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Standard Guide for Basic Assessment and Management of Greenhouse Gases[1]

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INTRODUCTION

This guide provides a *uniform* set of options for communicating and planning greenhouse gas (GHG) management as well as strategies for addressing GHGs associated with a facility's operations. This guide may not apply to entities where such GHG assessment and management is already widely available through standard, uniform sets of guidance (for example, the construction of green buildings; mandatory air quality rules), or other standards. This guide provides a *uniform* voluntary framework for identifying management options and steps that may be beneficial to evaluate (GHG) solutions. It provides basic management strategies for existing corporations, commercial businesses, and government facilities, even those currently outside of various voluntary and regulatory schemes. The environmental assessment and management strategies contained in this guide recognize the overall value of existing responses. This guide references and blends similar, effective programs and extends them to a consistent approach that will facilitate communication and be a basic tool for business and industry.

Background—Activities that reduce GHG emissions or limit their atmospheric releases have been initiated internationally. This guide offers a framework of initiatives for individual or local efforts in managing GHG. To facilitate best practices, most GHG management programs establish a baseline of current emissions, establish objectives for reducing or managing those emissions, monitor progress in meeting these objectives, and report (either internally or externally) the results of these efforts. This guide offers useful principles in determining options, and in the selection of prudent activities, based on various scenarios and technology improvements, to enhance preservation of life and environmental conservation.

1. Scope

1.1 *Overview*—This guide presents a generalized systematic approach to voluntary assessment and management of the causes and impacts of GHGs. It includes actions, both institutional (legal) and engineering (physical) controls for GHG reductions, impacts, and adaptations. Options for a tiered analysis provide a priority ranking system, to address the "worst first" challenges of a facility, addressing practicality and cost-benefit.

1.2 *Purpose*—The purpose of this guide is to provide a series of options consistent with basic principles and practices for GHG-related action. This guide encourages consistent and comprehensive assessment and management of GHG outcomes from facility and business operations.

1.2.1 The guide also provides some *high-level* options for the monitoring, tracking and performance to evaluate the effectiveness of the commercial entity's strategy to ensure that a reasonable approach is taken.

1.2.2 This standard ties into the ASTM Committee E50 standards series related to environmental risk assessment and management.

1.3 *Objectives*—The objectives of this guide are to determine the conditions of the facility and or/property with regard to the status of GHGs and actions to be taken to manage and reduce or offset those emissions.

1.3.1 The guide provides a three-tiered decision strategy that focuses on business risk, cost-effective solutions in response to greenhouse gases, and related issues such as the need for energy independence.

1.4 *Limitations of this Guide*—Given the variability of the different types of facilities that may wish to use this guide, and the existence of state and local regulations, it is not possible to address all the relevant standards that might apply to a particular facility. This guide uses generalized language and

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examples to guide the user. If it is not clear to the user how to apply standards to their specific circumstances, it is recommended that users seek assistance from qualified professionals.

1.4.1 *Insurance Industry*—The effects of GHG on insurers are not clear. The definition of an insurable occurrence and a commencement point for when insurable claims are made, along with when conditions were discovered and the actionable information leading to an insurable loss is not clear. It may be inappropriate to speculate on GHGs that are highly uncertain for purposes of insurance related to specific events.

1.4.2 This guide does not take a position on the science of climate change, its association with anthropogenic greenhouse gases, or various mathematical models generated by international bodies.

1.4.3 The guide does not address water vapor as a greenhouse gas.

1.4.4 The guide only addresses anthropogenic greenhouse gases.

1.5 The guide uses references and information on the control, management and reduction of GHGs from many cited sources such as the Intergovernmental Panel on Climate Change, ISO, the World Resources Institute, and the National Academy of Sciences.

1.6 Several U.S.-based federal regulatory agencies served as sources of information on existing and anticipated regulation and management of GHGs including the Environmental Protection Agency, the Department of Energy, and the Securities and Exchange Commission.

1.7 This guide relies on current regulatory information about GHGs from various state agencies, including the California Air Resources Board, the Massachusetts and Connecticut Departments of Environmental Protection, the Western Climate Initiative, and the Regional Greenhouse Gas Initiative.

1.8 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.9 *The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2114 Terminology for Sustainability Relative to the Performance of Buildings

E2432 Guide for General Principles of Sustainability Relative to Buildings

2.2 *International Standards:*[3]

ISO 14001 :1996 Environmental Management Systems—Specification with Guidance for Use[4]

ISO 14064–1 :2006–03–01, Greenhouse Gases—Part 1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals

ISO 14064–2 Part 2: Specification with Guidance at the Project Level for Quantification, Monitoring and Reporting of Greenhouse Gas Emission Reductions or Removal Enhancements

ISO 14064–3 Part 3: Specification with Guidance for the Validation and Verification of Greenhouse Gas Assertions

ISO 14065 Greenhouse Gases—Requirements for Greenhouse Gas Validation and Verification Bodies for Use in Accreditation or Other Forms of Recognition (ISO 14065:2007 (E))

2.3 *Voluntary Registries:*

California Air Action Registry

The Climate Registry (TCR) – A non-profit corporation and collaboration of states, provinces and tribes in North America. The TRC established a voluntary infrastructure for measuring and reporting greenhouse gas emissions. Its goal is the accurate, transparent and consistent measurement for GHGs.

2.4 *Regional Initiatives:*

Midwest Greenhouse Gas Accord

Regional Greenhouse Gas Initiative

Western Climate Initiative

2.5 *National Initiatives:*

American Clean Energy and Security Act of 2009 (by Congressmen Waxman and Markey)

America's Climate Security Act of 2007 (by Senators Lieberman and Warner)

NOTE 1—These bills were not enacted.

2.6 *Government References:*

Congressional Budget Office, 2008, Policy Options for Reducing CO_2 emissions

National Science and Technology Council, Committee on Environment and Natural Resources, 2008, Scientific Assessment of the Effect of Global Change on the United States

United States Climate Change Science Program

National Academy of Sciences, (NAS) 2008, Understanding and Responding to Climate Change

NOTE 2—Links to some references are provided in Appendix X3.

2.7 *WRI Document:*[5]

WRI Greenhouse Gas Protocol, Scope 1, 2, and 3

3. Terminology

3.1 *Definitions:*

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Products of ISO/TC 207 for which ASTM E50 was a participant on behalf of ANSI.

[5] Available from World Resources Institute (WRI), 10 G Street, NE, Suite 800, Washington, DC 20002, http://www.wri.org.

3.1.1 *allowance*—An authorization to emit a fixed amount of carbon dioxide. Generally one metric ton of emissions equals one allowance.

3.1.2 *baseline/credit*—A type of emissions trading scheme where firms are encouraged to reduce their greenhouse gas emissions below a projected "business as usual" path of increasing emissions. Any reductions below that future path earns credits for the difference which can be sold to other emitters struggling to contain increases to baseline levels.

3.1.3 *business risk*—The likelihood that the operation could be subjected to future government regulations, industry standards, customer demand or shareholder decisions requiring measurement, disclosures, actions and/or planning to document and reduce greenhouse gases.

3.1.4 *cap and trade*—The most popular type of emissions trading scheme where emissions are subject to a cap, permits are issued up to that cap, and a market allows those emitting less than their quota of the cap to sell their excess permits to emitters needing to buy extra to meet their quota.

3.1.5 *carbon dioxide equivalent (CO_2e)* —Schemes that measure other greenhouse gas emissions, such as methane, by computing the amount of CO_2 that would have the same effects.

3.1.6 *carbon footprint*—The impact of human activities in terms of the amount of greenhouse gases they produce. The emissions associated with the use of power, transport, food and other consumption for an individual, family or organization are added up to give one comparable measure in units of carbon dioxide equivalent.

3.1.7 *carbon tax*—One form of carbon price on greenhouse gas emissions. Set by governments, a price on emissions is fixed and emitters are allowed to emit whatever they want at that price.

3.1.8 *The Climate Registry*—A compact of 43 States, Provinces, and Tribes in the U. S., Canada, and Mexico that have agreed to recognize voluntary carbon measurements and improvements by facilities.

3.1.9 *direct greenhouse gas emission*—Air discharges from sources owned or controlled by the individual or organization.

3.1.10 *emission or removal factor*—Relating activity data to GHG discharge reductions which could include an oxidation component.

3.1.11 *energy conservation*—Performing less work, using less light, heat, and movement.

3.1.12 *energy efficiency*—Performing the same amount of work, using less light, heat, and movement.

3.1.13 *energy indirect greenhouse gas emission*—Discharges to the air from the generation of imported electricity, heat, or steam consumed by the individual or organization.

3.1.14 *Energy Star*—Appliance efficiency rating program for the U. S. Federal Government.

3.1.15 *financial statements*—Include, but are not limited to, statements associated with shareholder reporting, periodic reports, registration statements, loans, mergers, acquisitions, or divestures. Financial statements may include statements outside of SEC filings.

3.1.16 *green buildings*—As defined in Terminology E2114 and Guide E2432.

3.1.17 *greenhouse gases (GHGs)*—Vaporous constituents of the earth's atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths, including carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

3.1.18 *greenhouse gas activity data*—A quantitative measure of activity that results in an emission or removal. (Examples of activity data include the amount of energy, fuels or electricity consumed, material produced, service provided, or area of land affected.)

3.1.19 *greenhouse gas assertion*—A declaration or factual and objective statement made by the "responsible party" that may be presented at a point of time or may cover a period of time. It should be clear, identifiable, and consistent.

3.1.20 *greenhouse gas emission*—The total mass of a GHG released to the atmosphere over a specified period of time.

3.1.21 *greenhouse gas information system*—The policies, processes and procedures to establish, manage, and maintain GHG information.

3.1.22 *greenhouse gas inventory*—An individual's or organization's greenhouse gas sources, greenhouse gas sinks, GHG emissions and removals.

3.1.23 *greenhouse gas programs*—Voluntary or mandatory international, national, or sub-national system or scheme that registers, accounts, or manages GHG emissions, removals, emission reductions, or removal enhancements outside the organization or GHG project.

3.1.24 *greenhouse gas project*—An activity or activities that alter the conditions identified in the baseline scenario which cause GHG emission reductions or GHG removal enhancements.

3.1.25 *greenhouse gas removal*—The total mass prevented from being emitted to the atmosphere over a specified period of time.

3.1.26 *greenhouse gas report*—A stand-alone document intended to communicate an organization's or project's GHG-related information to its intended users. (A GHG report can include a GHG assertion.)

3.1.27 *greennhouse gas source*—A physical unit or process that releases a GHG into the atmosphere.

3.1.28 *hydrogen technologies*—Generally, a Tier 3 emerging technology that substitutes H2 for liquid petroleum hydrocarbon fuels.

3.1.29 *Kyoto Protocol*—An international treaty signed by over 300 countries, with commitments to address, among other issues, greenhouse gases.

3.1.29.1 *Discussion*—The Treaty was ratified by over 180 parties.

3.1.30 *mitigation*—Attempts to lower or compensate for greenhouse gas emissions through energy conservation, alternative forms of energy generation, carbon offsets, or sequestration of carbon dioxide and other gases.

3.1.31 *NOx*—Nitrogen oxide compounds measured and regulated in air emissions.

3.1.32 *offsets*—A technique of compensating for the greenhouse gas emissions of an organization through acquisition of outside resources that reduce carbon.

3.1.33 *other indirect greenhouse gas emission*—Air discharges, other than energy indirect, which are consequences of an organization's activities, but arise from sources that are owned or controlled by other organizations.

3.1.34 *Regional Greenhouse Gas Initiative (RGGI)*—A compact among states in the northeastern United States where governments have agreed to impose mandatory cap and trading programs for power sources of over 25 MW. The original Memorandum of Understanding, dated December 20, 2005, and the corresponding Model Rule established the regional program.

3.1.35 *reporting entity*—Any business or public agency preparing a financial statement.

3.1.36 *sequestration*—Attempts to trap carbon and other greenhouse gases through techniques such as photosynthesis from tree planting or ocean seeding of algae or injection of gases into the deep bedrock.

3.1.37 *USGBC-LEED*—United States Green Building Leadership in Energy and the Environment green building-rating program.

4. Significance and Use

4.1 The use of this guide would be directed toward prudent business decision making, communications regarding GHGs emissions/control/reduction conditions, insurance, high-level analysis of potential reductions and/or remedies, budgeting, strategic planning for an entity's management of GHGs produced *in relationship to its business*.

4.2 *Example Users:*

4.2.1 Small businesses or enterprises;

4.2.2 Service industries;

4.2.3 Federal, state or municipal facilities and regulators, including departments of health and fire departments;

4.2.4 Financial and insurance institutions;

4.2.5 Waste managers, including liquid and solid waste haulers, treatment, recycling, disposal and transfer;

4.2.6 Consultants, auditors, inspectors and compliance assistance personnel;

4.2.7 Educational facilities;

4.2.8 Property, buildings and grounds management, including landscaping;

4.2.9 Non-regulatory government agencies, such as the military.

4.3 This guide is a first step in crafting simplified management goals for assessing, managing and reducing GHGs. The framework describes a process by which the user may categorize current carbon footprints and a priority approach to manage those risks. The technique classifies common responses for both mitigation and adaptation. The guide groups responses and examples into tiers based on the relative speed in responding to GHG emissions. The tier classifications found in this guide reflect the general structures of state, federal, and local response programs. These authorities generally classify groups of similar responses according to the timely availability and cost effectiveness of GHG responses.

4.3.1 This guide *presents basic principles and strategies in the U.S. for conducting baseline assessment and reasonable mitigation/adaptation strategic options on a corporate, or small business voluntary basis*. The following principals apply to this priority system:

4.3.2 Ability to set specific GHG goals for activities. These goals may include maintaining existing outputs of GHG while increasing a facility's operations, or reducing GHG through engineering changes while maintaining current operations.

4.3.3 Marketing environmental awareness and sensitivity;

4.3.4 Assessing risks from future GHG events;

4.3.5 Risk management, underwriting; loss control and history; premiums and claims;

4.3.6 Liability assessment and qualifications for loans;

4.3.7 Standardization, consistency, and certification of facility specific evaluations;

4.3.8 Educating employees, clients, and customers;

4.3.9 Generating multi media and cross medium information;

4.3.10 Evaluating vendors, and

4.3.11 Reducing costs and preventing pollution.

4.4 Users may consider various benefits of GHG assessment and response.

4.4.1 This guide is a basic primer on GHG impacts and may serve to introduce the subject for organizations unfamiliar with the principles.

4.4.2 Some government enforcement agencies, fiduciaries and business organizations publish GHG strategies. Over 400 municipalities in the United States, for example, have signed the principles of international standards to address GHGs. The public has systematic ability to access or estimate information on individual businesses. Therefore, businesses need guidance on how to assess the nature and potential risks of GHGs, and a programmatic approach for reducing or eliminating those risks through energy conservation, pollution prevention, alternative and emerging technologies and other proactive management systems.

NOTE 3—Users may wish to consider establishing data quality objectives, data management procedures, and documentation.

4.4.3 Reduced operation and maintenance costs may be realized through a tiered evaluation of GHG response opportunities.

4.4.4 Responses may be streamlined and simplified so that all levels in an organization may participate.

4.4.5 Some enterprises may be more competitive in the marketplace with improved GHG response programs.

4.4.6 Setting priorities can allow planning and evaluation of new GHG response requirements.

4.5 *Institutional Risks*—Some of the risks posed by GHG include future actions taken by the Federal Government and state government agencies. Government programs will establish responses to GHG that include mandatory assessment, reporting and mitigation for various regulated entities. Early voluntary actions, including the use of this guide, may help organizations prepare for and reduce the impacts of future government regulations. Some of the possible government programs that may be instituted to address GHG are described below.

4.5.1 The Carbon Tax.

4.5.2 Cap on greenhouse gas emissions.

4.5.2.1 Flexible versus rigid emission cap.

4.5.2.2 With and without ceilings and floors on GHG allowance prices.

4.5.2.3 Eligibility of domestic and international offsets for compliance.

4.6 *Managing Risk Uncertainty:*

4.6.1 There is little doubt at the international level that greenhouse gases will continue to be regulated. However, there are still important questions regarding how large and how fast these regulatory changes will be implemented, and what effects they will have in different regions. The ability to predict future global levels of GHGs has improved, but efforts to understand the impacts of GHGs on society and analyze mitigation and adaptation strategies are still relatively immature.

4.6.2 The tiered analysis in this guide will help support decision-making, studying regional impacts, and communicating with wider group of stakeholders in the face of uncertainty.

4.6.3 The insurance industry has always played a role by insuring against weather-related risks, promoting stronger building codes, and better land-use decision-making.

NOTE 4—Consequently, weather-related impacts are not addressed in this guide.

4.6.4 Many GHG regulatory schemes require documentation and validation of baseline greenhouse gas production. Standard techniques are contained in ISO 14064–1, ISO 14064–2, ISO 14064–3: 2006-03-01, and in ISO 14065.

5. The Tiered Approach to Risk Management

5.1 This guide establishes a framework of common GHG risk management strategies in the United States, Canada, and Mexico and will allow the user to evaluate the potential level of risk from greenhouse gas production and other GHG issues. Responses would then be evaluated for timeliness and availability in order to continually reduce the risks from GHGs.

5.2 *Tiered Management Categories:*

5.2.1 Tier 1, conventional, GHG responses represent the fastest potential risk reduction, because Tier 1 responses prevent generation of greenhouse gases through energy conservation and process efficiency improvements. These actions may prevent business risk impacts by providing immediate cost savings and lowering a facility's regulatory profile relative to the potential production of greenhouse gases. The planning horizon is current and includes actions that can be reasonably taken within two years of the beginning of a program.

5.2.2 Tier 2 responses address mid-term greenhouse gas reduction through the development and use of alternative energy such as wind, solar, and geothermal or establishment of actions to offset greenhouse gas emissions, such as carbon sequestration using reforestation or construction of green roofs. The Tier 2 planning horizon generally includes actions that can be taken within two to ten years.

5.2.3 Tier 3 responses address long-term greenhouse gas reduction by development of emerging technologies such as deep rock carbon sequestration or use of hydrogen fuel in transportation. The planning horizon includes actions that may be available through research and development programs in ten to thirty years.

5.3 *Tiered Approach to GHG Assessment and Response*—The essential principles of this guide are:

5.3.1 Environmental assessment by objective;

5.3.2 Mitigation of GHG through prevention and reduction of greenhouse gases;

5.3.3 First steps in GHG response;

5.3.4 Priority planning;

5.3.5 Measuring greenhouse gas emissions, and checking reductions of a facility;

5.3.6 Establishing a facility fence line and base year;

NOTE 5—These are user defined.

5.3.7 Greenhouse gas emissions should be considered from three major sources:

5.3.7.1 Direct on-site emissions from heating, cooling, transportation, construction and other equipment,

5.3.7.2 Indirect emissions from electricity use, and

5.3.7.3 Other indirect impacts from extraction of raw materials, water use, product use, recycling, waste disposal, and employee transportation.

5.3.8 Implementing improvements, checking greenhouse gas reductions, and acting to correct and modify the plan accordingly.

5.3.9 This guide groups GHG assessment and response into three general categories: efficiency and conservation; alternative energy technologies; and emerging energy technologies.

5.4 *Tier 1: Conservation and Efficiency:*

5.4.1 Once the facility has established a baseline year for measuring and estimating greenhouse gases and a fenceline for analysis, the facility has initiated the first step in the GHG reduction and elimination process. Generally, in this step, the user will find and use energy conservation and efficiency to reduce greenhouse gases. These are also the most cost effective first actions for the facility.

5.4.2 Tier 1 Rresponses generally govern the prevention of and response to greenhouse gas emissions through immediate, conventional technologies such as energy conservation or more efficient equipment. In addition, implementation of strategies that increase recycling of solid waste and the composting of organic waste may translate into significant indirect reductions in fuel use associated with the transportation of these materials to off-site disposal facilities.

5.4.3 For example, replacement of electrically powered appliances with Energy Star appliances provides the same function or service to the facility with increased energy

efficiency and lower production of greenhouse gasses. See Appendix X1 for more specific examples.

5.4.4 In many cases the facility can formulate an energy management system with the "plan, do, check, act" approach to monitor improvements and greenhouse gas reductions.

5.4.5 During the planning stage the facility may construct a Tier I look-up table to calculate and track reductions in greenhouse gases, using certain standard assumptions. This might employ government, non-profit or international, web-based, carbon calculator tools, such as those listed in Appendix X3.

5.5 *Tier 2: Alternative Technologies:*

5.5.1 Once the facility has established and implemented energy conservation and efficiency options in Tier 1, use of alternative technologies is the second step in the GHG reduction and elimination process. Generally, in this step, the user will find and use alternative forms of energy production, whether from commercial utility sources or on the site of the facility itself, to reduce greenhouse gases. After Tier 1, these are the next most cost effective actions for the facility.

5.5.2 Tier 2 responses ensure the planning for longer-term activities involving alternative methods or technologies with lower greenhouse gas emissions. Examples include off-peak use, power storage, wind turbines, solar arrays, or geothermal energy production. They can also include purchase of alternative energy from the electric power utility or offsetting emissions by planting or restoring vegetation.

5.5.3 For example, planning and construction of green roofs for a facility provides energy conservation by lowering interior and exterior temperatures in the summer and conserving heat in the winter. Green roofs have the added benefit of directly lowering carbon dioxide emissions, and reducing storm water runoff through plant transpiration and water retention.

5.5.4 Use of Tier 2 technologies should be incorporated into the facility's overall energy management plan, using the "plan, do, check, act" approach.

5.5.5 During the planning stage, certain assumptions regarding greenhouse gas generation might be changed in order to estimate greenhouse gas reduction from alternative technologies. See Appendix X1 and Appendix X3 for more information.

5.5.6 Users should consider GHG production estimates for the manufacture of alternative energy.

5.6 *Tier 3: Emerging Technologies*—Tier 3 standards encompass the long-term investment in future, emerging technologies for later years of needed greenhouse gas reductions that may not be currently possible.

5.6.1 For example, the sequestration of carbon through underground gas injection may be a long-term option for some facilities that will still require combustion of fossil fuels such as coal or oil in the long-term planning horizon.

5.6.2 Generally, these technologies are the most expensive and least well proven GHG elimination or reduction techniques.

5.7 Facilities should focus on GHG response in a systematic way. The guiding principle for these programs is pollution prevention. By evaluating and implementing greenhouse gas reduction steps for each class of response, facilities will reduce both energy costs and ancillary impacts on the environment over time. Tier 1 and 2 responses generally show the greatest immediate GHG response opportunities.

5.8 The tiered GHG response planning analysis is shown in Fig. 1. This is an iterative process that first identifies the GHG footprint standards for mitigation and the user plans each tier of response to reduce GHG risk. The user then does selected responses, checks them against the risk reduction goals, and acts to implement improvements until goals are met. An example of this "plan, do, check, act" method is contained in ISO 14001. The user conducts the tiered evaluation in this iterative fashion until a long-term GHG response plan is formulated.

5.9 At each step in the process, the user should measure and evaluate the actions taken using a consistent, documented approach. Users should verify that GHG risk responses represent best management practices, given the circumstances of the organization, and the current status of technology.

5.10 The overall goal is for continuous improvement and reduction of GHG risks. See Appendix X1 for specific examples of this tiered analysis.

6. Keywords

6.1 air emissions; carbon dioxide; energy efficiency; environmental risk management; greenhouse gases; renewable energy

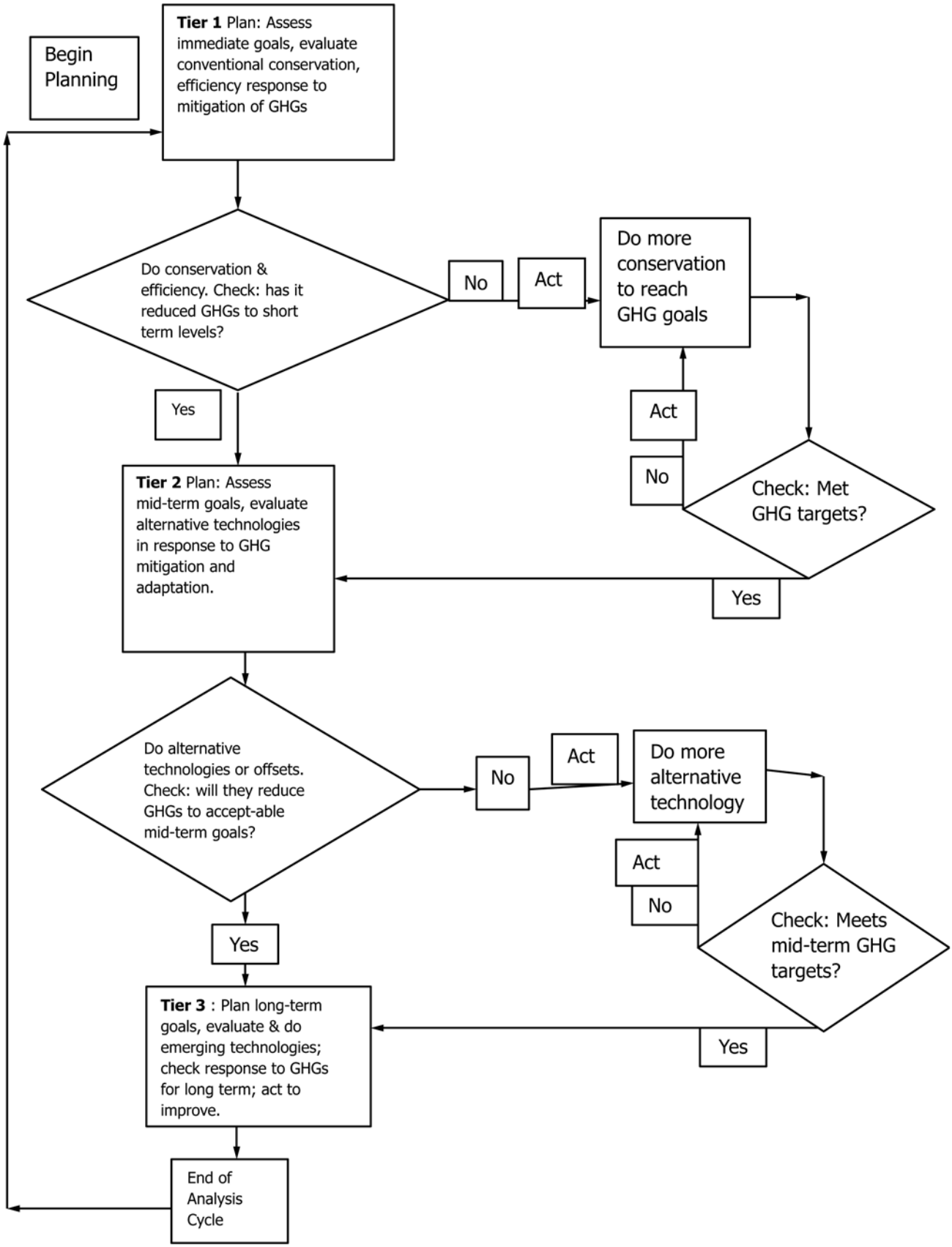

FIG. 1 Sample Flow Chart for GHG Response Analysis

TABLE 1 Sample Classification of GHG Responses

GHG Management Sector	Tier 1: Conventional Conservation	Tier 2: Alternative Technologies	Tier 3: Emerging Technology
Energy Consumption from grid	Energy conservation, change to fluorescent lighting.	Off peak energy use. Wind solar, hydro and other energy credits. Change to LED lighting.	Deep rock, ground-water carbon sequestration. Tidal power.
Transport	Commuter Car Pools. Public Transportation.	Carbon-off sets for plane trips. Hybrid and plug-in hybrid vehicles, compressed natural gas.	Hydrogen vehicles.
Facility Mitigation	Heating and cooling conservation insulation, replacement of doors, windows and thermostats. Water conservation, low flush toilets. Alternative disposal/use of process water. Retrofit boilers and chillers with more efficient units. Energy Star Appliances.	Solar hot water, photovoltaics, geothermal energy, architectural wind. Green roofs.	Zero Energy building.

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE GHG ASSESSMENT AND RISK MANAGEMENT

X1.1 Tier 1 Activities—Energy Efficiency and Conservation

X1.1.1 *Establish a Fence Line*—The user should decide what to include in the risk management analysis. Major sources of greenhouse gases and identification of the facility should be documented during the Tier I planning stages. The sample facility is a 5000 ft^2 commercial bakery located in New England, named Able Bakery. The fence line includes the entire building owned and controlled by the company and three major sources of greenhouse gases: (*1*) indirect electricity use for all power on the property, (*2*) direct emissions of refrigerants from commercial units, and (*3*) transportation costs for the bakery's raw materials. Direct emissions from heating the facility by natural gas were not included.

X1.1.2 *Establish a Base Line*—The baseline year for this analysis is 2007. Data include:

X1.1.2.1 The consumption of energy in kWh from the local electric utility.

X1.1.2.2 The estimation of energy use from the large commercial appliances such as refrigerators and ovens.

X1.1.2.3 The estimation of hydrofluorocarbon (HFC) gas losses from industry specifications and age of the refrigeration units, their global warming potential (GWP), and conversion to metric ton equivalents of CO_2 (Mt CO_2e).

X1.1.2.4 The estimation of emissions from the transportation of raw materials, especially flour from the Midwest, based on the number of tons purchased and distance traveled by diesel truck.

X1.1.3 Construct a lookup table from standard greenhouse gas calculators.

X1.1.4 *Plan*—In constructing a look-up table, the user should identify all facility specific sources of greenhouse gases for the fence line elements and baseline year of the analysis. Many voluntary programs of GHG management include three major categories for identification.

X1.1.4.1 Electricity consumption, indirect GHG production (WRI Scope 2 Emissions).

X1.1.4.2 Direct sources of greenhouse gases (WRI Scope 1).

X1.1.4.3 Other indirect sources of greenhouse gases (WRI Scope 3).

X1.1.5 The sample look-up table draws information from EPA's Energy Star Portfolio Manager (See Appendix X3 for links) to calculate estimates of greenhouse gas reductions at each tier of the analysis.

X1.1.6 *Do*—In Tier I, the facility implemented the replacement of refrigeration units and ovens for indirect reduction in greenhouse gases from lowered energy demand. In addition to energy saving characteristics, the facility chose units with refrigeration gases containing HFC gases with several orders of magnitude lower global warming potential.

X1.1.7 *Check*—The user then checked the energy use and the loss of HFCs at the end of the implementation period of one year, to document greenhouse gas reductions, act upon any malfunctioning equipment, and see if Tier I goals had been met.

X1.1.8 Table X1.1 shows that Able Bakery easily reduced the greenhouse gases included in its baseline by greater than 10 %—its Tier 1 goal.

X1.2 **Tier 2 Activities**:

X1.2.1 Modifying the lookup table, changing greenhouse gas generation assumptions through use of energy alternatives in electricity use.

X1.2.2 During the first year of analysis, the local utility installed new wind turbines that supply the town with an estimated 13 % of its power and an equivalent amount of greenhouse gas reduction.

X1.2.3 With change in the electricity mix, Able Bakery has achieved its Tier 2 goal of 20 % reduction in the greenhouse gas emissions included in the baseline.

X1.3 **Tier 3 Activities**:

X1.3.1 Modifying the look-up table, by changing greenhouse gas generation assumptions for other indirect emissions.

X1.3.2 Since the 2007 baseline, Able Bakery has purchased its flour from milling facilities in the Midwest and taken delivery of its raw materials through diesel truck transport. This results in approximately 50 Mt CO_2e emissions per year, included in its baseline assessment.

X1.3.3 Managers have been researching emerging technologies in commercial transport using biofuel blends, as well as more local sources of milled flour from experimental farms in New England.

X1.3.4 A more local supplier, using hydroponics in New England and biodiesel-fueled trucks, plans to open operations in two years. They estimated greenhouse gas savings to Able Bakery.

X1.3.5 Once implemented, the facility will check and document actual greenhouse gas savings in Tier 3.

X1.3.6 From all three Tiers of implementation. Able Bakery estimates it will reach a 37 % reduction in greenhouse gases, as compared to its baseline, by 2012.

TABLE X1.1 Example GHG Assessment and Risk Management Summary

Type of Analysis	GHG Goals	Annual Estimated GHG Emissions in Mt CO_2e			
Example: Able Bakery	% Reduction by year	Indirect Electricity (Scope 2)[A,B]	Direct HFC gases (Scope 1)[C]	Other Indirect Raw Material Transport (Scope 3)	Total GHG Fence Line
Baseline assessment	2007	180	15	50	245
Tier 1 Risk Reduction Goal	10 % by 2010				
Replace Refrigerators and Ovens '08[D]		165	1	50	216 (–12 %)
Tier 2 Risk Reduction Goal	20 % by 2030				
Locate Renewable Alternatives		145	1	50	196 (–20 %)
Tier 3 Risk Reduction Goal	50 % by 2050				
Find Local Raw Material Supplier		145	1	10	156 (–37 %)

[A] Derived from eGRID: Emissions and Generation Resource Integrated Database, EPA, Energy Star, 2009.
[B] Indirect CO_2 Emissions from the Consumption of Purchased Electricity, Heat and/or Steam. WRI/WBCSD GHG Protocol Initiative, 2007.
[C] Calculating HFC and PFC Emissions from the Manufacturing, Installation, operation and Disposal of Refrigeration and Air-conditioning Equipment (Version 1.00), GHG Protocol, 2005.
[D] Life Cycle Cost Estimates for Energy Star Qualified Commercial Refrigerators. Energy Star, 2009. Note—This is not a 'life-cycle assessment,' as that term may be defined in other standards.

X2. REGULATORY MECHANISMS TO REDUCE GREENHOUSE GAS EMISSIONS

X2.1 *Introduction* —The purpose of this appendix is to provide a description of the types of existing and potential regulatory mechanisms to control, measure, or reduce greenhouse gas (GHG) emissions in the U.S. and other countries. A sound understanding of the major features of these regulatory mechanisms is necessary for companies and organizations trying to assess their exposure to potential costs and benefits created by these regulations. The appendix provides a discussion of how each mechanism contributes to the reduction of GHG emissions, integrates with the major policy parameters, and affects the prices of GHG emissions allowances, major fuels, electricity, and investment.

X2.1.1 The main objective of every regulatory environmental policy is to take the previously free ability to emit and force emitters to internalize the societal costs of such emissions. A necessary element of these regulatory mechanisms is the inclusion of a monitoring system where either GHG emissions or the fossil fuel use for their GHG creation potential are directly measured or indirectly the machinery is rated for its fuel efficiency as is done with cars and appliances. For all policies, the cost of being able to emit GHG will be determined by the interplay of two factors: (*1*) the degree to which society wishes to limit GHG emissions; and, (*2*) the cost of abatement, that is, the economic costs to GHG emitters of reducing their emissions. If the cost of abatement and society's willingness to reduce GHG emissions is low, then the economic costs and business risks to emitters will be low too. In one extreme case, if it is costless for a set of emitters to reduce their emissions such that the aggregate GHG emissions limits are met, there will be no economic costs and no business risks from a socially mandated reduction in GHG emissions.

X2.1.2 Regulatory mechanisms to reduce GHG emissions can be generally described as systems of involuntary requirements or penalties imposed against sources of emission (such as generation plants, transportation using fossil-fuel, etc.), as well as direct or indirect awards for abatement technologies and activities (such as carbon sequestration or efficiency projects). Regulatory mechanisms can be categorized as market-based or command-and-control-based.

X2.1.3 Under "market-based" mechanisms, the main regulatory tool could be to set a fee (tax) per unit of emissions, or an aggregate emissions limit (cap) by issuing allowances, or a combination of both. In the case of a fee (or carbon tax), the government determines a time schedule of fees per unit of emission. In this market mechanism, those with higher cost of abatement than the predetermined fee choose to continue emitting (and pay the fee), while those with lower cost of abatement than the fee find it economic to reduce their emissions (and avoid the fee). In the case of an aggregate emissions cap, the regulated entities (emitters, or importers of fuels, or producers of fuels) are required to submit an allowance for each unit of GHG emitted. The allowances could be obtained either by paying for them (in auctions or bilateral trades) or through free allocations by government. The trading of allowances determines who obtains the right to emit GHGs and who reduces GHG emissions, Having established a system of tradable rights, the market then efficiently reallocates those rights to those who have the highest willingness to pay—those

who make profits or get utility from production whose byproduct is GHG emission. Those with lower cost of avoiding emissions would sell their emissions rights to those with highest cost of avoiding emissions. Depending on how property rights are allocated, the entities with lower abatement costs could receive a windfall, and, those who continue to emit could experience a wealth loss.

X2.1.4 The opposite approach is the "command-and-control" mechanism, in which mandatory requirements on emissions are either introduced for each emission source, or imposed to force the installation of a minimum amount of a specific technology to produce (such as requirements to use solar or wind units or some form of CO_2 capture for power generation).

X2.1.5 The regulatory mechanisms may be set up to apply to all sectors and uses (i.e., economy-wide), or sector-specific (such as carbon cap and trade for electric sector, or efficiency standards for new vehicles). In addition, regulatory mechanisms can apply to entities in both production activities (e.g., electric sector, refineries, farms, etc.), or consumption activities (e.g., home insulations, appliance standards, etc.).

X2.1.6 With that overview of regulatory mechanisms as background, the rest of the appendix provides a review of the characteristics and sectoral comparisons of GHG emissions in U.S. to identify the potential winners and losers from the regulatory mechanisms.

X2.2 *A Primer on GHGs*—Primary GHGs are carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), ozone (O_3), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).[6] The potential of a unit of each of these gases to contribute to global warming varies, and can be measured by the metric "global warming potential," or GWP. According to U.S. Energy Information Agency (EIA), the GWP of methane is 25 times that of CO_2, while GWP of sulfur hexafluoride is approximately 23 000 times that of CO_2.[7] Given the scientific uncertainties, the estimated relative global warming potentials of various gases may change over time. In addition, the timing and magnitude of any impact from global warming is highly uncertain. Finally, the political will to manage risks associated with the expected levels of global warming is also highly uncertain. This section does not address these uncertainties.

X2.2.1 Most GHGs are not directly made through human activities and instead arise from natural processes such as the formation of water vapor from the oceans or creation of carbon dioxide through the process of birth and death from all organic and living materials. Respiration and any other oxidation process (for example, decomposition) releases energy and produces carbon dioxide while photosynthesis and other processes that absorb solar, heat and kinetic energy reverse the oxidation process by breaking oxygen from carbon dioxide (or combining methane into other organic compounds). Most (83 %) of the anthropogenic (man-made) GHG emissions in U.S. in 2007 (7282 million metric tons, or MMt, of CO_2-equivalent) were from CO_2 (6022 MMt) and arise as a byproduct in releasing energy to be used in driving warming (heat exchange more generally), lighting and mechanical activities. Methane (700 MMt) and nitrous oxide (384 MMt) were the second and the third largest contributors.[8] A graphical depiction by U.S. Department of Energy[9] of the composition of GHG emissions in U.S in 2007 based on end use, fuel, and type of GHG is shown in Fig. X2.1.

X2.2.2 Ultimately all anthropogenic GHG emissions arise as a result of household's consumption of goods and services (including direct use of energy for heating or cooling). Therefore, one could quantify sectoral risk by the carbon content of the consumption of household goods and services. However, given the regulatory mechanisms being considered, for the purposes of assessing the business risks associated with the costs and benefits due to pricing of emissions, it makes most sense to categorize emissions, by their emissions sources and in the case of electricity and transportation, the sectors most exposed to electricity and transportation use. Direct CO_2 emissions from electric sector accounted for 2433 MMt (40 %) of the total 6022 MMt of total CO_2 emissions in U.S. in 2007.[10] Most of the electric sector CO_2 emissions come from coal (1980 MMt, or 81 %), followed by natural gas (376 MMt, 15 %). Transportation accounts for 34 % (1991 MMt) of CO_2 emissions, split approximately 60 % for households and remaining from commercial activity (heavy-duty vehicles and aircraft).[11] Households directly emit about 345 MMt through burning natural gas and petroleum products for (space and water heating), about 1200 MMt through their vehicle use, and indirectly emit about 900 MMt through their use of electricity.[12]

X2.2.3 When aggregated together, the GHG emissions from the main four end-use sectors in U.S. in 2007 were 1281 MMt from residential sector (18 %), 1355 MMt from commercial sector (19 %), 2610 MMt from industrial sector (36 %), and 2036 MMt from transportation sector (27 %).[13] The GHG emissions from electric sector are included in these figures based on the ratio of electric sales in each sector.

X2.2.4 Under GHG regulations that penalize the GHG emissions by assigning a price per unit of emissions (for

[6] IPCC Fourth Assessment Report, "Climate Change 2007—The Physical Science Basis—Annex 1—Glossary", 2007. Note that the list of GHGs here does not include other greenhouse gases such as the halocarbons and other chlorine- and bromine-containing substances since they are not dealt with under the Kyoto Protocol, but instead under the Montreal Protocol on Substances that Deplete the Ozone Layer.

[7] EIA, "Emissions of Greenhouse Gases in the United States 2007", December 2008, Table 4.

[8] EIA, "Emissions of Greenhouse Gases in the United States 2007", December 2008, Table 1.

[9] EIA, "Emissions of Greenhouse Gases in the United States 2007", December 2008, Page 4.

[10] EIA, "Emissions of Greenhouse Gases in the United States 2007", December 2008, Table 11.

[11] EIA, "Emissions of Greenhouse Gases in the United States 2007", December 2008, Table 10; and EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 –2006", April 15, 2008, page ES-8.

[12] EIA, "Emissions of Greenhouse Gases in the United States 2007", December 2008, page 16.

[13] EIA, "Emissions of Greenhouse Gases in the United States 2007", December 2008, page 5.

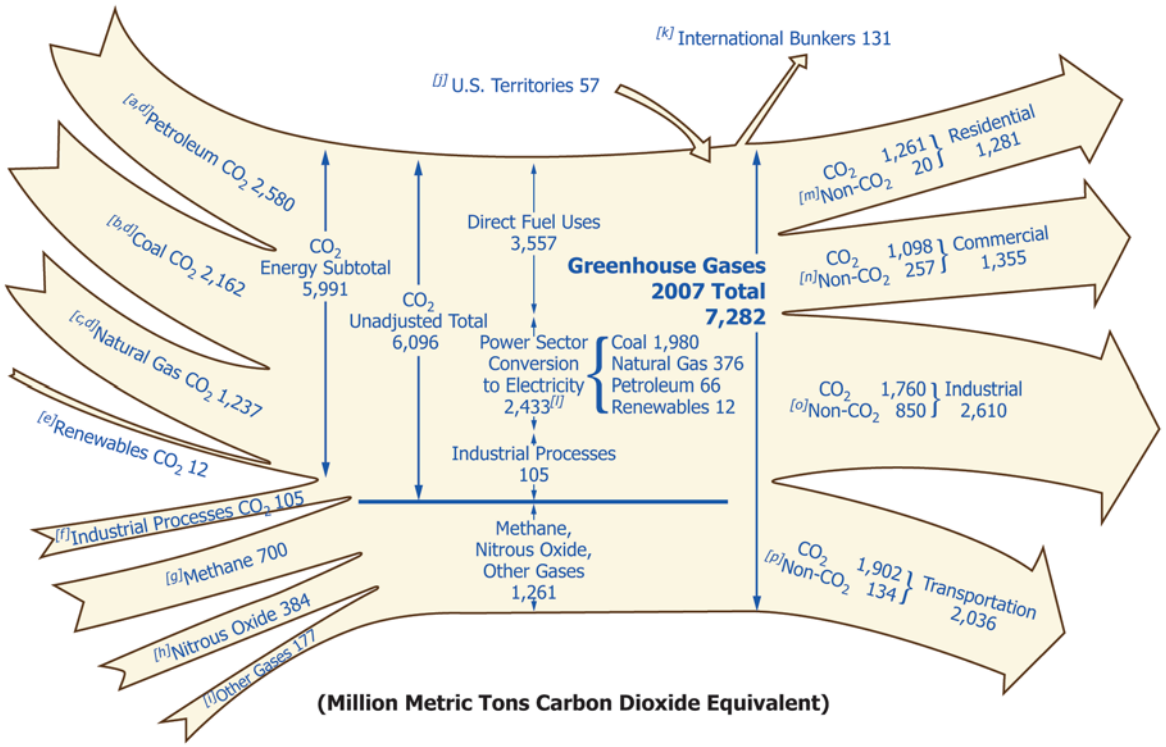

FIG. X2.1 GHG Emissions in U.S. in 2007

example, per ton of CO_2-equivalent), the cost exposure of companies and individuals to the emission prices depend on (*1*) the CO_2-intensity of their production and consumption (inputs to production and end-use), and (*2*) the amount of their production and consumption. The CO_2 intensity of production and consumption in turn is a function of the sources of energy used and the efficiency of converting the energy in source during the production and consumption process. For example, in the transportation sector, the CO_2 intensity of transporting goods and people depends on type of energy source (motor gasoline, diesel, jet fuel, solar, hydrogen, etc.) and the efficiency of transportation equipment (for example, 30 miles traveled per gallon of gasoline). As another example, in electric sector, the CO_2 intensity of electric power output depends on the energy source (coal, natural gas, wind, solar, nuclear, etc.) and the efficiency of generation (heat rates of generation units) and transmission and distribution system (losses due to heat dissipated from lines and other equipment).

X2.2.5 Among fuels, coal has the highest CO_2 content per unit of energy content (0.10 short tons per MMBtu for bituminous coal), followed by motor gasoline and jet fuel (0.08 short tons per MMBtu). Wind, solar, and nuclear energy sources have no CO_2 content, hence produce no CO_2 emissions. The direct CO_2 intensities (or emission factors) of major types of fuels are shown below in the Table X2.1.[14] The first column provides emission factors per volume or mass, and the second column per unit of energy content (million Btu).

X2.2.6 The CO_2 emission factors listed above can be used in assessing the impact of pricing CO_2 emissions on fuel prices. Using the emission factors in the first two columns of

[14] EIA, "Voluntary Reporting of Greenhouse Gases Program Fuel and Energy Source Codes and Emission Coefficients", posted at http://www.eia.doe.gov/oiaf/1605/coefficients.html. Note—These emission factors are for fuel use only and do not include construction, maintenance, or life-cycle assessment.

TABLE X2.1 CO_2 Emissions Factors and Cost Adders Due to Pricing CO_2

Fuel	CO_2 Emissions Factors		Average Price of Fuel in 2007	% Cost Adder due to $1/short ton of CO_2
	Short tons per volume or mass	Short tons per million btu	$ per volume or Mass	
Jet fuel (gallon)	0.01	0.08	2.17	0.5 %
Motor gasoline (gallon)	0.01	0.08	2.82	0.3 %
Natural Gas (1000 cubic feet)	0.06	0.06	6.39	0.9 %
Coal—Bituminous (short ton)	2.47	0.10	25.82	9.5 %
Wind	...	...		0.0 %
Photovoltaic and Solar Thermal	...	...		0.0 %
Nuclear	...	...		0.0 %

the table above, a $1 per short ton of CO_2 translates into $2.47 per short ton of coal and 10 cents per MMBtu of coal, and 1 cent per gallon of gasoline and 8 cents per MMBtu of gasoline. At average prices of $25.82 per short ton of coal and $2.82 per gallon of motor gasoline in U.S. in 2007 (shown in the third column), a $1 per short ton of CO_2 is about 9.5 % of coal price and 0.3 % of gasoline price.[15]

[15] Average prices of jet fuel, motor gasoline, natural gas, and coal (minemouth) from Tables 12, 13, and 15 in EIA's Annual Energy Outlook 2009, posted at http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html.

X3. ELECTRONIC LINKS FOR GHG ASSESSMENT AND MANAGEMENT

X3.1 Links:

X3.1.1 American Forests, nonprofit forest conservation organization (http://www.americanforests.org/resources/ccc)

X3.1.2 BeGreen, from Green Mountain Energy Co., which sells environmentally friendly energy products and carbon offsets (http://www.begreennow.com/calculator)

X3.1.3 Bonneville Environmental Foundation, nonprofit that markets renewable energy products (http://www.greentagsusa.org/greentags/calculator)

X3.1.4 California Climate Action Registry (http://www.climateregistry.org/)

X3.1.5 Clear Water, environmental advocacy group for the Hudson River (http://www.clearwater.org/carbon.html)

X3.1.6 The Climate Registry (http://www.theclimateregistry.org/)

X3.1.7 Emissions & Generation Resource Integrated Database (http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

X3.1.8 Energy Star (http://www.energystar.gov)

X3.1.9 Environmental Protection Agency (http://www.epa.gov/climatechange/emissions/ind_calculator.html)

X3.1.10 Greenhouse Gas Protocol Initiative (http://www.ghgprotocol.org)

X3.1.11 Midwestern Greenhouse Gas Reduction Accord (http://www.midwesternaccord.org

X3.1.12 Regional Greenhouse Gas Initiative (http://www.rggi.org)

X3.1.13 Western Climate Initiative (http://www.westernclimateinitiative.org)

X3.1.14 SafeClimate, from World Resources Institute, an environmental think tank (http://www.safeclimate.net)

X3.1.15 TerraPass, social enterprise that sells carbon offsets (http://www.terrapass.com/carbon-footprint-calculator)