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THE CONFERENCE BOARD

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

US Greenhouse Gas Abatement Mapping Initiative

US EPA Climate Leaders - Boulder, CO

December 5, 2007

Project background

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.

Not intended to advocate specific policies or approaches. All content and conclusions solely the responsibility of McKinsey & Company

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)

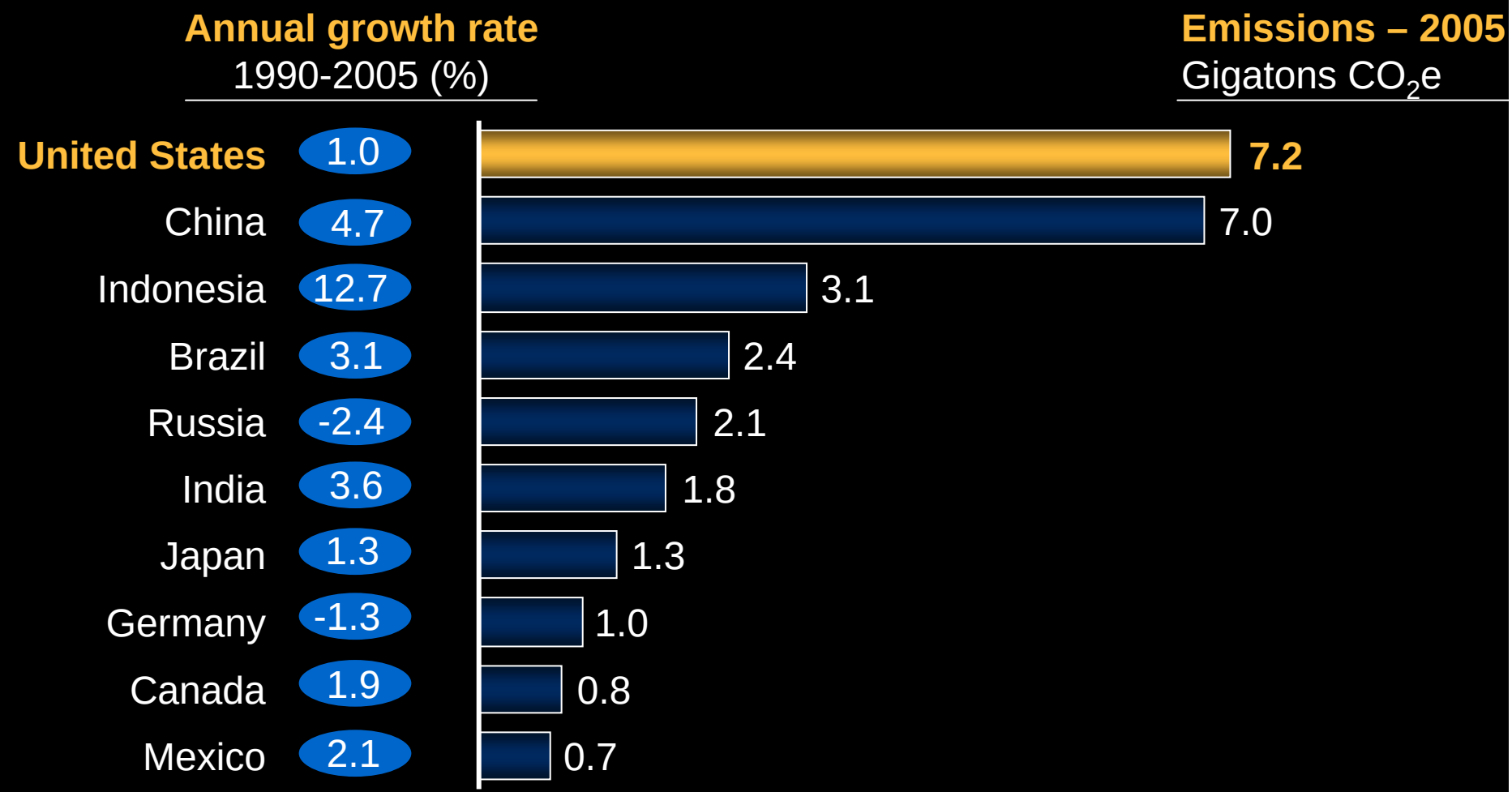
We did not look at:

- “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)
- Broader societal costs or benefits (e.g., impacts of mitigating climate change, less reliance on foreign oil)

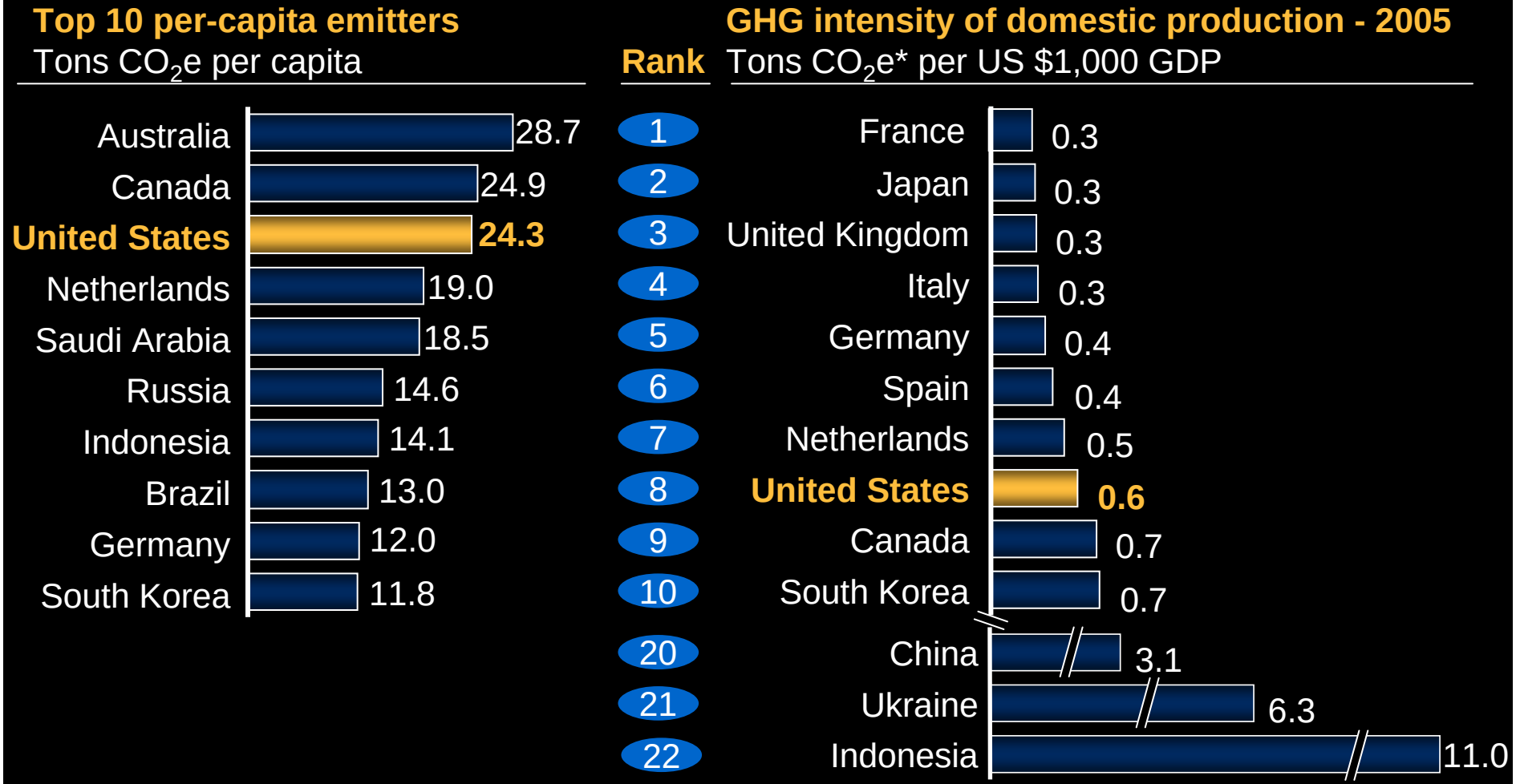
Major findings and conclusions

- 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

U.S. the largest greenhouse gas emitter in 2005



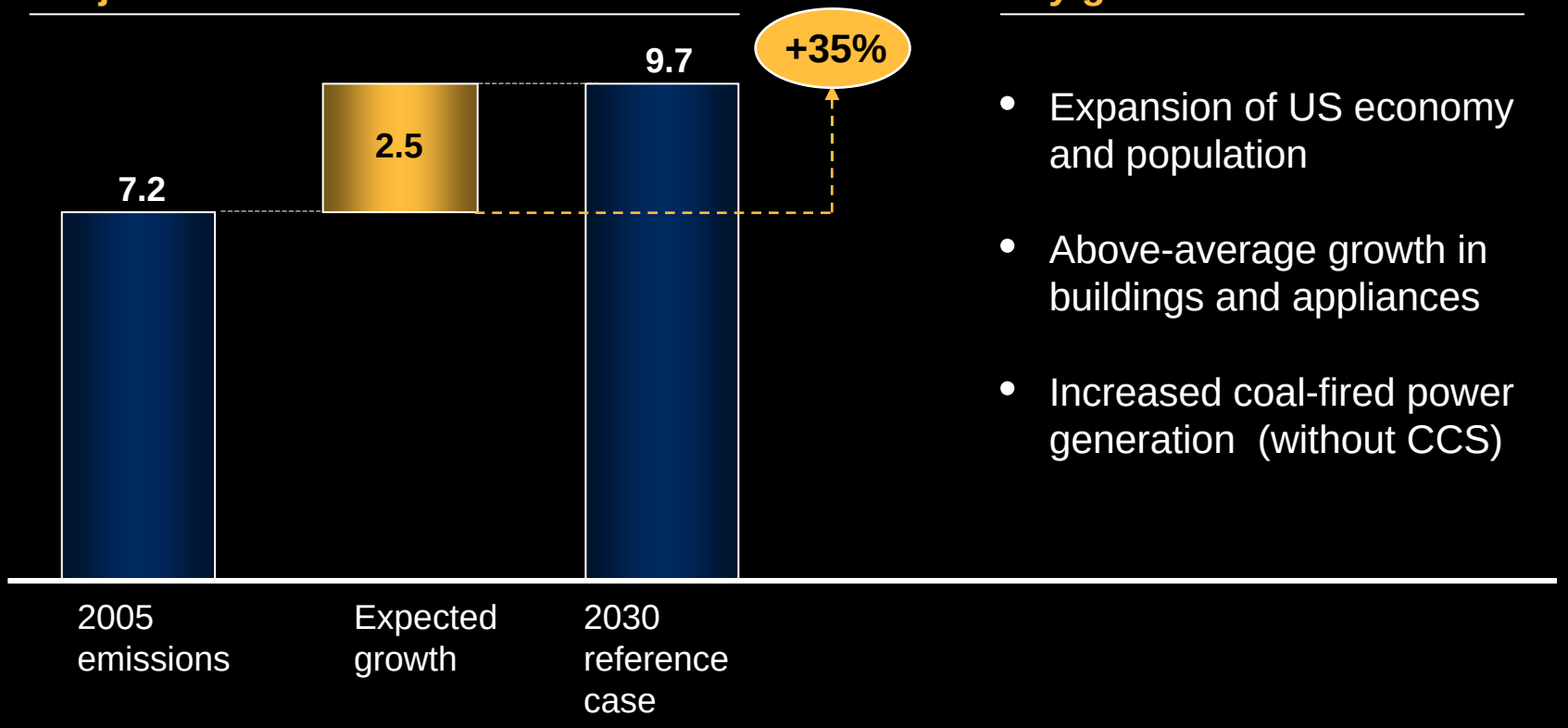
U.S. among the largest emitters per capita, but one of the least per $ of GDP



Government agencies forecast US emissions to rise 35% by 2030. . .

Gigatons CO_2e per year

Projected GHG emissions

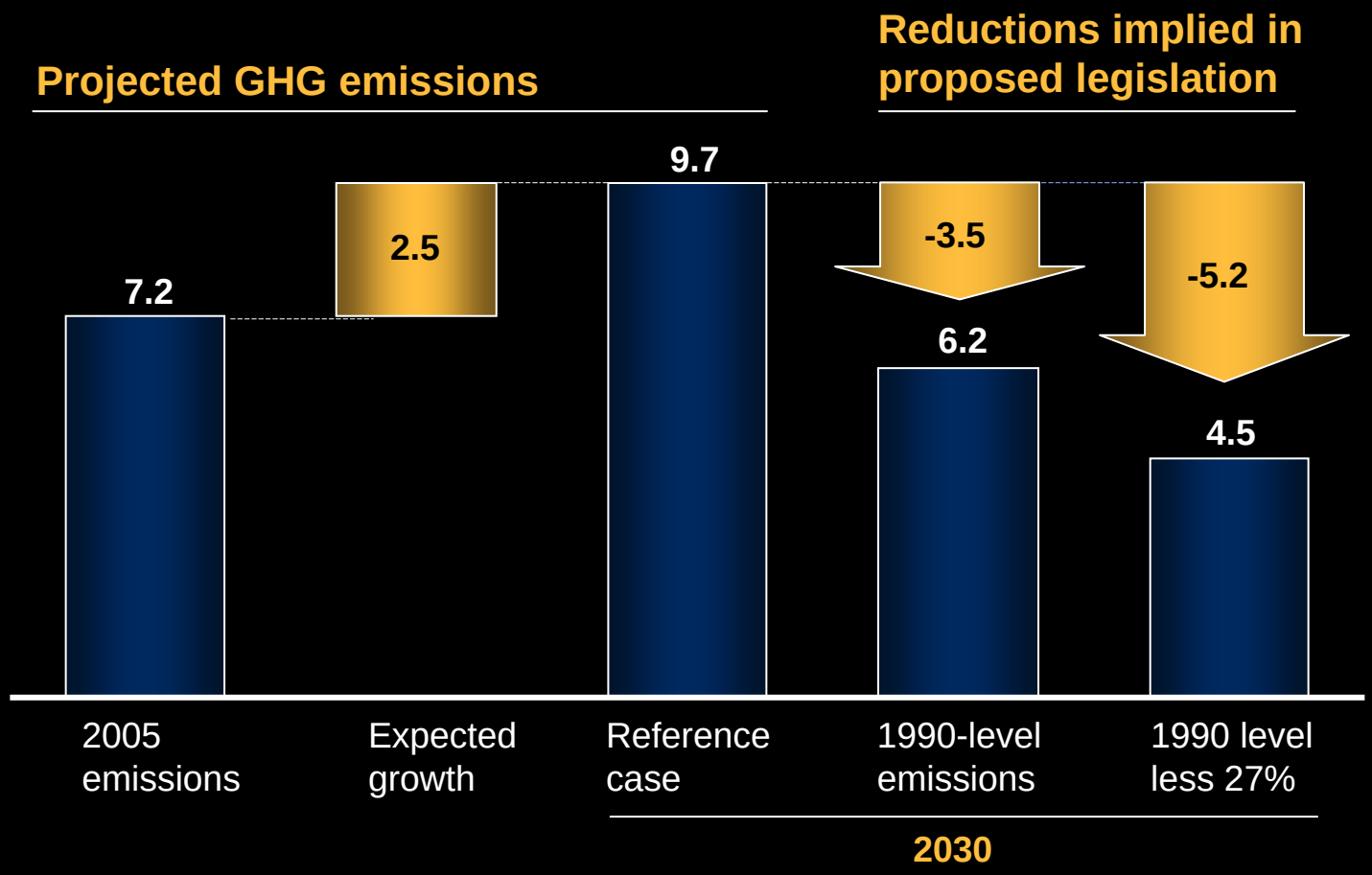


Key growth drivers

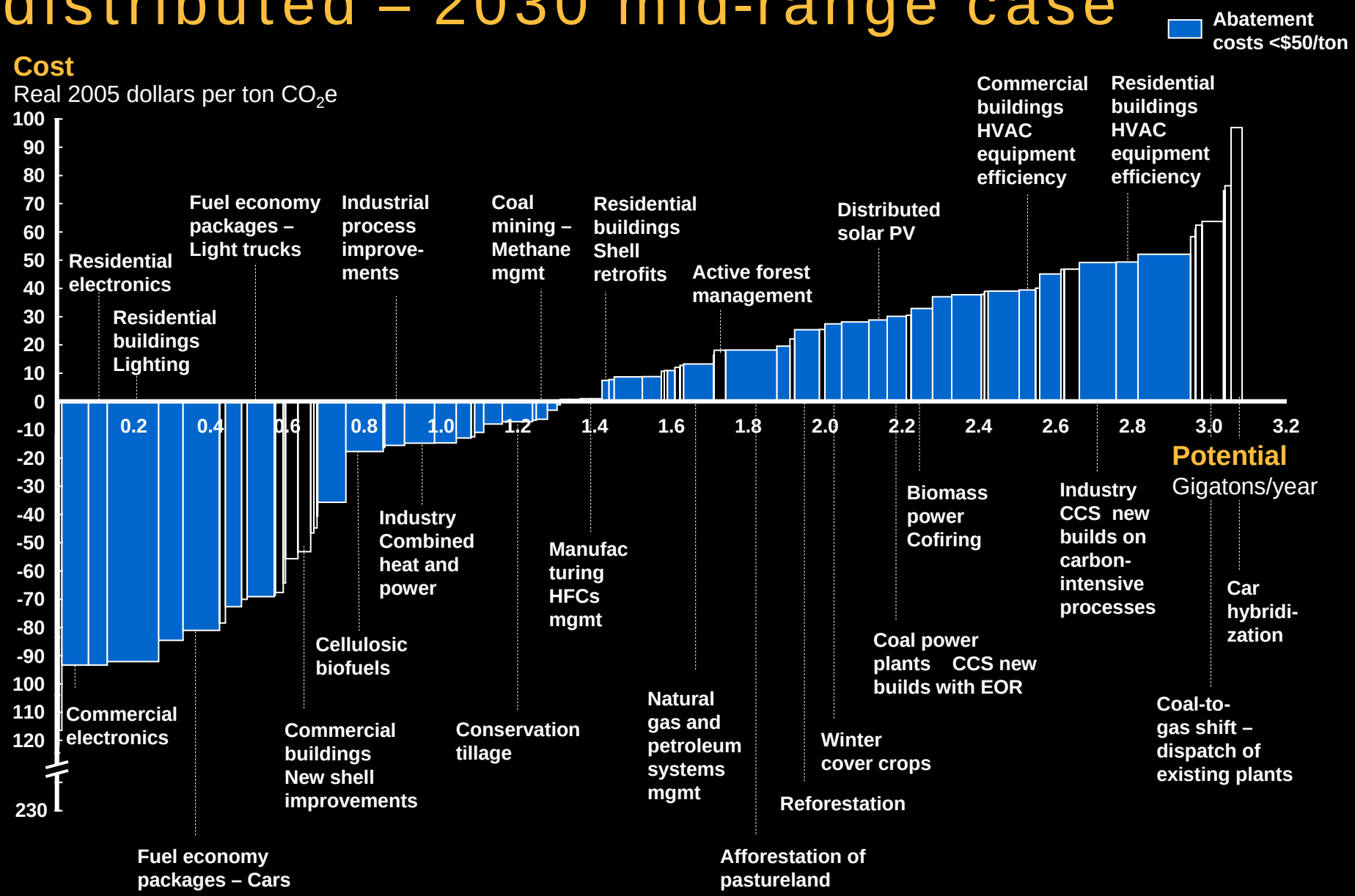
- Expansion of US economy and population
- Above-average growth in buildings and appliances
- Increased coal-fired power generation (without CCS)

. . .exceeding proposed legislative targets by a wide margin

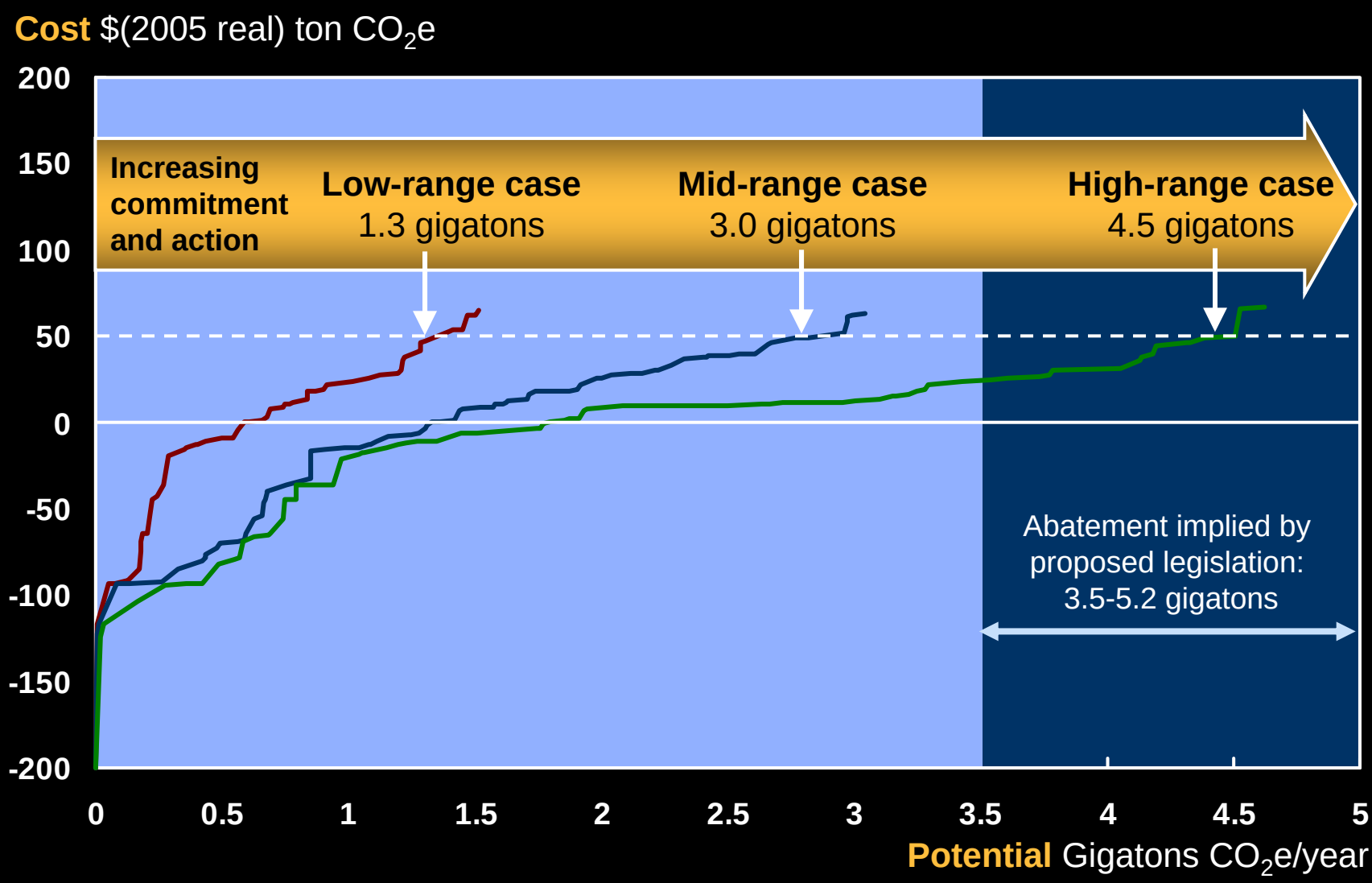
Gigatons CO_2e



GHG reduction opportunities widely distributed – 2030 mid-range case



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



Drivers of 2030 GHG abatement potential

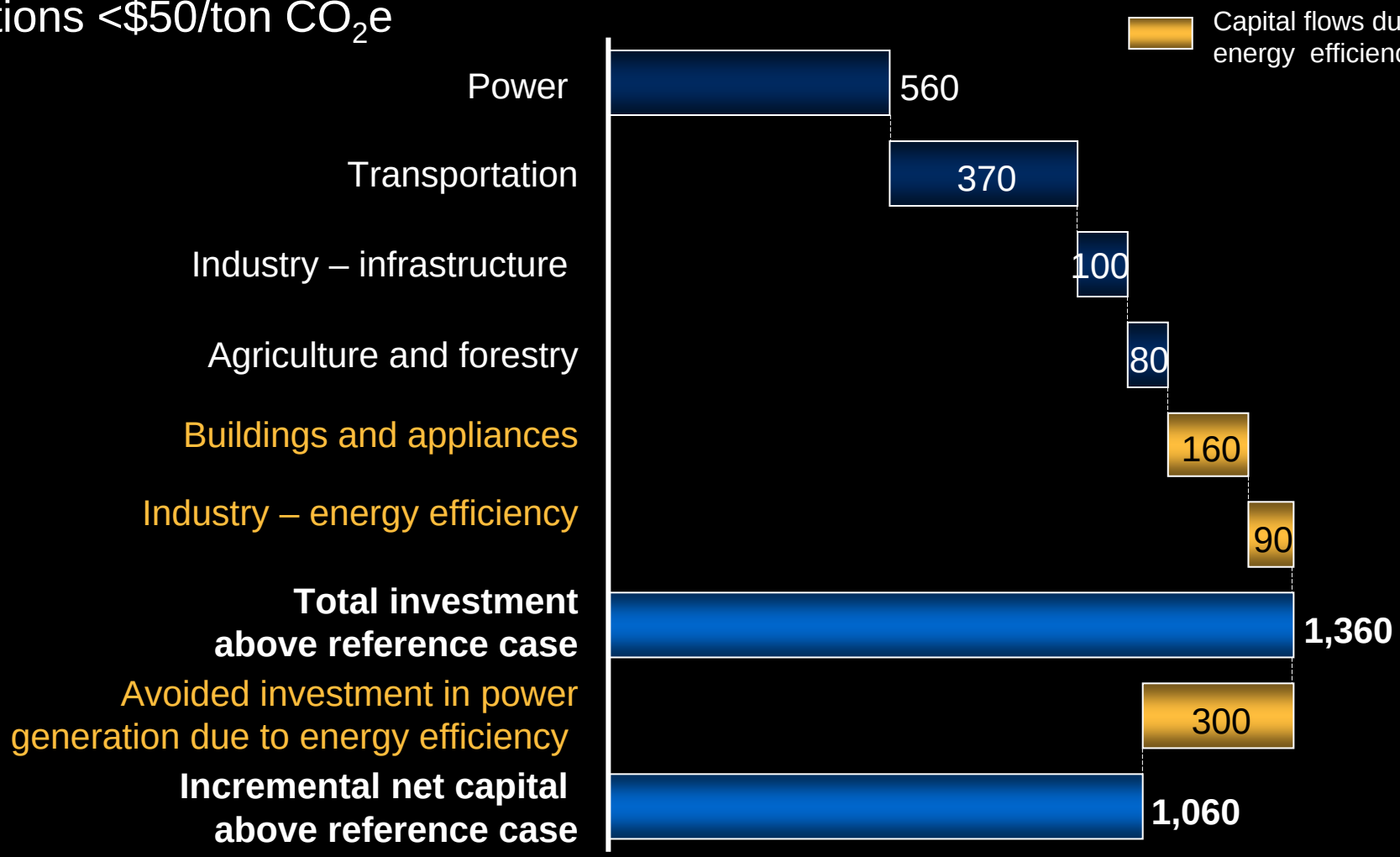
X Abatement potential below $50/ton, gigatons

	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
New car performance mpg	• 28 mpg	34	47	53
Efficient new residential lighting	• 8%	15%	70%	75%
		1.3	**3.0**	**4.5**

Incremental capital investment in mid-range case

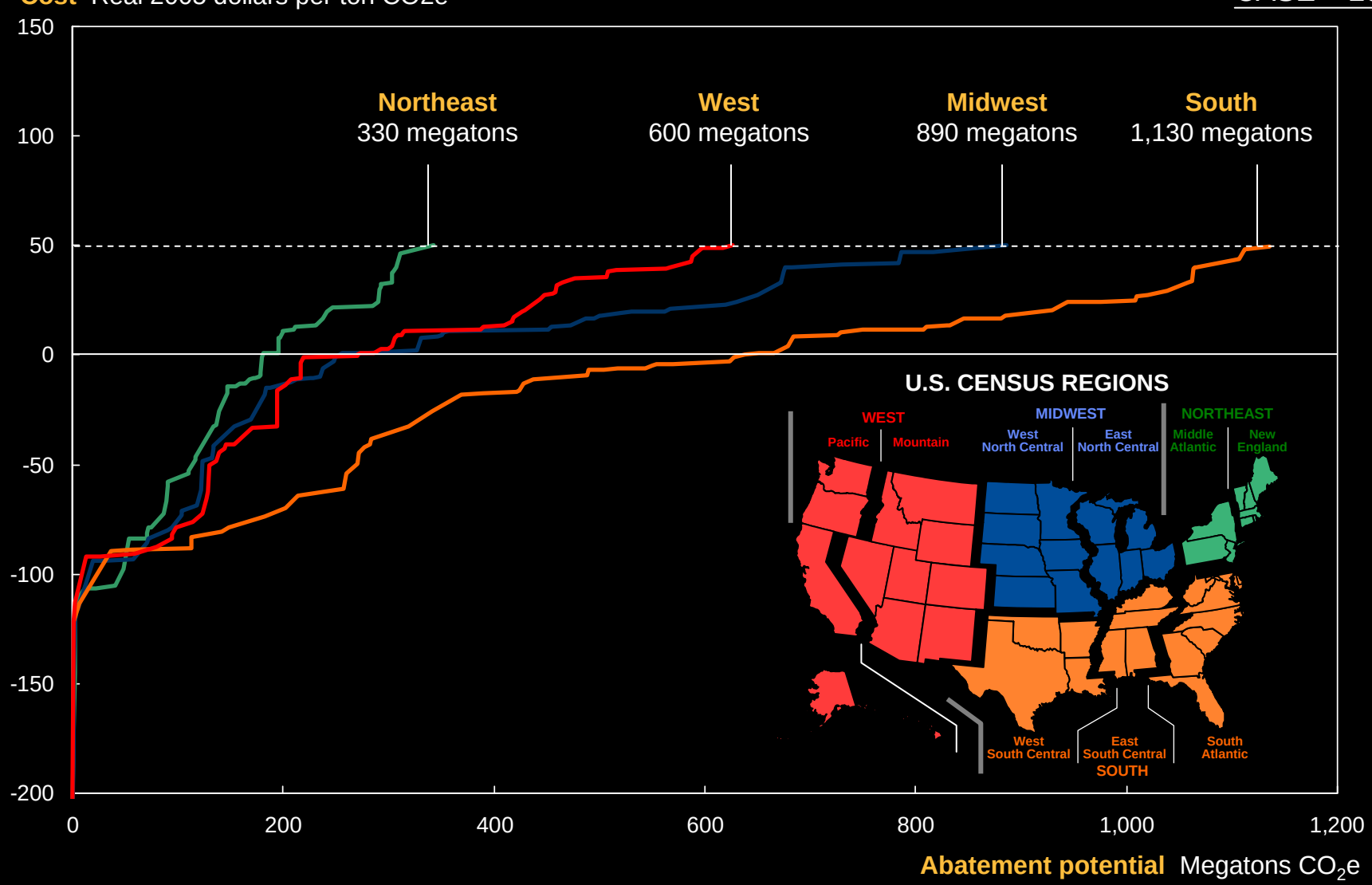
MID-RANGE CASE – 2030

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



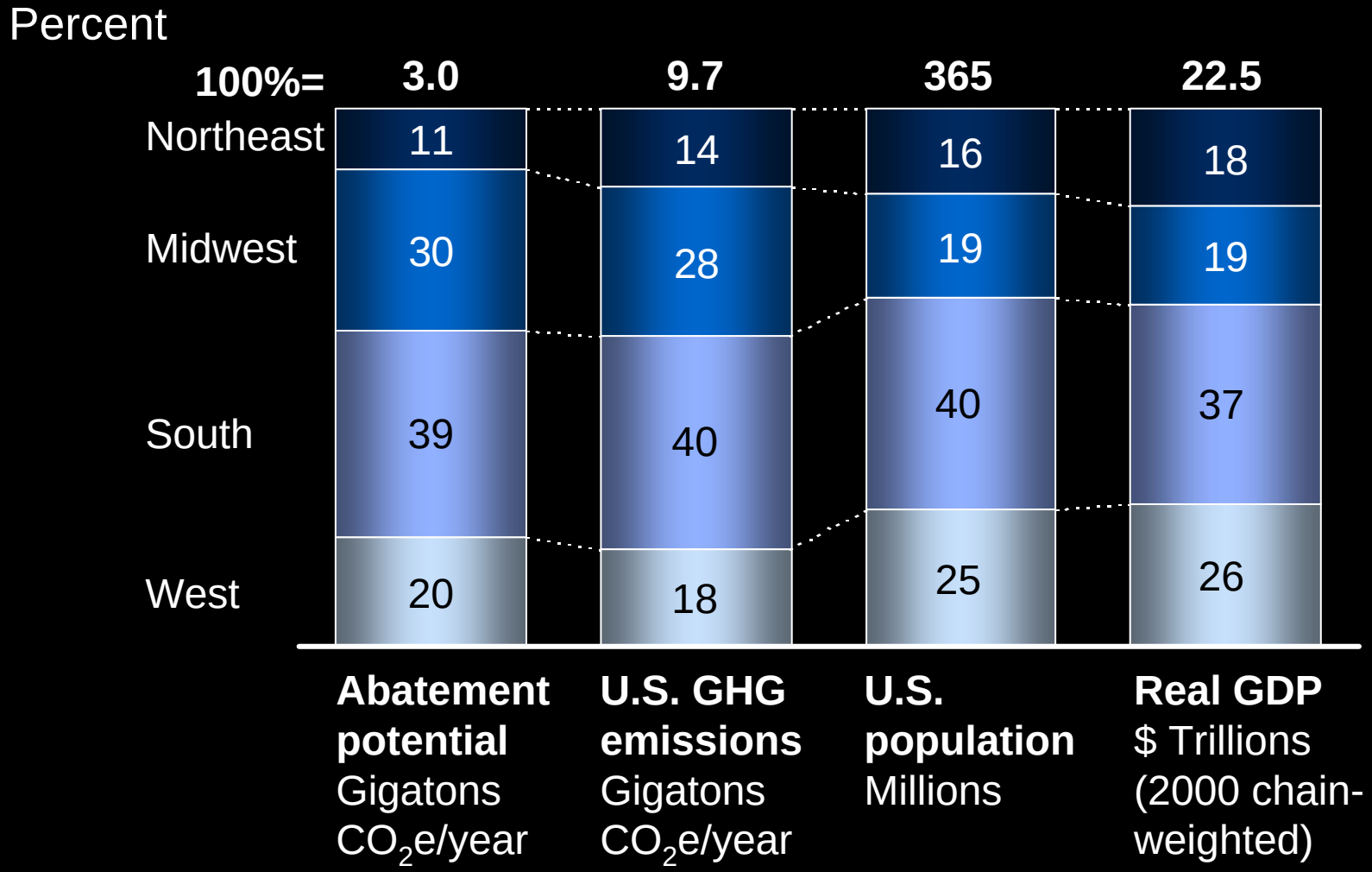
Geographic differences in abatement cost

MID-RANGE CASE – 2030



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

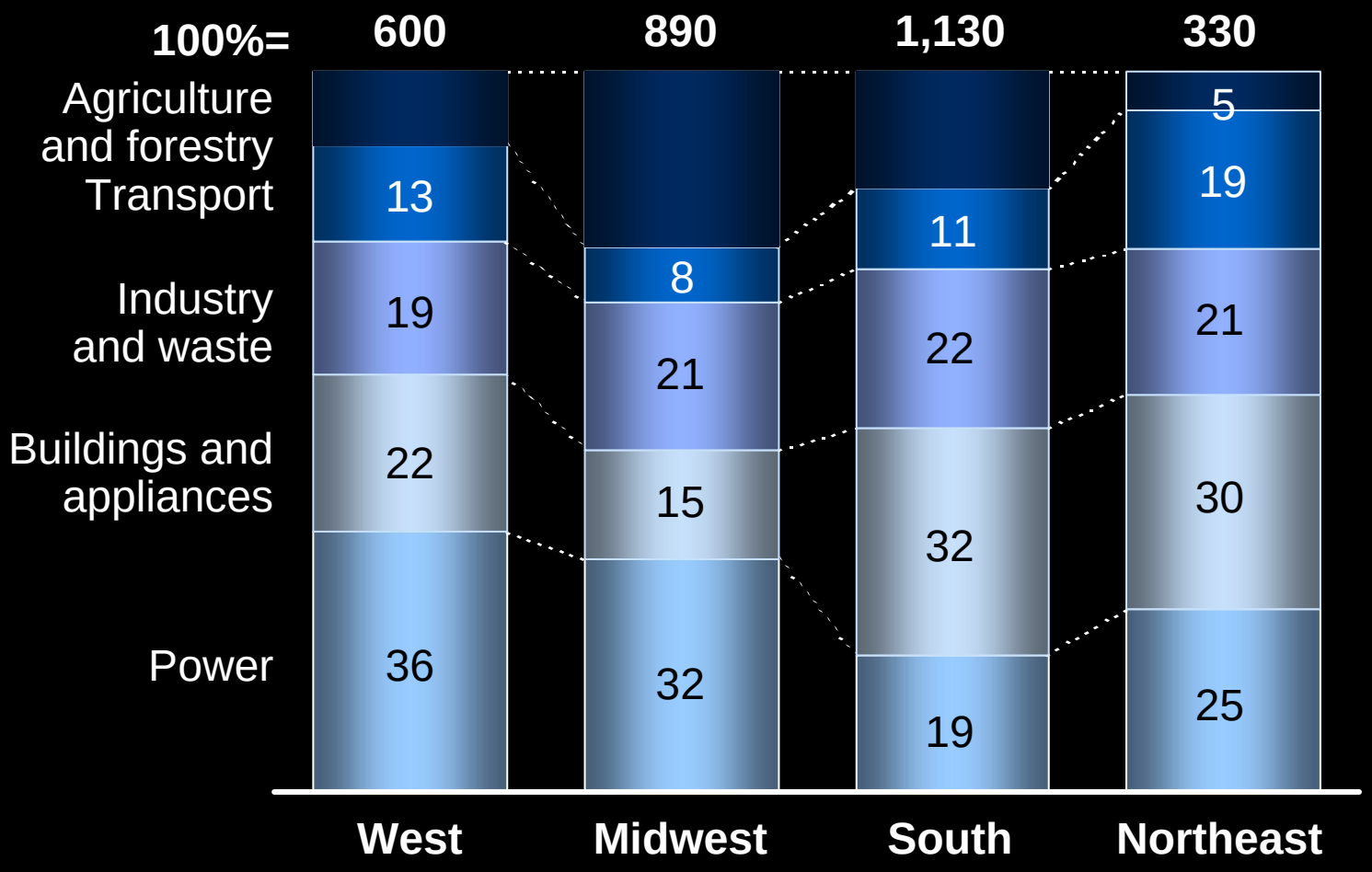
MID-RANGE CASE – 2030



Geographic differences in abatement potential by sector

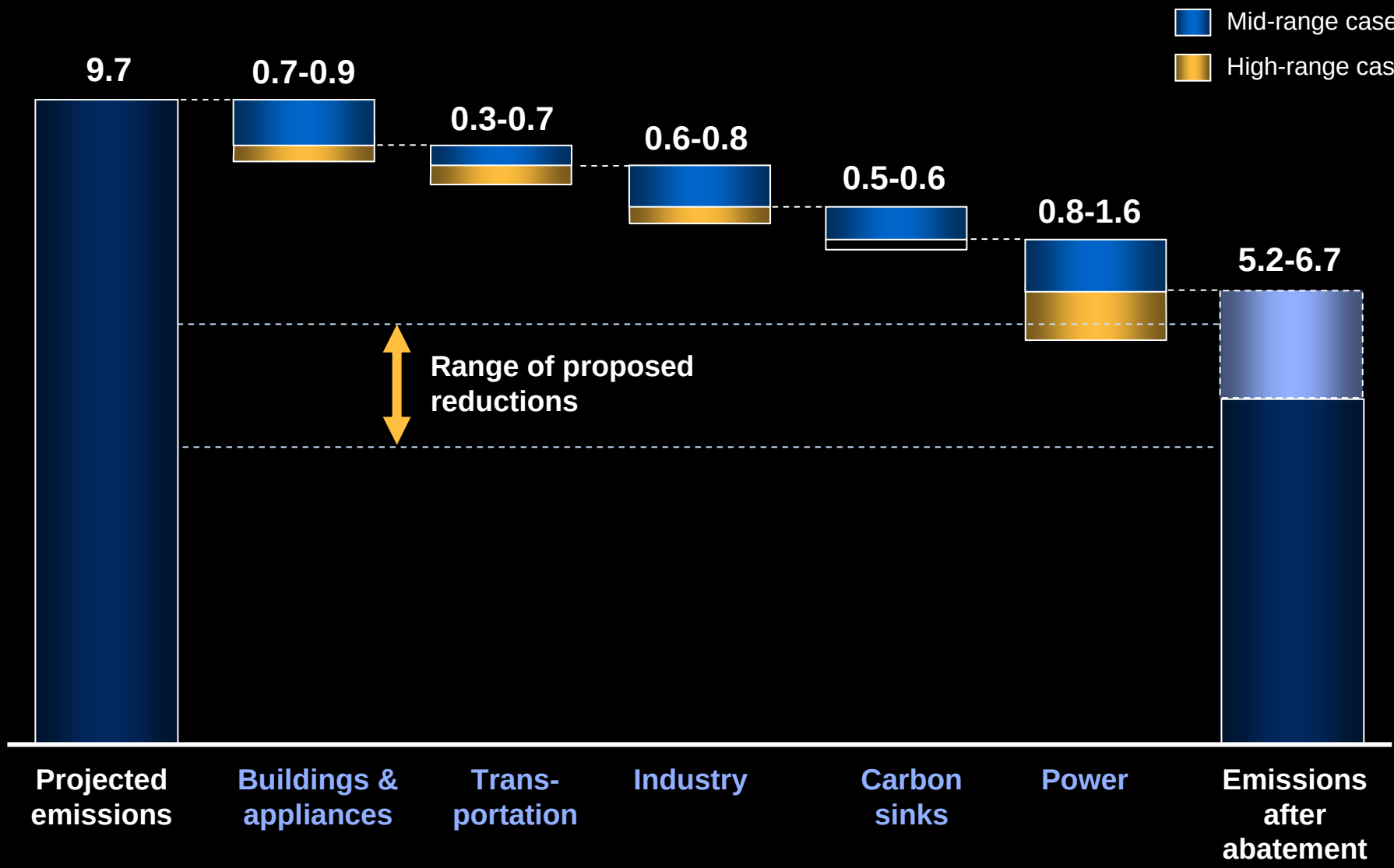
MID-RANGE CASE – 2030

Percent, Megatons CO_2e/year



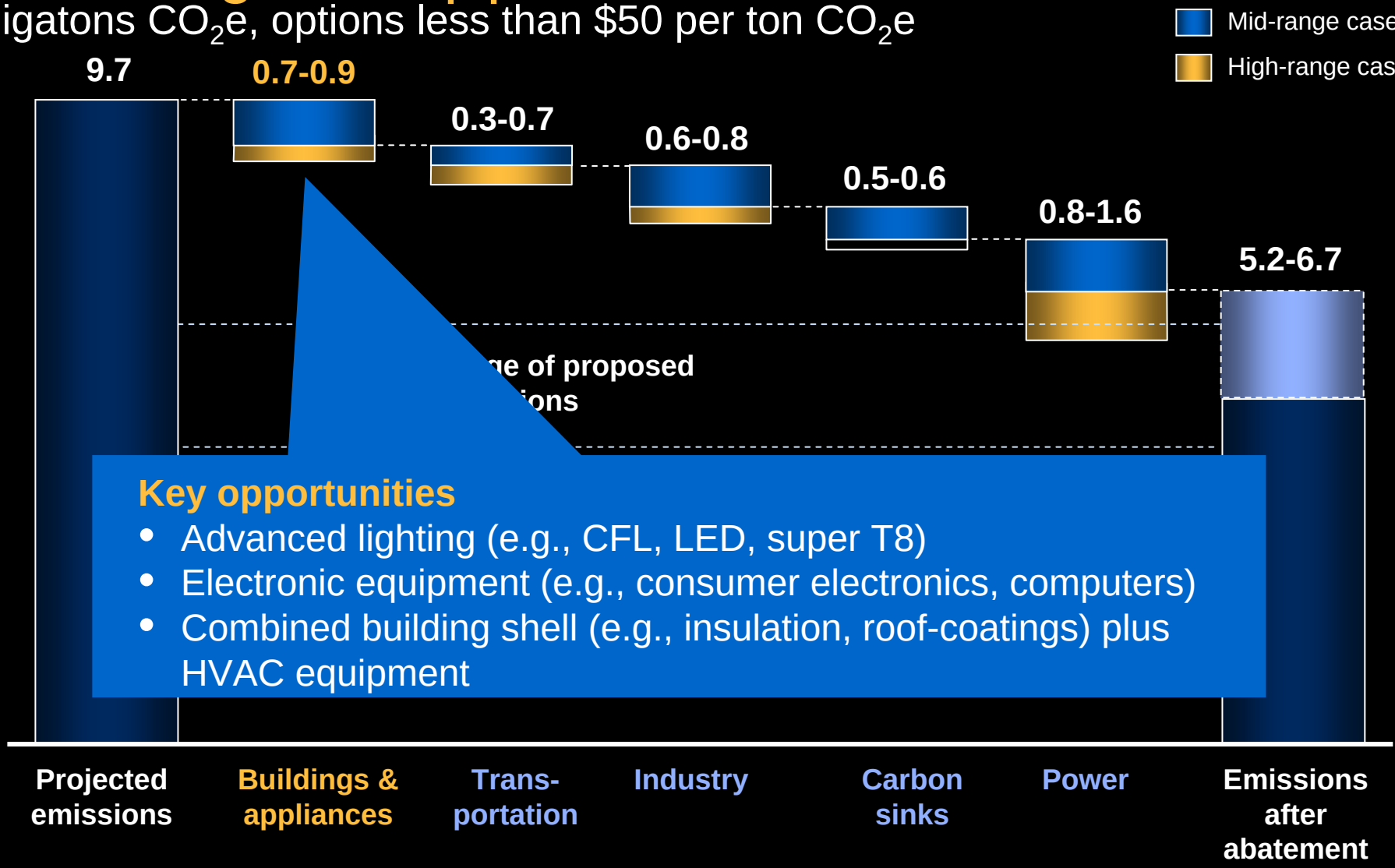
Five "clusters" offer significant potential

Gigatons CO_2e, options less than $50 per ton CO_2e



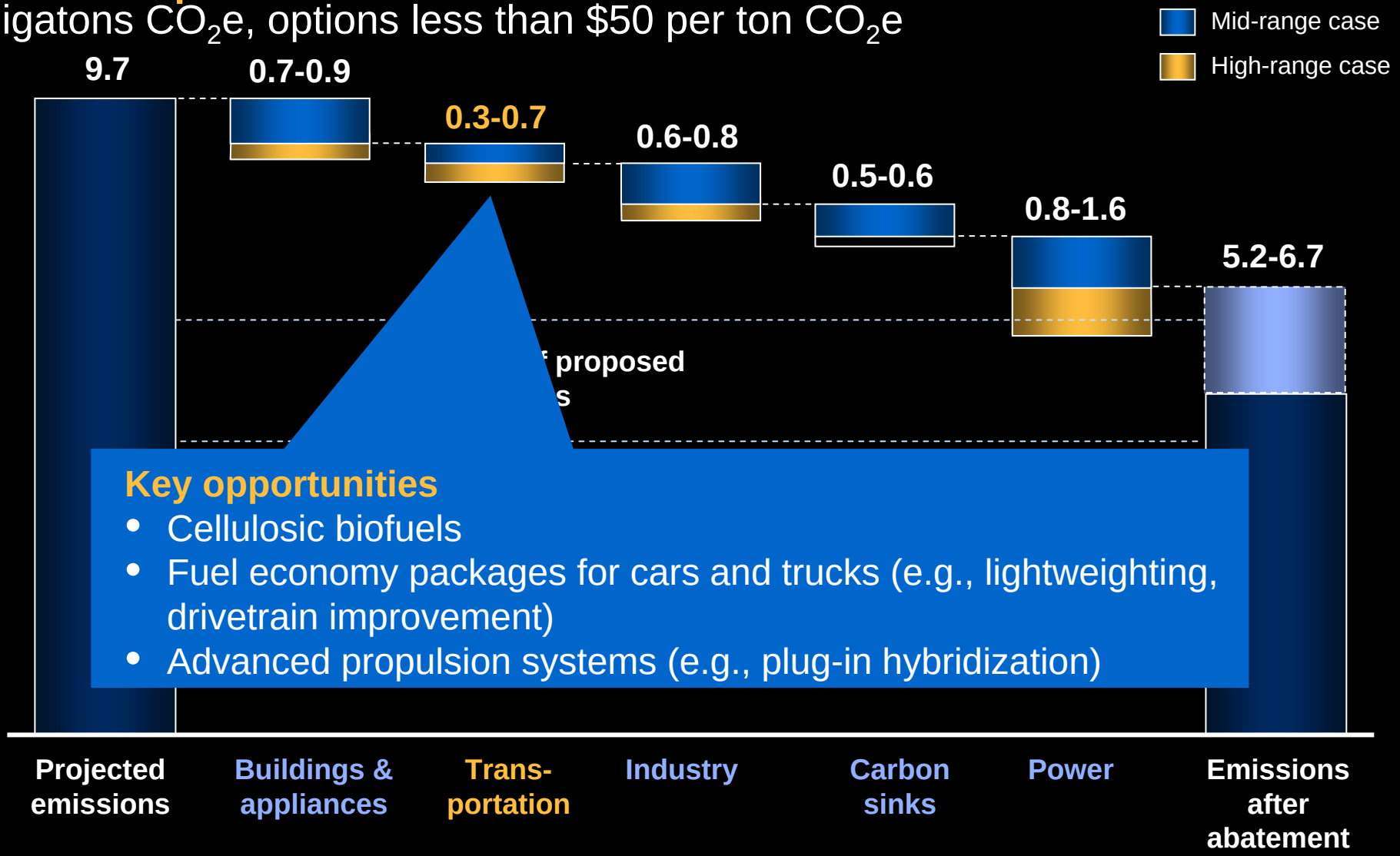
Key abatement opportunities: Buildings & appliances

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



Key abatement opportunities: Transportation

Gigatons CO_2e, options less than $50 per ton CO_2e

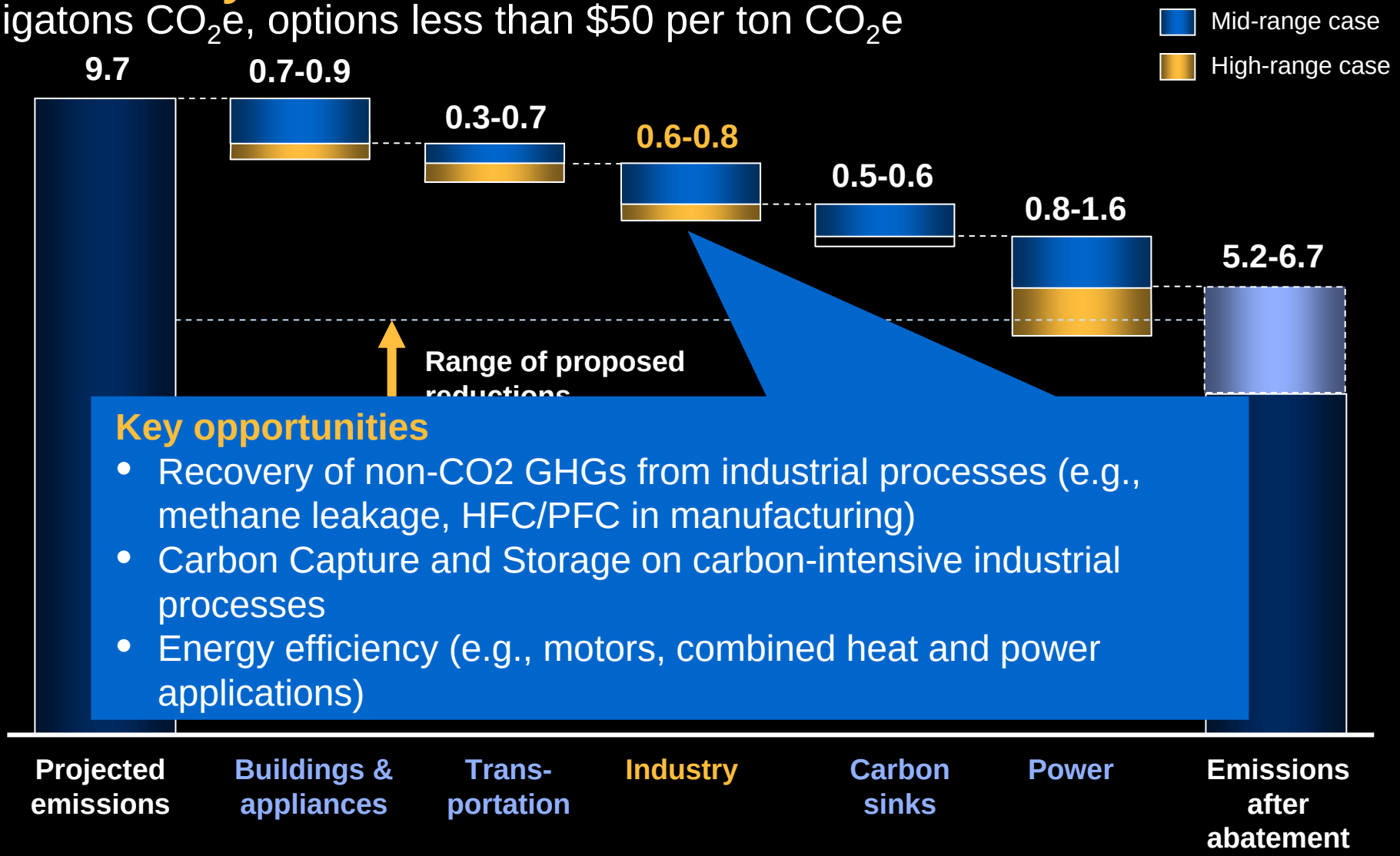


Key opportunities

- Cellulosic biofuels
- Fuel economy packages for cars and trucks (e.g., lightweighting, drivetrain improvement)
- Advanced propulsion systems (e.g., plug-in hybridization)

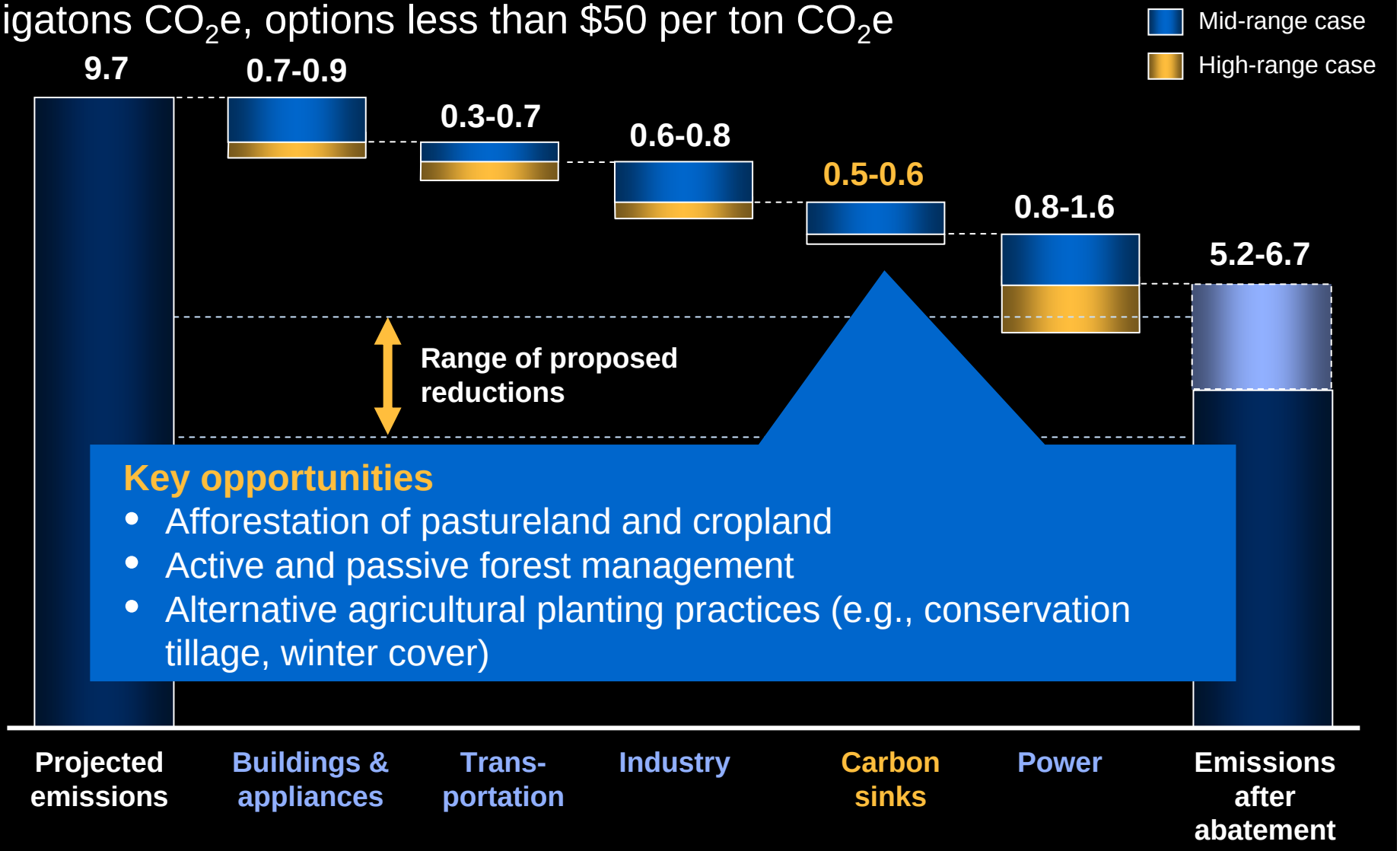
Key abatement opportunities: Industry

Gigatons CO_2e, options less than $50 per ton CO_2e



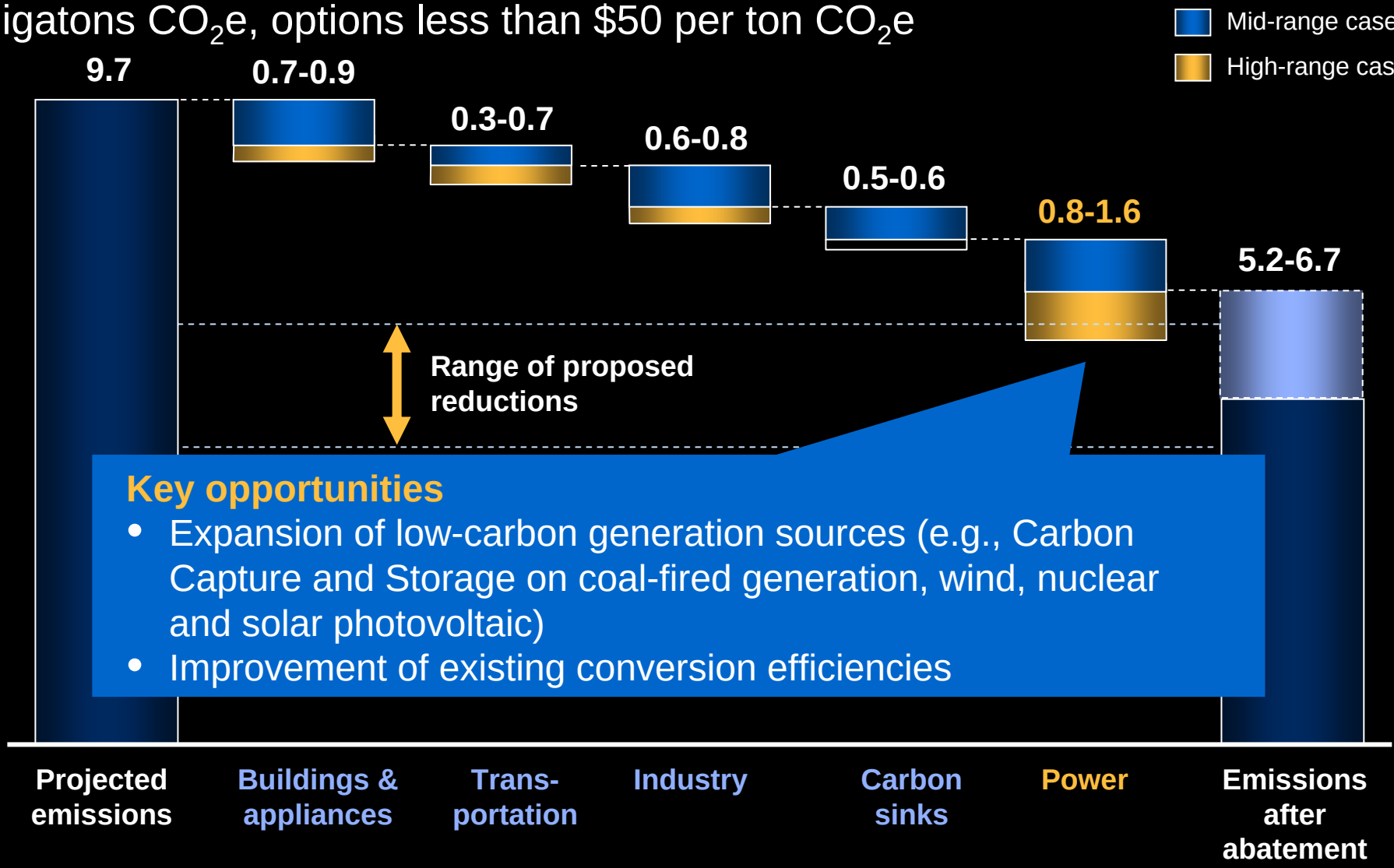
Key abatement opportunities: Carbon sinks

Gigatons CO_2e, options less than $50 per ton CO_2e



Key abatement opportunities: Power

Gigatons CO_2e, options less than $50 per ton CO_2e



Key opportunities

- Expansion of low-carbon generation sources (e.g., Carbon Capture and Storage on coal-fired generation, wind, nuclear and solar photovoltaic)
- Improvement of existing conversion efficiencies

Recap of major findings

- Government sources project US GHG emissions to rise 35 percent to 9.7 gigatons by 2030
- 3.0 gigatons (mid-range) to 4.5 gigatons (high-range) of CO_2e reductions vs. 2030 using tested approaches and high-potential emerging technologies
- Opportunities are spread widely across sectors and geographies
- Roughly 40 percent of reductions identified 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
- Five major “clusters” of reduction potential

Key takeaways for policymakers

1. Stimulate action through a portfolio of strong, coordinated policies to capture GHG reductions efficiently across industry sectors and geographies
   A. Visible, sustained signals
   B. Coordinated economy-wide abatement programs
   C. Exchange mechanisms to create fungibility
   D. Verification, management, and enforcement systems
   E. Safeguards against “leakage” overseas

2. Pursue energy efficiency and negative-cost options quickly

3. Accelerate development of a low-carbon energy infrastructure

4. Encourage research and development of promising technologies and stimulate deployment

5. Streamline approval and permitting procedures

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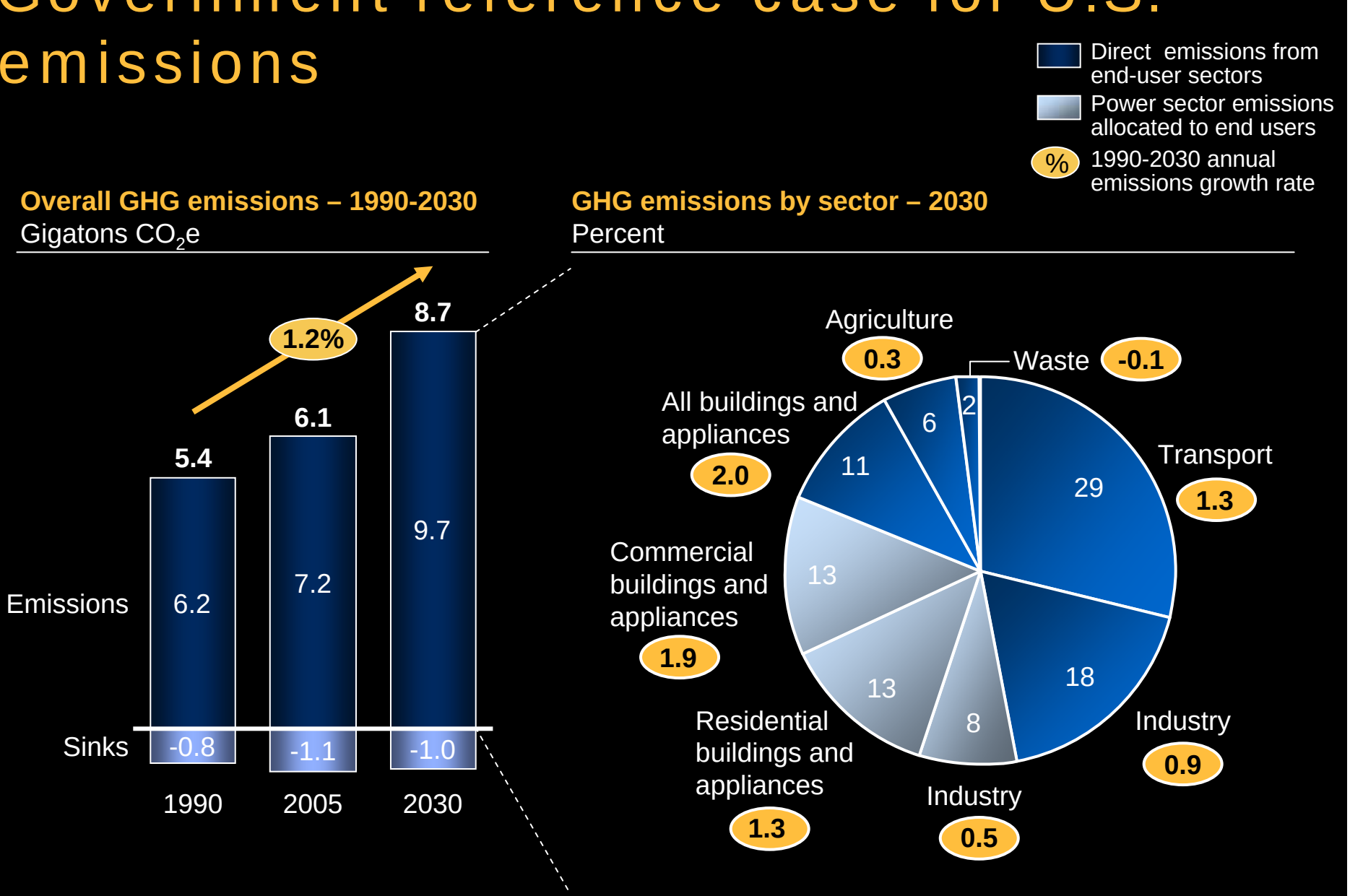
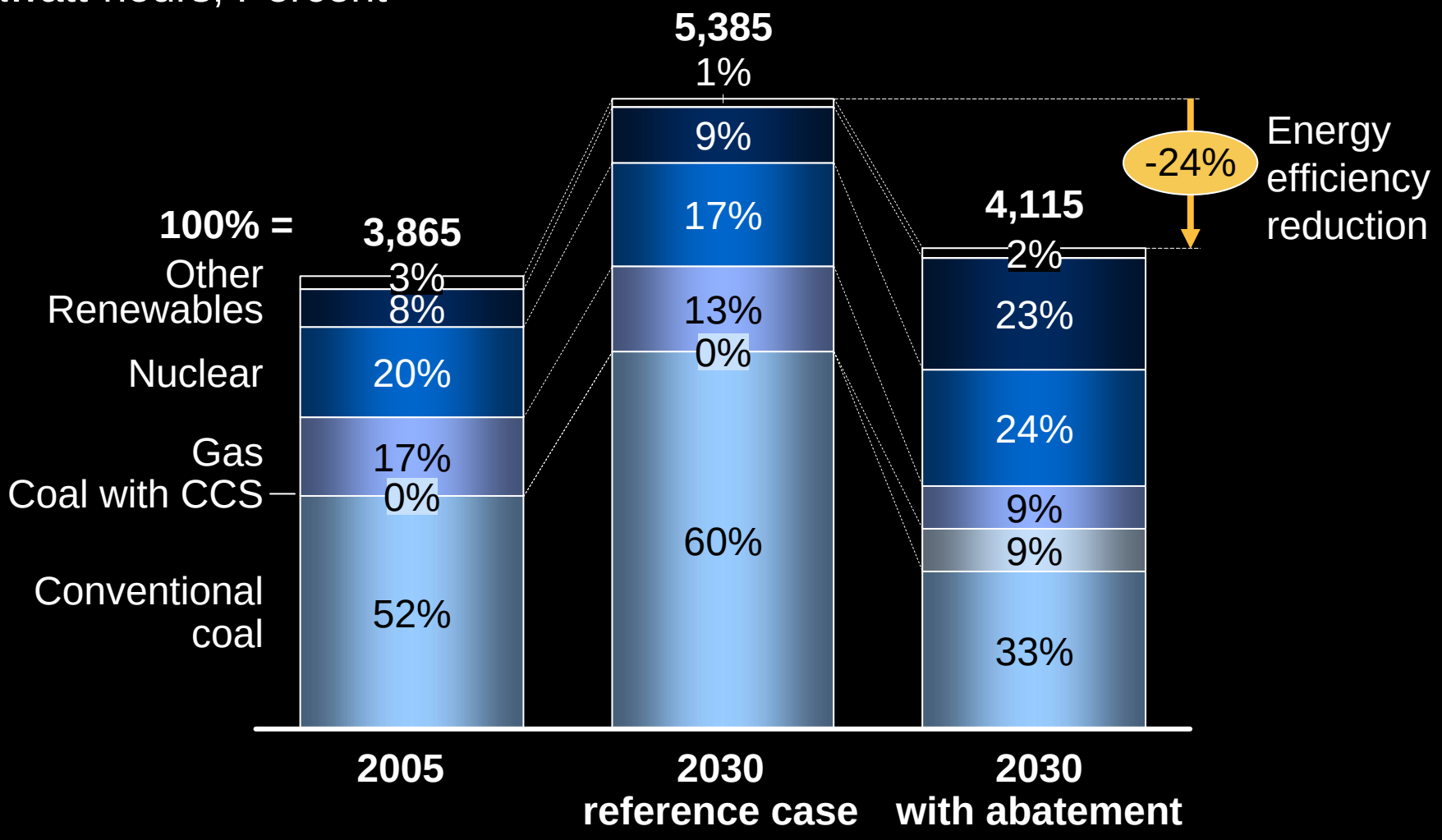
Government reference case for U.S. emissions



Changes in composition of U.S. power generation

MID-RANGE CASE – 2030

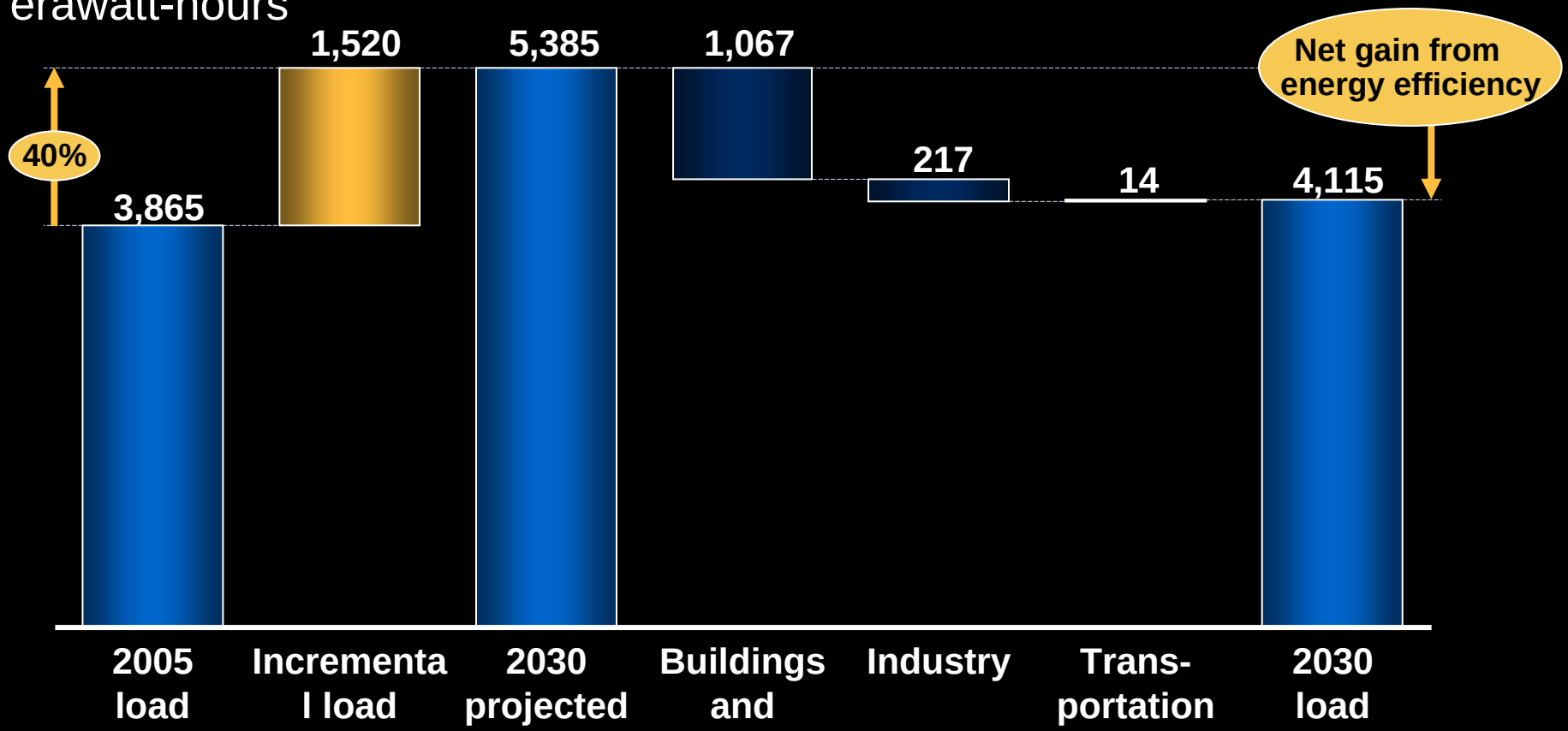
Terawatt-hours, Percent



Incremental power load vs. potential abatement from energy efficiency and transportation

MID-RANGE CASE – 2030

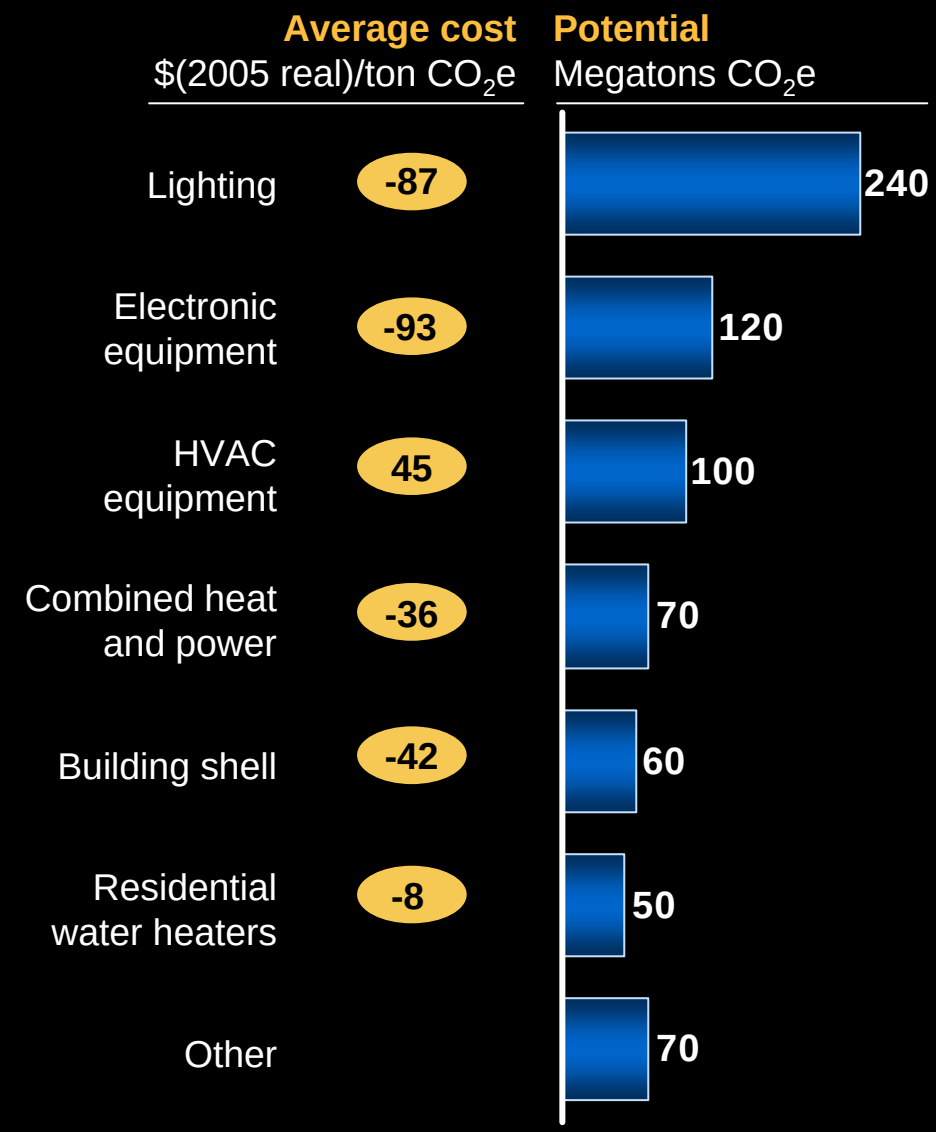
Terawatt-hours



Many "negative-cost" options in buildings and appliances

Options less than $50/ton CO_2e

MID-RANGE CASE – 2030



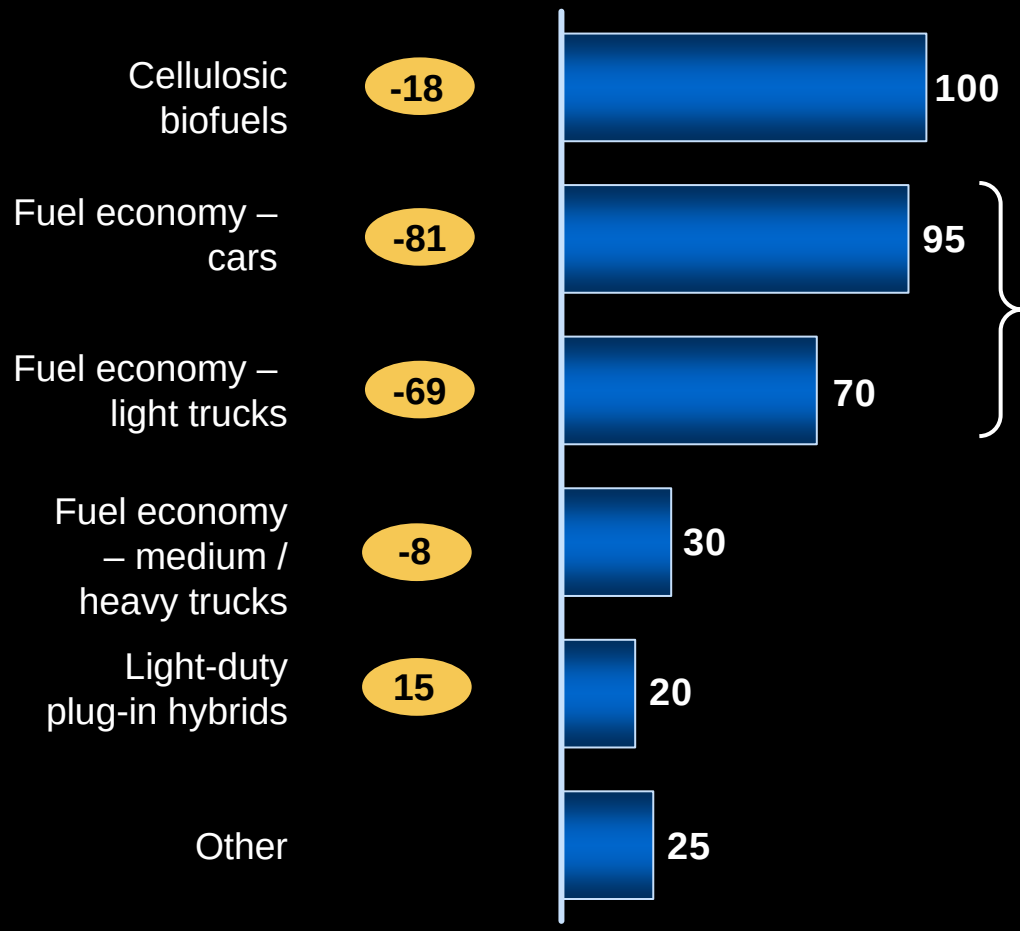
Description

- Substitution of advanced lighting technologies
- Greater in-use efficiency and reduced stand-by losses
- More efficient equipment for initial installation and retrofits
- Performance tuning for existing systems
- Increased use with office buildings >100,000 sq. ft, hospitals and universities
- Improved new-build shells and retrofits from better insulation, air tightening, reflective roof coatings
- Improved efficiency units and switch to alternative fuel/ technologies
- Building controls
- Residential and commercial appliances
- Commercial water heaters

Vehicle fuel economy and lower-carbon fuels crucial for transportation

Options less than $50/ton CO_2e

MID-RANGE CASE – 2030



Description

- Commercialization with various feedstocks and conversion processes
- Various technology upgrades to improve fuel efficiency
- Greater use of alternative propulsion systems (diesel)
- Technology upgrades to improve fuel efficiency
- Plug-in capability in addition to basic hybridization
- Hybridization of medium and heavy trucks
- Aircraft fuel efficiency from design and operations
- Reduced leakage from air conditioning systems

Options in industrial and waste sectors highly fragmented

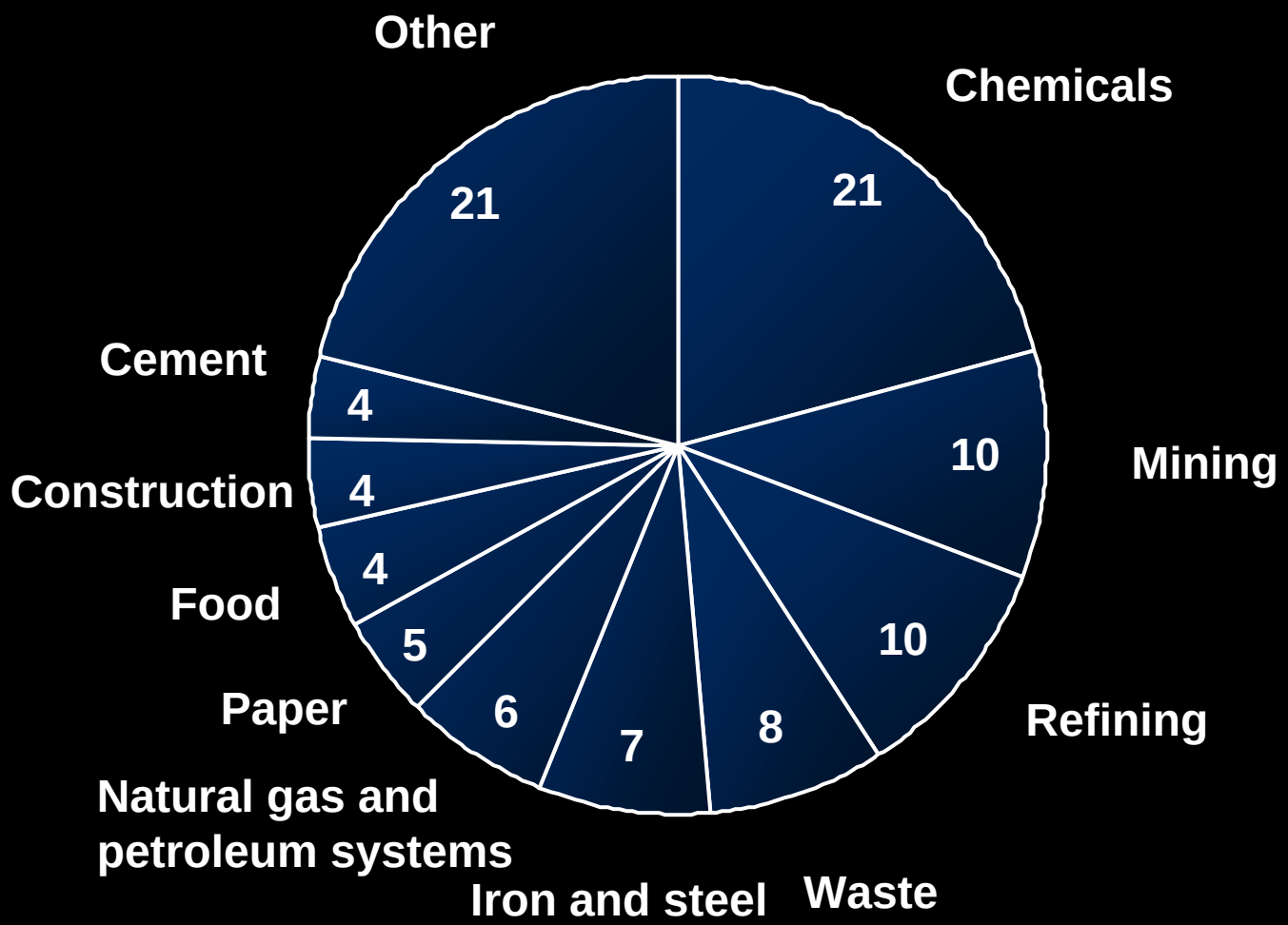
Options less than $50/ton CO_2e

MID-RANGE CASE – 2030

	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

GHG emissions in industrial and waste cluster – 2005

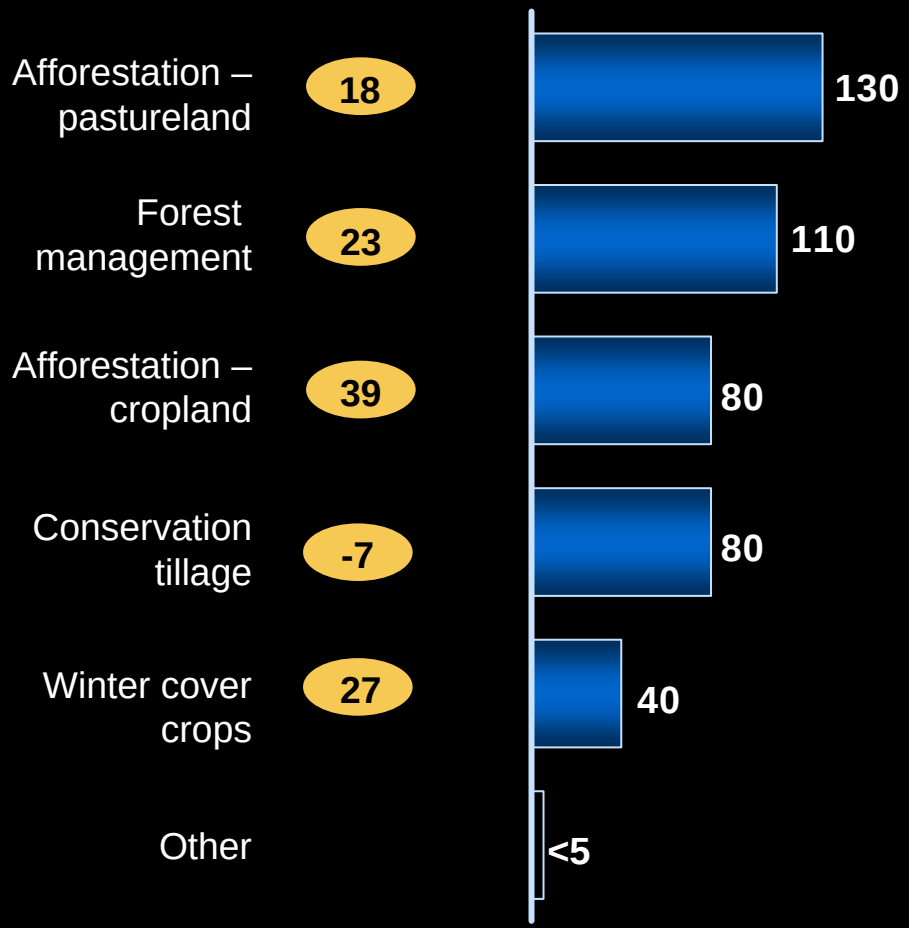
100% = 2.2 gigatons*



Significant potential at moderate cost in terrestrial carbon sinks

Options less than $50/ton CO_2e

MID-RANGE CASE – 2030



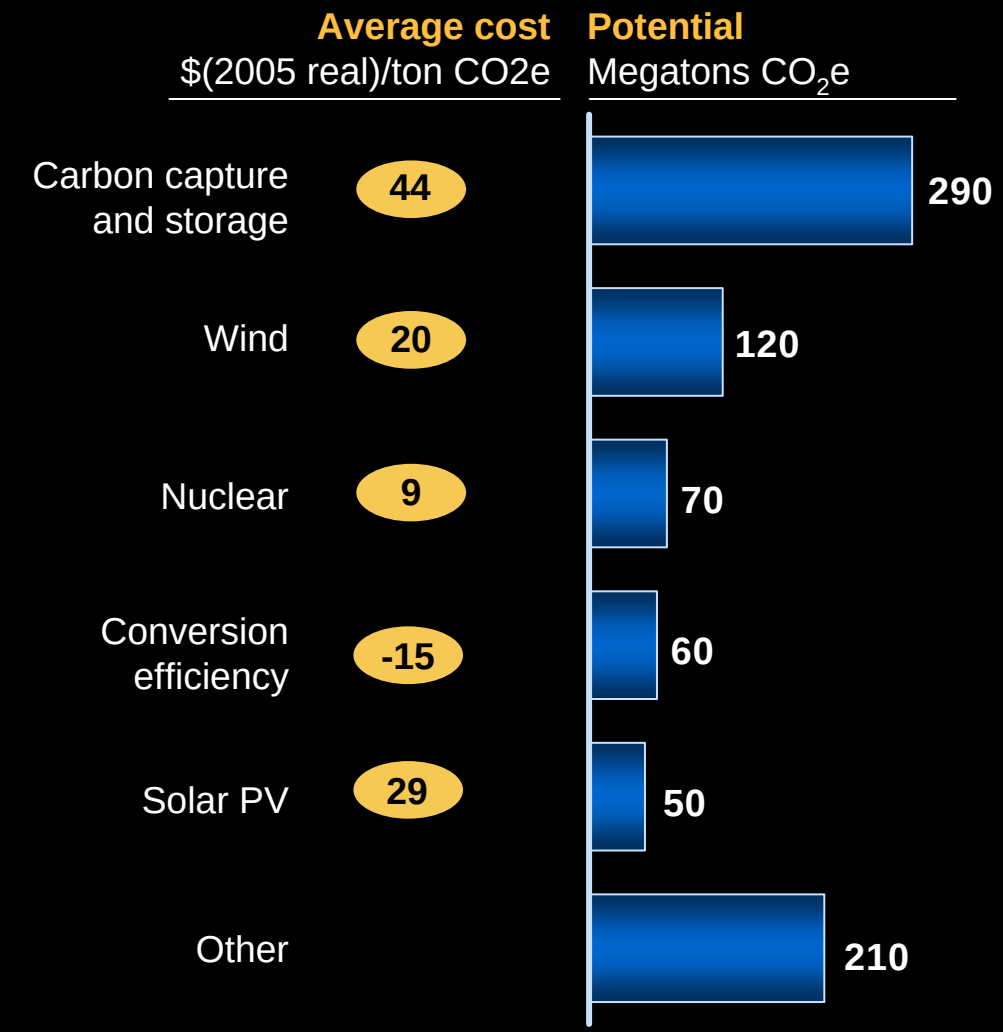
Description

- New trees primarily on marginal or idle land where erosion is high and/or productivity is low
- Active – thinning, stand improvement
- Passive – restricted grazing, natural regeneration
- Restoration of degraded forests
- New trees primarily on marginal or idle land where erosion is high and/or productivity is low
- Planting crops amid previous crop's residue, e.g., using ridge tillage and no-till farming
- Planting harvested cropland with grass or legume cover crop during winter
- Elimination of summer fallow

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

Options less than $50/ton CO_2e

MID-RANGE CASE – 2030



Description

- Rebuilds of pulverized coal plants with CCS, plus CCS new builds
- Includes injection to enhance oil recovery

- Class 5-7 on-shore winds with economic grid integration costs

- Nuclear power plant new-builds
- Up-rates for existing nuclear plants
- Reactivations

- Improved heat rates of base-load pulverized coal power plants

- Residential and commercial distributed power generation with solar photovoltaics

- Low-class on-shore and offshore wind (90 MT)
- Concentrating solar power (50)
- Biomass co-firing (50)
- Geothermal power (10)
- Small hydroelectric power (10)