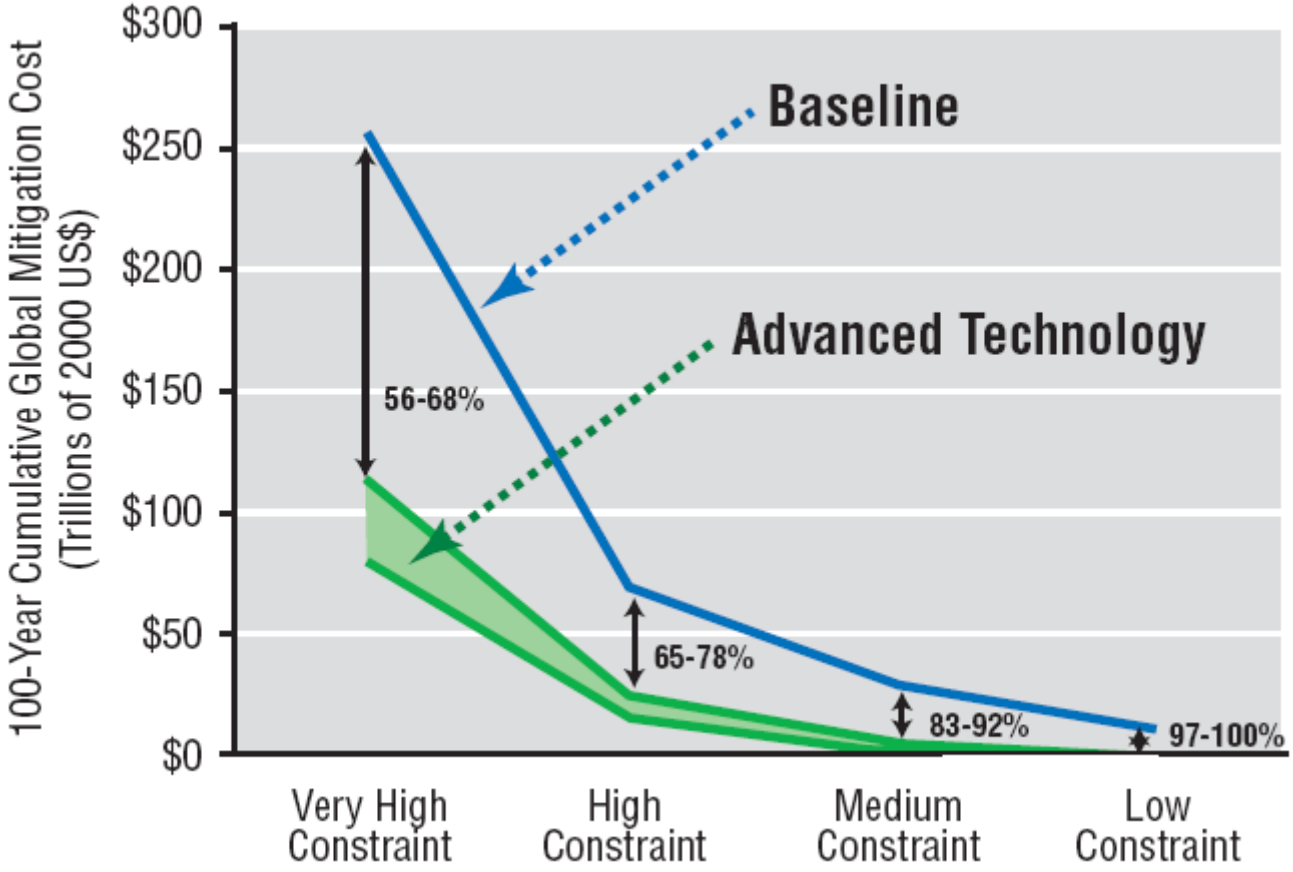
Source:: Clarke, L. *et al*. 2006. *Climate Change Mitigation: An Analysis of Advanced Technology Scenarios*. Richland, WA: Pacific Northwest National Laboratory.

Roadmap for Climate Change Technology Development

	NEAR-TERM	MID-TERM	LONG-TERM
GOAL #1 Energy End-Use & Infrastructure	• Hybrid & Plug-In Hybrid Electric Vehicles • Engineered Urban Designs • High-Performance Integrated Homes • High Efficiency Appliances • High Efficiency Boilers & Combustion Systems • High-Temperature Superconductivity Demonstrations	• Fuel Cell Vehicles and H_2 Fuels • Low Emission Aircraft • Solid-State Lighting • Ultra-Efficient HVACR • "Smart" Buildings • Transformational Technologies for Energy-Intensive Industries • Energy Storage for Load Leveling	• Widespread Use of Engineered Urban Designs & Regional Planning • Energy Managed Communities • Integration of Industrial Heat, Power, Process, and Techniques • Superconducting Transmission and Equipment
GOAL #2 Energy Supply	• IGCC Commercialization • Stationary H_2 Fuel Cells • Cost-Competitive Solar PV • Demonstrations of Cellulosic Ethanol • Distributed Electric Generation • Advanced Fission Reactor and Fuel Cycle Technology	• FutureGen Scale-Up • H_2 Co-Production from Coal/Biomass • Low Wind Speed Turbines • Advanced Biorefineries • Community-Scale Solar • Gen IV Nuclear Plants • Fusion Pilot Plant Demonstration	• Zero-Emission Fossil Energy • H_2 & Electric Economy • Widespread Renewable Energy • Bio-Inspired Energy & Fuels • Widespread Nuclear Power • Fusion Power Plants
GOAL #3 Capture, Storage & Sequestration	• CSLF & CSRP • Post Combustion Capture • Oxy-Fuel Combustion • Enhanced Hydrocarbon Recovery • Geologic Reservoir Characterization • Soils Conservation • Dilution of Direct Injected CO_2	• Geologic Storage Proven Safe • CO_2 Transport Infrastructure • Soils Uptake & Land Use • Ocean CO_2 Biological Impacts Addressed	• Track Record of Successful CO_2 Storage Experience • Large-Scale Sequestration • Carbon & CO_2 Based Products & Materials • Safe Long-Term Ocean Storage
GOAL #4 Other Gases	• Methane to Markets • Precision Agriculture • Advanced Refrigeration Technologies • PM Control Technologies for Vehicles	• Advanced Landfill Gas Utilization • Soil Microbial Processes • Substitutes for SF_6 • Catalysts That Reduce N_2O to Elemental Nitrogen in Diesel Engines	• Integrated Waste Management System with Automated Sorting, Processing & Recycle • Zero-Emission Agriculture • Solid-State Refrigeration/AC Systems
GOAL #5 Measure & Monitor	• Low-Cost Sensors and Communications	• Large Scale, Secure Data Storage System • Direct Measurement to Replace Proxies and Estimators	• Fully Operational Integrated MM Systems Architecture (Sensors, Indicators, Data Visualization and Storage, Models)

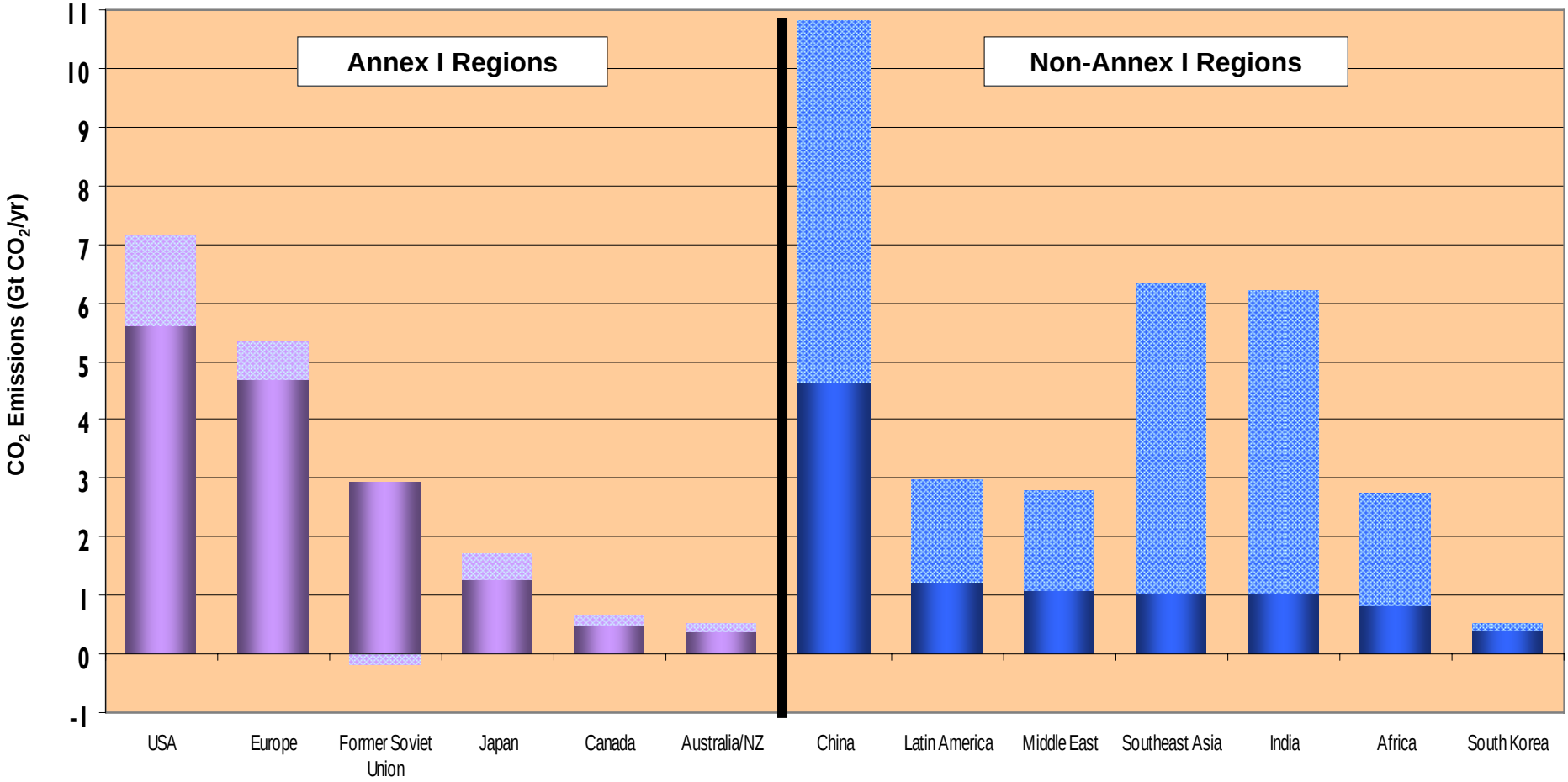
Estimated 100-Year Potential Cost Reductions

Comparative analysis of estimated cumulative costs over the 21st century of GHG mitigation, with and without advanced technology, across a range of hypothesized GHG emissions constraints.



Important Transitions Over the Coming Decades: CO_2 Emissions[1] by Region - 2000 & 2050

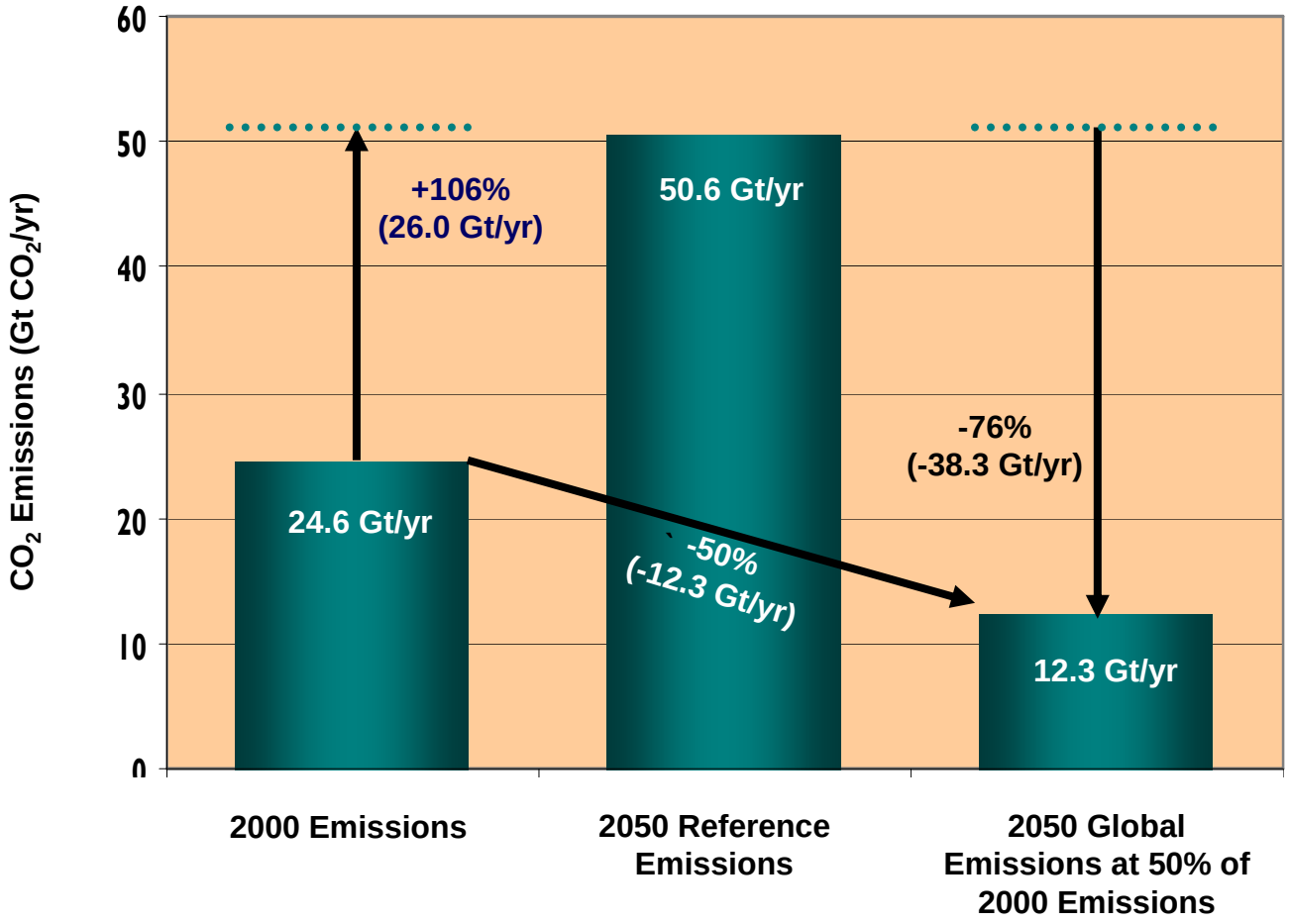
About 80 to 90% of the expected increase in GHG emissions between now and 2050 will come from developed countries, primarily China, India, and SE Asia.



[1] Includes Fossil and other industrial CO_2.

Source: Climate Change Science Program. 2007. *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations* (MINICAM Results).

Global CO_2 Emissions[1]—2000, 2050 Reference Case, and 2050 at 50% of 2000



[1] Includes fossil and other industrial CO_2.

Source: Climate Change Science Program. 2007. *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations* (MINICAM model results).

How Big is One Gigaton[1] of CO_2?

Technology	Actions that Provide 1 Gigaton per Year of Mitigation or Offsets[2]
Coal-Fired Power Plants	Build 320 "zero-emission" 500-MW coal-fired power plants (in lieu of coal-fired plants without CO_2 capture and storage) (73% capacity factor)
Geologic Sequestration	Install 1,000 sequestration sites like Norway's Sliepner project (1.0 $MtCO_2$/year)
Nuclear	Build 130 new nuclear power plants, each 1 GW in size (in lieu of new coal-fired power plants without CO_2 capture and storage) (90% CF)
Electricity from Landfill Gas Projects	Install 7,700 "typical" landfill gas electricity projects (typical size being 3 MW projects at non-regulated landfills) that collect landfill methane emissions and use them as fuel for electric generation
Vehicle Efficiency	Deploy 290 million new cars at 40 miles per gallon (mpg) instead of new cars at 20 mpg (12,000 miles per year)
Wind Energy	Install 170,000 wind turbines (1.5 MW each, operating at 0.45 capacity factor) in lieu of coal-fired power plants without CO_2 capture and storage
Solar Photovoltaics	Install 1.7 million acres of solar photovoltaics to supplant coal-fired power plants without CO_2 capture and storage (10% cell DC eff'cy; 1700 kWh/m2 solar radiance; 90% DC-AC conv. eff'cy).
Biomass fuels from plantations	Convert to biomass crop production a barren area about 5.4 times the total land area of Iowa (about 200 million acres)
CO_2 Storage in New Forest.	Convert to new forest a barren area about 2.5 times the total land area of the State of Washington (over 100 million acres) (Assumes Douglas Fir on Pacific Coast)

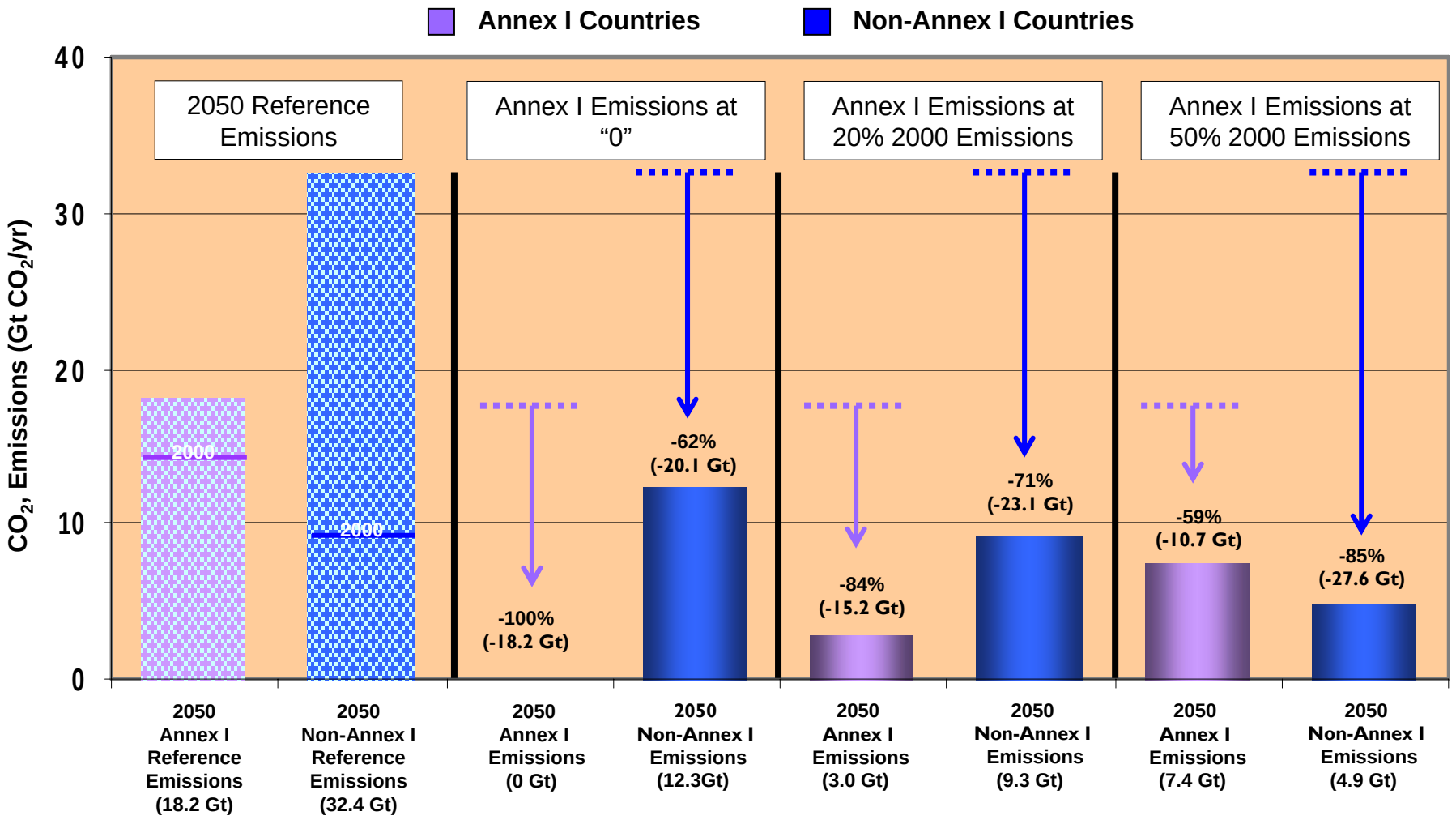
[1]Gigaton = 10^9 Metric Tons

[2] Based on current technology and U.S. data.

Source: Climate Change Technology Program. 2006. *Strategic Plan.* (Numbers updated and converted from carbon equivalents to carbon dioxide.)

A 50% Reduction in Global Emissions by 2050: Need Significant Reductions from Developing Countries

Annual Gigaton CO_2 and Percent Reductions from 2050 Reference[3]



[1] Includes fossil and other industrial CO_2.

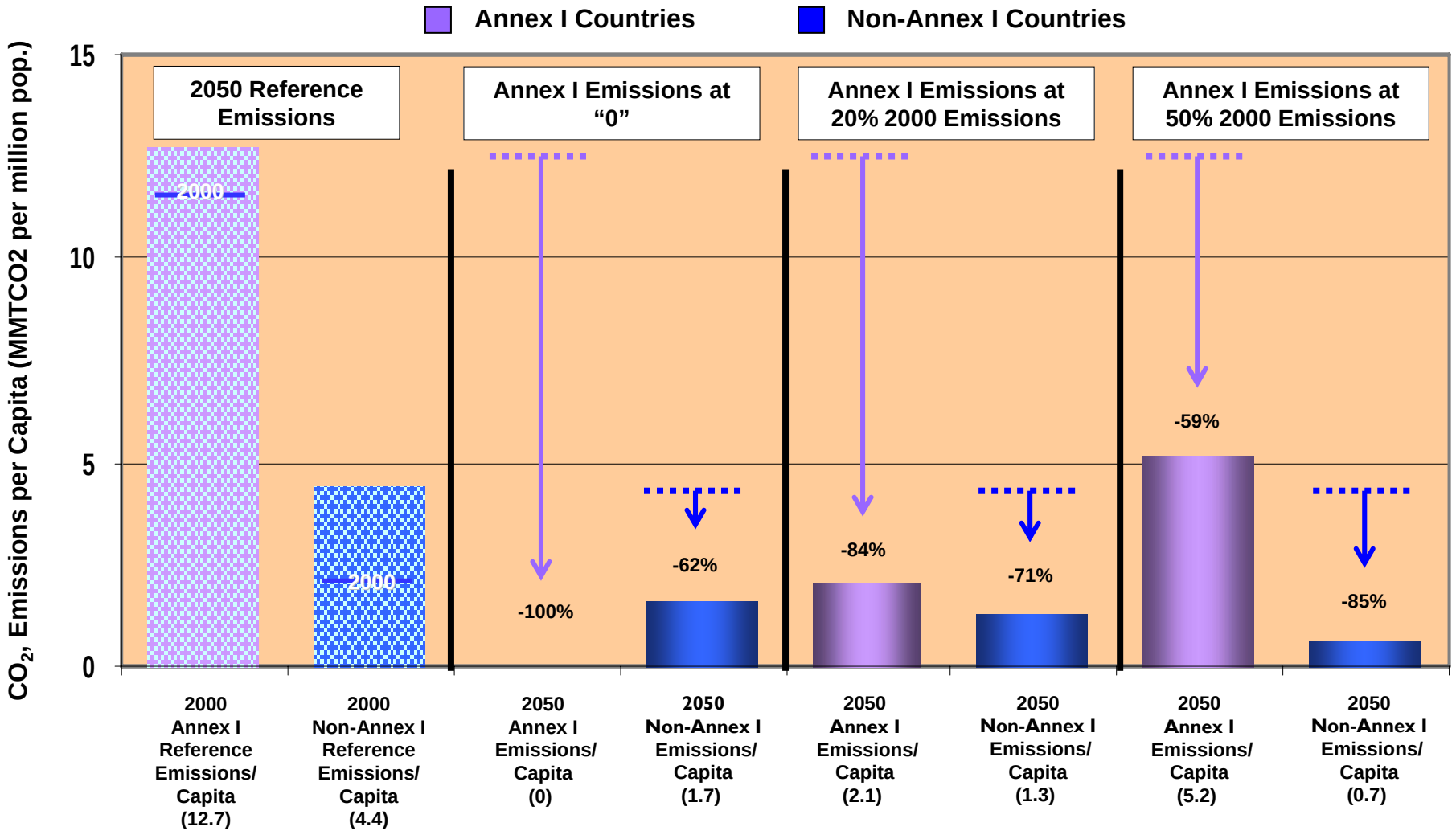
[2] 50% of 2000 global GHG emissions equals 12.3 Gt.

[3] Equals reduction from 2050 reference for that group (*i.e.*, Annex I or Non-Annex I).

Source: Climate Change Science Program. 2007. *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations* (MINICAM Model results).

A 50% Reduction in Global Emissions by 2050: Per Capita Emissions from Developing Countries Must Go Down

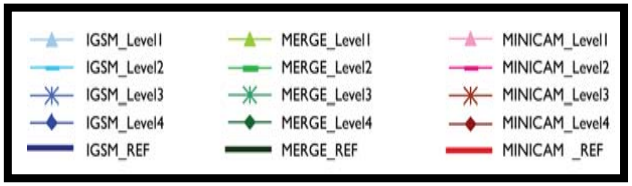
Percent Reductions from 2050 Reference[3]



[1] Measured as $MMTCO_2$ per million people, excluding LULUCF.
[2] 50% of 2000 global CO_2 emissions equals 12.3 Gt.
[3] Equals reduction from 2050 reference for that group (*i.e.*, Annex I or Non-Annex I).
Source: Climate Change Science Program. 2007. *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations* (MINICAM Model results).

Percentage of Global Electricity Production from Low- or Zero-Emissions Technologies by 2050

All three CCSP report models assume sufficient technological options—fossil power plants with CCS, nuclear power, and renewable energy—to allow for substantial reductions in global carbon emissions from electricity production. In all of the Level 1(≈450ppm CO_2) stabilization scenarios, the electricity sector undergoes significant decarbonization by 2050 (circles) and is essentially fully decarbonized by 2100.



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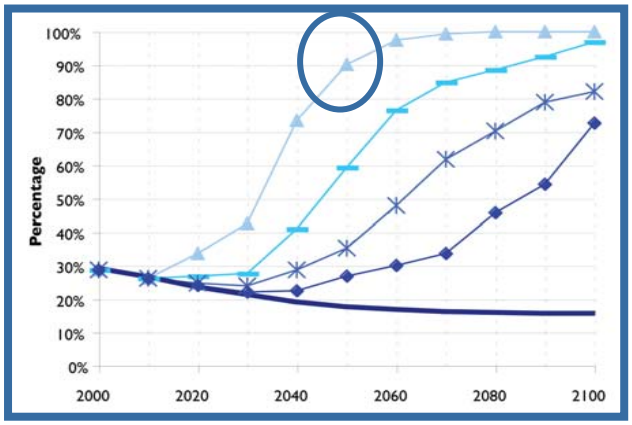

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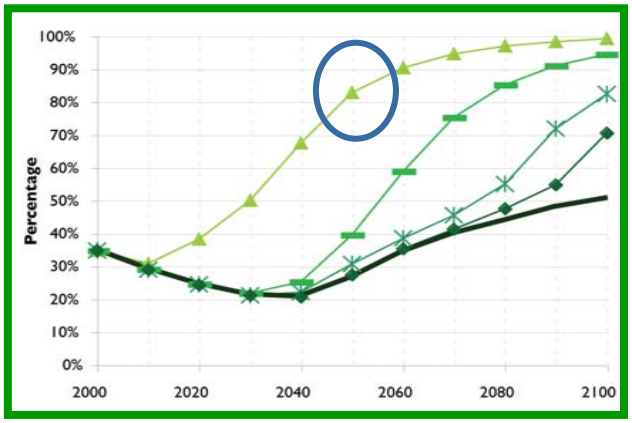
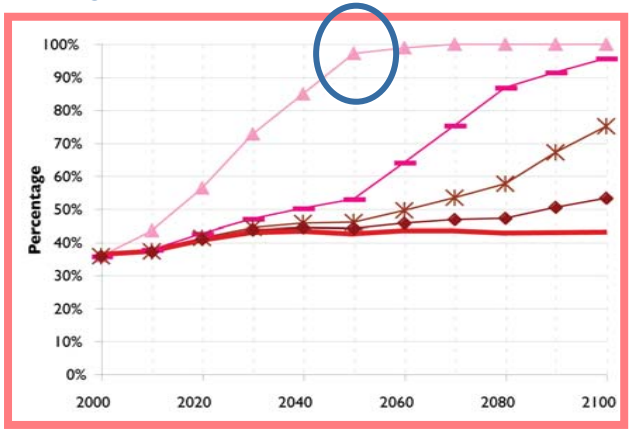


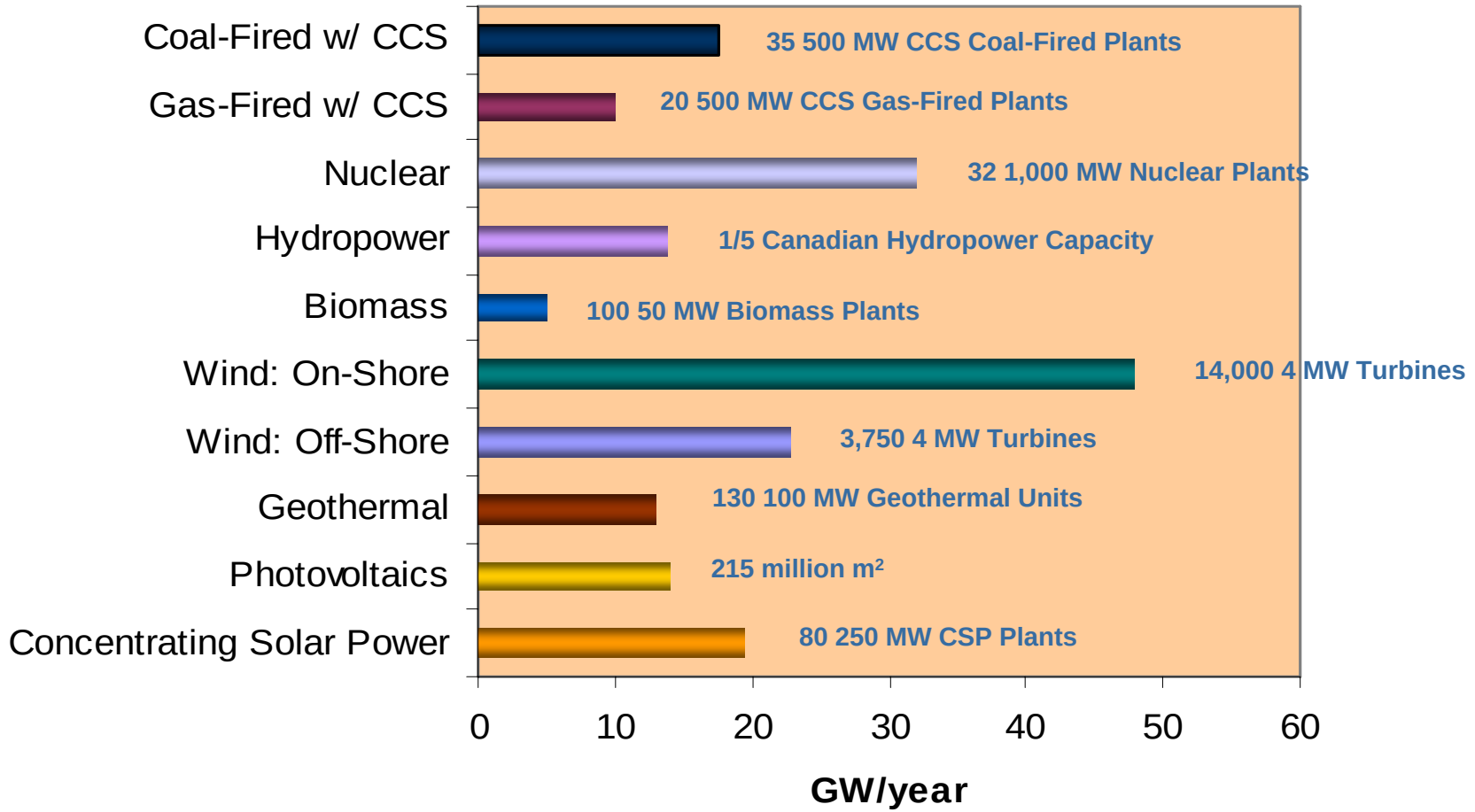
MINICAM



Source: Climate Change Science Program. 2007. *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*.

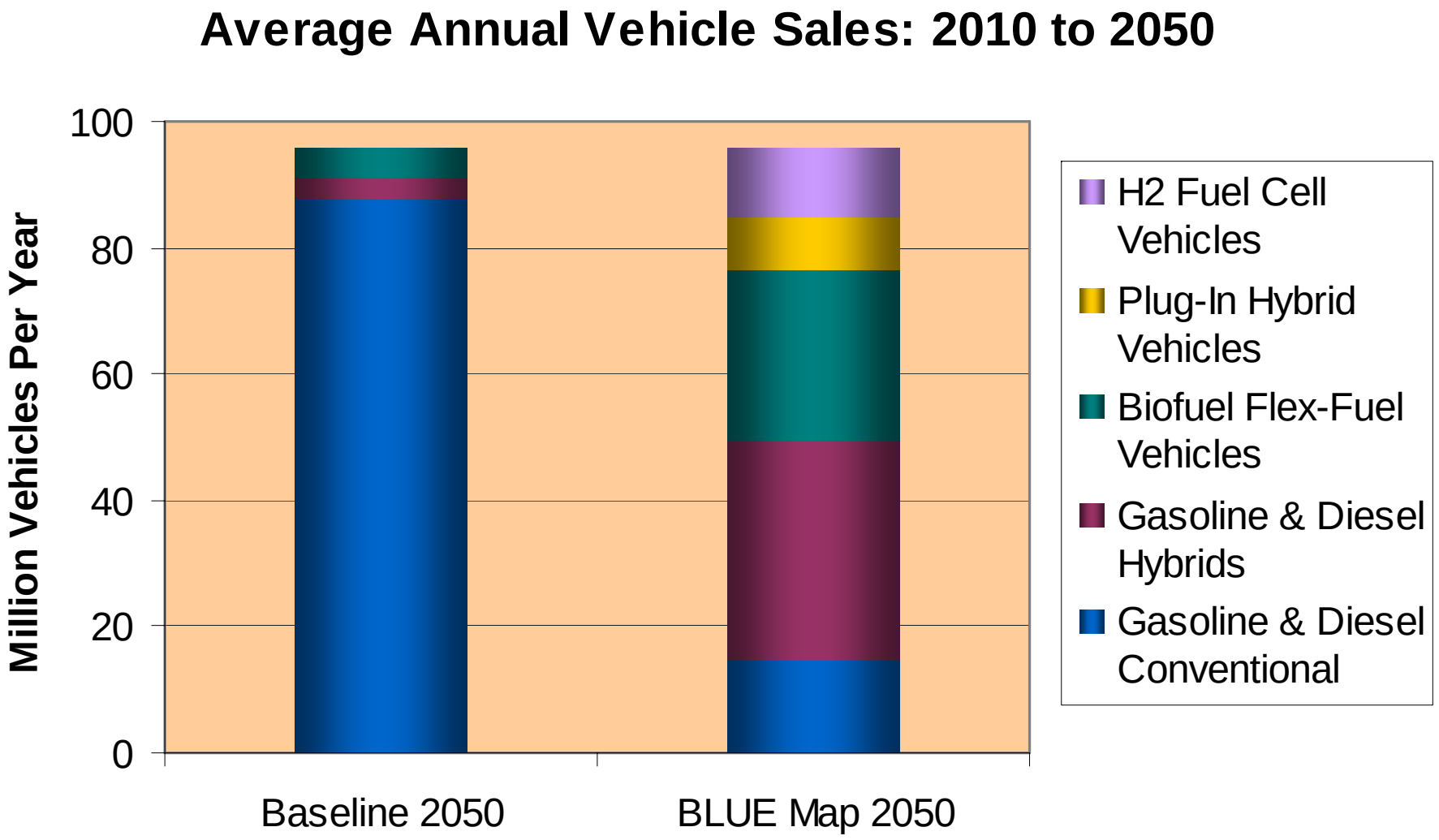
Scale of Changes in Power Sector: IEA "BLUE" Map

Average Annual Power Capacity Additions to Halve 2005 Global CO_2 Emissions by 2050: 2010 to 2050



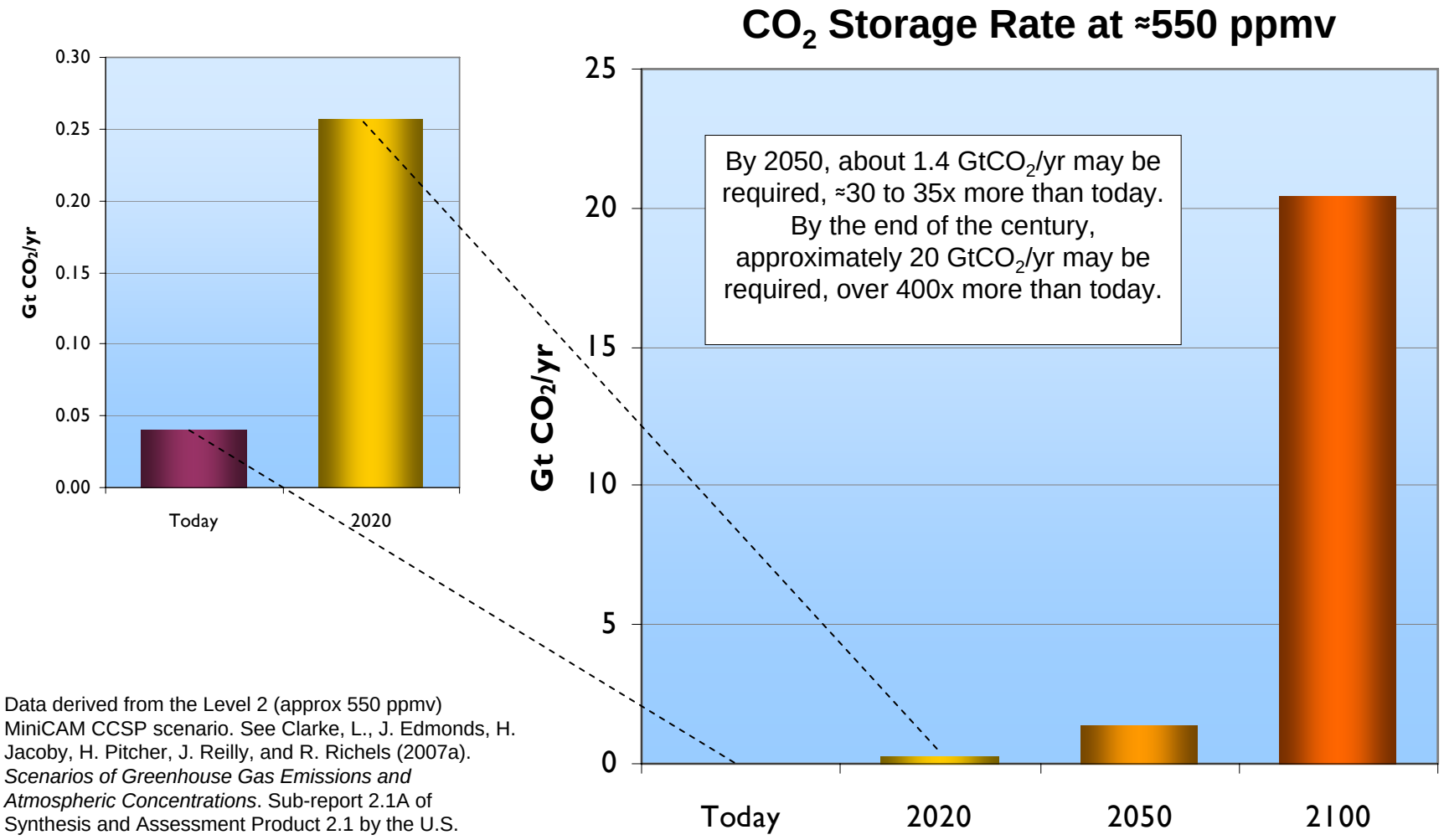
Source: International Energy Agency, Energy Technology Perspectives 2008, Scenarios and Strategies to 2050.

Scale of Changes in Transport Sector: IEA "BLUE" Map



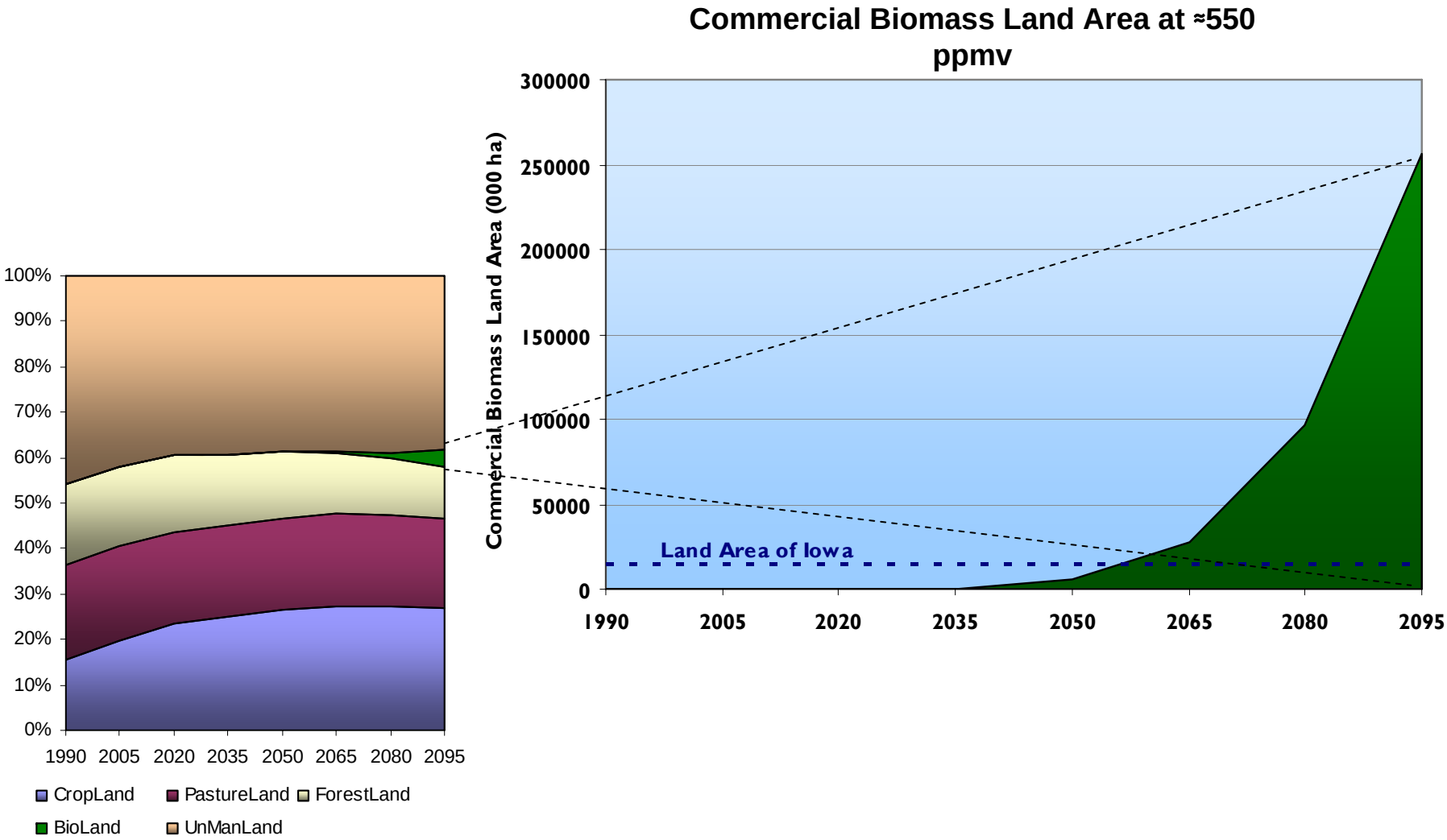
Source: International Energy Agency, Energy Technology Perspectives 2008, Scenarios and Strategies to 2050.

Scale of CO_2 Storage



Data derived from the Level 2 (approx 550 ppmv) MiniCAM CCSP scenario. See Clarke, L., J. Edmonds, H. Jacoby, H. Pitcher, J. Reilly, and R. Richels (2007a). *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*. Sub-report 2.1A of Synthesis and Assessment Product 2.1 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, D.C.: U.S. Department of Energy, Office of Biological & Environmental Research.

Scale of Biomass Land Area



Source: Climate Change Science Program. 2007. *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*. Data derived from the Level 2 (approx 550 ppmv) MiniCAM CCSP scenario.

A Path Forward Involves …

- International goal must be realistic and achievable.
- Progress in climate change technology to:
  - ✓ create new, better, and less costly solutions;
  - ✓ facilitate means for change and a smooth transition.
- Expanding finance & open trade in clean energy goods and services.
- Increasing opportunities for multilateral collaboration.
- Developing a new international framework that is economically sustainable and environmentally effective.