

EXAMPLES OF PRAXAIR SOLUTIONS THAT HELP TO MITIGATE THE EFFECTS OF CLIMATE CHANGE (2012)

The Intergovernmental Panel on Climate Change (IPCC) identified several key technologies & practices, by sector, which could play a significant role in mitigating the effects of climate change. This table shows examples of how Praxair applications present many of the climate mitigation solutions the IPCC has identified for now & the future.¹

Key Climate Change Mitigation Applications – Examples of Praxair Solutions			
Sector	Currently commercially available	Projected to be commercialized before 2030	Examples of Praxair applications, existing & under development
Energy supply	Improved supply & distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat & power (hydro-power, solar, wind, geothermal & bio-energy); combined heat & power; early applications of carbon capture & storage (CCS) - e.g. storage of removed CO2 from natural gas.	CCS for gas, biomass & coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal & waves energy, concentrating solar, & solar PV.	<p>EXISTING</p> <ul style="list-style-type: none"> In Texas, with the U.S. Department of Energy (DOE), demonstrated Praxair's <i>Seeper Trace™</i> technology as an effective CO2 sequestration monitoring technology Liquid Nitrogen & Liquid CO2 are used throughout North America to fracture oil-bearing rock formations Efficient supply of gases & sputtering targets for the production of photovoltaic cells & modules for solar power production <p>UNDER DEVELOPMENT</p> <ul style="list-style-type: none"> Participating with multi-stakeholder partnerships to demonstrate carbon capture & sequestration (CCS) at coal-fired power-plants in the U.S., Spain & Germany Comprehensive solution for CCS from coal-fired power plants Combustion technology; air separation units for oxygen production; carbon dioxide recycling & oxygen mixing; carbon dioxide processing Up to 99% carbon dioxide capture using proprietary partial condensation/VPSA process Development of CCS ready hydrogen plants Carbon-dioxide capture-ready for enhanced oil recovery (EOR) or underground storage Participating with multi-stakeholder partnerships in demonstration projects for CCS in U.S., Spain & Germany Cooling systems for superconducting power transmission cables for increased electricity distribution efficiency Efficient activated carbon production method to remove mercury from power plant exhaust High performance rotatable sputtering targets to enable lower cost thin film solar panels Technology that mitigates CO2 emissions from oil sands production in Canada

¹ IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom & New York, NY, USA. Fig SPM3, page 10: Key mitigation technologies & practices by sector. The column with Praxair examples has been added. This table was originally produced in 2008, and is here updated for 2012.

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Transport	More fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail & public transport systems; non-motorised transport (cycling, walking); land-use & transport planning.	Second generation biofuels; higher efficiency aircraft; advanced electric & hybrid vehicles with more powerful & reliable batteries.	<p>EXISTING</p> <ul style="list-style-type: none"> In Brazil, provide natural gas conversion kits for passenger vehicles, & work with the government to increase consumer access to natural gas for cleaner transportation & other uses <p>EXISTING</p> <ul style="list-style-type: none"> Proprietary technology to improve efficiency of biodiesel production Technologies to improve ethanol production rates Participating in commercial demonstrations & research programs to develop emissions-free hydrogen fuel cells for transportation <p>UNDER DEVELOPMENT</p> <ul style="list-style-type: none"> Hydrogenation for advanced cellulosic biofuels, which will create clean transportation fuels from non-food sources Optimization of trip planning to maximize product sold per mile traveled of internal distribution division [CJG] Efficient methods for producing LNG to fuel heavy vehicles Purifiers to allow hydrogen fuel cells to operate reliably
Buildings	Efficient lighting & day-lighting; more efficient electrical appliances & heating & cooling devices; improved cook stoves, improved insulation; passive & active solar design for heating & cooling; alternative refrigeration fluids, recovery & recycle of fluorinated gases.	Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback & control; solar PV integrated in buildings.	<p>EXISTING</p> <ul style="list-style-type: none"> Nitrogen & carbon dioxide in cryo-mechanical integration technology which improves the efficiency of mechanical freezers Technology to recover & recycle carbon dioxide in cryogenic food freezers Argon-filled energy efficient thermal insulated windows Rare gases for high performance lighting systems Gases and materials to manufacture LED lighting systems

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Industry	More efficient end-use electrical equipment; heat & power recovery; material recycling & substitution; control of non-CO2 gas emissions; & a wide array of process-specific technologies.	Advanced energy efficiency; CCS for cement, ammonia, & iron manufacture; inert electrodes for aluminium manufacture.	<p>EXISTING</p> <ul style="list-style-type: none"> • Helium to enhance fiber-optic manufacturing rates & product quality. Patented technology recovers up to 80% helium for reuse • Oxy-fuel combustion technology for the steel, glass & cement industries that increases fuel & electric power efficiency & production throughput & while reducing emissions • Heat recovery technology for glass production that reduces energy consumption by up to 30% • Ongoing equipment & control-systems upgrades that reduce the energy consumption of hydrogen and [CJG] air separation units such as advanced turbo-machinery, improved heat recovery integration [CJG], real time optimization & model predictive control • New materials like high-k precursors & tantalum sputtering targets that enable production of semiconductors with lower power consumption • Rare gases used in liquid-crystal-display (LCD) flat panels that lower unit power consumption in televisions, computers, cell phones • In the steel industry: <ul style="list-style-type: none"> ○ Stove oxygen technology that replaces the use of natural gas & reduces carbon dioxide emissions ○ Oxygen & oxy-fuel combustion technology that reduces the amount of natural gas required as fuel, increases production throughput & reduces NOx emissions by 80%-90% • Carbon dioxide to replace acids in the following industries: mining in hydrometallurgy; textiles for fabric neutralization; pulp & paper for pH control. These processes all serve as a carbon dioxide sink since a chemical reaction permanently removes carbon dioxide from the atmosphere <p>UNDER DEVELOPMENT</p> <ul style="list-style-type: none"> • Participating in an industry consortium to develop CCS for cement kilns • On-site fluorine generation for electronics industry which reduces the greenhouse gas impact compared to traditional use of more environmentally harmful agents • Participating in an industry/university consortium funding early-stage research in low-carbon-emission steel processing • Addition of hydrogen in flares to reduce the quantity of natural gas required to meet government emissions regulations • Catalytic reactor technology to remove organic sulfur from refinery gas streams thereby reducing atmospheric sulfur emissions

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Agriculture	Improved crop & grazing land management to increase soil carbon storage; restoration of cultivated peaty soils & degraded lands; improved rice management to increase soil carbon storage; restoration of cultivated peaty soils & degraded lands; improved rice cultivation techniques & livestock & manure management to reduce CH4 emissions; improved nitrogen fertilizer application techniques to reduce N2O emissions; dedicated energy crops to replace fossil fuel use; improved energy efficiency.	Improvements of crop yields.	<p>EXISTING</p> <ul style="list-style-type: none"> • Carbon dioxide to enhance plant growth in large-scale greenhouses • Oxygen-delivery technology to optimize sustainable fish farming
Forestry/ forests	Afforestation; reforestation; forest management; reduced deforestation; harvested wood product management; use of forestry products for bio-energy to replace fossil fuel use.	Tree species improvement to increase biomass productivity & carbon sequestration. Improved remote sensing technologies for analysis of vegetation/ soil carbon sequestration potential & mapping land use change.	<p>UNDER DEVELOPMENT</p> <ul style="list-style-type: none"> • In Italy, oxygen to improve the efficiency of a biomass gasifier fed with agricultural & tree-trimming waste for municipal heat & power

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Waste Management	Landfill methane recovery; waste incineration with energy recovery; composting of organic waste; controlled waste water treatment; recycling & waste minimization.	Biocovers & biofilters to optimize CH ₄ oxidation.	<p>EXISTING</p> <ul style="list-style-type: none"> • Carbon dioxide to neutralize alkaline wastewater streams, replacing the use of acids, creating a carbon dioxide sink by chemically changing the carbon dioxide & preventing its release into the atmosphere • Oxygen to enhance aerobic digestion of wastewater & in-situ oxygenation systems that reduce the release of volatile organics from wastewater treatment plants • In drinking water treatment, oxygen-fed ozone technology replaces chlorine as a disinfectant. Praxair supplied three water-treatment plants in Beijing to provide international standard quality drinking water during the Olympics & after • Sludge ozonation process provides a cost-effective means of reducing excess solids generated in wastewater treatment • By-product carbon dioxide from various processes (ethanol, chemicals & hydrogen production) converted to a usable product for customers • In Brazil, oxygen to reduce emissions in landfill waste. <p>UNDER DEVELOPMENT</p> <ul style="list-style-type: none"> • Developing means to recover helium from ammonia production plants that would otherwise be vented with purge stream • New membrane technology to allow hydrogen by-product from chemical processes to be efficiently recovered and purified