Reducing U.S. Greenhouse Gas Emissions: *How Much at What Cost?*

U.S. Greenhouse Gas Abatement Mapping Initiative

Beyond Science: The Economics and Politics of Responding to Climate Change

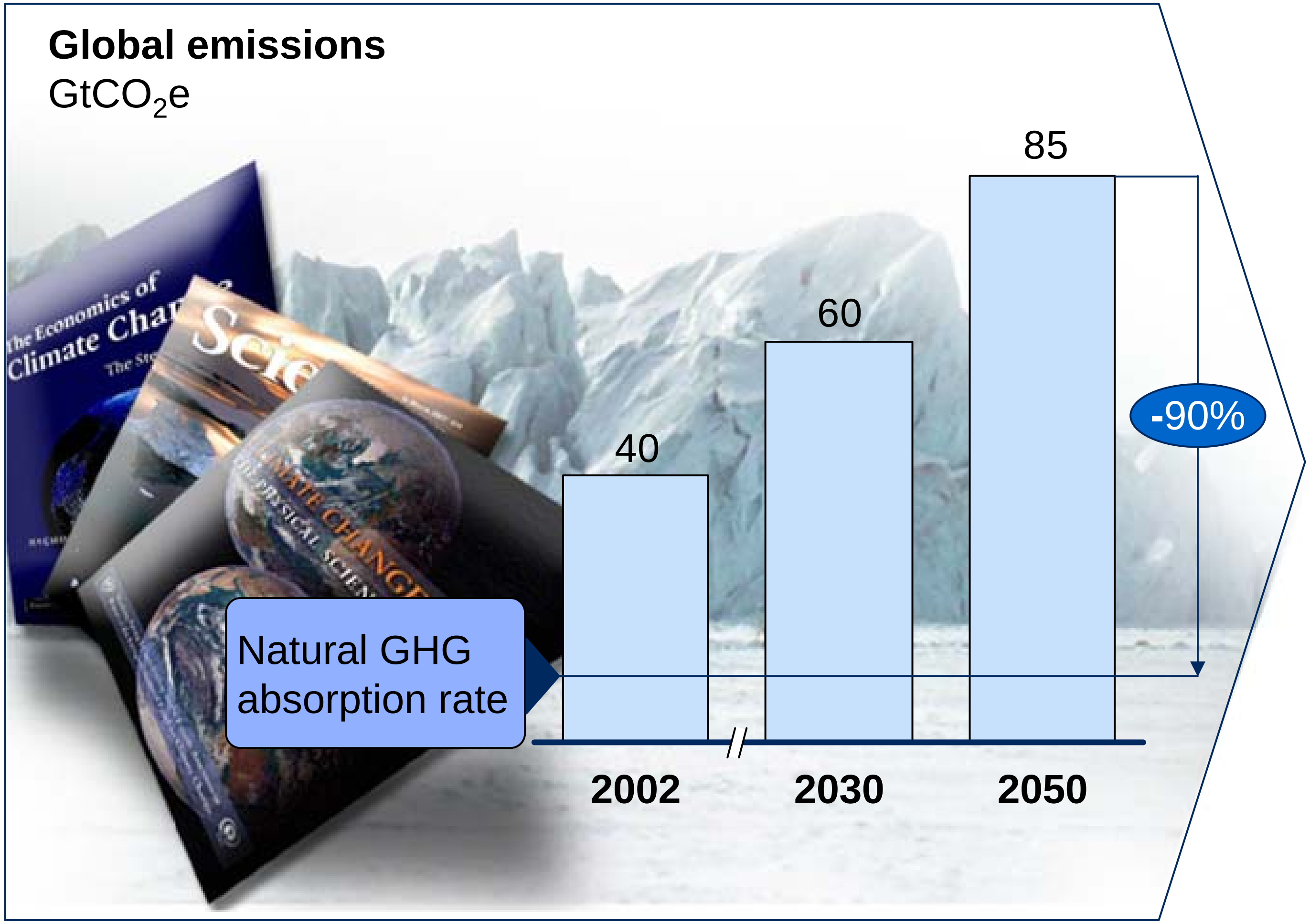
James A. Baker III Institute for Public Policy
Rice University

February 9, 2008

McKinsey&Company

The science suggests we need to "decarbonise" our economy by around 90% long term to stabilise the climate

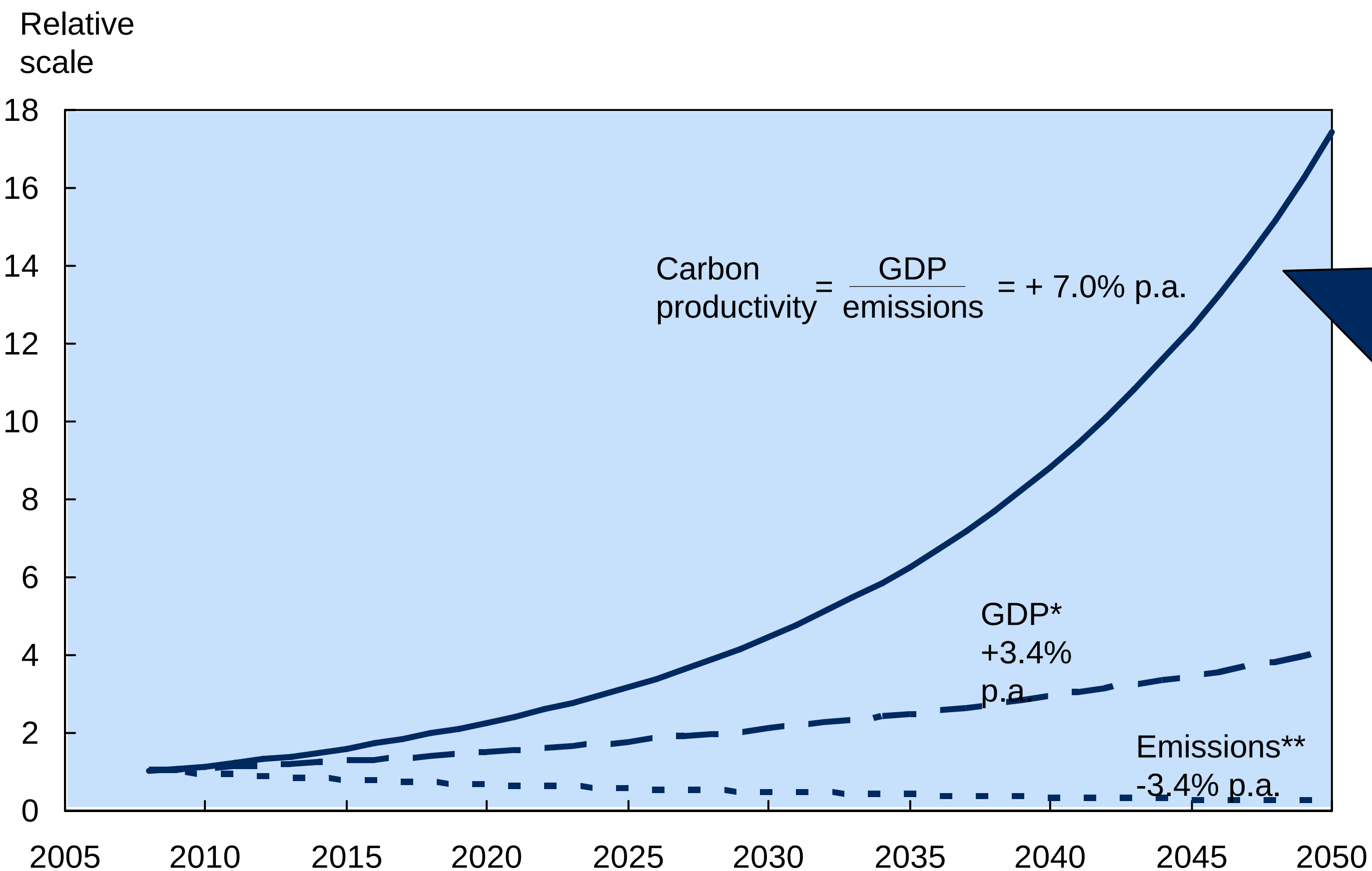
"Business as usual" GHG emissions



Requires a radical change towards a low carbon economy!

To achieve this carbon reduction with minimum impact on global economic growth, a massive increase in carbon productivity is needed

PRELIMINARY



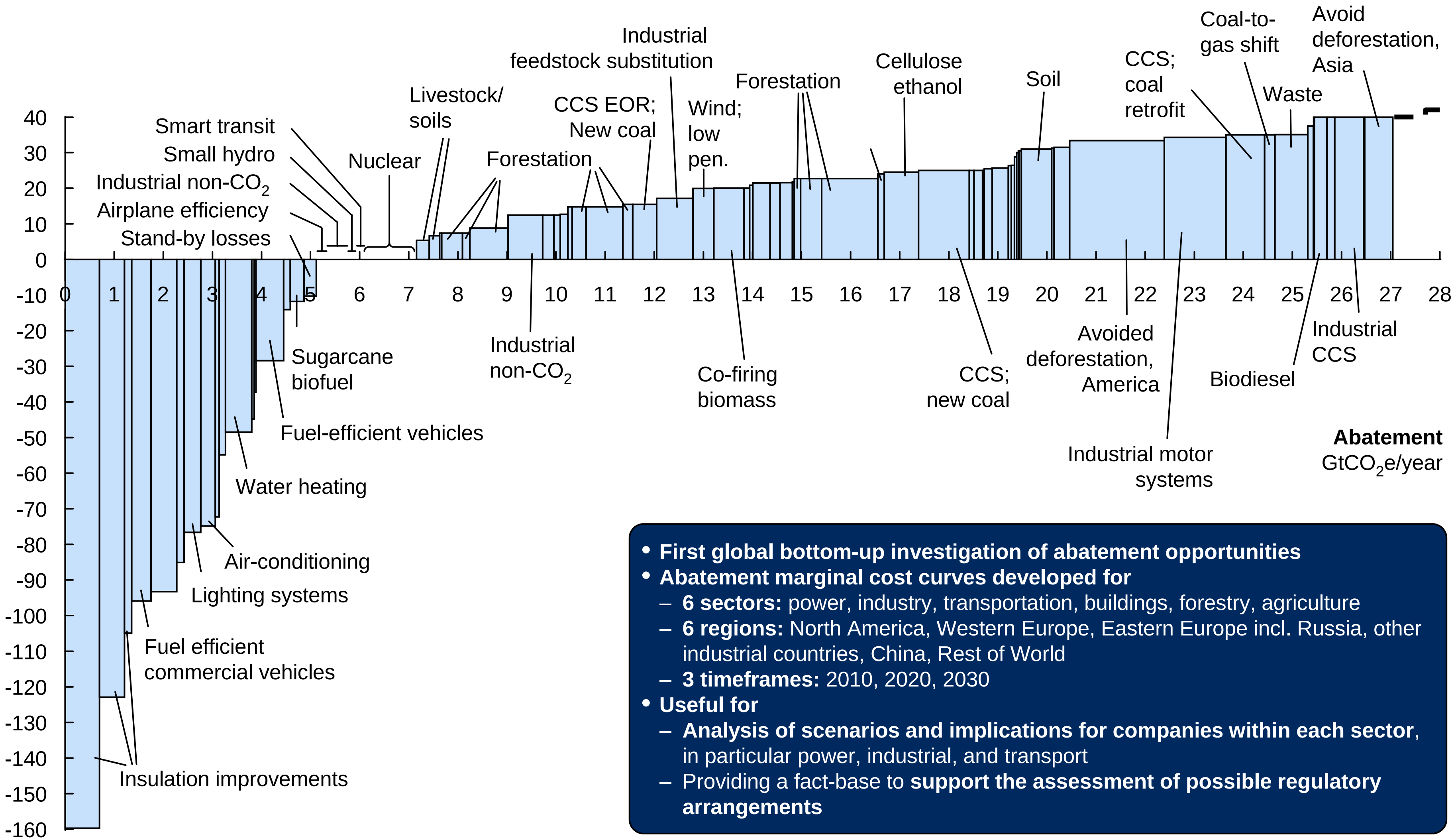
- For GDP growth to be held at 3.4% p.a. and carbon emissions to decrease by 3.4% p.a., carbon productivity has to increase by 7.0% p.a. (Historical improvement is just 1.0% p.a.)
- This is an increase of 4 times by 2030 and 17 times by 2050

* IEA estimated global GDP growth 2006-2030

** CAGR needed for emissions to drop to natural absorption rate of 10Gt/year by 2050

McKinsey has invested in a global mapping of greenhouse gas abatement opportunities

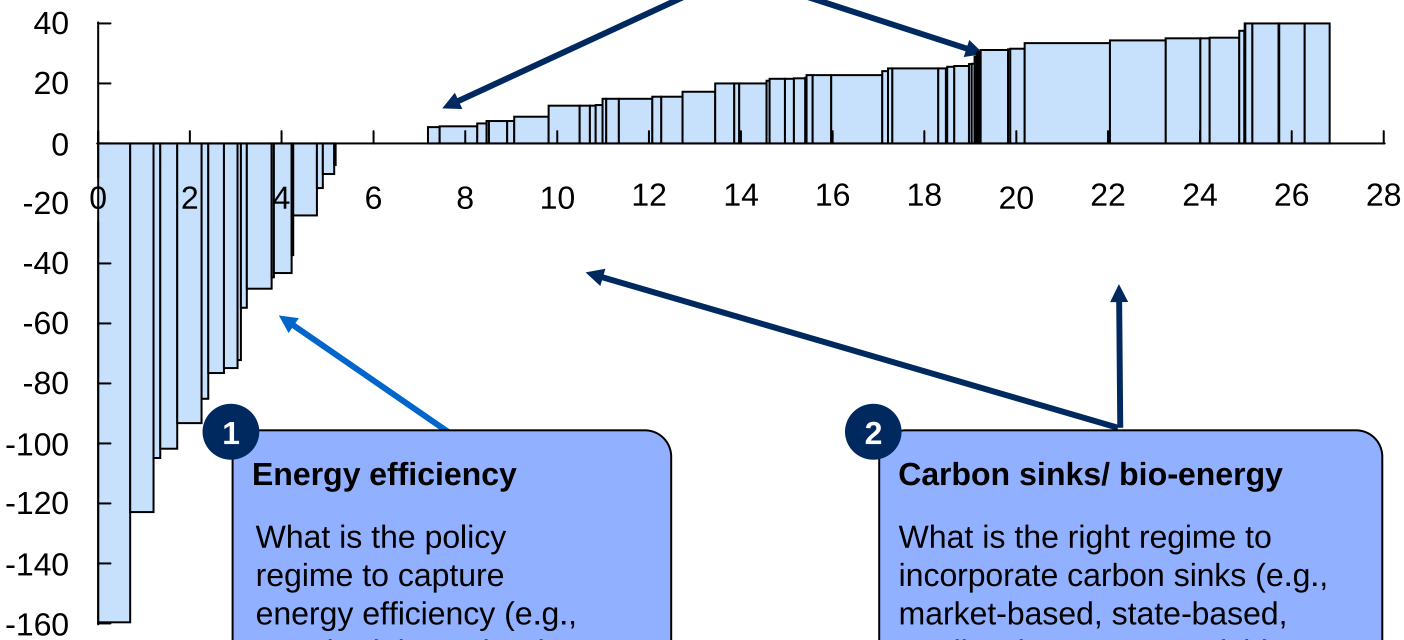
Cost of abatement, 2030, EUR/tCO_2e



- **First global bottom-up investigation of abatement opportunities**
- **Abatement marginal cost curves developed for**
  - **6 sectors:** power, industry, transportation, buildings, forestry, agriculture
  - **6 regions:** North America, Western Europe, Eastern Europe incl. Russia, other industrial countries, China, Rest of World
  - **3 timeframes:** 2010, 2020, 2030
- **Useful for**
  - **Analysis of scenarios and implications for companies within each sector**, in particular power, industrial, and transport
  - Providing a fact-base to **support the assessment of possible regulatory arrangements**

Source: Climate Change SI

Solution architecture – key policy issues



3 **Low carbon technology**

- What innovation policy levers should be adopted (e.g., learning curve subsidies, R&D incentives, tech transfer regime)?
- Should Nuclear be considered?

1 **Energy efficiency**

What is the policy regime to capture energy efficiency (e.g., standard, incentives)

2 **Carbon sinks/ bio-energy**

What is the right regime to incorporate carbon sinks (e.g., market-based, state-based, credit scheme, stewardship models)

Overall

- What should the global targets be?
- What market mechanism (e.g., cap and trade versus carbon tax, sectoral versus national models)
- How will adaptation be incorporated in climate change policies

U.S. Greenhouse gas abatement mapping

Objective: Develop a comprehensive, objective, consistent fact base to inform economically sensible approaches for reducing U.S. greenhouse gas (GHG) emissions

- Analyzed 250+ opportunities to reduce US GHG emissions by 2030
- Covered 7 sectors of the economy – buildings, power, transportation, industrial, waste, agriculture and forestry
- Relied on US government agencies (e.g., DOE, USDA, EPA) for emissions forecasts
- Conducted interviews with 100+ leading authorities and dozens of McKinsey subject matter experts around the globe
- Solicited guidance and support from top academics and corporate and environmental sponsors (DTE Energy, Environmental Defense, Honeywell, National Grid, NRDC, PG&E, Shell). The Conference Board is co-publishing and disseminating the report.

Project approach

We **did** look at:

- Man-made emissions within US borders
- Opportunities available under $50/ton of CO_2e
- Technologies and approaches with predictable costs and development paths
- Net capital, operating and maintenance costs (i.e., resource costs)

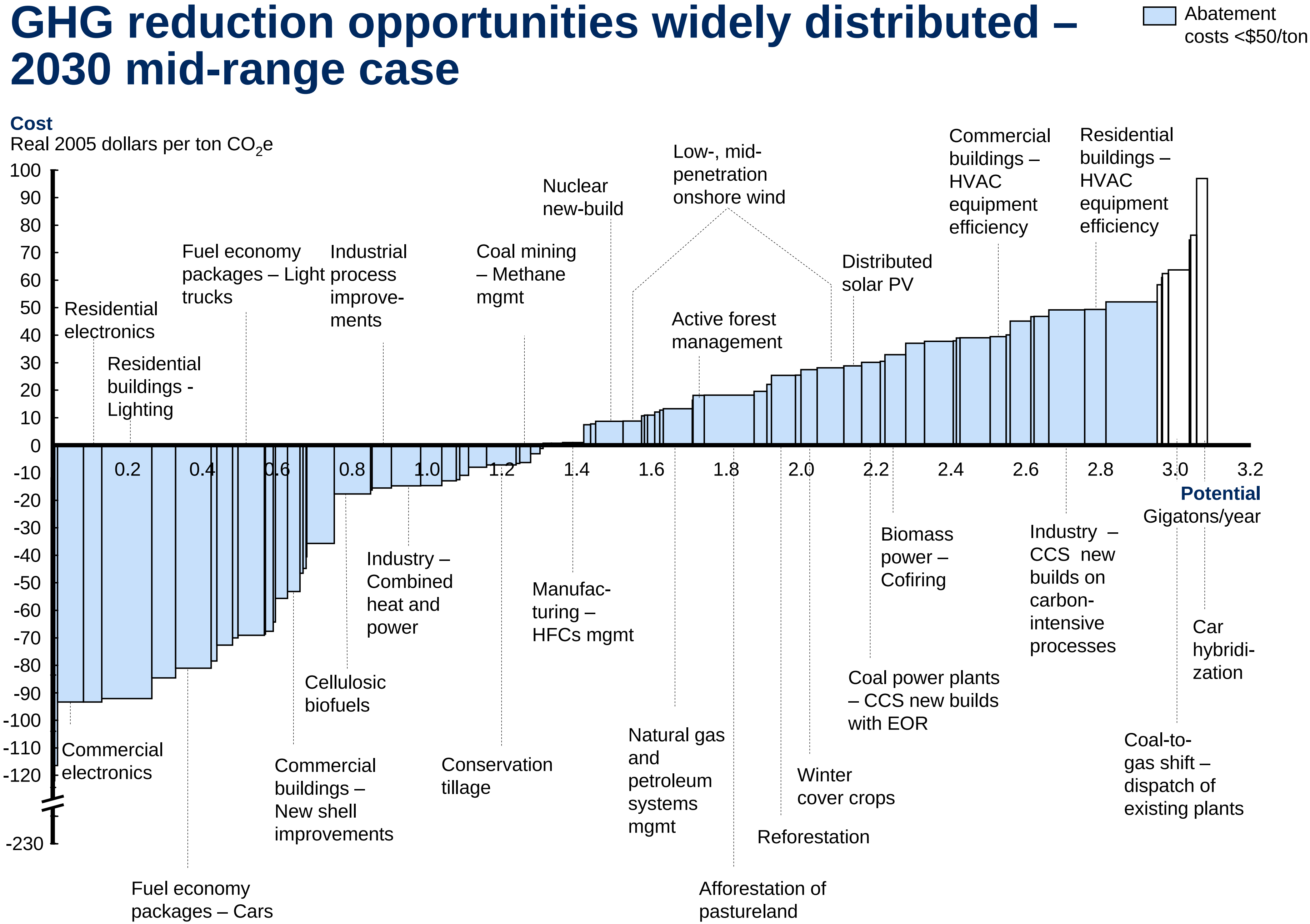
We **did not** look at:

- “Imported” carbon
- Policy implementation or transaction costs (e.g., enforcement)
- Dynamics of a potential carbon “price” (e.g., tax, cap and trade)
- Changes in consumer lifestyles (e.g., drive less, consume less)
- Potential “breakthrough” technologies to reduce GHG emissions
- Broader societal costs or benefits (e.g., impacts of mitigating climate change, less reliance on foreign oil)

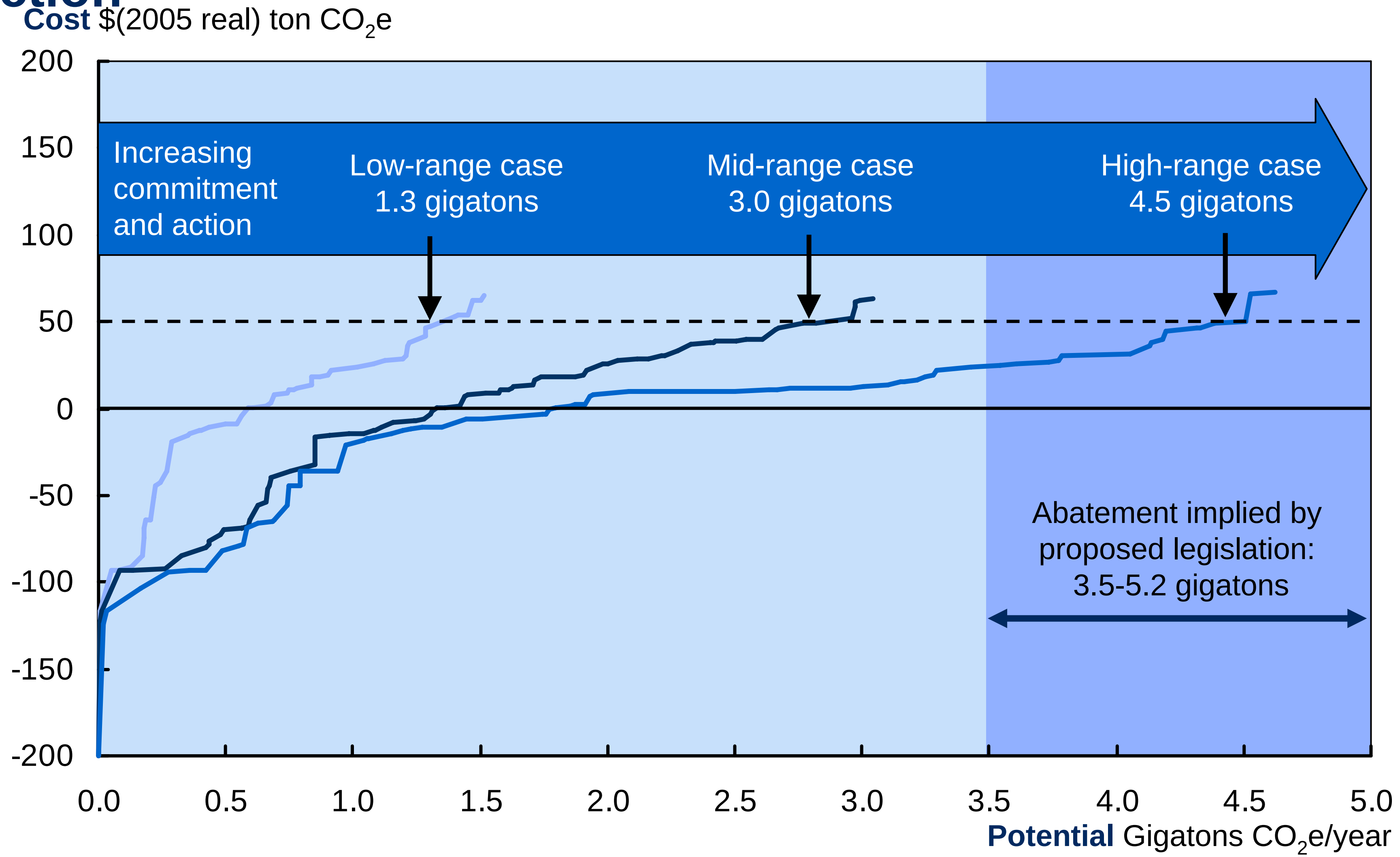
Major findings and conclusions

- Government sources project **US GHG emissions to rise 35 percent by 2030** – in contrast to reductions called for by climate scientists and proposed legislation
- Our project identified **3.0 gigatons (mid-range) to 4.5 gigatons (high-range) of CO_2e reductions** vs. the 2030 reference case emissions forecast of 9.7 gigatons, using tested approaches and high-potential emerging technologies
- Low cost **opportunities are distributed widely** across sectors and geographies
- Roughly **40 percent of reductions identified could generate net savings to the economy** over their lifetimes
- If captured, these **savings can substantially offset the remaining total capital, operating, and maintenance costs** required to reach mid-range abatement levels
- **Five major "clusters" of reduction potential identified** – each rich in GHG reduction potential
- Achieving reductions at lowest cost to the US economy requires **strong, coordinated, economy-wide action that begins in the near future**

GHG reduction opportunities widely distributed – 2030 mid-range case



3.0 to 4.5 gigatons of reduction potential available with concerted economy-wide action



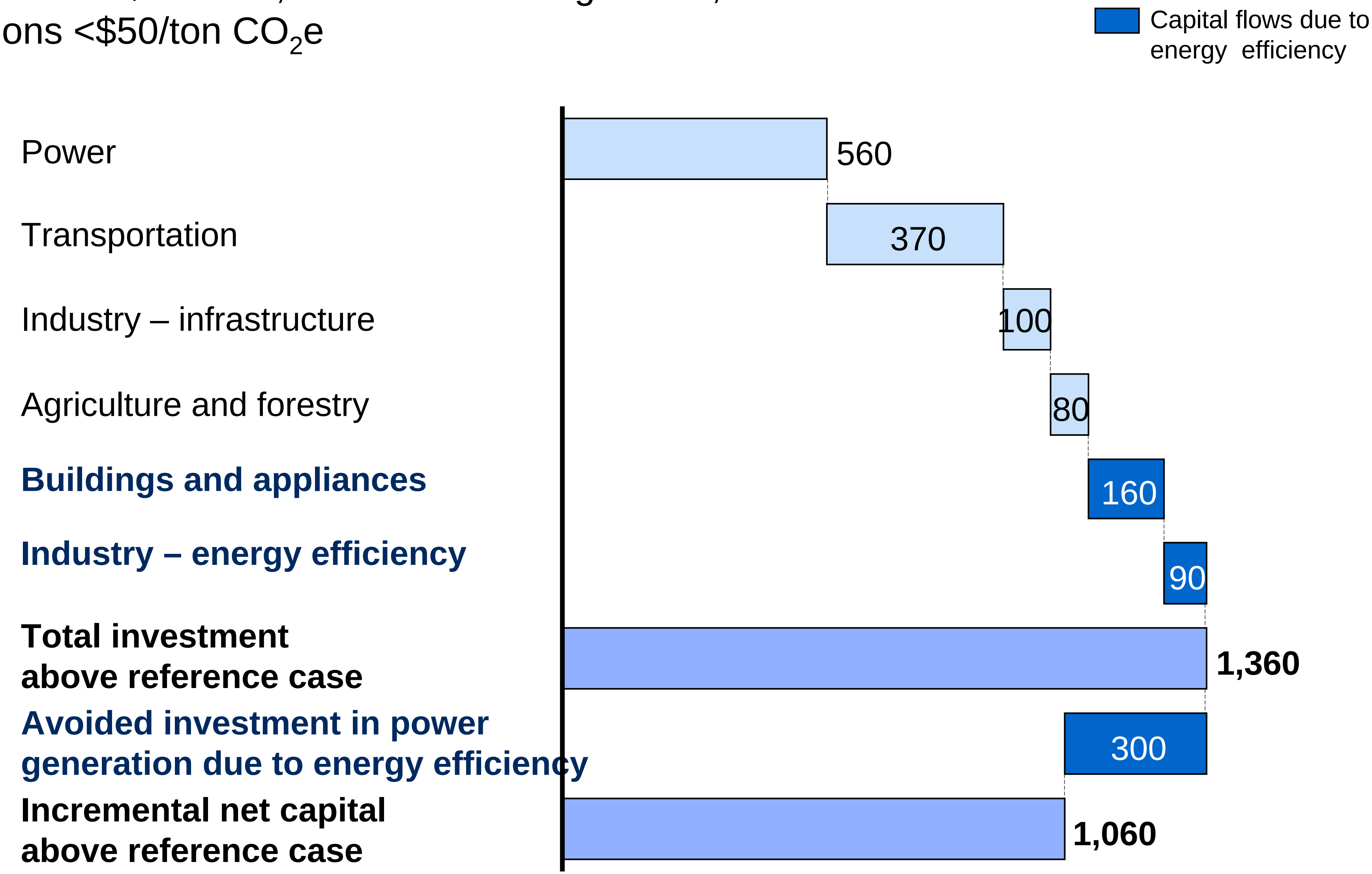
* Based on bills introduced in Congress that address climate change and/or GHG emissions on an economy-wide basis and have quantifiable targets; targets calculated off the 2030 U.S. GHG emissions of 9.7 gigatons CO_2e/year (reference case)

Source: McKinsey analysis

Incremental capital investment in mid-range case

MID-RANGE CASE – 2030

Real 2005 $ Billions, cumulative through 2030; options <$50/ton CO_2e

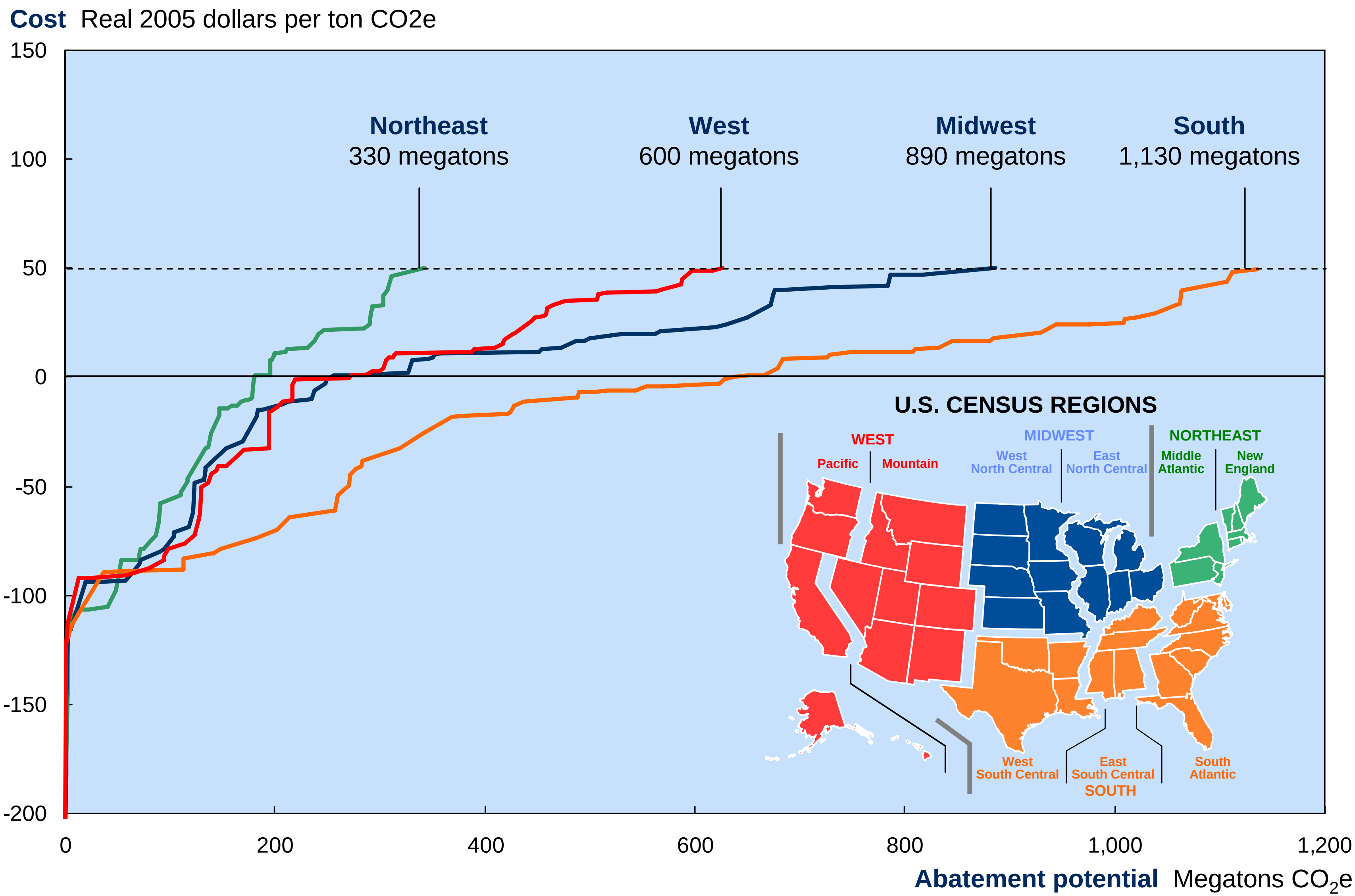


* Including Waste industry

Source: McKinsey analysis

Geographic differences in abatement cost

MID-RANGE CASE – 2030

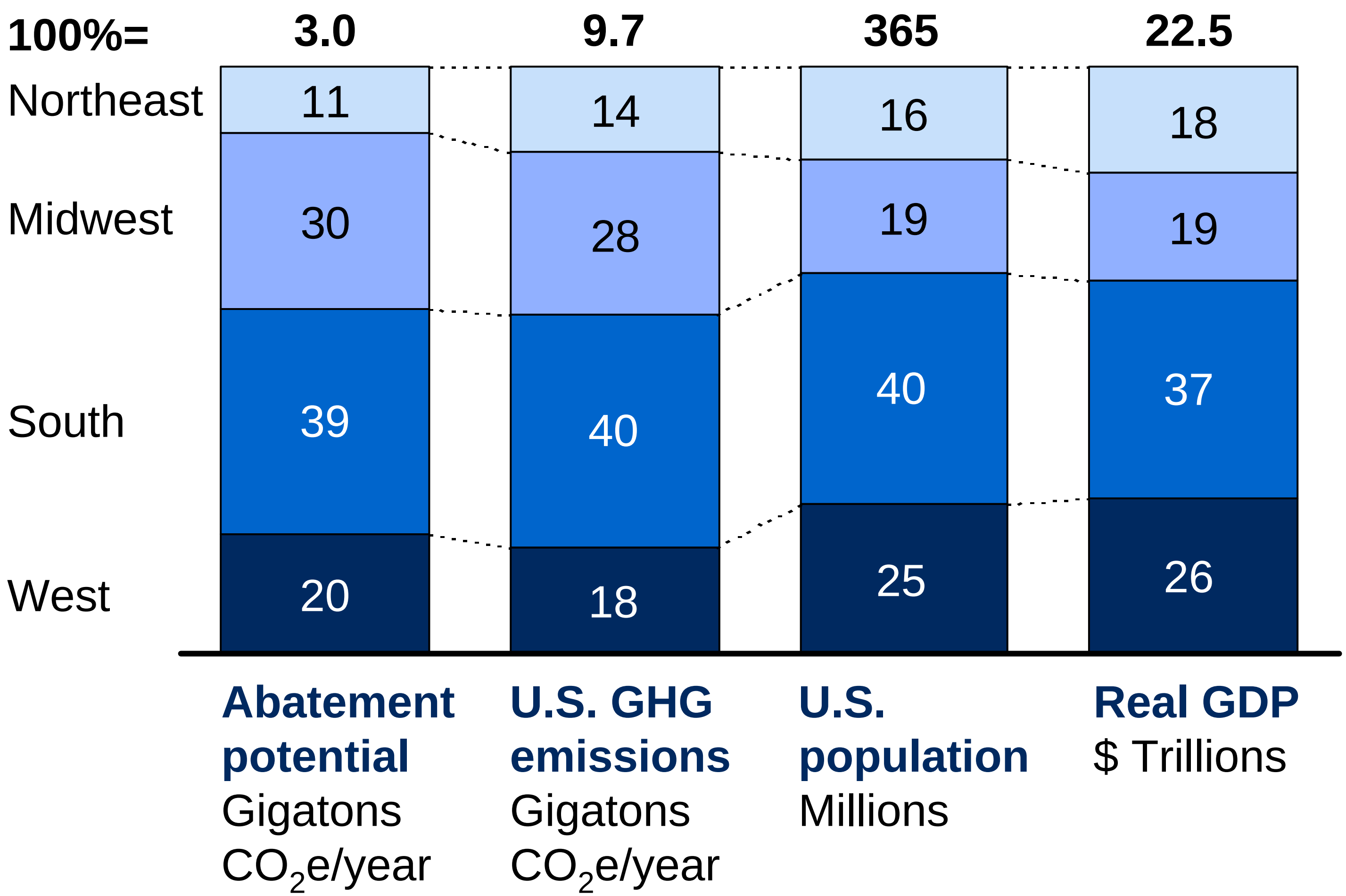


Source: McKinsey analysis

Geographic differences in abatement potential, emissions, population and GDP – 2030

MID-RANGE CASE – 2030

Percent

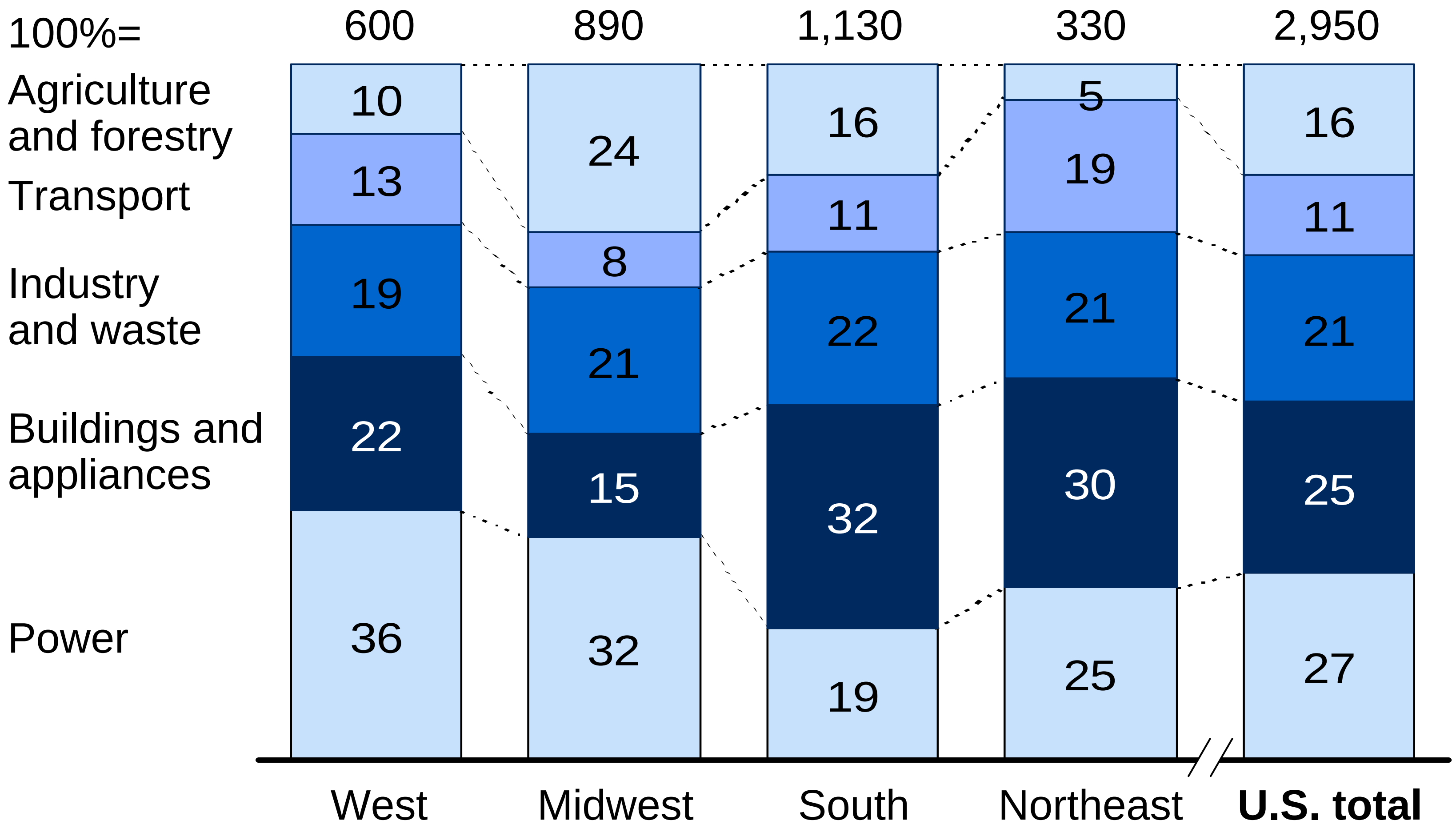


Source: U.S. EIA Annual Energy Outlook (2007) "Reference case," U.S. EPA; USDA; McKinsey analysis

Geographic differences in abatement potential by sector

MID-RANGE CASE – 2030

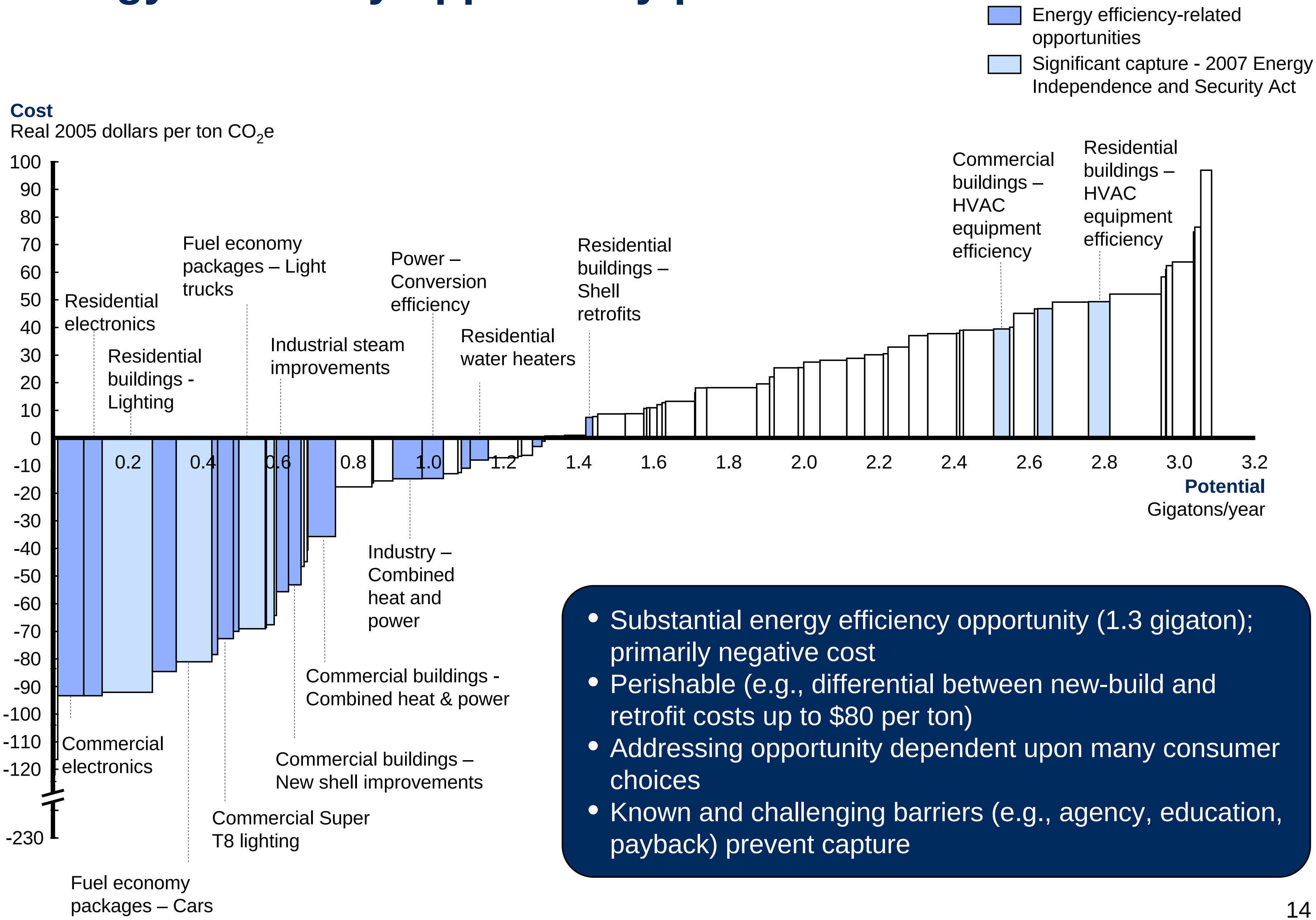
Percent, Megatons CO_2e/year



Source: McKinsey analysis

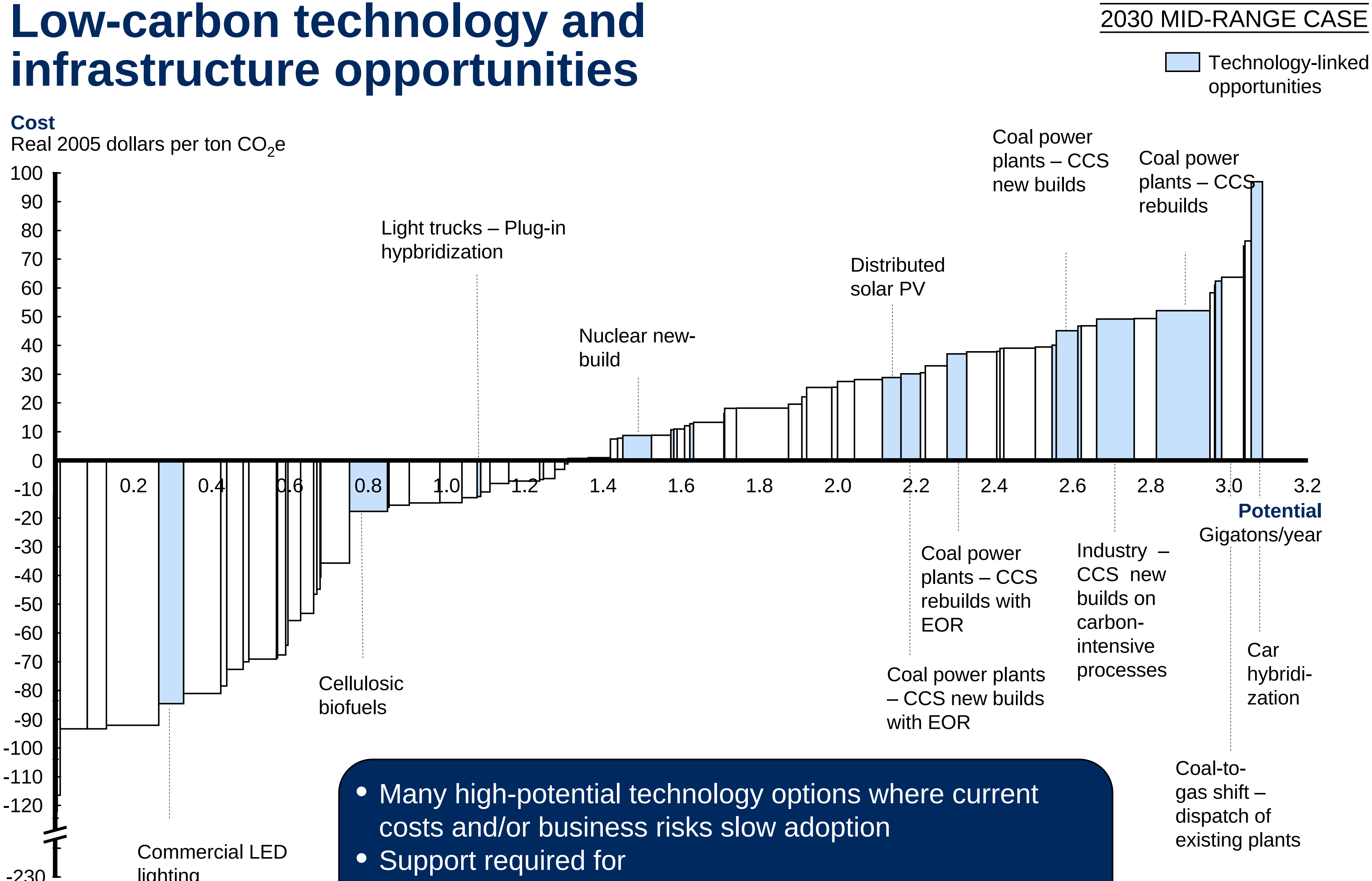
Energy efficiency opportunity profile

2030 MID-RANGE CASE



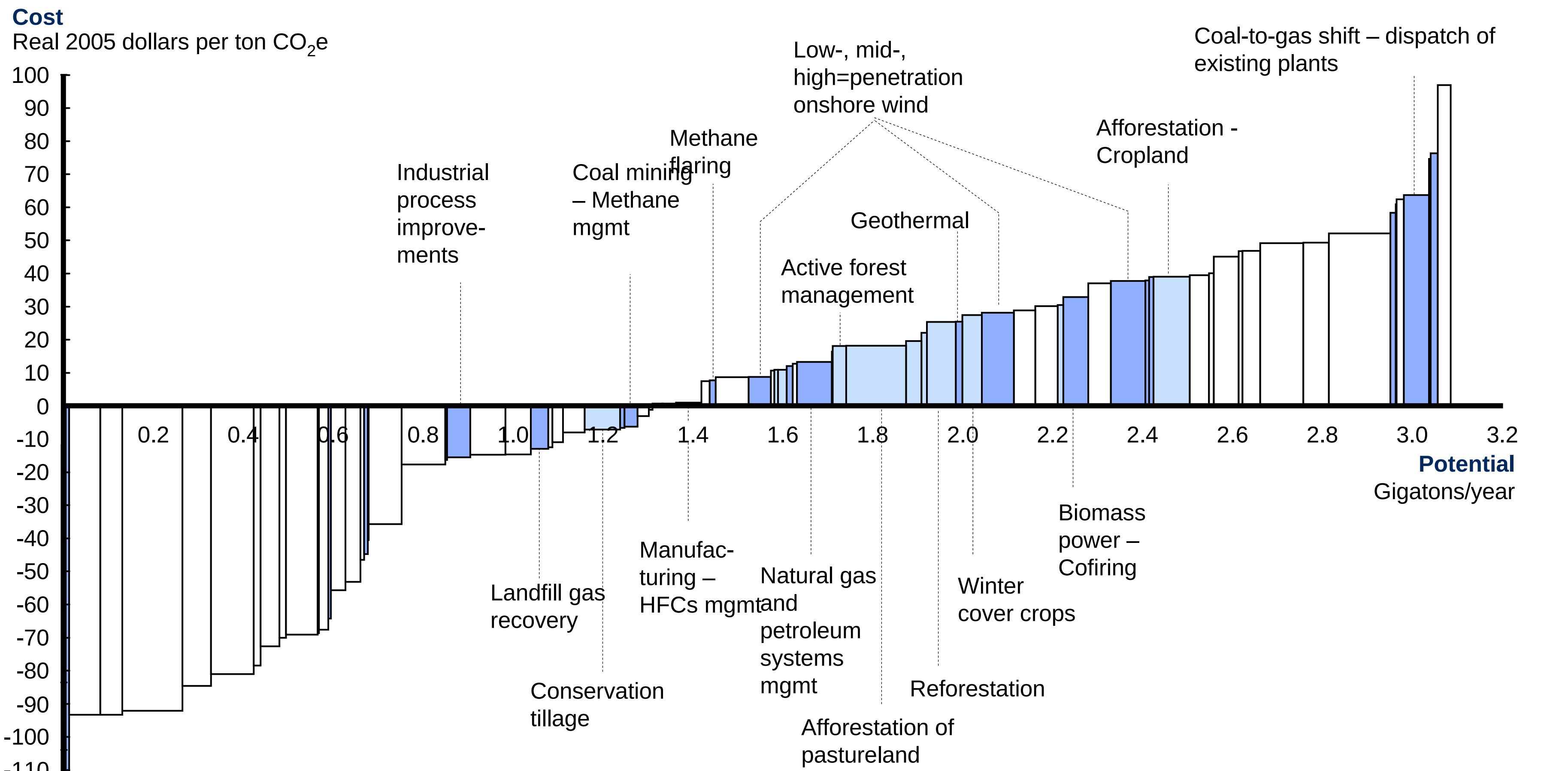
- Substantial energy efficiency opportunity (1.3 gigaton); primarily negative cost
- Perishable (e.g., differential between new-build and retrofit costs up to $80 per ton)
- Addressing opportunity dependent upon many consumer choices
- Known and challenging barriers (e.g., agency, education, payback) prevent capture

Low-carbon technology and infrastructure opportunities



- Many high-potential technology options where current costs and/or business risks slow adoption
- Support required for
  – Research, development and deployment
  – Debottlenecking of business and regulatory processes

Carbon sink and other industrial/ power potential



- Carbon sinks (e.g., forestry, land-use) are 16% of total abatement potential
- Impermanence is key issue; monitoring and verification processes critical
- Additional options in industrial (e.g., methane, HFC, PFC management; landfill, mining and transport gas recovery) and power (e.g., wind, geothermal, biomass, small hydro)

Drivers of 2030 GHG abatement potential

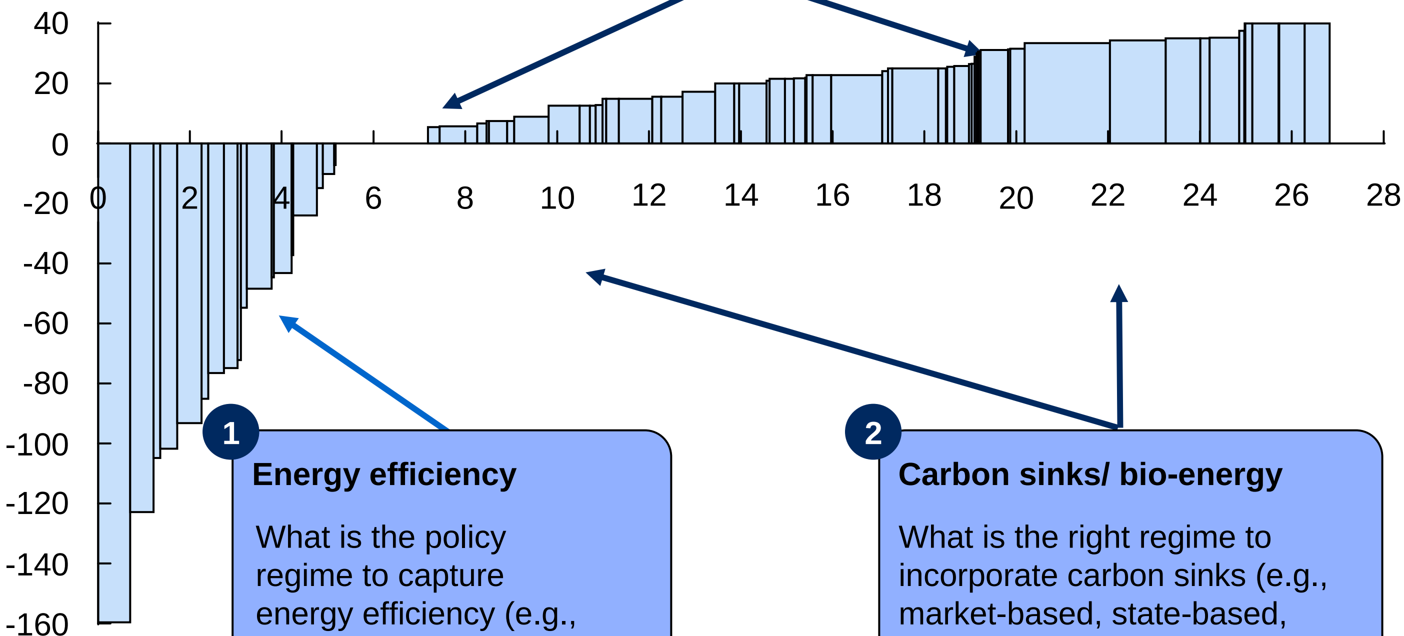
(x) Abatement potential below $50/ton, gigatons

	2005	Low-range case	Mid-range case	High-range case
Coal with CCS Gigawatts	• 0	22	55	83
Nuclear Gigawatts	• 100	113	129	153
Renewables Gigawatts	• Wind – 10 • Solar – <1	70 38	116 80	164 228
Cellulosic biofuels Billion gallons	• 0	5	14	51
Light duty vehicle performance - mpg	• 25 mpg	30	40	44
Efficient new residential lighting	• 8%	15%	70%	75%
		1.3	3.0	4.5

Solution architecture – key policy issues

3 **Low carbon technology**

- What innovation policy levers should be adopted (e.g., learning curve subsidies, R&D incentives, tech transfer regime)?
- Should Nuclear be considered?



1 **Energy efficiency**

What is the policy regime to capture energy efficiency (e.g., standard, incentives)

2 **Carbon sinks/ bio-energy**

What is the right regime to incorporate carbon sinks (e.g., market-based, state-based, credit scheme, stewardship models)

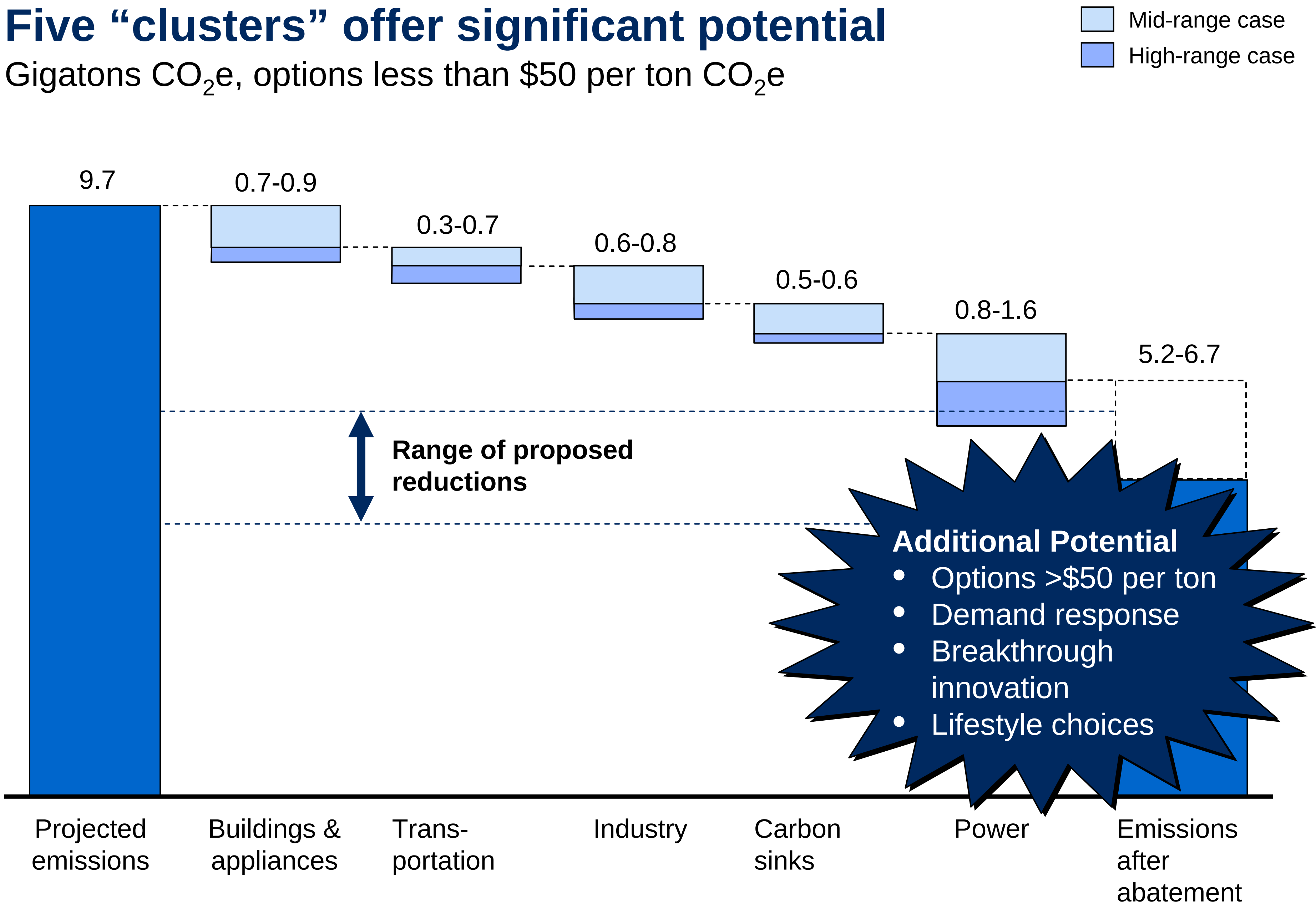
Overall

- What should the global targets be?
- What market mechanism (e.g., cap and trade versus carbon tax, sectoral versus national models)
- How will adaptation be incorporated in climate change policies

Appendix

Five “clusters” offer significant potential

Gigatons CO_2e, options less than \$50 per ton CO_2e



Many “negative-cost” options in buildings and appliances

MID-RANGE CASE – 2030

Options less than \$50/ton CO_2e

	Average cost \$(2005 real)/ton CO_2e	Potential Megatons CO_2e	Description
Lighting	-87	240	• Substitution of advanced lighting technologies
Electronic equipment	-93	120	• Greater in-use efficiency and reduced stand-by losses
HVAC equipment	45	100	• More efficient equipment for initial installation and retrofits • Performance tuning for existing systems
Combined heat and power	-36	70	• Increased use with office buildings >100,000 sq. ft, hospitals and universities
Building shell	-42	60	• Improved new-build shells and retrofits from better insulation, air tightening, reflective roof coatings
Residential water heaters	-8	50	• Improved efficiency units and switch to alternative fuel/ technologies
Other		70	• Building controls • Residential and commercial appliances • Commercial water heaters

Source: McKinsey analysis

Large – but higher-cost – potential in electric power generation

Options less than $50/ton CO_2e

	Average cost $(2005 real)/ton CO2e	**Potential** Megatons CO_2e	**Description**
Carbon capture and storage	44	290	• Rebuilds of pulverized coal plants with CCS, plus CCS new builds • Includes injection to enhance oil recovery
Wind	20	120	• Class 5-7 on-shore winds with economic grid integration costs
Nuclear	9	70	• Nuclear power plant new-builds • Up-rates for existing nuclear plants • Reactivations
Conversion efficiency	-15	60	• Improved heat rates of base-load pulverized coal power plants
Solar PV	29	50	• Residential and commercial distributed power generation with solar photovoltaics
Other		210	• Low-class on-shore and offshore wind (90 MT) • Concentrating solar power (50) • Biomass co-firing (50) • Geothermal power (10) • Small hydroelectric power (10)

Source: McKinsey analysis

Vehicle fuel economy and lower-carbon fuels crucial for transportation

MID-RANGE CASE – 2030

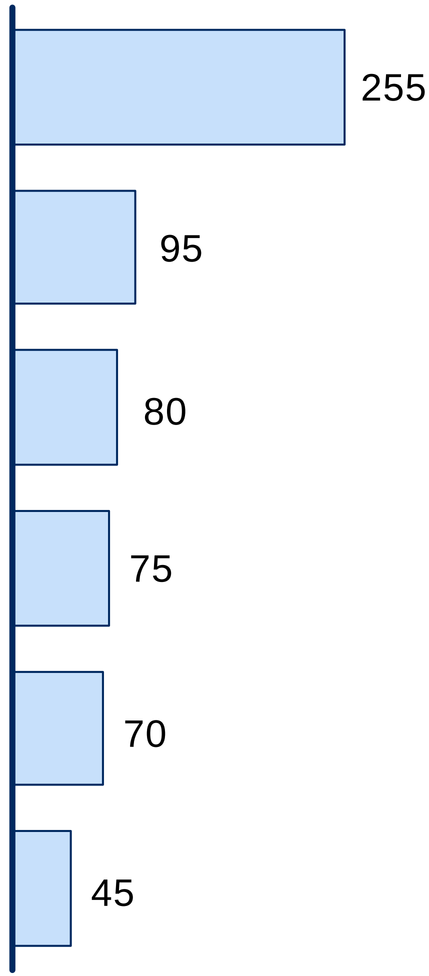
Options less than \$50/ton CO_2e

	Average cost \$(2005 real)/ton CO2e	Potential Megatons CO_2e	Description
Cellulosic biofuels	-18	100	• Commercialization with various feedstocks and conversion processes
Fuel economy – cars	-81	95	• Various technology upgrades to improve fuel efficiency • Greater use of alternative propulsion systems (diesel)
Fuel economy – light trucks	-69	70	(same as above: fuel economy – cars and light trucks)
Fuel economy – medium / heavy trucks	-8	30	• Technology upgrades to improve fuel efficiency
Light-duty plug-in hybrids	15	20	• Plug-in capability in addition to basic hybridization
Other		25	• Hybridization of medium and heavy trucks • Aircraft fuel efficiency from design and operations • Reduced leakage from air conditioning systems

Source: McKinsey analysis

Options in industrial and waste sectors highly fragmented

Options less than \$50/ton CO_2e



Option	**Average cost** \$(2005 real)/ton CO2e	**Potential** Megatons CO_2e	**Description**
Recovery / destruction of non-CO_2 GHGs	3	255	• Methane in mining, fossil-fuel systems, waste • HFCs/PFCs in manufacturing • N_2O in chemical processes
Carbon capture and storage	49	95	• Carbon-intensive processes like coal-to-liquids • Co-generation sites with CCS new-builds
Combined heat and power	-15	80	• For primary metals, food, refining, chemicals, pulp and paper processes • Medium and large turbine applications (>5 MW)
Energy efficiency	6	75	• Measures on fired and steam systems, process controls, energy recovery, maintenance • Electric motor upgrades and specific system improvements
Process and product innovations	-33	70	• Greater use of advanced processes, recycling and product recovery, product reformulation and commercial use of emerging technologies
Other		45	• Composting • Capping and restoration layers in land fills • Small-scale electric generation projects

Source: McKinsey analysis

Significant potential at moderate cost in terrestrial carbon sinks

Options less than \$50/ton CO_2e

	Average cost \$(2005 real)/ton CO2e	**Potential** Megatons CO_2e	**Description**
Afforestation – pastureland	18	130	• New trees primarily on marginal or idle land where erosion is high and/or productivity is low
Forest management	23	110	• Active – thinning, stand improvement • Passive – restricted grazing, natural regeneration • Restoration of degraded forests
Afforestation – cropland	39	80	• New trees primarily on marginal or idle land where erosion is high and/or productivity is low
Conservation tillage	-7	80	• Planting crops amid previous crop’s residue, e.g., using ridge tillage and no-till farming
Winter cover crops	27	40	• Planting harvested cropland with grass or legume cover crop during winter
Other		<5	• Elimination of summer fallow

Source: McKinsey analysis

For more information please contact:

Scott_Nyquist@McKinsey.com

Or visit our website at:

http://www.mckinsey.com/clientservice/ccsi/greenhousegas.asp