Version 1.0

USEA/USAID HANDBOOK OF CLIMATE CHANGE MITIGATION OPTIONS FOR DEVELOPING COUNTRY UTILITIES AND REGULATORY AGENCIES

USEA

United States Energy Association

USAID

prepared by

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DISCLAIMER

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The report was prepared by David W. South, Robyn Camp, Jack S. Siegel, and Thomas B. Meade of Energy Resources International, Inc. under the direction of John Hammond and Sridhar Samudrala of the USEA. The views expressed herein are those of the authors and do not necessarily reflect the views of the U.S. Agency for International Development.

PREFACE

This Handbook reflects the most current available information with respect to practices for the power sector.

This version of the Handbook is complete, yet represents a "work in progress." According to current USEA and U.S. Agency for International Development (USAID) plans, as additional information on impact of best practices on greenhouse gas emissions becomes available, it will be incorporated in future editions of this Handbook. A draft version of this Handbook was released to U.S. Energy Association (USEA) Energy Partnership Program (EPP) participants at the World Energy Congress in September 1998 for feedback. Where possible, their comments have been incorporated in this edition.

Entries marked by "N/A" indicate information that is not readily available or is too site specific as to be widely applicable. To increase the usefulness of this Handbook, users are encouraged to provide feedback, including actual experiences, successful applications, and other relevant information on any of the best practices included to the authors. Contact information is listed below. Information relevant to these entries marked N/A is especially of interest. This feedback will be incorporated in the next version of the Handbook, tentatively scheduled for release in mid-2000.

Caveats:

- Reference to particular experiences, programs, or U.S. utilities is not meant to be inclusive but illustrative based on the information sources accessible during preparation of the Handbook. The authors encourage users of this Handbook to submit their own experiences and lessons learned for the benefit of colleagues internationally.
- Some information is included on various companies, products and conferences. This is not intended as an endorsement, but is provided for informational purposes only.
- All worldwide web addresses were current at the time of inclusion, but given the dynamic nature of the web, may have changed or sites may have been discontinued.

For further information regarding this Handbook contact:

David W. South *south@energyresources.com*
Robyn Camp *camp@energyresources.com*

Energy Resources International, Inc.
1015 18th St., NW Suite 650
Washington, DC 20036 USA
Tel: + (202) 785-8833
Fax: + (202) 785-8834

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LIST OF ABBREVIATIONS AND ACRONYMS

°C	Degrees Celsius
°F	Degrees Fahrenheit
$	Monetary unit, United States dollar
AC	Alternating current
ACEEE	American Council for an Energy-Efficient Economy
ADB	Asian Development Bank
AFBC	Atmospheric fluidized bed combustion
AIJ/JI	Activities Implemented Jointly/Joint Implementation
ALGAS	Asia Least Cost Greenhouse Assessment Study
ALTENER	Alternative Energy program of the European Community
BPA	Bonneville Power Administration
Btu	British thermal unit
CADDET	Centre for the Analysis and Dissemination of Demonstrated Energy Technologies
CEE	Central and Eastern Europe
CEF	Clean Environment Fund
CEM	Continuous emissions monitoring
CESI	Centro Elettrotecnico Sperimentale Italiano
CIF	Carbon Investment Fund
CNG	Compressed natural gas
CO_2	Carbon dioxide
COP-3	Third Meeting of the Conference of the Parties (Kyoto, Japan)
COP-4	Fourth Meeting of the Conference of the Parties (Buenos Aires, Argentina)
CORECT	Committee on Renewable Energy Commerce and Trade
CRIEPI	Central Research Institute of Electric Power Industry
CSIR	Council for Scientific and Industrial Research
CTI	Climate Technology Initiative
DC	Direct current
DCA	Direct Credit Authority
DOE	Department of Energy
DSM	Demand-side management
ECBC	Emissions Control Byproducts Consortium
ECBCS	Energy Conservation in Buildings and Community Systems
EE	Energy efficiency
EEI	Edison Electric Institute
EJ	Exajoules
EM	Environmental management
EMF	Electromagnetic field
EMS	Energy management system
EMTP	ElectroMagnetic Transients Program
EPA	Environmental Protection Agency
EPP	Energy Partnership Program
EPRI	Electric Power Research Institute

ESCO	Energy Service Company
ESKOM	Electricity Supply Commission (South Africa)
ESMAP	Energy Sector Management Assistance Program
ESPC	Energy Savings Performance Contract
FACTS	Flexible AC transmission system
FBC	Fluidized bed combustion
FCCC	Framework Convention on Climate Change
FETC	Federal Energy Technology Center
FGD	Flue-gas desulfurization
FIDE	Mexican federal commission for energy efficiency
FINESSE	Financing Energy Services for Small Scale Energy
FPL	Florida Power and Light
GCI	Global Carbon Initiative
GEF	Global Environment Facility
GHG	Greenhouse gas
g/mi	Grams/mile
GT 4000	Geothermal 4000
GtC	Gigatons of carbon
GW	Gigawatts
GWh/yr	Gigawatt hours per year
ha/MW_e	Hectares/Megawatts of electricity
H_2S	Hydrogen sulfide
HOV	High Occupancy Vehicle
HVAC	Heating/Venting/Air Conditioning
HVDC	High Voltage Direct Current
IBRD	International Bank for Reconstruction and Development
IDA	International Development Agency
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IEEN	Industrial Energy Efficiency Network
IFC	International Finance Corporation
IFREE	International Fund for Renewable Energy and Energy Efficiency
IGCC	Integrated Gasification Combined Cycle
IIEC	International Institute for Energy Conservation
IPCC	Intergovernmental Panel on Climate Change
IRP	Integrated Resource Planning
IUEP	International Utility Electrical Partnerships
KEB	Karnataka Electricity Board
kV	Kilovolt
kVA	Kilovolt asynchronous current
kVAr	Kilovolt asynchronous current
kW	Kilowatt
kWh	Kilowatt-hour
$lb/CO_2/MWh_e$	Pounds of carbon dioxide per megawatt hour of electricity
LBNL	Lawrence Berkeley National Laboratory
LNB	Low-NO_x burner

LPG	Liquefied petroleum gas
mcf	Million cubic feet
MSW	Municipal solid waste
Mt	metric ton
MtC	Million metric tons of Carbon
MtC/MW_e/year	Million metric tons of Carbon per megawatt of electricity per year
MVA	Megavolt asynchronous current
MVAr	Megavolt asynchronous current
MW	Megawatt
MW_e	Megawatt of electricity
N/A	Not available, not applicable
NARUC	National Association of Regulatory Utility Commissioners
NEDO	New Energy and Industrial Technology Development Organization
NGCC	Natural gas combined cycle
NGO	Non-government organization
$NICE^3$	National Industrial Competitiveness for Energy, Environment and Economy
NIMBY	"Not In My Back Yard"
NO_x	Nitrogen Oxide
NRECA	National Rural Electric Cooperative Association
O&M	Operations & maintenance
OECD	Organization for Economic Cooperation and Development
OPIC	Overseas Private Investment Corporation
PACES	Power and Solar Chemical Energy Systems (IEA SolarPACES)
PCB	Polychlorinated Biphenyl
PECO	Philadelphia Electric Company
PFBC	Pressurized fluidized bed combustion
ppm	Parts per million
PREPA	Puerto Rico Electric Power Authority
PROCEL	Brazil's National Program for Electricity Conservation
PV	Photovoltaic
PVUSA	PhotoVoltaic USA
R&D	Research and development
RDF	Refuse-derived fuel
RE	Renewable energy
RE/EEF	Renewable Energy and Energy Efficiency Investment Fund
RFP	Request for proposal
ROI	Return-on-investment
SAVE	Specific Action on Vigorous Energy Efficiency
SCADA	Supervisory Control and Data Acquisition
SCR	Selective Catalytic Reduction
SNCR	Selective Non-Catalytic Reduction
SF_6	Sulfur fluoride
SMES	Superconducting magnetic energy storage
SO_2	Sulfur dioxide
sq.mm	Square millimeters

SVC	Static Var Compensation
T&D	Transmission & distribution
TCA	Technology Cooperation Activities
TCSC	Thyristor-Controlled Series Capacitor
TDA	Trade and Development Agency
TPD	Tons per day
TWh	Terawatt hours
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
UNIPEDE	Union Internationale des Producteus et Distributeurs d'Electricité
UPP	Utility Partnership Program
US	United States
USAID	United States Agency for International Development
U.S. DOE	United States Department of Energy
USEA	United States Energy Association
US/ECRE	United States Export Council for Renewable Energy
USIJI	United States Initiative on Joint Implementation
UWIG	Utility Wind Interest Group
V	Volt
VARS	Volt-amperes-reactive
VOC	Volatile organic compound
WEC	World Energy Council
WEEA	World Energy Efficiency Association

EXECUTIVE SUMMARY

This *Handbook of Climate Change Mitigation Options for Developing Country Utilities and Regulatory Agencies* is designed to provide an overview of "best practices" for generating, transmitting, distributing and consuming electric power in developing countries. The emphasis of the Handbook is on the climate change implications of these best practices, together with the associated climate change mechanisms and technical/financial resources available to implement them.

Many of the best practices discussed in this Handbook are promoted by and facilitated under the Energy Partnership Program (EPP), funded by the U.S. Agency for International Development (USAID) and executed by the United States Energy Association (USEA). The Energy Partnership Program strives to help developing countries achieve sustainable development through increased, more efficient, environmentally sustainable energy production and use. At the same time, EPP partnerships help developing countries avoid, reduce and mitigate the climate change impacts resulting from energy sector activities and access to energy services.

Since the United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992, there has been a growing concern about the potential climate change implications of power sector activities, even those classified as "best practices". Since many of these best practices are being implemented in developing countries to satisfy emerging power needs, the USAID and the USEA authorized compilation of this Handbook so that developing country utility personnel and regulators are apprised of the GHG emissions arising from power sector activities.

Information on more than 70 climate change action areas is provided in the Handbook for developing country utilities and regulatory agencies to avoid, offset or reduce the impact of GHG emissions. Many of these actions represent current activities by utilities and regulators in developing countries, but for which there is a lack of appreciation regarding their GHG emission implications. The climate change action areas are grouped by:

- Environmental Pollution Control
- Fuel Systems
- Conventional Power Generation Systems
- Transmission Systems
- Distribution Systems
- End-Use Efficiency and Demand-Side Management
- Renewable Energy
- Offset and Emissions Trading
- Data Research and Monitoring Actions
- Energy Sector Institutional Reform and Restructuring
- Regulatory Reform

Besides these action areas, the Handbook also discusses various market-based economic instruments that could be used to facilitate adoption of these best practices, as well as alternative sources of technical and financial support.

For each EPP best practice, the following information is provided:

- descriptive characteristics,
- climate change impact,
- issues associated with implementing the action, and
- resources and contacts for further information.

For the climate change impact, the potential GHG emissions avoided, offset or reduced is indicated. Where available, the percent improvement in the action area is related to the change in GHG emissions. Since understanding of, and data documenting the GHG emissions implications of various EPP actions related to the generation, transmission, distribution and end-use of electricity is still emerging, the Handbook provides both qualitative and quantitative information on the GHG impacts.

1.0 INTRODUCTION

This Handbook was developed to document the best practices available in the generation, transmission, distribution and end-use of electricity, and the associated GHG emissions avoided, reduced or offset via these practices. The objective is to apprise developing country utilities and regulators of the GHG emissions implications of power sector activities they are taking under the Energy Partnership Program (EPP) or investments required to meet the future power needs in their countries. This section provides background information on climate change (1.1), instructions for how to use this handbook (1.2), and a summary matrix of the GHG implications of the best practices examined (1.3).

1.1 Climate Change Overview

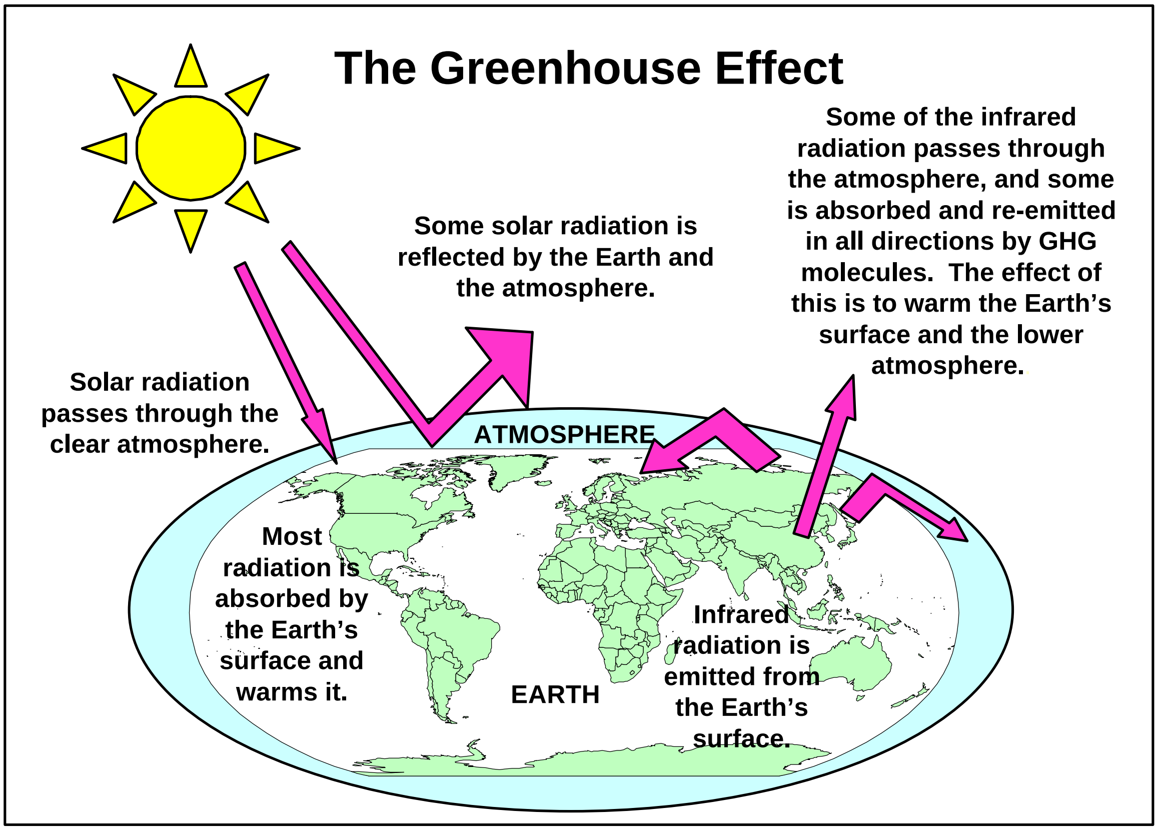
Concern over global climate change (GCC) has been growing over the past decade as scientific evidence appears to indicate that increased concentrations of GHGs in the atmosphere will cause changes in global temperature, precipitation, sea level and other weather-related effects (e.g., increased storm intensity). The concern centers around a phenomenon called the "greenhouse effect", where increased emissions of radiatively-active greenhouse gases retain more energy from the sun than is necessary to maintain current surface temperatures. By creating a "ceiling" in the upper atmosphere that prevents the re-release of the sun's energy, these gases function like the glass in a greenhouse—keeping heat from escaping (see Figure 1.1), thereby causing global temperature to rise and altering other weather-related patterns. Many negative environmental and health effects could arise as a result of these changes, including

- sea level rise that would inundate low-lying areas,
- increased disease due to increased temperature and moisture
- lost biota and animal species due to disrupted/relocated habitats

While it is documented that there has been an increase in global GHG emissions and related GHG concentrations in the atmosphere since the industrial revolution, there is considerable debate in scientific, policy and business circles over the:

- human-induced contributions to these increased GHG emissions and concentrations
- absorptive capacity of sinks (e.g., oceans, biota) to offset increased GHG emissions
- ability of the earth's atmosphere to adjust to increased emissions and concentrations of GHGs.

Figure 1.1 The Greenhouse Effect and Historical Emissions



Source: redrawn from Office of Science and Technology Policy, 1997, *Climate Change, State of Knowledge*.

The reason for the debate is that:

- the climate change data has considerable uncertainties and is subject to interpretation,
- there are considerable differences of opinion on whether the scientific evidence of global climate change is sufficient to warrant taking action at this time,
- the societal cost of responding to the threat of climate change has been estimated to be large, and
- there are different views on an appropriate response strategy.

In 1992, more than 150 nations met at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil to discuss global environmental issues. At this meeting, the United Nations Framework Convention on Climate Change (UNFCCC) was signed by more than 150 nations, committing **all Parties** to

> *Take climate change considerations into account, to the extent feasible, in their relevant social, economic and environmental policies and actions…* (Article 4.1f)

Developed country Parties and other Parties included in Annex I[1] committed themselves to

> *…adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs. These policies and measures will demonstrate that developed countries are taking the lead in modifying longer-term trends in anthropogenic emissions consistent with the objectives of the Convention, recognizing that the return by the end of the present decade to earlier levels of anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol would contribute to such modification, and taking into account the differences in these Parties' starting points and approaches, economic* (Article 4.2a).

No explicit action to reduce GHG emissions was required of developing countries or emerging economies. However, these countries could reduce their GHG emissions through an innovative market-based mechanism—joint implementation (JI)[2]—that was included in the UNFCCC on a pilot basis to reduce compliance costs in Annex I countries. JI projects are those undertaken in developing countries/emerging economies, with capital and technology provided by Annex I countries, that have the objective of offsetting or reducing the GHG emissions originating in the Annex I countries. The United States and several other Annex I countries have been very active in developing JI projects.[3]

By 1995, it became apparent that Annex I countries would not be able to meet their commitment under the UNFCCC. The voluntary actions, together with responses to regulations and taxes, would not induce a sufficient change in GHG emissions to return them to 1990 levels by 2000. Consequently, the Conference of Parties to the UNFCCC have been discussing policies and measures that could be taken after the year 2000 to reduce future GHG emissions.

There are many actions that can be taken to reduce GHG emissions in the power sector

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[1] Annex I countries include industrialized countries and countries in transition (underlined). These are: Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America.

[2] *Those Parties may implement such policies and measures jointly with other Parties and may assist other Parties in contributing to the achievement of the objective of the Convention and, in particular, that of this subparagraph…* (Article 4.2a).

[3] The United States Initiative for Joint Implementation (USIJI) was created in 1993 as a pilot program to encourage voluntary participation by private entities in projects that could diffuse innovative technologies to mitigate climate change concerns. The USIJI program consists of land use/forestry projects that seek to sequester carbon and energy projects that avoid or reduce emissions of greenhouse gases. USIJI criteria are consistent with criteria defining Activities Implemented Jointly (AIJ) agreed to in the Framework Convention on Climate Change.

through improved efficiency in the generation, transmission, distribution and end-use of electricity. Other actions include 1) use of lower (or non-) carbon fuels, 2) controlling the emissions of greenhouse gases emitted at various sources, 3) creating offsets through investment in GHG emission sinks, or 4) use the of market-based economic instruments to facilitate cost-effective compliance.

1.2 How To Use This Handbook

To compile this Handbook, available information was summarized from public and private reports, activities/experiences, programs and power sector experts. Reference to particular experiences, programs or U.S. utilities is not meant to be inclusive, but only illustrative based on the information sources accessible during preparation of the Handbook.

The most effective use of this Handbook by developing country utilities and regulatory agencies is as a screening tool to:

1) identify alternative “best practices” being performed within each segment of the U.S. power industry,
2) evaluate the characteristics of these practices and technologies (i.e., actions),
3) appreciate the issues associated with implementing these actions,
4) understand the type of emissions mitigation effect produced by each action (i.e., avoid, offset or reduce) and the conditions under which the action will result in the desired effect,
5) compare the GHG emissions effect and cost-effectiveness of actions, and
6) locate resources and contacts to obtain more detailed information.

The Handbook *does not* provide a methodology for 1) preparing a baseline emissions inventory, 2) defining a response strategy, or 3) projecting the impact of alternative power sector actions on GHG emission trends. There are a number of other reports, models and programs available to serve these functions. For example:

- *Greenhouse Gas Assessment Handbook* ¾ U.S. Country Studies Program
- *Guidelines for Climate Change Global Overlays* ¾ World Bank
- *Greenhouse Gas Mitigation Assessment: A Guidebook* ¾ World Bank
- *Intergovernmental Panel on Climate Change (IPCC) Technical Guidelines for Assessing Climate Change Impacts and Adaptations*
- *Steps in Preparing Climate Change Action Plans: A Handbook* ¾ U.S. Country Studies Program

1.3 Climate Change Mitigation Options For Developing Country Electric Utilities And Regulatory Agencies

A summary of best practices for over 70 climate change action areas is presented in this report organized by category:

- *Environmental Pollution Control*
- *Fuel Systems*
- *Conventional Power Generation Systems*
- *Transmission Systems*
- *Distribution Systems*
- *End-Use Efficiency and Demand-Side Management*
- *Renewable Energy*
- *Offset and Emissions Trading*
- *Data Research and Monitoring Actions*
- *Energy Sector Institutional Reform and Restructuring*
- *Regulatory Reform*

For each action area, available information on the characteristics, climate change impact, issues related to implementation and information resources/contacts is provided. Table 1.1 provides a synopsis of this information (presented in Sections 2-12) to facilitate screening and comparison of the alternative climate change actions.

The first column indicates the level of experience associated with deploying the climate change action (low-to-high). The second column relates the commercial benefit of the action—i.e., an action labeled “high” indicates that it makes commercial sense independent of any GHG benefit, while an action marked “low” requires GHG mitigation benefits to make commercial sense. The third column identifies the type of CO2 mitigation action: avoid, offset or reduce. The next column provides an assessment of the degree of mitigation: high-to-low. When available, the last column indicates the CO_2 cost-effectiveness of the action.

For instance, coal pretreatment and beneficiation (3.3) is an action that has a high commercial benefit—this action makes economic sense regardless of its environmental benefit. It also reduces carbon for a relatively low cost per metric ton, although companies have a relatively low level of experience with this practice.

Table 1.1 EPP Climate Change Action Matrix

Climate Change Action Areas	Level of Experience with Deployment	Commercial Benefit	Type of CO_2 Mitigation	Level of CO_2 Mitigation	CO_2 Cost-Effectiveness
2.0 Environmental Pollution Control Actions					
2.1 Understanding, Qualifying and Controlling GHG Emissions from Utility Operations	**L**	**L**	**A**	**L**	**N/A**
2.2 Improving Environmental Pollution Controls	**L**	**M/H**	**A**	**L**	**N/A**
2.3 Recycling of Coal-Combustion Byproducts	**L**	**M/H**	**A**	**L**	**N/A**
2.4 Utilizing Clean Coal Technologies—FBC	**M**	**M**	**A**	**M**	**M**
2.5 Utilizing Clean Coal Technologies—IGCC	**L**	**L/M**	**A**	**M**	**N/A**
3.0 Fuel System Actions					
3.1 Fuel Switching to Natural Gas	**M**	**L/M**	**A**	**M**	**M**
3.2 Fuel Switching from Carbon to Non-carbon Based Fuels	**L**	**L**	**A**	**H**	**M**
3.3 Coal Pretreatment and Beneficiation	**L**	**H**	**R**	**L**	**H**
3.4 Use of Non-petroleum Vehicles by Utilities	**L**	**L**	**A**	**L**	**L**
3.5 Fuel Quality Testing, Assessment and Assurance	**L**	**H**	**R**	**L**	**H**

LEGEND:

Level of Experience with Deployment of Action:
H – high **M** – moderate **L** – low

Commercial Benefit:
H – high (action makes commercial sense independent of any GHG benefit);
M – moderate (action is marginally cost-effective, but a benefit from GHG Mitigation improves economics)
L – low (action requires GHG mitigation benefit to make commercial sense)

Degree of Mitigation (*number of MtC avoided/offset/reduced*):
H - high **M** – moderate **L** – low

Type of CO_2 Mitigation Achieved:
A – avoided **O** – offset **R** – reduced

CO_2 Cost-Effectiveness:
H – low cost per ton/C avoided/offset/reduced
moderate cost per ton/C avoided/offset/reduced
L – high cost per ton/C avoided/offset/reduced

Climate Change Action Areas	Level of Experience with Deployment	Commercial Benefit	Type of CO_2 Mitigation	Level of CO_2 Mitigation	CO_2 Cost-Effectiveness
4.0 Conventional Power Generation System Actions					
4.1 Firing Equipment	**M**	**M/H**	**A/R**	**L/M**	**M**
4.2 Boiler Improvements	**M**	**M/H**	**R**	**L/M**	**N/A**
4.3 Turbine Cycle Improvements	**M**	**M/H**	**R**	**L**	**N/A**
4.4 Reducing Parasitic Loads from Auxiliary Equipment	**L**	**M/H**	**A**	**L**	**N/A**
4.5 Plant Instrumentation and Controls	**L**	**H**	**R**	**L**	**N/A**
4.6 Waste Heat Recovery Systems	**L**	**M/H**	**A/R**	**L/M**	**N/A**
4.7 Installing Cogeneration	**M**	**M/H**	**A**	**M**	**H**
4.8 Increase Capacity Availability by Reducing Planned Outages for Maintenance and Repair	**L**	**H**	**A**	**L**	**M/H**
4.9 Increase Capacity Availability by Reducing Unplanned Outages	**L**	**H**	**A**	**L**	**H**
4.10 Energy Management Systems	**L**	**H**	**A**	**L**	**M/H**
4.11 Using Competition to Increase Efficiency in Power Plant Operations and Power Marketing	**L**	**H**	**A**	**L**	**M/H**

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Climate Change Action Areas	Level of Experience with Deployment	Commercial Benefit	Type of CO_2 Mitigation	Level of CO_2 Mitigation	CO_2 Cost-Effectiveness
5.0 Transmission System Actions					
5.1 High Voltage Direct Current	**L**	**L/M**	**A**	**L**	**N/A**
5.2 Improving Line Flow Control	**L**	**H**	**A**	**L**	**N/A**
5.3 Conductor Loss Reduction and Phase Current Optimization	**L**	**M**	**A**	**L**	**N/A**
5.4 Installing More Efficient Transformers	**M**	**L/M**	**A**	**L**	**N/A**
5.5 Increasing and Stabilizing Line Voltage	**M**	**L/M**	**A**	**L**	**N/A**
5.6 Installing New, More Efficient Transmission Lines	**M**	**L**	**A**	**L**	**L**
5.7 Computer Software Systems and Models	**L**	**H**	**A**	**L**	**N/A**
6.0 Distribution System Actions					
6.1 Reduction in Reactive Power Losses	**M**	**M**	**A**	**L**	**N/A**
6.2 Upgrading and Automation of Distribution Instrumentation and Controls	**L**	**M**	**A**	**L**	**L**
6.3 Reducing Conductor Losses	**L**	**M**	**A**	**L**	**N/A**
6.4 Installing More Efficient Transformers	**M**	**M**	**A**	**L**	**N/A**
6.5 Reducing Forced Outages and Stabilize Line Voltage	**L**	**M**	**A**	**L**	**N/A**
6.6 Dispersed Energy Storage Systems	**L**	**L**	**A**	**L/M**	**N/A**
6.7 Improving Customer Service	**L**	**H**	**A**	**L**	**N/A**
6.8 Computer Software Systems and Models	**L**	**M**	**A**	**L**	**N/A**

LEGEND:

Level of Experience with Deployment of Action:
H – high **M** – moderate **L** – low

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H – high (action makes commercial sense independent of any GHG benefit);
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Climate Change Action Areas	Level of Experience with Deployment	Commercial Benefit	Type of CO_2 Mitigation	Level of CO_2 Mitigation	CO_2 Cost-Effectiveness
7.0 End-Use Energy Efficiency & Demand-Side Management (DSM) Actions					
7.1 Promote Residential DSM Programs	**L/M**	**H**	**R**	**L/M**	**M/H**
7.2 Promote Commercial DSM Programs	**L/M**	**H**	**R**	**L/M**	**M/H**
7.3 Promote Industrial DSM Programs	**L/M**	**H**	**R**	**L/M**	**M/H**
7.4 Improving Billing and Collection Systems to Reduce Demand	**L**	**H**	**R**	**L/M**	**M/H**
7.5 Charging Economic Tariffs to Reduce Demand	**L/M**	**H**	**A**	**L/M**	**M/H**
7.6 Promoting New, Energy-Efficient Electrotechnologies	**L**	**M**	**A**	**L/M**	**N/A**
7.7 Instituting Customer-Focused Education and Informational Programs	**L/M**	**H**	**A**	**L/M**	**M/H**
8.0 Renewable Energy Actions					
8.1 Biomass	**M**	**M**	**O**	**M**	**H**
8.2 Geothermal	**M**	**M**	**A**	**M**	**H**
8.3 Small-Scale Hydropower	**H**	**H**	**A**	**M**	**H**
8.4 Maintain or Increase Generation of Existing Hydropower	**H**	**H**	**A**	**H**	**H**
8.5 Photovoltaics (PV)	**M**	**L**	**A**	**L/M**	**M/H**
8.6 Solar Thermal	**L**	**M**	**A**	**L/M**	**M**
8.7 Waste-Derived Fuels	**L**	**M**	**A**	**L/M**	**N/A**
8.8 Wind Power	**M**	**M**	**A**	**M/H**	**M/H**
8.9 Financing Mechanisms for Renewable Energy Projects	**N/A**	**N/A**	***N/A***	**N/A**	**N/A**

LEGEND:

Level of Experience with Deployment of Action:
H – high **M** – moderate **L** – low

Commercial Benefit:
H – high (action makes commercial sense independent of any GHG benefit);
M – moderate (action is marginally cost-effective, but a benefit from GHG Mitigation improves economics)
L – low (action requires GHG mitigation benefit to make commercial sense)

Degree of Mitigation (*number of MtC avoided/offset/reduced*):
H - high **M** – moderate **L** – low

Type of CO_2 Mitigation Achieved:
A – avoided **O** – offset **R** – reduced

CO_2 Cost-Effectiveness:
H – low cost per ton/C avoided/offset/reduced
moderate cost per ton/C avoided/offset/reduced
L – high cost per ton/C avoided/offset/reduced

Climate Change Action Areas	Level of Experience with Deployment	Commercial Benefit	Type of CO_2 Mitigation	Level of CO_2 Mitigation	CO_2 Cost-Effectiveness
9.0 Offset and Emissions Trading Actions					
9.1 Preserving and Planting Forests, and Other Carbon Sinks	L	L	O	L	H
9.2 Supporting Institutions That Improve Carbon Sinks	L	L	O	L	H
9.3 Assisting in Trades of Emissions	L	L	O/A/R	L-H	M/H
10.0 Data, Research & Monitoring Actions					
10.1 Implementing Emission Reporting Programs	N/A	L	A	N/A	N/A
10.2 Inventory/Quantification of GHG Emissions	N/A	L	A	N/A	N/A
10.3 Calculate Costs and Benefits of Offsets	N/A	L	A	N/A	N/A
10.4 Transferring GCC Mitigation Research Findings	N/A	L	A	N/A	N/A
10.5 Supporting GCC Mitigation Research	N/A	L	A	N/A	N/A

LEGEND:

Level of Experience with Deployment of Action:
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Climate Change Action Areas	Level of Experience with Deployment	Commercial Benefit	Type of CO_2 Mitigation	Level of CO_2 Mitigation	CO_2 Cost-Effectiveness
11.0 Energy Sector Institutional Reform and Restructuring Actions					
11.1 Unbundling Generation, Transmission, and Distribution	L	H	A/R	L/M	N/A
11.2 Increasing Senior and Mid-level Management Performance and Efficiency	L	H	R	L	N/A
11.3 Increasing the Role of Independent Power Producers in the Generation Sector	L	H	A/R	L/M	N/A
11.4 Privatizing Utility Assets	L	H	A/R	L/M	N/A
11.5 Corporate Re-engineering to Employ More Market-Oriented Approaches	L	H	R	N/A	N/A
12.0 Regulatory Reform Actions					
12.1 DSM Regulations and Incentives	L	M	R	L/M	L/M
12.2 Energy Efficiency Regulation and Incentives	L	M	R	L/M	L/M
12.3 Energy Conservation Regulation and Incentives	L	M	A	L/M	L/M
12.4 Emission Control Regulations and Incentives	M/H	M	R	M/H	M
12.5 Other Regulations and Incentives that Contribute to Climate Change Mitigation	L	M	A	L	L

LEGEND:

Level of Experience with Deployment of Action:
H – high **M** – moderate **L** – low

Commercial Benefit:
H – high (action makes commercial sense independent of any GHG benefit);
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H – low cost per ton/C avoided/offset/reduced
moderate cost per ton/C avoided/offset/reduced
L – high cost per ton/C avoided/offset/reduced

2.0 ENVIRONMENTAL POLLUTION CONTROL ACTIONS

Power plants not only produce carbon dioxide (CO_2) by combusting fossil fuels in boilers/turbines but directly and indirectly in other unit operations at the power plants and in the fuel cycle. Greater awareness of the effects that each power plant operations has on the release of CO_2 can result in the use of practices and techniques that reduce such emissions. For example, understanding how each point in the coal fuel cycle contributes to carbon emissions could suggest the use of coal washing to reduce transportation and handling requirements that, in turn, would reduce carbon emissions. Similarly, coal combustion wastes could be used as substitutes for other carbon emitting processes, such as cement kilns.

Techniques, like energy audits, are available to quantify the energy losses at power plants. Methods are also available to perform cost-benefit analyses of options to reduce the losses. Many actions may be possible to reduce energy losses, and thereby carbon emissions, at very low, and in some cases, negative costs.

In addition, new power generation processes are being developed (and commercialized) that are more efficient, and therefore emit less CO_2 on a heat input (Btu) or electricity output (kWh) basis than conventional technologies. These systems offer opportunities for repowering or greenfield applications to increase efficiencies.

This section of the Handbook describes some of the techniques, approaches and technologies used by the power industry to understand its energy situation and to address shortcomings.

2.1 UNDERSTANDING, QUALIFYING AND CONTROLLING GHG EMISSIONS FROM UTILITY OPERATIONS

CHARACTERISTICS

Utilities are both electricity generators and end-users. In addition, they are part of an energy cycle that must be looked at in whole to optimize system efficiencies. Utilities may undertake a variety of programs that result in improved end-use efficiency, improved air quality, and/or minimized waste; these programs will likely also help to minimize GHG emissions.

Electric generating plants are just one part of the electric power fuel cycle and only one part of the GHG emissions equation. Energy is consumed and GHGs are emitted in: (1) the production and transport of fuels and other raw materials used by electric generators, (2) the handling of fuels and other raw materials fed to boilers, (3) other processes at or associated with generating plants, (4) the production, disposal and utilization of waste materials, and (5) the transmission, distribution and utilization of the electricity generated. Under a climate-constrained environment, any action, even the installation of pollution control equipment, must be assessed to determine how it will affect GHG emissions. Energy audits, performed by evaluating how energy is used throughout utility facilities and associated operations, are often the first step in identifying and qualifying the GHG emissions produced. Each utility can examine its own processes and business patterns to assess the best opportunities to minimize emissions.

To date, most electric utility-related environmental regulation has attempted to alleviate emissions of acid rain precursors (sulfur dioxide and nitrogen oxides), as well as particulate matter, fly and bottom ashes, and in some cases other pollutants. With the exception of a few European countries, countries do not regulate emissions of carbon and other greenhouse gases. Therefore, many utilities have never needed to measure or monitor their emissions of these substances. It is possible to "back into" emission estimates by multiplying the carbon content of fuels combusted by the number of kilowatt hours generated. However, more accurate measurements of GHGs are needed to develop an emissions profile and prepare a strategy for minimizing emissions and obtaining credit for emissions reductions. For example, under Section 1605(b) of the U.S. National Energy Policy Act of 1992, precise techniques to create GHG baselines must be followed to be given credit for voluntary emissions reductions.

SIZE: Will vary according to the size and operations of individual utilities. Programs may concentrate on one aspect of energy use (i.e., lighting) or may be more comprehensive (facility-wide or entire fuel cycle energy audit).

FEATURES: Energy audits can identify the most cost-effective actions to take. May include programs such as: reduce employee travel requirements through encouragement of telecommuting, carpooling or use of public transportation; office energy conservation through installation of energy-efficient lighting and teleconferencing; coal washing to reduce coal transportation requirements, installation of equipment with low parasitic energy requirements; use of low polluting motor vehicles, and switching to lower carbon fuels, where possible.

COST: May be minimal for administrative measurements, or may be significant if extensive equipment upgrades are purchased. Cost for conducting an energy audit varies greatly depending the scope of the audit; many options have reduced costs and/or improved operations, saving money and/or producing new revenue streams.

CURRENT USAGE: Many programs exist encouraging utilities to voluntarily reduce GHG emissions. The U.S. Department of Energy sponsors the Climate Challenge Program[4] in which more than 600 utilities have made voluntary commitments to reduce GHG emissions.

POTENTIAL USAGE: Any utility, whether large or small, with or without generation, having any resource mix, and experiencing high or low load growth, can identify, assess and reduce GHG emissions.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- The first step is to determine a baseline to understand the level, type and frequency of emissions being produced.
- Once the baseline is established, options to control emissions are assessed to determine their technical and economic feasibility (cost-effectiveness).
- Depending on available budgets, the most cost-effective actions are taken.
- Emissions can be *avoided* by utilizing best practices in greenfield applications; they can be *reduced* by actions taken at existing operations.

EMISSION ESTIMATE: N/A. Emissions reductions will vary depending on the actions taken.

COST-EFFECTIVENESS: Can vary greatly depending upon the actions taken.

SECONDARY EFFECTS: Understanding what GHG emissions are produced may also lead to identification of unnecessary emissions of other pollutants.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

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[4] Participating utilities commit to reduce, avoid, sequester a specified amount of CO_2 emissions and periodically report to the DOE of their progress. More than 600 utilities are participants, and have committed to reduce a total of 44 million metric tonnes of carbon equivalent in the year 2000. Many of the reductions will continue to be avoided in the future.

- Employees may be reluctant to change their work customs (i.e., to telecommute, carpool, etc.); utilities may need to restructure policies to allow flexible work schedules where appropriate and possible.
- Incentive mechanisms operate differently—how do utilities offer incentives to themselves (as they can, for example, to customers)?
- Processes/products may be selected on a lowest (initial) cost basis—even though efficient products that have a higher up-front capital cost may have a significantly lower life-cycle cost.
- One incentive for utilities to participate in such an effort would be the knowledge that controlling or reducing GHG emissions would yield future credit for having taken the action.

RESOURCES

- Information on the Climate Challenge Program, including background documents, sample memoranda of understanding and names/details of participants, can be found online at *http://www.eren.doe.gov/climatechallenge/factsheet.htm*.
- The Centre for Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) provides information on relevant programs at an energy efficiency website, *http://www.caddet-ee.org*.
- U.S. Environmental Protection Agency sponsors a series of EnergyStar programs to encourage the production and use of energy efficient appliances.

CONTACTS

U.S. Department of Energy
Energy Information Administration
Voluntary Reporting of Greenhouse Gases Program
Washington, DC
Tel: (800) 803-5182
infoghg@eia.doe.gov
http://www.eia.doe.gov/oiaf/1605/

U.S. Environmental Protection Agency
Energy Star Programs
Washington, DC
Tel: (202) 233-9002
http://www.epa.gov/energystar.html

2.2 IMPROVING ENVIRONMENTAL POLLUTION CONTROLS

CHARACTERISTICS

There are two classes of environmental pollution control used to comply with local or national criteria air pollutant emission requirements (i.e., SO_2, NO_x): precombustion/combustion and post-combustion. Flue gas desulfurization (FGD) equipment—"scrubbers"—are the most widely-used post-combustion technology for removal of sulfur dioxide. The current generation of scrubbers is able to remove up to 90% of SO_2 in stack gases. Advanced scrubbers use finely ground lime or limestone slurries to convert more than 95% of the SO_2 in flue gases to gypsum and other reusable byproducts. Sorbent injection, which is capable of reducing up to 70% of the SO_2 emissions, can be used in the convection pass or duct work; it is also referred to as dry scrubbing.

For NO_x, post-combustion technologies convert NO_x to nitrogen and water vapor by combining the (flue gas) waste stream with ammonia, urea or other compounds. The most effective currently available technology is Selective Catalytic Reduction (SCR). SCR injects ammonia in the presence of a catalyst; this reduces NO_x by 80-90% at a retrofit capital cost of $100-200/kW. Selective Non-Catalytic Reduction (SNCR), used for smaller boilers, injects a reagent into the flue gas at temperatures of 900-1100° Celsius without using a catalyst; this achieves 30-50% NO_x reductions at a cost of from $10-20/kW. Pre-combustion techniques for NO_x control include reburning (i.e., the controlled injection of coal or natural gas in the boiler reducing NO_x emissions by 50-70%), low-NO_x burners (LNB) (creation of a fuel-rich flame for efficient combustion and NO_x reduction of 40-50%), and advanced overfire air (the injection of air in the combustor to reduce NO_x emissions by 10-25%. Other more novel approaches (and combinations) are also being proposed, but have not been implemented extensively.

Neither pre- nor post-combustion control techniques significantly affect CO_2 emissions. However, modern post-combustion SO_2 technologies can consume about 1% of the energy produced in coal-fired power plants. Pre-combustion NO_x control techniques can improve the efficiency of the combustion process, thereby slightly reducing CO_2 emissions. However, the effect that these pollution control devices have on CO_2 emissions is small.

SIZE:	FGD: units up to 100-1000 MW: SNCR: small units 100-500 MW SCR: units from 100-1000 MW LNB: units from 100-500 MW.
FEATURES:	Addition of advanced scrubbers reduces plant electric output, but by less than 1%. The latest pre-combustion technologies can increase efficiency while reducing NO_X.[5]

[5] Full-scale demonstration projects of low-NO_x Cell Burner Retrofit increased efficiency by 16%; EPRI's

COST: FGD: \$75-200/kW
SCR: retrofit cost of \$100-200/kW
SNCR: \$10-20/kW (used for small boilers)

CURRENT USAGE: In U.S., scrubbers are installed at over 400 coal-fired facilities; LNB are used extensively; SNCR and SCR are being installed on U.S. utility boilers for compliance with new requirements under the 1990 Amendments to the Clean Air Act.

POTENTIAL USAGE: Cost may limit widespread deployment of SO_2 scrubbing technologies. Where low-sulfur fuels are available, it may be more cost-effective to switch fuels. As interest in the control of NO_x control grows, LNBs and, to a lesser extent, SCR, are growing in popularity.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- CO_2 will only be mitigated where the use of environmental control technologies increase the efficiency of the combustion process.

EMISSION ESTIMATE: CO_2 emissions may be reduced by 1-2% or increase by 1-2% depending upon the control technique used.

COST-EFFECTIVENESS: High. These techniques are not designed to control CO_2 emissions.

SECONDARY EFFECTS: These technologies are designed to remove high amounts of NO_x and SO_2

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Byproducts have to be disposed of.
- Capital costs of environmental pollution control technologies can be prohibitive.

RESOURCES

- The World Bank hosts information on a variety of environmental pollution control technologies on at its Environmental Management (EM) Power website, along with guidelines as to conducting environmental assessments. *http://www.worldbank.org/html/fpd/em/.*
- The U.S. DOE Federal Energy Technology Center (FETC) sponsors the Emissions Control Byproducts Consortium (ECBC), dedicated to develop and demonstrate technologies for solving problems related to the utilization of by-products from coal combustion processes. It is hoped that these technologies, by the year 2005, will lead to a doubling of the current rate of FGD by-product use, a 10% increase in the overall

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Generic NO_x Control Intelligent System for plant optimization raised efficiency by 0.5% and reduced NO_x 10-15%.

[5] Current applications have only been used on units of up to 650 MW.

national rate of byproduct use, and a 25% increase in the number of uses considered "allowable" under state regulations.

- Tavoulareas, E. Stratos and Jean-Pierre Charpentier, 1995, *Clean Coal Technologies for Developing Countries,* World Bank Technical Paper No. 286, Energy Series, (July).
- United States Department of Energy, 1998, *Clean Coal Technology Demonstration Program Project Fact Sheets 1997*, DOE/FE-0369. 150p
- South, D.W., et al., *Technologies and Other Measures for Controlling Emissions: Performance, Cost and Applicability*, NAPAP SOS/T-25, National Acid Precipitation Assessment Program, Acidic Deposition: State of Science and Technology, Volume IV., (Washington D.C.: December 1990).

CONTACTS

ABB Environmental Systems
Knoxville, TN
Tel: (800) 346-8944
ABBMarket@usapc.mail.abb.com
http://www.abb.com

Electric Power Research Institute
Palo Alto, CA
http://www.epri.com

Institute for Clean Air Companies
Jeffrey C. Smith
Executive Director
Washington, DC
Tel: (202) 457-0911
Jsmith@icac.com
http://www.icac.com

U.S. Department of Energy
Randolph Pennington
Program Manager
Environmental Systems
Germantown, MD
Tel: (301) 903-3485
Randy.Pennington@hq.doe.gov
http://www.doe.gov

World Bank
Stratos Tavoulearas
Washington, DC
Tel: (202) 458-9118
http://www.worldbank.org

2.3 RECYCLING OF COAL-COMBUSTION BYPRODUCTS

CHARACTERISTICS

Coal-fired electric power plants produce considerable amounts of solid by-products, — in excess of 100 million tons per year in the U.S., — primarily fly ash (80%) and bottom ash, of which less than 30 percent are recycled for productive purposes. These amounts will only increase with the rise in the number of power plants that use pollution control technologies.

Fly ash can be used in many cement and concrete applications as a substitute for portland cement. The manufacture of portland cement requires considerable amounts of energy, which generates GHG emissions, and emits CO_2 during the calcination process.

Currently, less than 25% of U.S. fly ash is utilized in any form, and less than 15% is being used as a portland cement substitute. Gypsum and other sludges generated from the flue gas desulfurization process can replace raw gypsum in industrial and agricultural processes. The energy costs and resulting emissions associated with the acquisition and use of raw gypsum can be avoided by recycling the desulfurization process byproducts.

SIZE: The capability exists for significantly increasing the use of by-products from power plants.

FEATURES: Use of by-products reduces the amount and cost of landfilling required. At the same time, it could be substituted for materials, that when processed, emit GHGs.

COST: O&M costs of existing landfills are $2-4/ton, but the cost of developing new landfills is up to $30/ton

CURRENT USAGE: <25% of U.S. fly ash is utilized.

POTENTIAL USAGE: The potential exists for most of the by-products from power plants to be utilized.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Great potential for significant reductions in GHG emissions.

EMISSION ESTIMATE: N/A. Varies from site to site.

COST-EFFECTIVENESS: Can be very cost-effective, especially where landfill costs are high.

SECONDARY EFFECTS: Additional benefit derived from eliminating need for landfill.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Must have sufficient market for by-product produced that is within economic distance of the power plant.
- Tipping for by-product must be less than landfill costs.
- Quality of by-product must meet the market specifications.

RESOURCES

- The U.S. Department of Energy has posted the *Climate Challenge Options* Workbook online at *http://www.eren.doe.gov/climatechallenge/*.
- U.S. DOE FETC Coal Combustion Byproduct Utilization Research & Development Program, *http://www.fetc.doe.gov/products/power/enviro/ccb/*. This site also provides links to related activities of other organizations and U.S. state governments.

CONTACTS

American Coal Ash Association
Barry Stewart
Director of Technical Services
Alexandria, VA
Tel: (703) 317-2400
Fax: (703) 317-2409
ACAA-USA@acaa-usa.org
http://www.acaa-usa.org

U.S. Department of Energy
Scott Renninger, Project Manager, Power & Environmental Systems Division
Federal Energy Technology Center
Coal Combustion By-product (CCB) Utilization Research and Development Program
Tel: (304) 285-4790
Fax: (304) 285-4403
srenni@fetc.doe.gov
http://www.fetc.doe.gov

2.4 UTILIZING CLEAN COAL TECHNOLOGY - FLUIDIZED BED COMUSTION

CHARACTERISTICS

Fluidized bed combustion (FBC) is a well-established power generation technology. In the combustor, a “bed” of crushed coal mixed with limestone is suspended on jets of air, tumbling in a manner that resembles a boiling liquid, hence the name “fluidized”. The limestone in the mixture acts as a chemical sponge, capturing more than 90% of the sulfur before it escapes the boiler. The resulting waste is removed with the ash, in the form of a benign solid easily disposed of or used in agricultural and construction applications. The lower combustion temperature needed in the process prevents the formation of 70-80% of the nitrogen oxides typically emitted by conventional pulverized coal boilers. FBC systems also have the ability to use high-ash coals. Compared to conventional sub-critical pulverized coal steam plants, FBC provides a high sulfur capture rate without degrading thermal efficiency.

There are two types of FBC systems, atmospheric (AFBC) and pressurized (PFBC), which operates at pressures 6 to 16 times higher than normal atmospheric pressure. PFBC systems can achieve higher thermal efficiencies than AFBC systems. The increased energy in the high pressure gases exiting the PBFC boiler can drive both a gas and steam turbine, known as a combined cycle system. Also, the higher thermal efficiencies of PFBC systems result in lower carbon-containing coal fuel requirements when compared to current conventional pulverized coal steam plants. This results in lower emissions of greenhouse gases.

Currently, AFBC is commercially available in the U.S.; PFBC has been demonstrated but is not in widespread commercial operations. Based on operating performance, future plants are expected to have significantly reduced capital costs.

SIZE:	10 to 100 MW equivalent for industrial boilers, 75 to 350 MW for electric utility applications.
FEATURES:	New baseload generation capacity or repowering of older conventional coal-fired plants. Can burn a wide variety of low-quality coals and municipal wastes. Repowering with PFBC increases plant efficiency and can raise plant capacity by 20-25%.
COST:	AFBC (200 MW): $1,500-2,000/kW AFBC (repowering): $500-$1,000/kW PFBC (demonstration): $1,900-$3,200/kW PFBC (commercial): $1,000-$1,500/kW *(expected)*
CURRENT USAGE:	Approximately 300 AFBC units supply heat to industrial processes, municipalities, oil producers, and farms in the U.S. and Europe. One 70 MW PFBC demonstration project has operated in the U.S., with a second 145 MW_e demonstration

project scheduled to begin operations in 2002. A 135 MW_e plus 224 MW heat PFBC operates in Stockholm Sweden. Single PBFC plants are also in operation in Spain (79 MW Escatron project) and Japan.

POTENTIAL USAGE: Older conventional coal-fired plants considering life extension or retirement could be repowered using FBC technology. In the U.S. alone, over 100 GWs of capacity are already greater than 30 years old, and are therefore potential candidates. Demand for new coal-fired generation capacity, where controls on sulfur and nitrogen oxide emissions must be included, are also candidates for FBC technology.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- AFBC efficiencies reduce carbon emission by approximately 3% compared to conventional steam coal plants.
- Near-term PFBCs that achieve efficiencies of 40-45% will reduce carbon emissions by 17-27% when compared to conventional steam coal plants with efficiencies of 33%. In the longer term, PBFC is expected to achieve 50% efficiency; carbon emissions will be reduced by 34% compared to conventional steam coal plants currently in operation.

EMISSION ESTIMATE: PFBC—reduce C emissions by 17-34% of current emissions
AFBC—reduce C emissions by 3% of current emissions

COST-EFFECTIVENESS: The capital costs of these systems are high. However, they inherently reduce CO_2 emissions.

SECONDARY EFFECTS: Higher efficiencies will also reduce associated air pollutant emissions from burning fossil fuels.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- PFBCs are currently being demonstrated, but are not yet commercially deployed.
- These technologies have a high capital cost relative to new, natural-gas combined cycle technologies. Therefore, to be competitive, they must use low and negative cost fuels (e.g., wastes).

RESOURCES

- United States Department of Energy, 1998, *Clean Coal Technology Demonstration Program Project Fact Sheets 1997*.
- International Energy Agency, 1993, *Electric Power Technologies: Environmental Challenges and Opportunities*.
- United States Department of Energy, Office of Fossil Energy, 1997, *Sustainable Development with Clean Coal*.

CONTACTS

American Electric Power Service Corp.
Mario Marrocco
Columbus, OH
Tel: (614) 223-2460
Fax: (614) 223-3204
http://www.aep.com

Lakeland Electric & Water Utilities
Alfred M. Dodd
Project Manager
Lakeland, FL
Tel: (941) 499-6461
Fax: (941) 499-6344

U.S. Department of Energy
Donald Bonk
Federal Energy Technology Center
Morgantown, WV
Tel: (304) 285-4889
dbonk@fetc.doe.gov
http://www.fetc.doe.gov

U.S. Department of Energy
Donald W. Geiling
Federal Energy Technology Center
Tel: (304) 285-4784
dgeili@fetc.doe.gov
http://www.fetc.doe.gov

2.5 UTILIZING CLEAN COAL TECHNOLOGY - INTEGRATED COAL GASIFICATION / COMBINED CYCLE SYSTEMS

CHARACTERISTICS

The integrated coal gasification combined cycle (IGCC) process reacts coal with high-temperature steam and an oxidant in a reducing atmosphere to form a fuel gas. The fuel gas is either passed directly to a hot-gas cleanup system to remove particulates and sulfur and nitrogen compounds, or cooled to produce steam and then cleaned conventionally. The clean fuel gas is combusted in a gas turbine generator, with residual heat in the exhaust gas recovered in a heat recovery steam generator and turbine.

More than 95% of the sulfur can be removed from coal, and 90% of the nitrogen is captured. Also, the higher thermal efficiencies of IGCC systems result in lower carbon-containing coal fuel requirements when compared to current conventional pulverized coal steam plants, resulting in lower emissions of greenhouse gases.

SIZE:	200 to 800 MW_e, modular designs of 50 to 150 MW_e may be the basis for future IGCC power plants.
FEATURES:	40% efficiency (demonstration plants) 45% efficiency (first generation commercial plant) 50% efficiency (second generation plant)
COST:	$1,200-3,000/kW for demonstration plants. $1,200-$1,900/kW for first generation plants. <$1,000/kW (projected) for second generation plants.
CURRENT USAGE:	Approximately 10 demonstration plants in the U.S. and Europe. Several commercial plants using refinery wastes are in operation or under construction.
POTENTIAL USAGE:	IGCC has potential for new baseload generation capacity or repowering of older conventional coal-fired plants considering life extension or repowering. In the U.S. alone, potential candidates include over 100 GW of capacity that is more than 30 years old. IGCC also has potential where planned coal-fired capacity additions are subject to strict controls on sulfur and nitrogen oxide emissions.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- High efficiencies (40% demonstrated and 50% expected) will reduce carbon emissions by 27%-34% compared to conventional steam coal plants.

EMISSION ESTIMATE: 27-34% reduction from current emissions

COST-EFFECTIVENESS: High capital costs. However, where natural gas costs are high, IGCC may be competitive.

SECONDARY EFFECTS: Significant SO_2 and NO_x reductions; production of wastes significantly reduced; potential to safely utilize a variety of wastes, including hazardous materials.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- IGCC is still in demonstration and is not yet considered commercial when using coal.
- Capital costs are currently much higher than some other options.

RESOURCES

- United States Department of Energy, 1998, *Clean Coal Technology Demonstration Program Project Fact Sheets 1997.*
- International Energy Agency, 1993, *Electric Power Technologies: Environmental Challenges and Opportunities*.
- United States Department of Energy, Office of Fossil Energy, 1997, *Sustainable Development with Clean Coal*.

CONTACTS

Duke Energy Corp.
Victor Shellhorse
Vice President
Charlotte, NC
Tel: (704) 373-8064
Fax: (704) 373-4986
http://www.duke-energy.com

Dynegy Power Corp.
Phil Amick
Director, Gasification Development
Wabash River Coal Gasification Project
Houston, TX 77002
http://www.dynegy.com

Sierra Pacific Power Company
Jeffrey Hill
Director, Power Generation
Reno, NV
Tel: (702) 834-5650
Fax: (702) 834-5704
http://www.sierrapacific.com

TECO Power Services, Inc.
Donald E. Pless
Director, Advanced Technology
Tampa, FL
Tel: (813) 228-1111
Fax: (813) 641-5300
http://www.teco.net

U.S. Department of Energy
Gary A Nelkin
Federal Energy Technology Center
Morgantown, WV
Tel: (304) 285-4216
gnelik@fetc.doe.gov
http://www.fetc.doe.gov

3.0 FUEL SYSTEM ACTIONS

Fuels have varying carbon contents—coal has a higher carbon content than does oil; oil has a higher carbon content than natural gas. Since emissions of greenhouse gases are directly related to carbon content, it follows that combusting coal produces more emissions than does burning the equivalent amount of natural gas. Roughly speaking, combusting gas produces 60% less carbon than combusting coal of equivalent energy (Btu) content; combusting oil emits approximately 30% less than coal on an equivalent energy basis.

Therefore, electric utilities can reduce carbon emissions by substituting lower carbon fuels for higher carbon fuels throughout its operations. Switching from oil- and coal-based boilers to gas can be economically viable in many regions. Cleaning coal used at utility sites can also reduce carbon emissions by reducing the coal transportation needs (by reducing the quantities and volumes of impurities shipped with the coal) and by improved boiler performance. Likewise, using low- or zero-carbon fuels can further reduce utility carbon emissions.

These fuel options offer a wide range of opportunities to economically reduce carbon emissions while meeting site specific constraints. This section describes several of the principal fuel alternatives currently employed.

3.1 FUEL SWITCHING TO NATURAL GAS

CHARACTERISTICS

Gas burning capability can be added to boilers originally designed to burn coal and oil. Boilers can be completely switched to gas, gas can be added to an existing coal boiler and co-fired, or a coal plant can be completely repowered to natural gas. Power plants designed to use natural gas are the most cost-effective plants to convert.

Because natural gas has a lower carbon content than coal or oil, burning natural gas instead of these fuels will reduce carbon emissions. Emissions of NO_x and SO_2 are also significantly lower for gas than for coal or oil. Burning one quadrillion (10^{15}) Btu of natural gas in electric generation emits about 16.3 MtC compared to 28.2 MtC for coal. Coal-fired power plants that are converted to burn natural gas will emit 60.% fewer carbon emissions per kWh generated than coal.

However, natural gas prices are usually considerably higher than coal prices. In addition, considerable capital expenditures may be required to add or upgrade natural gas pipelines and existing on-site equipment to make it suitable for natural gas consumption. Repowering results in significantly higher efficiencies, providing further reduction in GHG emissions, but significant capital investments are also required for the purchase of the new equipment.

SIZE:	Any size power plant can be converted subject to the inter-connection with a gas pipeline.
FEATURES:	Requires access to gas supply lines.
COST:	Cost of a new NG plant is <$400/kW. However, fuel cost of natural gas is almost double that of coal.
CURRENT USAGE:	288 billion kWh (annual natural gas generation in U.S.); over 20 quadrillion Btu gas-fired electricity generated world-wide.
POTENTIAL USAGE:	In the U.S. alone, up to 335 GW of coal capacity could potentially be switched to natural gas. The United Kingdom realized a substantial reduction in fossil fuel emissions when its electric power generation market repowered from coal to natural gas.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Natural gas prices per Btu are approximately double that of coal and tend to be more volatile.
- Seasonal availability of supply and pipeline capacity.
- There is insufficient natural gas infrastructure (in the U.S.) to reliably supply increased electric generation. Some plant locations may require pipeline installation before they can switch to natural gas.

- Natural gas co-firing with low-sulfur sub-bituminous coals has the potential for boiler fouling problems, leading to a loss of boiler efficiency and necessitating increased maintenance activities.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions/kWh of natural-gas fired power are less than those of coal-fired power, but if demand increases substantially, total emissions may increase as well.

EMISSION ESTIMATE: 0.67 MtC removed/GW converted

COST-EFFECTIVENESS: $90-104/ton of carbon (U.S. average)

SECONDARY EFFECTS: 40,000 tons SO_2 removed/GW converted; 17,000 tons NO_x removed/GW converted.

RESOURCES

- The U.S. Department of Energy hosts the *Climate Challenge Options Workbook* online at *http://www.eren.doe.gov/climatechallenge/.*
- Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, 1997, "Section 7.2, Repowering Coal-Based Power Plants with *Scenarios of U.S. Carbon Reductions, Potential Impacts of Energy Technologies by 2010 and Beyond*, prepared for the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy. *http://eande.lbl.gov/5lab/index.html*
- Smalley, G. and L. Makovich, 1993, *Technical Methodology for Analyzing Electric Utility Fuel Switching*, Gas Research Institute.
- Under the U.S. Initiative for Joint Implementation, a group of three U.S. utilities and the Center for Clean Air Policy worked with the City of Decin, Czech Republic to replace part of a lignite coal-fired district heating system with natural gas powered engines and associated heat exchange equipment. Over the next 25 years, this change is expected to reduce emissions by 165,600 mtC.

CONTACTS

American Gas Association
Arlington, VA
Tel: (703) 841-8400
Fax: (703) 841-8406
http://www.aga.org

Electric Power Research Institute
Palo Alto, CA
http://www.epri.com

IEA International Centre for Gas Technology Information
Mary Lang
Associate Director
Arlington, VA
Tel: (703) 526-7810
Fax: (703) 526-7811
icgti@gasinfo.gri.org
http://www.icgti.org

U.S. Department of Energy
Office of Fossil Energy
Washington, DC
Tel: (202) 586-1650
http://www.doe.gov

U.S. Initiative for Joint Implementation
Secretariat
Washington, DC
Tel: (202) 586-3288
Fax: (202) 586-3485
http://www.ji.org

3.2 FUEL SWITCHING FROM CARBON TO NON-CARBON BASED FUELS

CHARACTERISTICS

To reduce carbon emissions, non-carbon-based fuels like biomass, solar, wind and hydroelectricity can substitute for fossil fuels. In most cases, substitution would comprise shutting down the fossil plants or moving them down on the dispatch order as new non-carbon-based power plants begin operation. Biomass can substitute for or be blended with coal as a means of substitution.

Switching from carbon to non-carbon fuels directly reduces carbon emissions. In addition, most other air pollutants and many wastes would be greatly reduced since most renewable (non-carbon-emitting) technologies do not emit air or waste pollution.

However, switching from fossil to non-carbon sources can be expensive. In addition, many non-carbon-emitting technologies can produce power only on an intermittent basis—for example, when the sun shines or the wind blows. In addition, most non-carbon technologies are small in scale (kW renewable systems vs. multi-MW fossil fuel plants). Therefore massive numbers of units would be required to substitute non-carbon fuels for fossil fuels to achieve large carbon emission reductions.

SIZE:	<100 MW
FEATURES:	Most renewable systems are small in scale and offer siting flexibility.
COST:	\$0.05-0.25/kWh (renewables) vs. \$0.02-0.10/kWh (fossil)
CURRENT USAGE:	In the U.S., 100 GW renewable fuel capacity, (of which 80 GW is hydro). The world market for renewable energy production systems is estimated at approximately \$1 billion annually. Renewable energy use is rising all over the world, but most developing countries generate only 0.3% of electricity from renewable energy. Considerable new capacity using wind energy is being installed.
POTENTIAL USAGE:	In the U.S., resource potentials have been assessed at 9 GW of photovoltaics; 735 GW of wind

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- In regions of rapidly growing power demand, replacement of carbon-emitting sources with non carbon-emitting sources may be impractical. However, non-carbon technologies could be used as additional power sources.
- The cost of non carbon-emitting power generation is likely to be considerably higher than from carbon-emitting sources.

- Most non-carbon emitting technologies produce power intermittently. Therefore power sources would have to be available for back-up power, to be used when the renewable sources are not producing power.
- The largest potential for most non carbon-emitting sources is far from current power demand centers requiring construction of new transmission systems—with the accompanying infrastructure costs and transmission losses.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Low electric power demand growth.
- High value provided for clean power (green power).

EMISSION ESTIMATE: No carbon emitted from these sources

COST-EFFECTIVENESS: $21-400/ton carbon removed

SECONDARY EFFECTS: Emits no SO_2, NO_x, or most other wastes

RESOURCES

- U.S. Department of Energy Office of Renewable Energy and Energy Efficiency hosts a website with links to all of its programs on renewable energy at *http://www.eren.doe.gov*.
- The Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) provides an on-line directory of technical reports and development status for renewable energy technologies. *http://www.caddet-re.org/*

CONTACTS

CADDET Centre for Renewable Energy
Mike Landy
ETSU
Harwell
Oxfordshire OX11 0RA
United Kingdom
Tel: + 44 1235 432719
Fax: + 44 1235 433595
caddet.renew@aeat.co.uk
http://www.caddet-re.org

National Renewable Energy Laboratory
Golden, CO
Tel: (303) 275-3000
http://www.nrel.gov

U.S. Department of Energy
Office of Energy Efficiency and
Renewable Energy
Washington, DC
Tel: (202) 586-8121
http://www.eren.doe.gov

3.3 COAL PRETREATMENT AND BENEFICIATION

CHARACTERISTICS

Steam coal can be cleaned prior to burning to remove impurities and increase the coal's heating value. This added step adds a front-end cost for power generators, but this extra cost is outweighed by the savings achieved in fuel handling, plant efficiency, availability, and environmental controls.

Physical coal cleaning involves crushing the coal and screening it into differently-sized particles to separate out impurities that are not chemically bound to the coal. Water sprayed over the coal particles loosens the remaining mineral matter. Specific gravity differences are used to separate the coal from other constituents such as ash. Physical cleaning typically removes 10-30% of the sulfur and 60% of the ash-forming minerals. The coal "fines" are either discarded or can be cleaned using froth flotation. With coal-water slurry technologies, these coal "fines" can be utilized as a cost-effective fuel instead of being discarded as waste, which also reduces emissions. Physical cleaning is now commercially viable; more complicated chemical and biological coal cleaning processes under development may also soon be used commercially.

Subbituminous and lignite coals have lower heat contents and high moisture contents. These coals can be upgraded by physical cleaning, followed by drying to lower the moisture content; this process, called beneficiation, alters the coal so that it has a higher heat content, and lower ash and sulfur contents. Coal drying (or briquetting) is promoted in some countries, particularly China, where over 1000 coal briquetting kilns have been constructed. There are three basic technology types of coal beneficiation, of which one, physical beneficiation, is commercially available; two other types, chemical cleaning—which uses chemical reactions to remove impurities that are organically bound to the carbon in coal—and biological cleaning—that uses microbes to attack and break down impurities in coal—are under development.

Coal pretreatment and beneficiation marginally reduces GHG emissions, but significantly reduces other air pollutants (sulfur) and combustion byproducts (ash). Also, by cleaning the coal prior to combustion, boiler availability is improved and maintenance reduced, the heat content of the coal is increased corresponding to lower CO_2 emissions/kWh of electricity generated, and SO_2 and dust emissions are significantly reduced as well. In addition, washed coal reduces transportation needs since it is of lower weight and volume than run-of-mine coal. This reduces carbon emissions from transportation.

SIZE: 100-1,000 tons per hour throughput. A 500 MW conventional steam-coal plant requires 200-250 tons per hour of bituminous coal.

FEATURES: Pulverized coal steam plants using bituminous coals with high sulfur and/or ash contents and plants using subbituminous and lignite coals with high moisture content.

COST: The feasibility of coal cleaning is very specific to the requirements of the user and the characteristics of the coal. Capital costs of the preparation plant range from $25,000 to $100,000 per metric ton per hour of cleaning capacity. Related non-fuel O&M costs range from $1-5/metric ton of coal cleaned. These costs are offset by reduced ash disposal requirements, increased generation per metric ton of coal, reduced SO_2 and particulate emissions, decreased transportation costs, reduced equipment wear and tear, and lower operating and maintenance costs. Coal washing in China was estimated to increase the value of the coal from $5.05 per ton to $8.45 per ton.

CURRENT USAGE: About 75% of U.S. steam coal is cleaned prior to combustion, by 700 facilities with capacities ranging between 200-20,000 tons per day. Far less pretreatment and beneficiation currently takes place in developing and emerging market countries.

POTENTIAL USAGE: Chemical and biological cleaning methods are still under development.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Beneficiation increases the cost of coal because of processing costs as well as cost for the disposal of solid and liquid waste products produced. However, use of the waste products as fuel in a non-pulverized boiler (i.e., fluidized bed) can its increase cost-effectiveness.
- There are potential problems with collection of fly ash using electrostatic precipitators due to changes in the ash resistivity.
- Lignite coals have a tendency to degrade or even spontaneously combust over time.
- Most coal beneficiation systems require large quantities of water, although some of the water may be recycled.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Reduces transportation-associated emissions as less ash and more Btus per pound are transported. Boiler thermal efficiency is generally marginally improved, resulting in a corresponding reduction in greenhouse gas emissions.

EMISSION ESTIMATE: Improves power plant efficiency by 0.5%-2%

COST-EFFECTIVENESS: $20-110/ton of carbon removed

SECONDARY EFFECTS: Reduces SO_2 and particulate emissions from combustion as well as transport of coal. Can also benefit boiler operations through reduced O&M.

RESOURCES

- EPRI/DOE Research, *Advanced Physical Fine-Coal Cleaning: Spherical Agglomeration*.
- DOE Clean Coal Technology Program has a number of resources and technical documents on technologies for coal beneficiation. Information is available online at *http://www.fe.doe.gov/coal_power/cct.html*
- United States Department of Energy, Office of Fossil Energy, 1997, *Sustainable Development with Clean Coal*, 1997, DOE/FE-0363.

CONTACTS

CQ Inc.
Clark Harrison
Homer City, PA
Tel: (412) 479-6016

Rosebud SynCoal Partnership
Ray W. Sheldon
Director of Development
Billings, MT
Tel: (406) 748-2366

U.S. Department of Energy
Joseph B. Renk
Federal Energy Technology Center
Pittsburgh, PA
Tel: (412) 892-6249
renk@fetc.doe.gov
http://www.fetc.doe.gov

U.S. Department of Energy
Douglas Archer
Office of Clean Coal Technology
Germantown, MD
Tel: (301) 903-9443
douglas.archer@hq.doe.gov
http://www.doe.gov

3.4 USE OF NON-PETROLEUM VEHICLES BY UTILITIES

CHARACTERISTICS

The large majority of motor vehicles in use today are internal combustion and diesel engines operating on petroleum and petroleum products. These engines are inefficient and emit a variety of air pollutants, including CO_2. In fact, 31% of all man-made CO_2 emissions in the U.S. derive from petroleum-based motor vehicles.

Utilities operate large fleets of vehicles, including cars, vans and trucks of many types and sizes. Options exist for reducing CO_2 emissions from these vehicles by using alternative fuels. For example, petroleum-based motor vehicles can be substituted with: compressed natural gas or liquefied petroleum gas vehicles, hybrid vehicles, alcohol fueled (neat or mixed with petroleum) vehicles, electric vehicles, and in the near future, fuel cells. In each case, fuels with less carbon content are substituted for petroleum.

However, non-petroleum based options may cost more than conventional motor vehicles and require the construction of infrastructure (alternative fuel filling stations or, in the case of electric vehicles, charging stations) to be viable options. The viability of reducing CO_2 emissions by using electric vehicles is dependent upon how clean the power plants are that provide the electricity to be used by the vehicles.

SIZE: Applicable for most any type of vehicle (automobiles, trucks, buses).

FEATURES: Alternative fuels include compressed natural gas (CNG), liquefied petroleum gas (LPG), alcohol fuels (e.g. ethanol). Non-carbon fuel vehicles include electric vehicles. Technologies under development include hybrid and fuel cell vehicles.

COST: Retrofit of existing and purchase of new automobiles for natural gas can cost an additional $1,500 or more per vehicle. Electric vehicles may cost $1,000 to $3,000 more per vehicle. Fuel switching to alcohol fuels can be done at no extra cost if less than 10% alcohol/petroleum combinations are used.

CURRENT USAGE: In the U.S., natural gas vehicles are used primarily in auto fleets in major cities that have serious ozone pollution problems. Alcohol fuels are used in the Midwest where federal subsidies are provided to farmers and alcohol fuel producers.

POTENTIAL USAGE: These options can be used for the majority of motor vehicles. Vehicle technologies under development (e.g., fuel cells, hybrids) may be cost-competitive with traditional fuel sources for vehicles within a number of years.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- The cost of retrofitting existing vehicles or purchasing new vehicles for using non-petroleum fuels is high.
- Limited infrastructure exists for the widespread use of these options.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- The CO_2 emissions reductions that result are dependent upon the fuel used, the source of electric power (for electric vehicles), and the options it is replacing (some petroleum-fueled vehicles are more efficient than others).
- If petroleum vehicles currently in use are converted to use non-petroleum fuels, emissions will be reduced. If new/additional vehicles are purchased instead of petroleum vehicles, emissions will be avoided.

EMISSION ESTIMATE: gasoline – 610 g/mi
CNG – 500 g/mi
LPG – 500 g/mi
electric – 480 g/mi
ethanol/wood – 100 g/mi

COST-EFFECTIVENESS: $450-$3,500 additional capital cost/vehicle

SECONDARY EFFECTS: These options may also reduce NO_x emissions.

RESOURCES

- U.S. Department of Energy, 1997, *Scenarios of U.S. Carbon Reductions, Potential Impacts of Energy Technologies by 2010 and Beyond.*
- Over a dozen U.S. utilities have significant experience with using non-carbon fuel vehicles, especially electric vehicles, for their fleets. Programs include development of electric vehicles for use by meter readers, pilot programs for electric car battery trade-ins. Some utilities have committed to building infrastructure to support the use of CNG vehicles to further develop their use.

CONTACTS

U.S. Department of Energy
Electrical Vehicle Program
Pandit Patil
Office of Advanced Automotive Technologies
Washington, DC
Tel: (202) 586-6055
http://www.ott.doe.gov/oaat/

Idaho National Engineering & Environmental Laboratory
EV America Program
Idaho Falls, ID
http://www.inel.gov/

3.5 FUEL QUALITY TESTING, ASSESSMENT AND ASSURANCE

CHARACTERISTICS

The type, quality and consistency of fuels used at a power plant can affect its performance and, as a result, its emissions. Fuels that are high in quality (e.g., high heat rate, few impurities) combust more efficiently and more cleanly and result in less boiler down time.

For boilers to operate as efficiently as possible, electric utilities can take actions to ensure that fuels fed to boilers are close to design specifications. For example, fuels shipped to the power plant can be tested to ensure that they meet specifications and, if not, can be blended with other fuels to improve total quality. Also, assessments of fuel performance can be made using model boilers or computer assistance to determine what effect changes in fuel specifications will have on boiler performance and emissions.

The higher the quality of the fuel, the more efficient the operation of the power plant. Efficiently operating power plants minimizes the emission of greenhouse gases produced per kWh.

SIZE:	Can be performed at any size power plant.
FEATURES:	Testing devices can be continuously operated.
COST:	Minimal, when compared with power plant operations costs.
CURRENT USAGE:	Fairly widespread use in the U.S.
POTENTIAL USAGE:	Can be used at all liquid- and solid-fueled power plants.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Continuous monitors are not foolproof and may not identify all contaminants that may adversely affect boiler performance.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Monitors must be in good working condition to accurately test fuel quality.
- Improved fuel quality improves efficiency of combustion process, avoiding emission of greenhouse gases.

EMISSION ESTIMATE:	Can improve heat rate by as much as 2-3%, decreasing the total amount of emissions.
COST-EFFECTIVENESS:	Experience to date has found use of testing devices to be very cost effective.
SECONDARY EFFECTS:	Will reduce other pollutants proportional to improvements in heat rate.

RESOURCES

- The Coal Quality Impact Model, has been developed by CQ Inc. to assist companies in testing fuel quality.
- U.S. Department of Energy, Office of Fossil Energy website provides links to program information and technical documents on fuel quality testing at *http://www.fe.doe.gov/programm.html*

CONTACTS

CQ Inc.
Homer City, PA
Tel: (412) 479-6016

U.S. Department of Energy
Office of Fossil Energy
Washington, D.C.
Tel: (202) 586-1650
http://www.fe.doe.gov

4.0 CONVENTIONAL POWER GENERATION SYSTEM ACTIONS

Electric utility carbon emissions can be reduced by improving and maintaining existing utility equipment and by proper attention to using best practices throughout the entire fuel cycle—drilling or mining, transport, processing or refining, and its eventual combustion. Improved firing equipment (including co-firing with natural gas or biomass), boiler improvements, turbine maintenance and improvements, proper selection and maintenance of auxiliary equipment, and use of modern plant instrumentation and control systems are among many actions that can be taken to improve the performance of power plants and therefore to reduce its carbon emissions.

The efficiency of energy conversion is dependent on its design and on its condition relative to design specifications. When condition of the technology has deteriorated, efficiency deteriorates as well. As plants age, their heat rates (without any preventive maintenance) increase; CO_2 emissions directly correspond to heat rates (if there are no end-of-pipe controls). Any technical or design improvement that lowers heat rates or improves the efficiency with which the power system operates will also reduce CO_2 emissions.

The mean design efficiency of thermal plants in 63 developing countries in 1990 was 25%, or at least 5% below the average efficiency of thermal generation among OECD countries. Improving the operating efficiency of power generating technologies can have a significant benefit to reducing the GHG emissions/kWh produced. Efficiency gains of 5-10% are possible with very minor “tune-ups” (depending on the operating condition prior to servicing).

This section provides information on a range of actions that can be taken to improve the performance of conventional power generation systems. Indications of the GHG effects are provided when available; however, GHG effects are largely site-specific since they are dependent on the fuels and technologies used to generate the electricity.

4.1 FIRING EQUIPMENT

CHARACTERISTICS

The reliability, availability and heat rate of power plants are critical to profitability of power companies. However, maintaining effective operation of the firing equipment is complex and is often given low priority. Variability of feedstocks, deterioration of pollution control equipment, load swings, startup difficulties, etc. can all lead to poor power plant performance that also leads to poor environmental performance. Also, stokers are fairly inflexible with respect to their performance during load variations, and contribute to low efficiency.

Improving firing equipment—through regular maintenance, ensuring fuel specifications are met, training of operators, proper management attention, etc.—can mitigate these operational and environmental problems. In addition, firing equipment performance can be improved through adjustments to fuel quality, fuel injection systems and other adjustments to boiler operations.

SIZE: Improvements to existing equipment can be performed on any and all equipment. Retrofitting the firing equipment system can require additional space within the facility to add equipment.

FEATURES: Significant operational improvements and economic returns have been demonstrated by making firing improvements or by installation of co-firing equipment.[6]

COST: Regular inspection of firing equipment will help to avoid expensive repairs. To install co-firing, costs range from $100,000-500,000 depending on boiler size and other conditions.

CURRENT USAGE: Many utilities routinely inspect their firing equipment for necessary repairs. For example, the Electric Generating Authority of Thailand (EGAT) saw boiler improvement when it inspected and repaired firing equipment.

POTENTIAL USAGE: Opportunities for upgrading equipment to improve its performance exist on all utility boiler operations. The cost-effectiveness of the many options to improve performance need to be assessed at each boiler site to determine the most cost-effective actions to take.

[6] In August 1995, in Dover, Ohio, a gas co-fire retrofit was completed on a 17 MWe spreader stoker that installed gas burners and upgraded the stoker controls. Since the upgrade, 10-15% co-firing improved boiler efficiency by 2-3% while reducing emissions of particulate matter by 24%. Co-firing has also allowed the plant to recover lost capacity, thereby reducing the need to purchase power.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Improvements in firing equipment can increase production costs that may not be recoverable unless the level of improved efficiency more than offsets the higher costs. Management and operators at power plants need to be up-to-date on the tools and techniques available to improve performance.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- By improving the operation of the firing equipment, the amount of emissions produced by the boiler is reduced.

EMISSION ESTIMATE: N/A

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Improved heat rates will reduce emissions of all pollutants emitted from power plants. In addition, improved performance will result in plants being dispatched more often, possibly offsetting emissions from less-efficient plants.

RESOURCES

- The Gas Research Institute (GRI) is participating in demonstration projects on stoker boilers with the City of Dover (Ohio), Oberlin College, and Hoover Company of Canton (Ohio).
- The World Energy Congress maintains a power plant performance committee. Information on the Committee can be obtained from the USEA.

CONTACTS

Association of Energy Engineers
Atlanta, Georgia
Tel: (770) 447-5083
Fax: (770) 446-3969
http://www.aeecenter.org

Gas Research Institute
John Pratapas
Chicago, IL
Tel: (312) 399-8301

World Energy Council
Robert Richwine
Chair, Power Plant Performance Committee
Tel: 770-379-6982
Fax: 770-379-7726

4.2 BOILER IMPROVEMENTS

CHARACTERISTICS

Aging equipment makes reliable load-following increasingly risky and inefficient. Plant personnel need tools and methods to pinpoint the causes of failures in boilers. On-line monitoring techniques have been developed to assist plant personnel in analyzing and improving boiler performance. Older boilers can be modified through capacity enhancement, repowering and/or fuel switching to be better positioned to compete in a competitive market.

Aspects of boiler performance that should be evaluated include: whether heat exchanger sections have been removed from service and/or bypassed; presence of boiler heat containment/insulation; the amount of high unburned carbon content in ash; off-design operation; high flue gas exhaust temperature; any acid dew point problems in rear gas passes including air heaters; if desuperheating systems are on manual control or inoperable; any excessive valve leakages; whether there is serious plugging of convective passes with unburned fuel and/or ash; manual control of boilers; and lack of accurate fuel measurement.

SIZE:	Boilers in any size range.
FEATURES:	To optimize boiler performance, actual vs. design operating characteristics can be compared for fuel consumption, efficiency, air flow, distribution losses, boiler controls. Also, comparisons can be made to similar units at other power plants throughout the world.
COST:	Varies significantly, although many improvements involve little or no cost.
CURRENT USAGE:	Considerable use throughout the world.
POTENTIAL USAGE:	Potential benefit from boiler improvements is substantial. For instance, if China's industrial boiler efficiency were raised from the current 65% average to the 80% average attained by developing countries, then energy waste could be reduced by 1.6 quadrillion Btu (1.7 EJ)/year.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- There is a lack of awareness as to the potential benefits of improving boiler conditions.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Total emissions will vary according to the technologies employed, but the U.S. DOE has calculated that making boiler improvements results in an emissions reduction of 116.2 lbs/CO_2 for every million cubic feet (mcf) of gas or methane saved.

EMISSION ESTIMATE: 116.2 lbs/CO_2/mcf of gas or methane saved.[7]
Emissions from coal-fired boilers: N/A.

COST-EFFECTIVENESS: Costs will vary, but many improvements can be made at little or no cost.

SECONDARY EFFECTS: Emissions of air pollutants will decrease in proportion to improvements in boiler performance.

RESOURCES

- Schweitzer, J., J. de Wit, M. Koot, and O. Paulsen, 1994, *Annual Efficiency of Boilers; Development of an EU Harmonized Method of Calculation*, Conference on the Specific Action on Vigorous Energy Efficiency (SAVE) Programme, Florence, (October). *http://www.icgti.org/*.
- The Electric Power Research Institute is developing technologies and software tools for improved coal-fired boilers; gas/oil-fired boilers, as well as boiler upgrades and diagnostic and life assessment tools. *http://www.epri.com/gg/fossil/*
- The 1999 First Quarter issue of the CADDET Energy Efficiency Newsletter focuses on boilers and burners, including information on technological advances and performance improvements. The newsletter is available at *http://www.caddet-ee.org/991_co.htm*, or by requesting a copy from CADDET.
- The Association of Energy Engineers presents workshops on optimizing boiler performance. *http://www.aeecenter.org*.

CONTACTS

Association of Energy Engineers
Atlanta, Georgia
Tel: (770) 447-5083
Fax: (770) 446-3969
http://www.aeecenter.org

CADDET Energy Efficiency
Sittard, The Netherlands
Tel: +31-46-420-2224
Fax: +31-46-451-0389
caddet@caddet-ee.org
http://www.caddet-ee.org

Electric Power Research Institute
Tony Armor
Fossil & Renewables Generation
Tel: (650) 855-2961
Fax: (650) 855-2954
AArmor@epri.com

[7] Blue Earth Light & Water, a participant in the U.S. Climate Challenge Program, improved the efficiency of its boilers from 62% to 70%, and estimates that this improvement will save 5,035 mcf of gas per year, and will avoid the emission of 292.5 tC per year.

4.3 TURBINE CYCLE IMPROVEMENTS

CHARACTERISTICS

The efficiency of a turbine depends on its condition relative to its design. With use, the condition of the turbine deteriorates, and its efficiency deteriorates proportionately. Efficiency can be improved by evaluating the design and operating condition of the turbine. Improvements can be made in one or more of three areas: (1) combustion to improve fuel utilization and minimize environmental impact; (2) heat transfer and aerodynamics to improve turbine blade life and performance; and (3) materials to permit longer life and higher operating temperatures for more efficient systems. For maximum efficiency in utility applications, a steam turbine can be added to convert steam to electricity; adding a second cycle can increase efficiency to 45-53%.

Turbine improvements can improve the heat rate, thereby decreasing economic cost and improving efficiency of operation. With greater efficiency, emissions of GHGs will be avoided. Because of the widespread deployment of turbines, turbine improvements are an area with large potential for reducing GHG emissions with the added benefit of decreasing turbine operating costs.

SIZE: Turbines range in size from micro (<5 MW) to large (100 MW and larger)
Combined Cycles: 50-800 MW_e

FEATURES: Specific aspects to be evaluated include: poorly maintained steam seals, eroded/damaged first stage nozzle block; damaged rotating elements and diaphragms; feedwater heaters in/out of service; reduced load operation; manual control of turbine; valve and horizontal joint leakages; operation of turbine at unusually low steam flows to support the district heating system; operating low pressure turbines in condensing mode. Also, steam turbines can be re-bladed to improve turbine efficiency. Other turbine cycle improvements could include a program to monitor leaking valves and replace them when necessary (valve cycle isolation).

COST: Natural gas - $480 to $570/kW (120 to 440 MW_e); lower costs have recently been reported;
Distillate fuel oil - $540 to $580/kW (120 to 210$MW_e$).
Investment costs are approximately 30% less than for a conventional steam power plant, and costs may decrease over the next 2 decades.

CURRENT USAGE: Gaseous and liquid fueled-turbines are widely used. Advanced turbines systems with efficiencies >60% and NO_x emissions in the single digits (ppm) are under development.

POTENTIAL USAGE: Demand for electricity all over world is rapidly increasing; demand is estimated at close to 4500 GW by 2020—approximately one-third of this will be filled by gas turbines.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- May not be technically feasible to upgrade from a simple to a combined cycle application due to space limitations and technical incompatibilities (steam turbine inlet pressure and temperature).
- Only feasible where gas (or low cost liquid fuels) are available and economically competitive.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions will decrease in proportion to heat rate improvements.

EMISSION ESTIMATE: Natural gas-fired turbines emit about 425 gCO_2/kWh; Oil-fired turbines emit about 550 gCO_2/kWh

COST-EFFECTIVENESS: Increasing efficiency of turbines will decrease fuel costs.

SECONDARY EFFECTS: Turbines emit the following air pollutants:
SO_2: 0.5 to 0.7 g/kWh for high-sulfur distillate fuel oil
NO_X: 0.4 to 1.3 g/kWh for natural gas or distillate oil
CO : 0.07 to 0.12 g/kWh for natural gas
0.8 to 0.2 g/kWh level for distillate fuel oil
Particulates: 0.01 to 0.03 g/kWh.
VOCs: 0.03 to 0.07 g/kWh.

RESOURCES

- Electric Power Research Institute, *Heat Rate Improvement Guidelines For Existing Fossil Plants,* Report No. CS-4554.

CONTACTS

Association of Energy Engineers
Atlanta, Georgia
Tel: (770) 447-5083
Fax: (770) 446-3969
http://www.aeecenter.org

Gas Turbine Association
Jeff Abboud
Washington, DC
Tel: (202) 298-1806
Fax: (202) 338-2416
Advocates@erols.com
http://www.gasturbine.org

4.4 REDUCING PARASITIC LOADS FROM AUXILIARY EQUIPMENT

CHARACTERISTICS

Auxiliary equipment includes all of the equipment except the boiler and turbine (e.g., fans, pumps, drive motors, valves, gauges, bag filters, water treatment, lighting) needed to complete the generation process. While essential to smooth operation of the power plant, many auxiliaries use energy and contribute to overall efficiency loss. The difference between gross and net generation is called parasitic load. For coal-fired power plants, approximately 6% of electrical output is lost to parasitic load. For plants that have a SO_2 scrubber installed, total electrical consumption by all auxiliary equipment may be as high as 9%. To improve efficiency, utilities can upgrade to more efficient auxiliary equipment, and can take auxiliary equipment out of operation to reduce auxiliary power requirements.

Upgrading of plant equipment can result in direct energy consumption savings, reduced maintenance costs, extended equipment life, and better power plant performance. Reducing the amount of fossil energy consumed in producing electricity will also result in a reduction of greenhouse gas emissions.

Some of the techniques that can be used to reduce this electrical requirement are: upgrading to higher-efficiency design motors; using variable speed drives on large fans and pumps; using higher-efficiency lighting and other auxiliary support equipment; converting from centrifugal to variable pitch axial flow fans; and improved electrostatic precipitator controls. Redesign of the path that the flue gas takes through the boiler, ductwork, and environmental control equipment can improve the efficiency of the production process by reducing the power requirements for fans, minimizing pluggage from fly ash, and increasing boiler output.

SIZE: Varies. Parasitic load can be reduced by as much as 1%.

FEATURES: Most of station auxiliary use powers the large, forced-draft and induced-draft fan motors as well as condensate, boiler feed and circulating water pump motors. By using air foils (instead of straight vanes) in fans and guarding against excessive pump clearances, equipment efficiency can be improved by 10%. The U.S. Energy Information Administration estimates that in 1998, U.S. parasitic load associated with steam turbines was 3%; parasitic load of renewable energy technologies is closer to 1%.

COST: High efficiency motors typically cost about 20% more than standard motors, and save about 5% in electricity (depending on the size of the motor). Variable speed drive motors reduce electricity use by about 20%.
Efficient lighting can result in energy lighting savings of about 50-60%. It is likely that all costs can be recovered by savings from improved operation.

CURRENT USAGE: In the U.S. and other countries, utilities are beginning to upgrade their auxiliary equipment.

POTENTIAL USAGE: Every utility can use upgraded auxiliary equipment.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Augmenting existing plant controls can allow greater integrated control of the entire plant, especially where such control can decrease net heat rate.
- Can install variable speed motors.
- Wind turbines and other renewable energy technologies have none of the auxiliary equipment common to coal-burning power plants (coal pulverizers, fans, emission controls, etc.). However, parasitic load is not null; windfarms, for instance, use automatic control systems to control blade pitch and speed which affects generator electricity output.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions will be reduced directly because of increased efficiency of generation and distribution; and indirectly through reduced electricity demand. Emission reductions will correspond inversely to efficiency improvements—i.e., 10% improvement in efficiency will result in a 10% reduction in emissions.
- Renewable energy technologies produce no emissions.

EMISSION ESTIMATE: Varies according to the fuel used for electricity generation.

COST-EFFECTIVENESS: N/A as is site specific, but likely to be marginally cost-effective.

SECONDARY EFFECTS: Varies.

RESOURCES

- *Steam, Its Generation and Use*, 40th Edition, Babcock & Wilcox, Barberton, Ohio.
- The U.S. Department of Energy sponsors a variety of programs designed to improve the efficiency of auxiliary equipment including: Motor Challenge, and the Golden Carrot Program for pumps, fans and drives. Information about these programs is available at the DOE website at *http://www.doe.gov/*

CONTACTS

Electric Power Research Institute
Industrial Technologies & Services
Palo Alto, CA
Tel: (614) 841-7585
http://www.epri.com/

U.S. Department of Energy
Office of Industrial Technologies
Marsha Quinn
Director, Technology Access
Washington, DC
Tel: (202) 586-2097
Fax: (202) 586-9234
quinn@ee.doe.gov
http://www.oit.doe.gov

4.5 PLANT INSTRUMENTATION & CONTROLS

CHARACTERISTICS

Instrumentation and control systems are essential to all steam-generating installations for safe, economic, and reliable operation. Advances in control technologies allow plant operators to better monitor plant performance thereby improving plant management and increase overall availability.

With well-operating control technologies, the equipment will operate at maximum efficiency, keeping emissions to the minimum possible.

Upgraded instrumentation and control systems, used in conjunction with new sophisticated software programs, allow plant operators to identify factors affecting equipment performance more quickly and accurately. The latest generation control technologies help improve operating flexibility, reduce maintenance costs through enhanced ability to detect equipment malfunctions, and allows operators to reduce equipment operating stress, thereby helping to extend equipment life.

SIZE:	Used with all plant sizes.
FEATURES:	Improves heat rate from 0.5-1% on average, but for systems with pneumatic controls, heat rate can improve up to 5%.
COST:	$1-4 million/unit
CURRENT USAGE:	Modern instrumentation and control systems are in use in many countries, including the United States,
POTENTIAL USAGE:	Broad applicability. Research and development continues towards continually improving instrumentation and control systems.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- If capacity factor significantly increases, regulators may classify facilities as new thereby requiring either a new or review of the existing permitting.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Reduces emissions through better management of combustion process and pollution control equipment.

EMISSION ESTIMATE:	Varies according to a utility’s generating fuel mix.
COST-EFFECTIVENESS:	N/A
SECONDARY EFFECTS:	Varies according to a utility’s generating mix.

RESOURCES

- The Electric Power Research Institute is sponsoring research and development of improved plant instrumentation and control equipment. Some information is available through their website at *http://www.epri.com/csg/pq/targ-jnt.html*

CONTACTS

Electric Power Research Institute
Bill Winnerling
Power Quality Area Manager
Palo Alto, CA
Tel: (650) 855-2075
wwinnerl@epri.com
http://www.epri.com

4.6 WASTE HEAT RECOVERY SYSTEMS

CHARACTERISTICS

In the process of electricity generation, only a portion of the available energy can be converted into useful energy. A significant portion of the heat energy available in the combustion of fuel is wasted, as demonstrated by operating efficiencies in the range of 34%; today's most efficient combined-cycle systems have average efficiencies in the low 50% range. The largest source of waste heat is the warm water produced by steam condensation. This waste heat can be used for process steam, hot water heating, space heating, and other thermal needs. If the energy content is sufficiently high, the steam could also be used to generate additional electricity in a cogeneration (or combined heat and power) system.

Current water heating system design methods focus on meeting hot water needs and generally ignore energy consumption, operating costs, and other effects. As a result, utility customers often fail to make informed decisions and consequently sacrifice potential savings and benefits. It is possible to funnel this steam through a steam turbine to cogenerate electricity. Doing so can improve the efficiency of the system to as much as 80 or 85%. Using the heat from this source to generate electricity could displace fossil fuel consumption, thereby avoiding the emission of greenhouse gases.

Hot flue gases from boilers can provide a source of waste heat for a variety of uses. The most common use is for pre-heating boiler feed water. Heat exchangers used in flues must be constructed to withstand the highly corrosive nature of cooled flue gases.

SIZE:	Wide range of sizes from <25 MW to 300 MW.
FEATURES:	Water temperature above 60°C to 82°C (140°F to 180°F) is required for domestic applications. Some equipment also acts as a silencer to replace or supplement noise reduction equipment needed to meet noise requirements.
COST:	Installation costs can be $1000/kW (for industrial systems).
CURRENT USAGE:	Waste heat recovery is used extensively in Central Europe and at industrial facilities around the world.[8]
POTENTIAL USAGE:	With increasing industrial markets worldwide, this represents an opportunity for relatively low-cost increase in power capacity.

[8] The City of Renville, Minnesota has implemented a waste heat recovery system in which an effluent hot waste stream (6,000 gallons of water/minute @ 90-120º F) is pumped to one of two hot water heat exchangers. The heat from the hot waste stream is captured by a heat exchanger; the cooled waste stream is returned to a plant for further cooling and treatment. The captured heat is transferred to water in a closed loop that travels 4,000 feet to the industrial user, in this case, a fishery (other users may include greenhouse or hydroponic farming, e.g.). After the heat is extracted for use, the water in the closed loop is reheated and recirculated. The present system of four pumps and two heat exchangers can be doubled. As presently configured, the project provides 35 million Btu's from 2,000 gallons per minute of hot water circulating through a 24-inch diameter pipe system. Total cost of reconfiguration was approximately $657,000, part of which will be repaid by industrial park user fees. *http://www.bolton-menk.com*

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Waste heat streams from the electricity generation process are not readily adaptable to conventional heating or process use.
- A lack of space may prohibit the establishment of a waste heat application.
- Need for a backup heat supply during outages.
- It may be difficult to find a thermal host able/willing to locate near a power plant.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions will be reduced directly because of increased efficiency of generation and distribution; and indirectly through reduced electricity demand.
- In many instances to date, the waste heat is used to replace electric capacity from retired, less-efficient units.

EMISSION ESTIMATE: To the extent that overall system improves efficiency, fewer GHG emissions will be emitted.

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: NO_x and SO_2 reductions will depend on the generation mix.

RESOURCES

- The Electric Power Research Institute has sponsored the development of HOTCALC, a microcomputer software program that simulates the performance of commonly available commercial water heating systems to provide information for applications and design.
- *Thermal Energy Storage for Process Heat and Building Applications*, SERI/TR-231-1780, *http://www.epri.com*.
- Center for the Analysis and Dissemination of Demonstrated Energy Technologies, *Heat Exchangers in Aggressive Environments*, Analysis Series # 16, 1995.
- Goldstick, R. and A. Thumann, 1986, *Principles of Waste Heat Recovery*, The Fairmont Press, Inc. Provides information about recovering heat at low, medium, and high temperatures for reducing operational costs.
- The U.S. Department of Energy provides a reference brief on heat recovery in commercial buildings, that includes a reference list of additional information. *http://www.eren.doe.gov/consumerinfo/refbriefs/ea4.html*

CONTACTS

Energy Efficiency and Renewable Energy Clearinghouse (EREC)
Merrifield, VA
doe.erec@nciinc.com

Electric Power Research Institute
Palo Alto, CA
http://www.epri.com

4.7 INSTALLING COGENERATION

CHARACTERISTICS

Cogeneration is the joint production of electricity and heat from a single combustion process. A typical cogeneration system consists of an engine, steam turbine, or combustion turbine that drives an electrical generator. A waste heat exchanger recovers waste heat from the engine and/or exhaust gas to produce hot water or steam. Cogeneration produces a given amount of electric power and process heat with 10% to 30% less fuel than it takes to produce the electricity and process heat separately.

Cogeneration can be used wherever there is a need for both electricity and steam. Wherever on-site electric generation is required, thermal energy can also be created; conversely, thermal energy users can also generate electricity.

By offering significantly higher efficiencies than conventional power generating technologies (when used with combined cycle applications, cogeneration can achieve up to 90% efficiency), cogeneration is an excellent means of increasing overall energy efficiency in the generation mix. The amount of useful energy obtained per amount of greenhouse gases emitted increases and where low-carbon fuels (i.e., biomass) are used, emissions are reduced even more.

SIZE: Steam turbines (extraction-condensing type): 30-300 MW_e; back pressure type: 20-200 MW_e.
Combustion gas turbines: 10-100 MW_e.
Indirectly fired gas turbines: open-cycle: 10-85 MW_e; closed-cycle: 5-350 MW_e.
Diesel engines: 0.05-25 MW_e.

FEATURES: Can be used wherever there is a need for both electricity and steam, and whenever on-site electric generation is required or thermal energy users are in close proximity. When used with combined cycle applications, can achieve up to 90% efficiency.

COST: $1000/kW combined output for industrial engine.
Cogeneration is the cheapest form of thermal power generation.

CURRENT USAGE: Currently, manufacturers use 90% of all cogeneration systems. Another large-scale application of cogeneration is for district heating.

POTENTIAL USAGE: Several initiatives are underway to actively promote increased use of cogeneration. Industrial customers with steam demands are ideal candidates for cogeneration, but commercial establishments can also cogenerate electricity from the energy they use for space conditioning and water heating. Another potential deployment opportunity can be as a substitute for heat-only boilers used for district heating. Smaller systems are being developed for residential uses. Small-scale (20-650 kW and up to 5 MW) packaged or "modular" systems that produce electricity and hot water from engine waste heat are being manufactured for commercial and light industrial applications. However, small-scale cogeneration has not been widely used in the United States due to the initial costs associated with buying and installing the system.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Design of cogeneration applications are site-specific making system replications (or standardization) difficult or impossible.
- Time-of-use characteristics of electrical generation and thermal host needs must be conducive to economic operation of both.
- It can be difficult to set tariffs for grid sales and purchase of complementary power.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Because of high operating efficiency, carbon emissions will be much less than with conventional power systems.[9]

EMISSION ESTIMATE: Carbon emissions will be significantly less than from conventional systems because of the much higher efficiencies of cogeneration systems.

COST-EFFECTIVENESS: Where located close to industrial facilities that demand the steam and electricity, cogeneration is a highly cost-effective way to reduce GHG emissions.

SECONDARY EFFECTS: SO_2: Produces no emissions from natural gas, but other fossil fuels will produce some emissions.

NO_x: Emissions will vary according to the turbine design/boiler/combustion chamber type/fuel.

Particulates: No particulates when natural gas is combusted; amounts for solid fuels will depend on the type of control technology.

Hydrocarbons: Varies according to operating conditions and type of fuel.

[9] One project, in Decin, Czech Republic expects to achieve 20,000 tons/year C avoided from retiring coal boilers and adding two gas turbines and a cogeneration systems to its approximately 20 MW system (6,000 tons/year C reduction will result from fuel-switching). Cost of these reductions is estimated to be US $5.56 tons of CO_2 per year. This project also virtually eliminates SO_2 and ash.

RESOURCES

- DOE Office of Industrial Technologies demonstrations of improved steam and gas turbine systems. This same office also sponsors the Combined Heat and Power Challenge, working with states to promote dialogue and innovation to increase the use of CHP. *http://www.oit.doe.gov/chpchallenge/#addresses*
- Wilkinson, B.W., and R.W. Barnes. 1980. *Cogeneration of Electricity and Useful Heat*, CRC Press, Inc., Boca Raton, FL (US).
- Brown, Michael, 1996, *Industrial Cogeneration: Towards a New Vision for Electricity Production*, COGEN Europe (October), Belgium.
- NERAC, Inc., 1996, *Cogeneration: Economic and Technical Analysis*, (Latest citations from the INSPEC database), National Technical Information Service.

CONTACTS

Association of Energy Engineers
Atlanta, GA
Tel: (770) 447-5083
Fax: (770) 446-3969
http://www.aeecenter.org

Electric Power Research Institute
Palo Alto, CA
Tel: (650) 855-2000
http://www.epri.com

International District Energy Association
Washington, DC
Tel: (202) 429-5111
Fax: (202) 429-5113

U.S. Department of Energy
Office of Industrial Technologies
Combined Heat and Power Challenge
Patricia Hoffman
Washington, DC
Tel: (202) 586-6074
Patricia.Hoffman@hq.doe.gov
http://www.doe.gov

U.S. Environmental Protection Agency
Washington, DC
Skip Laitner
Tel: (202) 564-9833
laitner.skip@epa.gov
http://www.epa.gov

4.8 INCREASE CAPACITY AVAILABILITY BY REDUCING PLANNED OUTAGES FOR MAINTENANCE AND REPAIRS

CHARACTERISTICS

Unit maintenance is important in slowing the rate or deterioration of equipment or restoring part of the performance loss. Regular outages for maintenance and repair are essential to ensuring that a power plant operates efficiently and according to design specifications. However, when baseload plants are taken off-line, their load is usually met by operating other, less-efficient units.

Utilities can avoid the higher emissions produced by less-efficient units by taking steps to reduce the duration and frequency of planned outages for maintenance and repairs. With careful planning, prioritizing and scheduling, utilities can reduce the length of time required to perform the repairs. Also, by performing preventive maintenance during plant operation, utilities can minimize the frequency of necessary outages for repairs. By scheduling downtime during periods of low-demand, use of less-efficient units can also be minimized.

Modern computer databases/systems are available to help utilities better manage equipment and O&M processes. Accessing resources such as the EPRI Power Delivery Group will help companies remain up-to-date on advanced technologies. Use of Supervisory Control and Data Acquisition (SCADA) and benchmarking systems can also help to improve communication and performance of regional control centers.

SIZE:	Applicable to all sizes of units.
FEATURES:	Can involve steps to reduce both the duration of and frequency of planned outages. Some independent power producers report availability around 90%.[10]
COST:	Costs will be minimal for administrative actions, but may be substantial if the purchase of computer/software tools is required. However, any actions that improve overall load management will likely be cost-effective.
CURRENT USAGE:	Emission reductions are already enjoyed as a result of improved maintenance efforts in Georgia, Senegal and India as well as in the U.S.[11]
POTENTIAL USAGE:	Every utility can benefit from increasing plant availability of its most-efficient plants.

[10] The independent power producer AES, which owned 11,000 MW of capacity worldwide in 1996, reported a 94% overall availability factor in 1995, and 88% or better every year since 1990. *AES Corporation Annual Report 1996*, (p. 11), and *1994*, (p. 4).

[11] Over a four-year period, Florida Power & Light, a U.S. investor-owned utility, implemented a series of large-scale capital projects to improve the availability of its fossil power plant fleet. As a result of these improvements, FPL was able to defer construction of a new 720 MW unit by at least six years.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Utilities have a considerable experience base with O&M actions.
- Collaboration between operations, maintenance and engineering is required to incorporate best practices.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions will be reduced directly because of increased efficiency of generation, and indirectly through avoiding higher emissions from operation of less-efficient units.
- This action will not produce large reductions in GHG emissions, but can be useful in achieving modest reductions in the short-term.

EMISSION ESTIMATE: Will vary according to the "down" and "replacement" generation sources used.

COST-EFFECTIVENESS: Since power is dispatched using least-cost source first, any actions that reduce the downtime of least-cost, baseload power will be cost-effective.

SECONDARY EFFECTS: If reducing planned outages avoids emissions from fossil-fuel sources, then air pollutants will be lower. However, if replacement power comes from renewable energy sources, then reducing planned outages may actually increase emissions.

RESOURCES

- The Electric Power Research Institute's Generation Group hosts a webpage describing its tools to optimize power plants, *http://www.epri.com/gg/fossil/pub_ppo/index.html*.
- The International Quality & Productivity Center sponsors an annual conference and workshops on Shutdowns, Turnarounds, Outages & Overhauls—Best Practices in Process and Power. *http://www.iqpc.com*.

CONTACTS

Electric Power Research Institute
Generation Group
Palo Alto, CA
http://www.epri.com

International Quality & Productivity Center
Little Falls, NH
Tel: (973) 256-0211
Fax: (973) 256-0205
info@iqpc.com
http://www.iqpc.com

4.9 INCREASE CAPACITY AVAILABILITY BY REDUCING UNPLANNED OUTAGES

CHARACTERISTICS

When efficient power plants suffer unplanned outages, less efficient plants must operate to replace that lost generation. Because these outages often occur during peak demand conditions (unlike planned outages that generally occur during off-peak periods) the efficiency differential between the plants is often large, resulting in high incremental increases in emissions, as well as greatly increased generation cost and/or decreased revenue/profits. Reducing the frequency and duration of unplanned outages has become the focus of many utilities throughout the world with outstanding success in many cases.[12]

Many techniques have been effectively utilized to achieve these improvements including: benchmarking, computerized maintenance management systems, reliability-centered maintenance, reliability modeling, outage trend analysis, plant assessments, boiler tube workstations, coal quality evaluation software, and many others. In addition, advanced project investment evaluation systems have been used to prioritize projects, helping to ensure that the most cost-effective projects are implemented first.

Advanced management methods have also been successfully implemented helping to achieve the inherent potential of each individual power plant at the least possible cost. Techniques such as condition monitoring can avoid unexpected outages and help plant management move from a reactionary to an anticipatory style, giving more control over when the plant is removed from service for repair (ideally during times when the incremental efficiency and cost difference is minimal).

SIZE: Applicable to all unit sizes.

FEATURES: Can involve steps to reduce both the duration of and frequency of unplanned outages.

COST: Costs will be minimal for administrative actions, but may be substantial if purchase of computer/software tools is made. However, any actions that improve overall load management will likely be cost-effective.

CURRENT USAGE: Emission reductions are already enjoyed as a result of improved maintenance in Ireland and South Africa as well as in the U.S.

POTENTIAL USAGE: Benefits from increasing availability can be obtained by every utility.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

[12] The U.S.-based Southern Company, a large investor-owned electric utility whose annual profits are #1 among the world's electric utilities, was able to reduce its annual unplanned unavailability from 19% to less than 3% (with even lower values during its peak season), achieving a yearly savings equal to the company's total annual profitability.

- Most utilities have a reasonable understanding of the range of technical options available. However, a wider range of technical "best practices" options should be developed as well as methods allowing utilities to prioritize options according to their economics.
- Making improvements at existing plants will help management to more fully realize the inherent potential of advanced technologies, facilitating use of advanced, highly efficient technologies for new capacity.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions will be reduced directly because of increased efficiency of generation, and indirectly through avoiding higher emissions from operation of less-efficient units.
- This action will not produce large reductions in GHG emissions, but can be useful in achieving substantial reductions in the short-term.

EMISSION ESTIMATE: Will vary according to the "down" and "replacement" generation sources used.

COST-EFFECTIVENESS: Since power is dispatched using least-cost source first, any actions that reduce the downtime of least-cost, baseload power will be cost-effective. This action is highly cost-effective, enabling savings to be used for further improvements (boot-strapping).

SECONDARY EFFECTS: If the outage avoids the emission of fossil-fuel sources, reducing the length of the outage will also reduce emissions of air pollutants. However, if replacement power comes from non-emitting sources, emissions may actually increase.

RESOURCES

- The World Energy Council and UNIPEDE jointly sponsor a Committee on Performance of Thermal Generating Plants.
- Utilities that have reduced annual unplanned availability include Southern Company, Electricity Supply Board of Ireland, and the Republic of South Africa's ESKOM. More information is available in reports published by the joint UNIPEDE/WEC Committee on Performance of Thermal Generating Plant.
- The International Quality & Productivity Center sponsors an annual conference and workshops on Shutdowns, Turnarounds, Outages & Overhauls—Best Practices in Process and Power. http://www.iqpc.com.

CONTACTS

Electric Power Research Institute
Generation Group
Palo Alto, CA
http://www.epri.com

International Quality & Productivity Center
Little Falls, NH
Tel: (973) 256-0211
Fax: (973) 256-0205
info@iqpc.com
http://www.iqpc.com

Southern Electric International, Inc.
Robert Richwine
Atlanta, GA
Tel: (770) 379-6982

Performance of Thermal Generating Plant Committee
World Energy Council
E.V. Nekhaev
London, UK

4.10 ENERGY MANAGEMENT SYSTEMS

CHARACTERISTICS

It remains common practice in industry to leave electrical equipment on between production shifts. Large energy savings can be achieved by using an energy management system—a microprocessor connected to major energy distribution lines that records and partly controls energy use—to turn off, or turn down equipment when not in use.

Most facilities have not yet installed energy management systems (EMS), in part because of their high cost. Systems can cost as much as $750,000, but can provide an energy savings of as much as 10%. A site-specific cost-benefit analysis must be performed to determine the value of installing such systems.

Current analysis has concentrated on providing guidelines for selecting appropriate systems, the development of management rules, diagnostic and fault detection techniques, and the evaluation of emulation methods.

SIZE:	Relevant for all sizes of systems. May be used with existing or applied to new systems.
FEATURES:	EMS is typically applied to the largest electrical loads, including HVAC equipment, cooling towers, pumps, water heaters and lighting. Control functions may include basic stop/start functions or more complex chiller optimization routines.
COST:	Typical cost of an energy management system in a manufacturing plant with a load of 100 million kWh/year is about $750,000; an energy savings of about 10% is typically achieved, although exact costs and savings are site-specific.
CURRENT USAGE:	Energy management systems have been implemented successfully in several countries including the United States, Argentina, Colombia, Portugal, Germany and more.
POTENTIAL USAGE:	Site-specific analyses must be conducted to determine the benefit of installing energy management systems. Systems work with distributed and direct networks.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Energy management systems may require installation of wiring and switching, which can be expensive.
- An EMS can be used on new or existing facilities and can interface with existing controls, such as pneumatic damper actuators.
- EMS automates responsibility that may have previously been performed by personnel, eliminating positions.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Where total electricity use is decreased, GHG emissions are avoided. However, if energy use shifts, there may be no difference in total emissions.
- Fully functional (automated) systems provide the greatest potential for energy (and emissions) savings.

EMISSION ESTIMATE: Emissions are reduced in proportion to the amount of electricity use that is reduced.

COST-EFFECTIVENESS: Must be determined on a site-specific basis.

SECONDARY EFFECTS: Where electricity is generated by fossil fuel, there will also be positive impacts on NO_x and/or SO_2 reductions.

RESOURCES

- Electricnet.com provides contact information for several vendors of energy management systems at *http://www.electricnet.com/category/energymt.htm*.
- The U.S. Government Federal Energy Management Program provides detailed information on the use of energy management systems at

http://www.eren.doe.gov/femp/greenfed/3.0/3_8_1_energy_manage_sys.htm

Electric Power Research Institute, *Energy Management Systems*, Technical Brief TB.EMU.121.4.87.

CONTACTS

Electric Power Research Institute
Ken Priest, Target Manager
Grid Operations and Planning Group
Palo Alto, CA
Tel: (650) 855-2832
Fax: (650) 855-8997
Kpriest@epri.com

4.11 USING COMPETITION TO INCREASE EFFICIENCY IN POWER PLANT OPERATIONS AND POWER MARKETING

CHARACTERISTICS

Some countries have deregulated their electricity sectors and opened their markets to competitive pressures. The introduction of competition is accompanied by independent power production, power wheeling, the removal of monopoly service territories and the separation of the generation, transmission and distribution sectors. Because of the highly competitive nature of the new electricity market, all participating companies have an incentive to manage, operate and maintain their systems as efficiently as possible.

Competitive pressures have been met in part by the development of advanced technologies that have lowered costs, reduced risks, improved performance and reduced emissions. Power marketers, that control the purchase and sale of electricity, rely on advanced software systems that respond instantly to market fluctuations. These changes result in a highly-efficient market.

To gain a competitive advantage and maintain customer loyalty, companies in a competitive market are offering services such as energy efficiency and "green power"—electricity generated from renewable energy or other low-emission sources.

SIZE:	Can affect one or more electricity sectors.
FEATURES:	Existence of power wheeling/third-party access to the grid.
COST:	Cost is not quantifiable. However, competition encourages efficiency improvements that increase output and decrease operating costs.
CURRENT USAGE:	These phenomena are seen in competitive markets around the world.
POTENTIAL USAGE:	Countries that do not yet have competitive power markets will gain from letting market forces drive efficiency increases.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Where environmental standards are not high, or are not enforced, the lowest-cost power sources will be used the most; these may also be the most-polluting sources.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- With greater efficiency, more energy is produced/kWh meaning that emissions/kWh are reduced.

- However, where environmental standards are not enforced or are not stringent, less-expensive but more highly-polluting technologies may be used; this may actually increase total emissions.

EMISSION ESTIMATE: Varies.
COST-EFFECTIVENESS: N/A
SECONDARY EFFECTS: Varies.

RESOURCES

- CRIEPI, 1996, *Impact of Competition in the Power Market on the Environment and Energy Conservation*, Annual Research Report. *http://criepi.denken.or.jp/* National Council on Competition in the Electric Industry, 1996, *Electric Industry Restructuring Series* (6 Volumes), (October 1996. This series of reports explores the frontier of restructuring the electric industry. (Available from NARUC).
- NARUC, 1995, *Promoting Environmental Quality in a Restructured Electric Industry*, (December).

CONTACTS

National Association of Regulatory Utility Commissioners
Washington, D.C.
Tel: (202) 898-2200
Fax: (202) 898-2213
http://www.naruc.org

5.0 TRANSMISSION SYSTEM ACTIONS

Improvements in transmission system operations and transmission equipment efficiency can reduce GHG emissions through a reduction in system losses. Decisions about investing in transmission & distribution (T&D) systems affect how much of the power generated is actually delivered to customers. Energy losses occur due to under-investment in T&D infrastructure, inefficient operation and theft. While energy losses range widely, *average* losses among 88 developing countries was greater than 18%, significantly higher than average 5-10% losses of OECD countries.

Transmission capacity also affects the ability of utility systems to engage in power trading. Some countries/regions experience transmission bottlenecks that prevent regional/international power exchanges; this inhibits the use of existing generation capacity in the system and may cause electricity shortages, because of the inability to transmit power between areas with surplus power and power deficits. The environmental impacts of this may vary—it may lead to increased use of older, less efficient (and higher emitting) plants, and may also lead to the construction of new units or individual back-up units to compensate for the shortfall.

Transmission system reliability should be evaluated with regard to GHG emissions. Consumers will adopt alternative energy strategies when transmission reliability is poor. When alternatives include small generators powered by internal combustion engines, then there will be a contribution to GHG emissions. This is especially the case when poor transmission reliability results in nonpolluting generating capacity, such as hydropwer, being replaced by internal combustion engines.

This section discusses some of the predominant transmission system actions being undertaken in developing countries to improve system operations. Indications of the GHG effects are provided when available; however, GHG effects are largely site-specific since they are dependent on the fuels and technologies used to generate the electricity.

5.1 HIGH VOLTAGE DIRECT CURRENT

CHARACTERISTICS

Most transmission lines use alternating current (AC), where the current direction typically reverses itself 60 times per second. High Voltage Direct Current (HVDC) systems transmit power using direct current, which flows in (only) one direction. 80% of the losses occurring during transmission and distribution are due to resistance, which is inversely related to voltage—therefore, the higher the voltage, the lower the T&D losses. Electrical resistance losses in HVDC systems can be less than half of those in AC transmission lines, making HVDC well-suited for bulk transfer of electricity over large distances.

With lower losses, less electricity generation is required. With lower generation, there is also a reduction in GHG emissions when the transmitted electricity is generated by emitting sources.

Experience with HVDC dates to 1954 when the first HVDC line—with a power rating of 20 MW and 1900 kV over a distance of 96 km—was built in Sweden. Lines are now capable of larger loads—Brazil has a 6,300 MW and 600 kV line that spans 800 km. Current world HVDC capacity is approximately 63 GW, with plans for additional expansion underway. New methods of power generation that generate in direct current (thermoelectric, magnetohydrodynamic, fuel cells) will further improve the attractiveness of HVDC.

SIZE: 20 MW and 100 kV to 6,300 MW and 600 kV.

FEATURES: Overhead lines can extend more than 800 km. Cables can be strung for more than 40 km. Transmission lines are perpetual, but the lifetime of HVDC components (rectifiers, invertors, thyristors and DC circuit breakers) is about 30 years.

COST: Total cost of HVDC systems includes conductors, insulators, converters, tower and right-of-way costs. HVDC lines are less expensive than AC, but require converters at each terminal. HVDC is more economical than AC transmission for distances over 500 km for overhead transmission lines; 20-50 km for submarine cables; and 40-100 km for underground cables. These break-even costs do not include any credit for avoided emissions, or for avoided generation costs.

CURRENT USAGE: In 1993, world HVDC capacity was 58,000 MW.

POTENTIAL USAGE: An additional 9,000 MW planned (as of 1993).

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- There is a lack of industry familiarity with HVDC technology, and environmental criteria are not well defined.

- No DC circuit breaker exists, restricting DC use to point-to-point. Switching or fault clearing cannot be accomplished without total outage of all connected DC lines.
- “Back-to-back” HVDC installations are needed to connect two alternating current systems. Need further development of DC breakers to increase HVDC system flexibility and development of lower cost converters at terminals.
- HVDC does not create an electromagnetic field.
- There is a limited ability to respond to large generator outages or system faults, resulting in potential system instability.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Typical transmission line losses on the order of 7-10% in the United States and other developed countries could be reduced to 3-5%, resulting in a corresponding reduction in GHG-emitting generation demand. Transmission system line losses are often much higher in developing countries, affording the opportunity for even greater reductions.

EMISSION ESTIMATE: Because DC transmission is more efficient than AC, use of HVDC reduces generation needed and the associated emissions of greenhouse gases.

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Use of more efficient DC transmission also minimizes associated emissions avoided from electricity generation.

RESOURCES

- Thallam, R.S. 1993. "High-Voltage Direct-Current Transmission," *The Electrical Engineering Handbook*, Dorf, R.C. (ed.), CRC Press, Boca Raton, FL (US).
- There is a partnership between the U.S. Department of Energy, (U.S.) Federal Marketing Authorities, the Electric Power Research Institute, several electric utilities and equipment manufacturers to develop and demonstrate HVDC. Projects have been conducted in the following areas: the DC Pacific Intertie, New England/Hydro Quebec Line, and HVDC Lines in the Mid-Continent Area Power Pool.
- HVDC transmission lines are installed from Sardinia-Corsica-Italy, Greece-Crete, Zaire-Egypt, Russia-Finland and Finland-Sweden, Brazil, India, and more.
- An HVDC interconnection project between TNB of Malaysia and EGAT (Thailand) is scheduled to be operational by mid 1999. With the development of the project, the present 132/115 kV AC interconnection will be upgraded in terms of power capacity and controllability which will further enhance system integrity, security and economic interchange between the two parties.
- An example transmission service agreement for the use of an HVDC line can be found on the www at *http://www.nees.com/oasis/hvdcts.htm*.
- The Electric Power Research Institute (EPRI) has and is developing HVDC support equipment including a revenue meter and an HVDC transmission line reference handbook.

CONTACTS

ABB Power T&D
Henry Chao
Raleigh, NC
Tel: (919) 856-2394
http://www.abb.se/pow/home.htm

Electric Power Research Institute
Mark Wilhelm
Director, Power Delivery Group
Palo Alto, CA
Tel: (650) 855-2771
mwilhelm@epri.com
http://www.epri.com/pdg/trans/

Electricité de France
Alain Le Du
Paris, France
Tel: +33 1 47 65 33 88
Fax: +33 1 47 65 32 51
Alain.Ledu@edfgdf.fr

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

Oak Ridge National Laboratory
Jim Van Coevening
Power Systems Technology Program
Energy Division
Oak Ridge, TN
Tel: (615) 574-4829
http://www.ornl.gov

5.2 IMPROVING LINE FLOW CONTROL

CHARACTERISTICS

Power electronics can be used to control the flow of electrical energy, making better utilization of the transmission system possible, effectively increasing transmission capacity.

The Thyristor Controlled Series Capacitor (TCSC) uses advanced solid-state switches that direct the flow of electric power more precisely along specific transmission lines and swiftly stabilize power swings caused by short circuits and other disturbances; this gives significantly greater control and efficiency on utility transmission lines compared with conventional equipment. TCSC also makes it possible to achieve a much higher level of compensation and optimization of power delivery strategies

System optimization will allow more effective integration and use of renewables, energy storage, and demand-side management leading to possible GHG reductions. Spinning reserve requirements—the generating capacity used as backup power—could be reduced, also resulting in lower air pollutant and GHG emissions. The balancing of phase currents reduces the losses associated with residual currents. However, increasing current flow on a transmission line increases line losses, which can reduce or offset the net GHG emission reductions.

SIZE:	Feasible for all transmission voltages
FEATURES:	Increases transmission capacity on existing lines while improving control of power flow. by increasing stability and decreasing the effective “length” of the lines.
COST:	Prices are quoted in $ per kVAr of capacitor rating
CURRENT USAGE:	Currently in use on power systems in U.S., Canada and Europe
POTENTIAL USAGE:	Can be used on any bulk power alternating and direct current transmission systems. Development is underway of a Flexible Alternating Current Transmission Systems (FACTS)—a collection of power transmission control technologies that are faster and less susceptible to wear than conventional mechanical devices, that will improve controls of system volt-amperes-reactive (VARS) and system impedances (TCSC) (also system voltages).

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- In many cases, transmission line flows may already be sufficiently controlled such that further line flow controls may not be cost-effective.
- Research and development is needed in protection and real time control areas, and in flexible AC transmission system (FACTS) device technology.
- Higher line currents will produce greater magnetic fields, resulting in electro-magnetic health concerns.

- Series capacitor installations that compensate more than 25% of line impedance should be studied for potential sub-synchronous resonance problems.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Reduces losses thereby avoiding demand. However, if demand shifts, total emissions may not be reduced.

EMISSION ESTIMATE: Varies according to the fuel source used to generate electricity.

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Varies according to the fuel source used to generate electricity.

RESOURCES

- Numerous applications of improved power electronics exist in the U.S. including: 1) series compensation of a 500 kV line and other projects to improve power flow and system stability, 2) projects testing EPRI/Slatt Thyristor switched capacitor; 3) investigation of dynamic rating of transmission line conductors. More specific information is available in the U.S. DOE *Climate Challenge Options Workbook*. *http://www.eren.doe.gov/climatechallenge/*
- The Institute of Electrical and Electronics Engineers (IEEE) has a Capacitor Subcommittee of its Transmission & Distribution Committee. The Subcommittee has various working groups including: Thyristor Controlled Series Capacitor Working Group. Shunt Capacitor Standard Working Group and a Series Capacitor Standard Working Group. *http://www.electrotek.com/ieee/capsub/capsub.htm*.
- West Virginia University Electricity Restructuring Research Group, 1998, "Transmission Enhancement and Expansion," Interim Report No. 5 (January). *http://www.nrcce.wvu.edu/special/electricity/elecpaper5.htm*.
- Electric Power Research Institute, *Guide for Economic Evaluation of Flexible Access Transmission Systems (FACTS) in Open Access Environments* (TR-108500).
- Institute of Electrical and Electronics Engineers, *Subsynchronous Resonance Counter-Measures*, PES publication 81 TH0086-9-PWR.

CONTACTS

ABB Power T&D
Henry Chao
Raleigh, NC
Tel: (919) 856-2394
http://www.abb.se/pow/home.htm

Electric Power Research Institute
Mark Wilhelm
Director, Power Delivery Group
Palo Alto, CA
Tel: (650) 855-2772
mwilhelm@epri.com
http://www.epri.com

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

Oak Ridge National Laboratory
Jim Van Coevening
Power Systems Technology Program
Energy Division
Oak Ridge, TN
Tel: (615) 574-4829
http://www.ornl.gov

Tennessee Valley Authority
Jeffrey Nelson
Chairman
IEEE Capacitor Subcommittee
Knoxville, TN
Tel: (423) 751-8275
Fax: (423) 751-4788
jhnelson@tva.gov
http://www.tva.gov

5.3 CONDUCTOR LOSS REDUCTION AND PHASE CURRENT OPTIMIZATION

CHARACTERISTICS

Maximum utilization of existing transmission assets while ensuring transmission reliability makes good business sense. Especially where transmission lines are operated with open access, it is critical for operators to be able to assess and uprate existing lines at minimum cost.

Conductor performance may be affected by line sag, wind damage, corrosion, and other causes. Conductor loss rates are determined by the resistance of the transmission line conductor. As conductor line diameter is increased, resistance is lowered. Resistance, and thus losses, is also a function of the type of material of which the conductor is made. Replacing a conductor with one of a larger diameter and/or changing to a lower resistance material will reduce power loss. Segmenting shield wires eliminates losses associated with loop flow through this path. Lower loss rates result in lower generation demand and a decrease in GHG emissions.

SIZE: Transmission line conductors range in size according to voltage, line length and power transfer requirements.

FEATURES: Transmission conductors are fabricated from electrical grade aluminum (copper is no longer used). At higher voltages multiple bundles of conductors per electrical phase are used.

COST: Cost is based on cost of material, installation and when replacing an existing conductor there is an added cost to strengthen support towers. Conductor costs in low labor cost markets are about 20-25% of total line costs.

CURRENT USAGE: Upgrading of existing overhead transmission lines may be considered on shorter lines and where procurement of new right of way is difficult.

POTENTIAL USAGE: As right of way becomes more difficult to obtain, consideration of the conductor upgrade option will increase.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Replacing existing conductor lines is generally only cost-effective when a thermal capacity increase is required. Conductor losses should be considered in designing transmission lines.
- Existing transmission line pole, tower and cross arm strength may not be sufficient for a larger conductor requiring a complete rebuild of the transmission line, not just conductor replacement.
- Public misperceptions about electro-magnetic fields (EMF) increase difficulties in siting and extensive environmental permitting can be required, especially where structure rebuilding is necessary.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- The U.S.-based Commonwealth Electric Companies, participating in the U.S. DOE-sponsored Climate Challenge, estimates that upgrades to its transmission & distribution systems including voltage and equipment upgrades, conductor loss optimization and the use of loss transformer and other equipment will reduce CO_2 emissions by approximately 12,400 tons of CO_2 annually.

EMISSION ESTIMATE: N/A
COST-EFFECTIVENESS: N/A
SECONDARY EFFECTS: N/A

RESOURCES

- Power Technologies, Inc. sponsors educational programs on modifying conductors when uprating transmission lines. *http://www.pti-us.com*
- Electric Power Research Institute Reports, EL-5478, *Shield Losses in Medium-Voltage Cables*, details how to design neutral conductors for maximum cost-effectiveness and includes calculations of circulating current losses and ampacities for commonly used cables.
- Electric Power Research Institute Reports, EL-6759-D, *Transmission Cable Magnetic Field Research*, provides magnetic field data for one cable configuration.

CONTACTS

ABB Power T&D
Henry Chao
Raleigh, NC
Tel: (919) 856-2394
http://www.abb.se/pow/home.htm

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

5.4 INSTALLING MORE EFFICIENT TRANSFORMERS

CHARACTERISTICS

Transformers are used to step-up the generator voltage for transmission and to step-down the transmission voltage to intermediate levels for distribution and customer use. Commonly used transformers are oil-filled, pole-mounted types for overhead distribution; and oil-filled, pad-mounted models for underground feeds. Dry-type transformers, used for smaller, special applications, are typically located inside buildings away from harsh environments. Current standard practice is to design large power transformers based on economic considerations, rather than on maximum operating efficiency. Transformers consume power even when loads are switched off or disconnected, and every time a transformer is energized, an electrical loss in the transformer known as "core loss" occurs.

Recent technological advances have succeeded in reducing core losses, thereby improving efficiency. Increasing transformer efficiency requires less electricity generation to provide the same level of customer service; this will reduce fuel consumption and GHG emissions. Also, because of the large number of transformers installed throughout the world, even small improvements in transformer performance can add up to a significant reduction in greenhouse gas emissions.

Transformer failure may be catastrophic and cause power interruptions; other transformer problems are more subtle and may result in energy waste that goes unchecked for years. Current research is seeking ways to further reduce core losses as well as decreasing winding loss.

SIZE: Transmission grid power transformer: 110 kV to 765 kV, 200 MVA to 1,500 MVA
Distribution transformer: 37.5 kVA, 120 to 600 V.

FEATURES: Transmission power substation transformers; pad or pole mounted distribution transformers. Many transformers operate at more than 98% efficiency, but even losses of 2% of total electricity generation translates into billions of kilowatt hours of wasted electricity each year.

COST: Transformers are evaluated in terms of total ownership cost, equal to net selling price plus discounted value of future load and no-load losses. Transmission power substation: ~$4,145/MVA plus $4,100-6,000/kW for load loss Distribution transformer: ~$750/kVA plus $3,000-6,000/kW for load loss.

CURRENT USAGE: Conventional steel core transformers are commercially available. In newer transformers, PCB-containing oils are not used in cooling systems, which increases their attractiveness.

POTENTIAL USAGE: Low temperature and high temperature superconducting transformers are under development. Amorphous core transformers offer potential loss reduction benefits.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Increased capital cost of high efficiency transformers may not be offset by direct cost-savings from reduced generation demand.
- Replacement of older transformers requires treatment and disposal of PCB containing oils.
- Transformers consume power even when loads are switched off or disconnected. Disconnecting the primary side of transformers to save transformer standby losses is safe provided that critical equipment such as clocks, fire alarms, and heating control circuits are not affected.
- For three-phase transformers, ensure that each phase balances in voltage with others to within the minimum transformer step. If this fails to yield equal tap settings, redistribution of loads is necessary.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- If demand shifts as a result of improved efficiency, total emissions may not be reduced.

EMISSION ESTIMATE: Produces no direct emissions. Avoids the emissions associated with a 0.25% reduction in total transmission losses (usually 5% to 6%).

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: N/A

RESOURCES

- Dirks, J., et al. September, 1993. *High-Temperature Superconducting Transformer Performance, Cost, and Market Evaluation,* Battelle Pacific Northwest Laboratory, PNL-7318.
- Fink, D., and H. Beaty, 1993, *Standard Handbook for Electrical Engineers*, 13th Edition, McGraw-Hill.
- Oak Ridge National Laboratory, *The Feasibility of Replacing or Upgrading Utility Distribution Transformers During Routine Maintenance*, Oct 1972.
- The U.S. EPA's Energy Star Transformer Program has information about manufacturers of distribution transformers that have committed to produce and market efficient transformers. *http://www.epa.gov/appdstar/transform/*

CONTACTS

ABB Power T&D
Henry Chao
Raleigh, NC
Tel: (919) 856-2394
http://www.abb.se/pow/home.htm

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

U.S. Environmental Protection Agency
EnergyStar Transformer Program
Alison ten Cate
Tel: (202) 544-9023
Fax: (202) 565-2079
tencate.alison@epamail.epa.gov
http://www.epa.gov

5.5 INCREASING AND STABILIZING LINE VOLTAGE

CHARACTERISTICS

Increasing transmission line voltage improves the efficiency of electricity transmission over the line. Using the highest transmission voltage that is operationally and economically justified reduces line losses and increases line utilization.

Conventional line designs use porcelain or composite silicon insulators. Cable systems use oil-impregnated paper insulated cables and solid dielectric insulation. Static Var Compensation (SVC) devices are thyristor controlled devices installed at transmission line terminals, and control the flow of reactive power to maintain terminal voltage within pre-set limits; typically +/- 5% or 10% of nominal.

The increased efficiency means less electricity must be generated to provide the same level of customer service, reducing fuel consumption and greenhouse gas emissions.

SIZE:	110 kV to 765 kV alternating current transmission lines. SVC ratings in the range of hundreds of MVAr at costs in the range of $50 to $100 per kVAr of capacity rating.
FEATURES:	SVC's control terminal voltage on overhead transmission lines and cable systems.
COST:	Voltage upgrades can range from 50% of original line cost to total replacement of existing lines — costs range from $50,000 to $750,000 per km. SVC ratings (hundreds of MVAr) cost from $50-100 per kVAr of capacity rating.
CURRENT USAGE:	Conventional line designs use porcelain or composite silicon insulators. Cable systems use oil-impregnated paper insulated cables and solid dielectric insulation.
POTENTIAL USAGE:	Development of gas insulated systems with SF_6 gas and superconducting cables is underway

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Energy loss reductions alone do not offset the cost of additional equipment or the replacement of existing line and terminal components. Voltage upgrades are generally only cost-effective when used to increase capacity. Also, higher voltage transmission facilities have increased costs.
- Public concerns and misperceptions with electromagnetic fields (EMF) exist. Increased voltage is incorrectly associated with increased EMFs.
- Existing lines may need to be rebuilt to obtain sufficient clearance required for increased voltage. New permitting may be required for higher voltage lines.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Increasing and stabilizing line voltage indirectly avoids emissions through increasing efficiency and reducing energy demand.

EMISSION ESTIMATE: N/A

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: N/A

RESOURCES

- Institute of Electrical and Electronics Engineers, 1993, *Suggested Techniques for Voltage Stability Analysis*, PES publication 93 THO 620-5
- Institute of Electrical and Electronics Engineers, 1993, *System Protection for Voltage Stability*, PES publication, 93 THO 596-7-PWR

CONTACTS

ABB Power T&D
Henry Chao
Raleigh, NC
Tel: (919) 856-2394
http://www.abb.se/pow/home.htm

Electric Power Research Institute
Palo Alto, CA
http://www.epri.com

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
Pdonalek@harza.com
http://www.harza.com

5.6 INSTALLING NEW, MORE EFFICIENT TRANSMISSION LINES

CHARACTERISTICS

The location of power transmission lines often does not optimize power delivery efficiency. This may be due to normal changes in customer demand, shifting of demand centers, or attempts to avoid installation of new facilities. However, proper placement of new transmission lines—especially in populated areas—may achieve significant reductions in transmission losses, and allow for trading of electricity from systems that may have excess capacity to those with capacity shortfalls.

Lowering transmission losses results in reduced generation requirements, with subsequent reductions in GHG emissions.

New transmission lines between utility systems allow excess capacity in one system, which may be more efficient and produce less GHG, to be made available to other systems with capacity shortages or more carbon-intensive fueled generation. Energy consumption for spinning reserves may also be reduced. New transmission line capacity connecting utility systems is generally required to achieve these results.

SIZE:	Alternating current transmission lines operating at voltages from 110 kV up to 765 kV.
FEATURES:	Design of lines to provide greater reliability, reduced resistance losses, reduced leakage currents and improved lightning performance.
COST:	Increase total line construction costs by 10% to 25%.
CURRENT USAGE:	Transmission line designs use composite silicon-based insulators, more precise design calculations of shielding angles, and economic conductor selection.
POTENTIAL USAGE:	Improved relaying with high speed re-closing, improved insulation to reduce Corona and pollution losses, and high phase order (six phase) transmission lines. Also some potential for use of Gas Insulated Transmission and solid dielectric insulated cable systems.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Inter-utility transmission lines may not be considered “used and useful” by regulators, and could possibly be excluded from the utility rate base.
- Competitive opportunities may be created when electricity users have transmission alternatives.
- The regulatory process for the routing and permitting of transmission line projects can be a deterrent.

- Public opposition and concern with EMF and the construction of new transmission lines can increase the difficulties in undertaking new projects.
- Underground transmission lines are expensive.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions are avoided when generation is shifted from lower-emitting sources to meet demand that would otherwise be met by higher-emitting source. For example, installing a new line to transport power generated by a natural-gas burning facility instead of adding capacity at a coal-fired power plant.

EMISSION ESTIMATE: N/A
COST-EFFECTIVENESS: N/A
SECONDARY EFFECTS: N/A

RESOURCES

- U.S. Office of Technology Assessment*; Electric Power Wheeling and Dealing; Technological Consideration for Increasing Competition"; OTA-E0409;* Washington D.C.; U.S. Government Printing Office, May, 1989.

CONTACTS

ABB Power T&D
Henry Chao
Raleigh, NC
Tel: (919) 856-2394
http://www.abb.se/pow/home.htm

Electric Power Research Institute
Mark Wilhelm
Director, Power Delivery Group
Palo Alto, CA
Tel: (650) 855-2771
mwilhelm@epri.com
http://www.epri.com/pdg/trans

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
Pdonalek@harza.com
http://www.harza.com

5.7 COMPUTER SOFTWARE SYSTEMS AND MODELS

CHARACTERISTICS

Computer software provides the necessary analytical tools required to establish technical and economic feasibility of improved transmission facilities for reduction of GHG. There are a large number of software tools available from industry-based research organizations such as the Electric Power Research Institute (EPRI) in the United States, the Central Research Institute of Electric Power Industry (CRIEPI) in Japan, and the Centro Elettrotecnico Sperimentale Italiano (CESI) in Italy. With the shift toward a restructured electric utility industry these organizations are now making their software products available on a semi-commercial basis. In addition to traditional load flow, short circuit, transient stability and electromagnetic transient programs, transmission line design work stations and individual transmission line design programs are also available.

SIZE: Available for design of transmission lines from 110 kV to 765 kV

FEATURES: Economic conductor selection, shielding angle lightning protection, tower and foundation design, structural upgrading, right of way mapping, tower spotting, and cable rating

COST: Cost of individual software packages begins at $25,000; other software is available by membership. (Membership also includes access to future upgrades and benefits from access to new research efforts and information).

CURRENT USAGE: Software such as the ElectroMagnetic Transients Program (EMTP) has been in use since the 1960s and is supported by the Bonneville Power Administration. In the U.S., Europe and Japan electric utilities, consultants, contractors, and equipment suppliers use up-to-date software to prepare transmission line designs.

POTENTIAL USAGE: With the improved access available from the Internet it is possible to download software to utility company work stations anywhere in the world.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- The cost of software in addition to the subsequent need for computer hardware, software training and maintenance may be difficult for management to justify.
- Annual membership fees and software maintenance charges are expensive for utilities in developing countries.
- Software license, copyright protection and membership agreement language create bureaucratic barriers.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Models may be able to quantify expected emissions mitigation.

EMISSION ESTIMATE: N/A

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: N/A

RESOURCES

- Most industry-based research groups host websites with detailed descriptions of their products. These include:
- ➢ Central Research Institute of Electric Power Industry, *http://criepi.denken.or.jp/*
- ➢ Centro Elettrotechnico Sperimentale Italiano, *http://www.cesi.it/*
- ➢ Electric Power Research Institute, *http://www.epri.com*

CONTACTS

Electric Power Research Institute
Mark Lauby
Palo Alto, CA
Tel: (415) 855-2282
Fax: (415) 855-2065
mlauby@epri.com

6.0 DISTRIBUTION SYSTEM ACTIONS

Reduction in GHG emissions through improved electric distribution systems is a worthwhile goal. As electric service is extended into every home and business in the world, the efficiency of the distribution network takes on a greater impact as a contributor to GHG emissions.

In a well-run system, total transmission and distribution system losses are on the order of 9%, and of this 2-3% are in the distribution system. In the developing world equivalent numbers are total losses of 15% and distribution losses in the 5-7% range. Given the immense number of kilometers of electrical conductors installed throughout the world it is clear that if electric resistance losses can be reduced by even a portion of one percent then there will be a dramatic impact on the total amount of generation, and subsequently GHG emissions.

Distribution system reliability and quality of service also play a role in GHG reductions. Consumers will adopt alternative energy strategies when distribution reliability is poor. When alternatives include small generators driven by internal combustion engines, then there will be a contribution to GHG. The contribution is all the more dramatic when a non-polluting generation source, such as hydropower, is replaced by an internal combustion engine.

This section presents a collection of discussions about basic technical segments of electric distribution technology. GHG effects are directly related to reduction in electrical resistance losses. However, there are also significant improvements that can be accomplished through improved reliability and quality of service.

6.1 REDUCTION IN REACTIVE POWER LOSSES

CHARACTERISTICS

The use of electric motors requires that the distribution system deliver a form of power known as "reactive power". This is generally not a problem for residential power distribution, due to the limited number and small size of motors. Commercial and industrial users often require large quantities of reactive power, which increases current and energy losses. Connecting capacitors to the distribution system compensates for the reactive power, and reduces current and energy losses back through the system, since transmission losses are related to current and line resistance.

When reactive power-related losses are minimized, generation demand and the corresponding GHG emissions are reduced.

SIZE: Power factor correction capacitors for application on primary distribution feeders are commercially available for use on the full range of voltage levels and in practical kVAr sizes.

FEATURES: Power factor correction capacitors can be installed with switches and relays that sense low and high voltage. The insulating fluid used in early capacitors contained PCB, but new insulating fluids are now in use.

COST: The cost of power factor correction capacitors installed on primary distribution feeders in close proximity to low power factor loads is in the range of $12-20 per kVAr.

CURRENT USAGE: Power factor correction capacitors are in common use on primary distribution systems through out the world.

POTENTIAL USAGE: Every utility can benefit from installing more efficient capacitors.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Customers are reluctant to correct their own power factor, especially where rate tariffs do not allow a penalty for large users.
- Possible negative impacts on power quality.
- Energy loss reductions alone do not offset the capital costs of required new equipment.
- There are operating and maintenance (O&M) costs associated with many dispersed capacitor installations, and failure of accessory (fuses, switches, etc.) equipment is common.
- The VAR control function can be optimized under the Distribution System Automation Option.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- When losses are reduced, GHG emissions are also reduced due to the accompanying reduction in demand for generation.

EMISSION ESTIMATE: Varies according to the fuel mix used in generation.

COST-EFFECTIVENESS: Total losses of 9% are attributable to transmission and distribution from the point of generation to the point of use. From 2-3% of the total can be assigned to losses in feeder conductors and transformers.

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- The U.S. Department of Energy sponsors a *Real Time System Control Program*, that awards contracts to utility consultants, manufacturers and universities.

CONTACTS

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

National Rural Electric Cooperative Association (NRECA)
James Willis
Electrical Engineer
International Programs Division
Arlington, VA
Tel: (703) 907-5669
Fax: (703) 907-5532
Jim.willis@nreca.org
http://www.nreca.org

6.2 UPGRADING AND AUTOMATION OF DISTRIBUTION INSTRUMENTATION AND CONTROLS

CHARACTERISTICS

Distribution automation refers to a system that enables an electric utility to remotely monitor, coordinate and operate distribution components in a real-time mode. Automation components include remote switch control, integrated volt-var control, service restoration, feeder configuration, trouble call, fault location and isolation, load checks and safety checks. Customer automation options include remote metering, load control, load shedding and shaping, economic operation, cold load pickup, remote connect/disconnect, trouble call and tamper detection.

Together, these services help optimize line power flow and increase system efficiency (and reduce cost), which reduces generation demand and the emission of greenhouse gases, while providing the same level of service.

Work on superconducting technology (and other products) is underway that is expected to further increase efficiency of distribution controls.

SIZE:	The most widely-used distribution voltages are 12.47, 13.2 and 13.8 kV although complete range is from 4.16-34.5 kV. A primary distribution system uses transformers that step the primary distribution voltage down to voltages in the range of 120-600V.
FEATURES:	Automation components include remote switch control, integrated volt-var control, service restoration, feeder configuration, trouble call, fault location and isolation, load checks and safety checks. Design lifetime of transformers is 30 years.
COST:	Varies with the voltage (higher voltage systems are more expensive). Cost of developing communications systems is relatively expensive.
CURRENT USAGE:	In the U.S. and other countries, a number of companies have automated their distribution systems.[13]
POTENTIAL USAGE:	Automated distribution systems can be used in every country.

[13] The Karnataka Electricity Board (KEB) has a pilot Distribution Automation project to improve energy efficiency in its 192,000-mile distribution system. This pilot will use automatic control hardware including a complete line of capacitor controls and a state-of-the-art auto-reconfiguration system for automated switching requirements. KEB anticipates that automating distribution will make significant contributions to KEB's operating efficiency.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Conventional utility accounting may not justify implementing a distribution automation system.
- There is a high cost associated with developing the required communication system, together with the equipment and electronic database maintenance. However, as communication systems and distribution automation hardware costs decrease, expansion of distribution automation systems will become increasingly viable.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Distribution (and transmission) do not directly produce carbon emissions, but indirectly impact GHG emissions.

EMISSION ESTIMATE: Varies according to the fuel mix used in generation.

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- Several U.S. utilities have undertaken projects to improve distribution systems. More information on their projects is available in the U.S. Department of *Energy Climate Challenge Options Workbook. http://www.eren.doe.gov/climatechallenge/*
- The Electric Power Research Institute is sponsoring a research project to address distribution system impacts of dispersed energy systems and technologies.
- EPRI has prepared *Guidelines for Evaluating Distribution Automation* to assist firms in determining the costs and benefits of various automation options for distribution systems. More information is available at *http://www.epri.com/pdg/products/.*
- Tepel, R.C. et al., 1987, *Customer System Efficiency Improvement Assessment: Supply Curves for Transmission and Distribution Conservation Options*, Battelle Pacific Northwest Laboratory, PNL-6076.

CONTACTS

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

National Rural Electric Cooperative Association (NRECA)
James Willis
Electrical Engineer
International Programs Division
Arlington, VA
Tel: (703) 907-5669
Fax: (703) 907-5532
jim.willis@nreca.org
http://www.nreca.org

Oak Ridge National Laboratory
Jim Van Coevening
Power Systems Technology Program
Energy Division
Oak Ridge, TN
Tel: (615) 574-4829
http://www.ornl.gov

6.3 REDUCING CONDUCTOR LOSSES

CHARACTERISTICS

Losses in distribution feeder conductors are the result of current flow through electrical resistance of the conductors. The resistance a conductor offers to the flow of electricity is inversely proportional to its cross-sectional area — i.e., the larger the diameter of the conductor, the less resistance the current will encounter.

Resistance is also a function of the type of material of which the conductor is made. Thus, by replacing a conductor with one of a larger diameter or changing to a material that offers less resistance, power loss can be reduced when the same current is flowing through the conductor. Lower resistance losses will reduce generation and decrease GHG.

Distribution feeder losses can be minimized by upgrading existing feeders with larger-size conductors, reconnection of customers, and sectionalizing feeders with switching. On single phase systems there is also a need to balance loading among the three phases. Segmenting shield wires can also eliminate losses associated with loop flows through this path.

SIZE:	Conductors are aluminum and range in size from 35-240 sq.mm., and operating voltages range from 2,400 Volts to 69 kV.
FEATURES:	Distribution feeders can be overhead or underground. Overhead distribution uses aluminum conductors; cables use either copper or aluminum.
COST:	Costs to upgrade vary according to size of conductor, type of feeder (overhead or underground) and length. Feeder construction costs can vary from $15,000-50,000 per km.
CURRENT USAGE:	Feeder loss reduction is a regular part of distribution system operation and maintenance.
POTENTIAL USAGE:	With distribution automation, demand-side management, and time-of-use pricing there will be more sophisticated methods by which feeder resistance losses can be controlled.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Requires accurate load information and estimates of type and number of consumer connected. Installation of demand metering on primary distribution feeders is a necessary data source.
- A modular standard approach to feeder design is essential — this necessitates use of computer software to optimize feeder sectionalizing
- Reconductoring existing lines is generally only cost-effective when a thermal capacity increase is needed, but existing load flow models or regional models for economic evaluation of conductor losses can be developed.
- Pole, tower, and cross arm strength are a concern for existing lines. Most distribution

facilities are built and designed to the size of the conductor on the line. A larger conductor adds greater windage, weight, and ice loading levels which may exceed the design capability of the tower equipment. Therefore, in many cases, increasing the line capacity requires a complete rebuild of the line, not just reconductoring.

- Environmental permitting can be extensive, especially where structure rebuilding is necessary. Environmental regulations are often unclear for this type of project. Lengthy permitting processes and costly conditions in permits may preclude consideration of or implementing a reconductoring project. Examine ways to clarify and simplify environmental permitting, taking into account the advantages of using an existing transmission corridor and the fact that line losses would be reduced.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Avoids the emission of greenhouse gases indirectly by reducing generation demand.

EMISSION ESTIMATE: Varies according to the fuel mix used in electricity generation.

COST-EFFECTIVENESS: Total losses of 9% are attributable to transmission and distribution from the point of generation to the point of use. From 2-3% of the total can be assigned to losses in feeder conductors and transformers.

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- Institute of Electrical and Electronics Engineers, 1992, *Tutorial Course: Distribution Planning*, PES publication 92 EHO 361-6-PWR.
- Institute of Electrical and Electronics Engineers Computer Application, 1995, *Distribution Engineering Tool Features a Flexible Framework*, Power Magazine, (July), pp.21-24.

CONTACTS

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

National Rural Electric Cooperative
Association (NRECA)
James Willis
Electrical Engineer
International Programs Division
Arlington, VA
Tel: (703) 907-5669
Fax: (703) 907-5532
jim.willis@nreca.org
http://www.nreca.org

Virginia Polytechnic Institute and
State University

Prof. Robert Broadwater
The Bradley Department of
Electrical Engineering
Blacksburg, VA
Fax: (703) 231-3362
http://www.vt.edu

6.4 INSTALLING MORE EFFICIENT TRANSFORMERS

CHARACTERISTICS

Transformers are the devices that change the voltage of an AC electric circuit. They are most commonly used to reduce the voltage from the distribution level of 4-69 kV to the level required by the customer. However, whenever the transformer is energized, regardless of load, an electrical loss known as "core loss" occurs. Of the 9% total losses attributable to transmission and distribution from the point of generation to the point of use, 2-3% of the total can be assigned to losses in feeder conductors and transformers.

There are significant numbers of distribution transformers in the electricity supply system. The minimization of core and winding losses through the use of more efficient transformers reduces generation demand and the emission of greenhouse gases.

Significant advances have been made in reducing core losses, through improved manufacturing and treatment of steel cores, and through the development of amorphous metals (including steel). Decrease in winding loss, which is a function of the transformer load, is also possible.

SIZE:	5 kVA to 500 kVA single phase distribution transformers and 15 kVA to 1,500 kVA three phase distribution transformers.
FEATURES:	Most commonly used is the oil-filled transformer, transformers are installed on poles, in surface level distribution centers and in underground vaults. Design lifetime is 20-30 years.
COST:	Distribution transformer costs vary from $10-25 per kVA. Maximum efficiency designs may not be the most economic, since increasing the efficiency usually results in an increase in capital cost of the transformer.
CURRENT USAGE:	Conventional transformer designs are based on steel core oil filled transformers.
POTENTIAL USAGE:	Development of amorphous core distribution transformers offers the prospect for reduced excitation losses.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- The high cost of new transformer equipment may not be offset by the reductions in energy loss.
- There is only one supplier of amorphous core material (in the U.S.).

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Produces no carbon emissions directly, but more efficient operation will reduce demand for electricity.

EMISSION ESTIMATE: Varies according to the fuel mix used to generate electricity.

COST-EFFECTIVENESS: Depends on the size of transformer. The most efficient size may not be the most cost-effective size.

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- The Electric Power Research Institute (EPRI) has sponsored a study as part of which Minnesota Power has installed 25 amorphous core distribution transformers. Another EPRI collaborative research project with Potomac Electric Power Company to demonstrated a cooling design for forced-oil/air-cooled transformers with advanced winding technology involved installation of a low loss transformer at a distribution substation in 1994.
- Approximately 55% of the distribution transformers purchased by the New England Electric System in 1993 were of the amorphous core design.
- The U.S. Environmental Protection Agency sponsors an *Energy Star Transformer Program*, whose participating utilities agree to purchase qualifying transformers and to institute early replacement where economically warranted.

  http://www.epa.gov/appdstar/transform/utility.html

CONTACTS

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

National Rural Electric Cooperative Association (NRECA)
James Willis
International Programs Division
Arlington, VA
Tel: (703) 907-5669
Fax: (703) 907-5532
jim.willis@nreca.org
http://www.nreca.org

U.S. Environmental Protection Agency
Energy Star Transformer Program
Washington, DC
http://www.epa.gov/energystar/

6.5 REDUCING FORCED OUTAGES AND STABILIZING LINE VOLTAGE

CHARACTERISTICS

Electric energy is supplied to customers at a utilization voltage that is maintained within prescribed limits to insure proper operation of customer equipment. Maintaining the voltage as close to the standard as is practical controls electrical losses and contributes to improved system efficiency. Careful engineering of distribution system components and the use of voltage-regulating equipment are required. Connecting single-phase load in a careful way eliminates losses associated with residual current flow. These reductions in distribution system losses in turn reduce generation demand and GHG emissions.

SIZE: Applicable to all voltages.

FEATURES: Voltage regulation is accomplished by adjusting the turns ratio of transformers and by the control of reactive power. Automatic control of transformer taps and shunt capacitors and shunt reactors can be accomplished with Supervisory Control and Data Acquisition (SCADA) and automation systems.

COST: The cost of the voltage control function is bundled into the overall cost of SCADA and automation systems.

CURRENT USAGE: Power factor control capacitors are installed on primary distribution feeder circuits.

POTENTIAL USAGE: Advances in distribution automation will allow improved control over voltages on distribution feeders.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Voltage regulating equipment has high capital costs, and increases the equipment operating & maintenance costs. Savings due to energy loss reductions may not offset the costs of new equipment or replacement of existing line and terminal components; voltage upgrades are generally only cost-effective when done to increase capacity.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☒ Y OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Reducing distribution system losses reduces generation demand and GHG emissions.

EMISSION ESTIMATE: Varies according to the source of electricity generation.

COST-EFFECTIVENESS: Improved reliability means that consumers will not use GHG producing alternative energy sources.

SECONDARY EFFECTS: Improved reliability through reduction in forced outages will have a secondary benefit in the form of fewer hours of lost production and a higher quality of life for customers.

RESOURCES

- The National Rural Electric Cooperative *Association Closed-Loop Voltage Control Project* (RER #91-8) led to the development of a new system to control voltage regulators remotely, achieving a better voltage profile on distribution feeders.
- National Rural Electric Cooperative Association, 1991, *The Distribution System Loss Manual*.

CONTACTS

General Reliability Consultants
Sudhir K. Agarwal
San Diego, CA
Fax: (760) 737-0941
Agarwal@gri-us.com

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

National Rural Electric Cooperative Association (NRECA)
James Willis
International Programs Division
Arlington, VA
Tel: (703) 907-5669
Fax: (703) 907-5532
jim.willis@nreca.org
http://www.nreca.org

6.6 DISPERSED ENERGY STORAGE SYSTEMS

CHARACTERISTICS

The integration of dispersed generation, particularly renewable energy technologies that are intermittent generators (i.e., solar and wind power) is facilitated by dispersed energy storage systems. Energy storage systems use electricity during non-peak hours or from intermittent sources to convert water to ice or chilled water (for cooling), or to store energy in batteries. During peak periods, this stored energy can be converted back to electricity for use.

The use of these systems, in addition to filling the traditional role of meeting peak demand needs, increases overall system efficiency and reduces total system losses. A reduction in generation demand and GHG emissions results. The utilization of dispersed energy storage systems also reduces GHG emissions by allowing greater use of local low- or non-carbon fueled generation systems at the local level.

Use of dispersed storage systems will enable utilities to lower costs through deferrals of upgrades and new construction, supply new generation to customers, and improve reliability. The use of dispersed energy storage systems throughout the distribution system will improve dynamic operating capabilities and asset utilization, allowing existing generation to function more efficiently and improve the overall efficiency of the system. Emerging energy storage systems, which can be dispersed throughout the distribution system include batteries, flywheels and superconducting magnetic energy storage (SMES).

SIZE:	Uninterruptible Power Supplies and other forms of disbursed storage and generation range from a few kilowatts to several hundred kilowatts.
FEATURES:	Chilled water or battery storage systems
COST:	Installed costs of such units must be competitive with the low end of alternative forms of supply with installed costs under $450 per kW.
CURRENT USAGE:	Many companies are using dispersed energy storage systems. For instance, the U.S.-based Southern Company will begin to use dispersed energy storage (with a number of other T&D system upgrades) and expects to reduce distribution losses by about 15,000 MWh per year by the year 2000.
POTENTIAL USAGE:	Development of these systems is key to successful and widespread deployment of renewable energy systems.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Dispersed energy storage equipment has a high capital cost, and low energy capacity is available from existing dispersed storage technologies.
- Energy storage systems dispersed throughout the system may require additional dispatch and control systems.

- There is a lack of planning practices that fully assess the value of dispersed storage and generation.
- Dispersed resources may not all be under the ownership of a single company. This poses challenges in the control, protection, operation, and maintenance of distribution systems.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Unless the source of power to charge storage devices is non-carbon fueled generation, use of storage would actually increase, not decrease, emissions of greenhouse gases as the overall efficiency of a generator and a storage device is lower than the straight generator itself.

EMISSION ESTIMATE: Varies according to fuel source of the charging device.

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Varies according to the fuel source of the charging device.

RESOURCES

- Demonstration projects underway include the Electric Power Research Institute (EPRI) Battery Storage Project at Southern California Edison; the Puerto Rico Electric Power Authority (PREPA) 10 MW battery storage system, with Sandia National Laboratories assistance on performance testing; and a Metropolitan Edison/GPU study to determine if a battery storage facility to "shave" peak load for a specific application is feasible and/or practical. This dispersed storage project would reduce transmission losses in addition to peaking requirements.
- The U.S. Department of Energy sponsors an Energy Storage program to aid in the transfer of dispersed storage technology to utility systems.
- EPRI's *Engineering Handbook for Dispersed Energy Systems on Utility Distribution Systems* (TR-105589) provides a summary of available information on methods and tools for evaluating dispersed energy systems from economic, reliability, and power quality perspectives. The handbook identifies the costs and benefits, integration and engineering requirements, and projected performance of expansion options and also includes general background on development, methods for including dispersed energy sources in distribution planning, and application issues such as system protection.

CONTACTS

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

National Rural Electric Cooperative Association (NRECA)
James Willis
International Programs Division
Arlington, VA
Tel: (703) 907-5669
Fax: (703) 907-5532
jim.willis@nreca.org
http://www.nreca.org

U.S. Department of Energy
Russell Eaton III
Office of Project Management
Golden, CO
Tel: (303) 275-4740
Fax: (303) 275-4753
http://www.doe.gov

6.7 IMPROVING CUSTOMER SERVICE

CHARACTERISTICS

Improved customer service can be described in terms of improved reliability. Service reliability is measured in terms of frequency and duration of outages. Other measures of service include prompt and accurate billing and payment procedures, as well as providing information to users. In the case of commercial and industrial customers, service assistance may include energy audits and surveys. Some service programs include assistance in conversion to energy efficient lighting.

SIZE: N/A

FEATURES: Can consist of a variety of programs, for example: reducing outages, institution of easy-to-use payment procedures, provision of customer assistance programs, etc.

COST: Improving service reliability is the cost to upgrade and improve protective relaying, and repair feeders, and may be bundled into the cost of distribution maintenance activities.

CURRENT USAGE: Utilities in the U.S. and other countries are instituting programs to improve customer service.

POTENTIAL USAGE: Every utility can benefit from customer service improvement programs. Especially in countries where competition is being introduced, maintaining and improving customer services is essential to profitability.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Need to establish “benchmark” values for acceptable and unacceptable service performance.
- Rates must be adjusted to provide adequate funding to repair and maintain feeders and substations at a proper level.
- Need to build a database of outage events recording of details of each service interruption.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- There is no guarantee that improving customer service will result in reduced energy use.

EMISSION ESTIMATE: Will vary according to the generator’s fuel mix as well as to the nature and duration of the program.

COST-EFFECTIVENESS: Improved service performance is measured in the reduction in energy not served as maximum revenue.

SECONDARY EFFECTS: Varies.

RESOURCES

- The Energy and Utility Partnership Programs, sponsored by the U.S. Agency for International Development and the U.S. Energy Association has sponsored a number of programs teaching customer service.

CONTACTS

American Society of Quality Control
Reliability Division
Milwaukee, WI
Tel: (414) 272-8575
Fax: (414) 272-1734
http://www.asqc.org

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

National Rural Electric Cooperative Association (NRECA)
James Willis
International Programs Division
Arlington, VA
Tel: (703) 907-5669
Fax: (703) 907-5532
jim.willis@nreca.org
http://www.nreca.org

6.8 COMPUTER SOFTWARE SYSTEMS AND MODELS

CHARACTERISTICS

In modern utility systems, distribution system engineering and operations are highly computerized. Several comprehensive distribution engineering workstations are available that can accomplish all distribution system operating steps including load forecasting, feeder design, sectionalized switching and fuse and protective relay coordination studies. There have also been significant developments in the combination of automated mapping systems with geographical information systems and field operations. Supervisory Control and Data Acquisition (SCADA) and other distribution automation systems are also being adopted by more utility companies. Improved service efficiency and reliability will translate into lower losses and reduced GHG emissions.

SIZE: Techniques can be applied to large and small distribution service areas.

FEATURES: Software provides for load forecasting, feeder design, customer databases, transformer load management, and control of voltage and power flows.

COST: Cost depends on the total area and number of customers. Costs for distribution control systems range from less than one million dollars for a small system to tens of millions for large, comprehensive systems.

CURRENT USAGE: Industrialized countries need to automate because of demand for high reliability and to save on high labor costs.

POTENTIAL USAGE: The introduction of expert systems, artificial intelligence and fuzzy set logic with more sophisticated computers is being studied for application to electric distribution systems.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- The cost of software and distribution control centers may be difficult to justify in cost benefit analysis, especially when combined with need for annual outlay to pay for new computer hardware and software maintenance fees.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions are avoided indirectly though lower power losses, meaning less generation is demanded.

EMISSION ESTIMATE: Varies according to the fuel mix used to generate electricity.

COST-EFFECTIVENESS: The measure of cost-effectiveness is improved reliability, increased responsiveness to customer requests, and reduction in installed costs of feeders and transformer installations.

SECONDARY EFFECTS: Varies according to the generation fuel mix.

RESOURCES

- A number of vendors and consultants provide expertise on selecting and implementing appropriate computer software.

CONTACT

Harza Engineering
Peter Donalek
Electric Power Systems Department
Chicago, IL
Tel: (312) 831-3170
Fax: (312) 831-3999
pdonalek@harza.com
http://www.harza.com

National Rural Electric Cooperative Association (NRECA)
James Willis
International Programs Division
Arlington, VA
Tel: (703) 907-5669
Fax: (703) 907-5532
jim.willis@nreca.org
http://www.nreca.org

7.0 END-USE ENERGY EFFICIENCY AND DEMAND SIDE MANAGEMENT (DSM) ACTIONS

Demand-side management projects are designed to reduce energy consumption at the consumer level while maintaining the same level of energy services as prior to project implementation. There are two types of DSM projects:

Energy Efficiency (EE): focuses on modifications in end-use technology (e.g., lighting).

Energy Conservation: focuses on changing energy consumption use patterns through educational projects and the use of time-of-day tariffs.

Many DSM projects involve a combination of both energy efficiency and energy conservation measures that can result in low- and no-cost climate change mitigation options. The level (and cost) of reduction is dependent on the source of electricity. If the electricity was generated by a fossil fuel (e.g., coal, oil, natural gas), then the reduced demand would translate into less generation and reduced GHG emissions.

However, the supply and corresponding emissions response is not always straightforward. Reduced electricity demand could cause a price adjustment and a "rebound effect"—where the reduced demand is offset by increased demand elsewhere on the system so there is no net change in generation or GHG emissions, or there is a realignment in the sources of generation, so that even with reduced electricity demand lower GHG emissions may not be realized. Quantifying the environmental impacts of EE/DSM actions should involve a detailed, system-specific analysis that recognizes the magnitude as well as the timing of the actions on the resultant electricity savings and generation capacity of the utility.

This section discusses some of the EE/DSM actions that are available to utilities and regulators to reduce GHG emissions. Estimates of the GHG emissions reduced or avoided by these actions are provided where available. But, since these actions are dependent on the mix of fuels/technologies used to generate the electricity being displaced, a more precise estimate of carbon emissions reduced/avoided requires site-specific details.

Some of the information sources used to prepare the discussion of EE/DSM actions, and in which more detailed discussions exist, are:

- *International Directory of Energy Efficiency Institutions,* World Energy Efficiency Association (WEEA). A searchable version is also available online at *http://www.weea.org*. The WEEA site also hosts the Energy Efficiency Technical Library and case studies of energy efficiency projects by country and region.
- The Centre for the Analysis and Dissemination of Demonstrated Energy

Technologies (CADDET), based in the Netherlands, provides information (and case studies) on energy efficiency and renewable energy technologies installed in industrialized nations. The CADDET site, *http://www.caddet-ee.org/*, includes copies of newsletters, announcements and events, and a publications catalog.

- *The Impact of Global Power Sector Restructuring on Energy Efficiency*, and accompanying *Bibliography*, Hagler-Bailly, prepared for USAID Office of Energy, Environment, and Technology, Reports No. 98-02 and 98-05 (1998). The Bibliography provides a detailed listing of authoritative resource documents and articles on energy efficiency, including the "Top 25 Key Reference Documents" and publication and distribution information.
- The International Institute for Energy Conservation (IIEC) posts several project summaries and other guidance documents at *http://www.iiec.org*.
- The Alliance to Save Energy (ASE) has a variety of programs promoting energy efficiency in buildings and industry, energy policy reform, education and outreach, and NGO development. Information on the Alliance's initiatives and publications are found at *http://www.ase.org.*
- The American Council for an Energy-Efficient Economy (ACEEE) provides links to industry conferences, consumer information, and other websites, as well as information on ACEEE publications. *http://www.aceee.org/index.html*
- The National Association of Regulatory Utility Commissioners published *Incentives for Demand-Side Management* in October 1993. This report profiles U.S. state commission policies and activities encouraging utility investments in demand-side management resources, including a table that provides a quick summary of each State commission's DSM activities, with each type of shareholder incentive mechanism explained in the summary. This, and other documents can be found at the NARUC website, *http://www.naruc.org.*
- The International Energy Agency hosts a website dedicated to the compilation of summaries of demand-side management and energy efficiency efforts around the world. The site provides country by country information on electric power restructuring, existing mechanisms, and any issues affecting uptake or success of EE/DSM programs. *http://dsm.iea.org.*
- The U.S. EPA (Region 4) provides an energy efficiency action plan checklist for companies interested in improving their energy efficiency at: *http://www.epa.gov/region04/air/cai/eea.htm.*
- Lawrence Berkeley National Laboratory's (LBNL) Energy and Environment Division has developed a number of energy efficient technologies, and technical support services. Information on these products and services is provided on the LBNL website at: *http://eetd.lbl.gov/.*

7.1 PROMOTE RESIDENTIAL DEMAND-SIDE MANAGEMENT (DSM) PROGRAMS

CHARACTERISTICS

The IPCC estimates that by 2010, residential buildings will account for approximately 60% of energy use in buildings, regardless of the country. Therefore, reducing energy use in residential buildings will have a significant impact on future GHG emissions. By reducing (or avoiding) energy and electricity use, residential DSM programs will avoid the associated emission of greenhouse gases that would have otherwise been produced.

Residential DSM activities encompass a broad range of utility/customer interactions. Activities typically involve energy conservation, or "load shaping"/"load shifting" methods to reduce peak demand requirements by encouraging 1) the installation of energy-efficient equipment, or 2) voluntary reduction in consumption by means of behavioral adjustments.

SIZE:	Scaleable to any size residential building.
FEATURES:	Residential DSM programs are primarily directed at: 1) improving energy efficiency of customer appliances (heating, cooling and lighting); 2) improving energy efficiency of new and existing construction (through weatherization and design); and 3) managing residential load (home automation systems, rate structures that encourage off-peak electricity consumption, etc.).
COST:	Varies with program. Can be minimal (load shifting) or can involve installation of new computer equipment, etc. that may require significant upfront costs (although these costs can be recovered/saved over the lifetime of the equipment).
CURRENT USAGE:	Many OECD countries have achieved considerable energy savings through DSM programs. Non-OECD countries with significant DSM programs underway include Brazil, Pakistan, Thailand, Mexico, Jamaica and the Philippines.
POTENTIAL USAGE:	One estimate is that DSM can reduce worldwide energy demand 3-7% by the year 2010 and 5-6% by the year 2050. Conservation programs are applicable in every country. Implementation is limited only by willingness of utilities to engage in programs.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- A lack of uniformity in residential building energy codes and retail energy efficiency standards contributes to the difficulty of producing energy-efficient residences and technologies.

- Inadequate information on costs and benefits of residential DSM activities is available, which contributes to the lack of familiarity and information on the installation of energy-efficient technologies.
- There is a lack of capital for customer purchase of new, high-efficiency equipment. Incentives from utilities, including financing, can reduce the cost of energy-efficient equipment and encourage participation in load management and conservation programs. Utilities can increase the direct installation of cost-effective conservation measures by targeting applications where customers lack sufficient motivation and/or resources.
- There is no real-time pricing for residential customers.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- The level of GHG emissions decreased or avoided will depend on the technologies used and the generation mix before and after the energy efficiency program.[14] For example, improving the efficiency of refrigerators—or other appliances that operate continuously—would result in larger energy savings than would efficiency improvements in peak technologies, such as air conditioning units. However, if baseload power is provided by a clean source (e.g., hydro) and peak power by a fossil-fuel powered source, then improving the efficiency of the peak appliance would have a greater effect on emissions.
- The greatest energy and carbon savings can be achieved in lighting, space conditioning, water heating, and miscellaneous electricity usage.

EMISSION ESTIMATE: Varies according to the change in electricity demand before/after implementation of the DSM program.[15]

COST-EFFECTIVENESS: Varies according to the administrative or investment costs required. Some investments are cost-effective regardless of the energy savings achieved.

SECONDARY EFFECTS: Varies according to the decrease in electricity demanded. For every kWh of fossil fuel power generation avoided, the associated emissions of air pollutants are also avoided.

[14] The Ilumex project in Mexico helped consumers purchase compact fluorescent lights using an innovative financing scheme that allowed consumers to purchase the lamps with a loan that could be repaid from electricity bill savings. More than 600,000 lamps have been sold to date at a cost of U.S.$1.64 each, resulting in estimated annual energy savings of: 160 GWh/year, 34,400 tons C, 2510 tons SO_2. The program has also allowed the Mexican utility to avoid the construction of 78 MW of new peak generating capacity.

[15] To quantify the level of emissions reductions, a utility can use a planning and dispatch model (or production cost model) to identify planned electricity dispatch; and an estimate of the load shape and magnitude of its DSM programs.

RESOURCES

- The U.S. Department of Energy has sponsored a variety of residential DSM programs including:
  1. The *Cool Communities Program*, develops community partnerships to plant trees and increase the use of highly reflective exterior surfaces on buildings and roads in order to reduce heating and cooling costs, and improve the environment.
  2. The *National Earth Comfort Program*, an industry/government partnership to increase the geothermal heat pump market from 40,000 units/year to 400,000 units/year.
  3. *E-Seal*, a national initiative to promote energy efficiency and environmental awareness in both new construction and retrofit home programs.
  4. The Office of Building Technology hosts a website, containing links to technical information, case studies, and other background information promoting residential energy efficiency at *http://www.eren.doe.gov/buildings*/.
- The U.S. Environmental Protection Agency has also sponsored several residential DSM initiatives. These include:
  1. *Energy Star Programs* to encourage the production and use of energy-efficient equipment. *http://www.epa.gov/energystar/*.
  2. *Green Lights*, whose more than 1,650 participants have invested in efficient lighting. Those involved have reduced their lighting electricity consumption by an average of 47%, saving approximately $90 million.
- *Power$mart*, a brochure published by the Alliance to Save Energy, identifies a range of residential DSM actions that home-owners can take to conserve energy and use energy-efficiently. *http://www.ase.org*.
- ACEEE produces the *Consumer Guide to Home Energy Savings*, a directory of the most efficient products available.

CONTACTS

Alliance to Save Energy
Bill Prindle
Washington, DC
Tel: (202) 530-2214
Fax: (202) 331-9588
bprindle@ase.org
http://www.ase.org

American Council for an Energy-Efficient Economy
Washington, DC
Tel: (202) 429-8873
aceee@ix.netcom.com
http://solstice.crest.org/efficiency/aceee

Energy-Efficient Building Association
Silver Spring, Maryland
Tel: (301) 589-2500
Fax: (301) 588-0854
info@eeba.org
http://www.eeba.org

International Institute for Energy Conservation (IIEC)
Washington, DC
Tel: (202) 842-3388
Fax: (202) 842-1565
iiec@iiec.org
http://www.iiec.org/

U.S. Department of Energy
Diane Pirkey
Manager of DSM Programs
Washington, DC
Tel: (202) 586-9839
Fax: (202) 586-1640
diane.pirkey@ee.doe.gov

U.S. Environmental Protection Agency
Atmospheric Pollution Prevention Division
Washington, DC
Tel: (202) 564-9190
Fax: (202) 564-9569

7.2 PROMOTE COMMERCIAL DEMAND-SIDE MANAGEMENT (DSM) PROGRAMS

CHARACTERISTICS

Commercial DSM projects are sponsored by utilities to encourage commercial customers to control their energy bills, and simultaneously enable the local utility to achieve its own load goals. In the U.S., commercial buildings—including commercial construction and multi-family residential buildings—consume 11% of total energy. Energy is used in commercial buildings to provide a variety of services such as lighting, space heating and cooling, refrigeration, and electricity for electronics and other equipment. Commercial DSM projects encourage builders and occupants of commercial spaces to increase both energy conservation and energy efficiency.

Analysis indicates that substantial reductions in future GHG emissions can be realized through the use of more energy-efficient technologies. In addition to avoiding GHG emissions, energy-efficient technologies also can improve indoor air quality, reduce noise, improve process control and increase amenities or convenience.

Current commercial DSM initiatives target heating and cooling systems, lighting and engineering systems. Commercial DSM programs can include 1) technical and financial assistance for local efforts to promote commercial efficiency partnerships between manufacturers, utilities and end-users to develop highly efficient equipment, 2) grants and training to local officials to update commercial building codes, etc. Such programs lower operating expenses, improving cash flow for building owners. In commercial buildings where occupants pay utilities, energy-efficient buildings are more attractive to potential tenants. Energy costs can be reduced as much as 50% with installation of efficient lighting, space conditioning and building controls.

SIZE:	Can be adapted to any size building.
FEATURES:	Can include building envelopes; efficient equipment (e.g., lighting, motors, variable speed drives, HVAC equipment); thermal storage equipment; subsystems control; load management; and community energy systems (district heating and cooling).
COST:	Varies with the program. Can be minimal (shifting usage) or can involve installation of new computer equipment, etc. that may require upfront capital investment, but can be recovered through energy savings over the system's lifetime.
CURRENT USAGE:	Organizations in OECD countries are very active in promoting commercial DSM programs. Non-OECD countries with significant DSM programs underway include Brazil, Pakistan, Thailand, Mexico, Jamaica and the Philippines.

POTENTIAL USAGE: One estimate is that DSM can reduce worldwide demand 3-7% by the year 2010 and 5-6% by the year 2050. To achieve these targets, DSM programs must be universally applied.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- There is a lack of customer and designer awareness of energy-efficient technologies. Many products that can reduce GHG emissions are relatively new or are not the standard approach to design. Designers tend to specify what they know and have used in the past. Providing product information, design assistance, and public seminars/training programs may increase familiarity with technology.
- It may not be the decision-maker who pays the utility bill. A high percentage of commercial space, (office, retail, etc.), is leased rather than owned by the occupant. Price signals, DSM incentives, and economic paybacks are distorted by disconnects between building ownership, energy usage, and responsibility for energy bills.
- There is a lack of available energy-efficient equipment in the marketplace, and what *is* available usually has a higher initial cost relative to conventional technologies. Technical potential for improved electric products exists, but will not be produced until manufacturers are assured of sufficient demand.
- Conflicting priorities influence investment decisions, and investment in energy efficiency improvements usually compete with aesthetic improvements, employee productivity investments, comfort or safety concerns, product integrity protection, and other concerns for commercial business owners. In some cases energy efficiency improvements not only compete for capital expenditures; they may be viewed as a trade-off that requires a sacrifice in comfort or aesthetics.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- The greatest carbon (and energy) savings are achieved in space conditioning, lighting and miscellaneous electricity use.

EMISSION ESTIMATE: Varies according to the change in electricity demand before/after implementing the DSM program.

COST-EFFECTIVENESS: Varies according to the administrative or investment costs required. Some investments are cost-effective regardless of energy savings achieved.[16]

SECONDARY EFFECTS: Varies according to the decrease in electricity demand. For every kWh of fossil fuel power generation avoided, the associated emissions of air pollutants are also avoided.

[16] To quantify the level of emissions reductions, a utility can use a planning and dispatch model (or production cost model) to identify planned electricity dispatch; and an estimate of the load shape and magnitude of its DSM programs.

RESOURCES

- *Green Buildings for Africa* program, South Africa. The Council for Scientific and Industrial Research (CSIR) launched this voluntary program in June 1997 to encourage building owners to improve energy efficiency. Participants commit to assess their needs/options within six months and make upgrades within three years. CSIR provides technical assistance, and participants earn the right to use the program logo in their advertising. This program is expected to reduce building energy consumption by 30% over a three-year period.
- United Nations Environmental Program, 1997, *Reducing Greenhouse Gas Emissions: The Role of Voluntary Programmes*.
- Koomey, J.G. et al, 1994, *Buildings Sector Demand-Side Efficiency Technology Summaries*, Lawrence Berkeley National Laboratory, LBNL-33887.
- Lawrence Berkeley Laboratory has worked with the U.S. Agency for International Development to support efforts to implement existing energy standards in new commercial buildings in the Philippines.
- The U.S. Environmental Protection Agency sponsors the Energy Star Buildings and Green Lights Programs whose participants agree to install energy-efficient lighting where profitable as long as lighting quality is maintained or improved. *http://www.epa.gov/greenlights.html/*
- The U.S. Department of Energy Office of Building Technology website *http://www.eren.doe.gov/buildings* contains links to technical information, case studies, and other background information on energy-efficient technologies appropriate for commercial use.

CONTACTS

Alliance to Save Energy
Bill Prindle
Washington, DC
Tel: (202) 530-2214
Fax: (202) 331-9588
bprindle@ase.org
http://www.ase.org

International Institute for Energy Conservation
Washington, DC
Kelly Gordon
Director of Internatioanl Programs
Tel: (202) 842-3388 x508
kgordon@iiec.org
http://www.iiec.org

Lawrence Berkeley National Laboratory
Steve Wiel
Energy Analysis Division
Berkeley, CA
Tel: (510) 486-5396
swiel@lbl.gov
http://eetd.lbl.gov/EA.html

United Nations Environment Program
Industry and Environment
Paris, France
Tel: 33 (1) 44 37 14 50
Fax: 33 (1) 44 37 14 74
http://www.unep.org

U.S. Department of Energy
Diane Pirkey
Manager of DSM Programs
Washington, DC
Tel: (202) 586-9839
Fax: (202) 586-1640
diane.pirkey@ee.doe.gov

U.S. Environmental Protection Agency
Atmospheric Pollution
Prevention Division
Washington, DC
Tel: (202) 564-9190
http://www.epa.gov/greenlights.html/

7.3 PROMOTE INDUSTRIAL DEMAND-SIDE MANAGEMENT (DSM) PROGRAMS

CHARACTERISTICS

Industrial DSM programs target one of the four groups of primary end-use electricity applications: motor drives and controls; process applications; lighting; and space conditioning.[17]

Currently, industrial energy use produces almost half of global CO_2 emissions, yet energy intensity varies dramatically. In many developing countries, energy intensity is two-to-four times greater than the average in OECD countries. Improvement in industrial energy efficiency can potentially have a tremendous impact on reducing GHG emissions.

Industrial DSM activities can encompass a broad range of utility/customer interactions including: load management; interruptible rates; time-of-use pricing; and end-use applications. Electricity reductions can be achieved through fuel switching, cogeneration and process energy efficiency improvements. Results of industrial DSM programs can include: reduced capital requirements; reduced energy consumption; reduced spoilage/waste; flexibility of raw material base; greater control over production; improved product quality and yield; decoupling of production from fuel supply; increased competitiveness; increased production at less energy per unit produced; and reduced environmental impacts (net and/or site).

SIZE:	Programs can target individual facilities, specific industries or the entire industrial sector.
FEATURES:	In the U.S., the industrial sector accounts for approximately 40% of energy and electricity consumption. This large industrial market represents major opportunities for large increments of load growth, conservation, and load management.
COST:	Varies with program. Can be minimal (shifting usage) or can involve installation of new computer equipment to manage load, etc.
CURRENT USAGE:	In addition to OECD countries, countries such as India, Senegal, Georgia, Jamaica and Mexico have successfully employed DSM programs to reduce industrial demand.
POTENTIAL USAGE:	One estimate is that DSM can reduce worldwide electricity demand (from business-as-usual) 3-7% by the year 2010 and 5-6% by the year 2050. Significant emissions reductions to date have been experienced in OECD countries in the chemicals, steel, aluminum, cement, paper and petroleum refining industries.

[17] The industrial sector includes all manufacturing, agriculture, mining and construction activities.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Existing capital has a long life; equipment upgrades may not be needed for a number of years.
- At many plants, there may not be anyone directly responsible for energy efficiency; and decision-makers are often located far from regional plant sites.
- Modifications to industrial manufacturing processes are complex, and can affect product quality and productivity. Because of the high cost of process modifications and limitations to coordinating them with facility shutdowns, energy cost savings alone may not be sufficient to meet industry's payback and return-on-investment (ROI) requirements.
- Energy efficiency expenditures are not competitive on a rate-of-return basis with product improvement expenditures. Also, electricity is a small part of many companies' overall costs so they may dismiss potential energy cost savings as insignificant.
- It is difficult to standardize industrial DSM applications because many companies consider their production processes proprietary, and need assurances that their operations will be kept confidential.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- The amount of emissions decreased or avoided will depend on the technologies used before and after the energy efficiency program and the generation mix.

EMISSION ESTIMATE: Varies according to the change in electricity demand before/after implementation of the DSM program.

COST-EFFECTIVENESS: Varies according to the administrative or investment costs required. Some investments are cost-effective regardless of energy savings achieved.[18]

SECONDARY EFFECTS: Varies according to the decrease in electricity demand. For every kWh of fossil fuel power generation avoided, the associated emissions of air pollutants are also avoided.

RESOURCES

- The Industrial Energy Efficiency Network (IEEN) was established by the Norwegian government in 1989 to promote energy efficiency. IEEN works with individual companies in 13 industrial sectors, to disseminate information, provide technical data on new technologies, and compile statistics on energy usage. Results have varied within industrial sectors, but many companies have achieved from 10-50% reductions in energy consumption. *http://www.ife.no/departments/energy/index.html*
- The U.S. Department of Energy has sponsored the following industrial DSM programs:
    1. *Motor Challenge* to promote voluntary collaborative efforts between the private

[18] To quantify the level of emissions reductions, a utility can use a planning and dispatch model (or production cost model) to identify planned electricity dispatch; and an estimate of the load shape and magnitude of its DSM programs.

and public sectors to demonstrate, evaluate, and accelerate the use of efficient industrial electric motor systems.

2. *National Industrial Competitiveness for Energy, Environment and Economy* (NICE[3]) that awards grants to improve industrial process efficiency, reduce waste, and cut greenhouse gas emissions in several key industries.

- Brazil's PROCEL, the national electricity conservation program, developed demand-side management projects saving 250 MW in electricity and US$500 million in power plant development costs.
- Mexico's federal electricity conservation program, Fideicomiso de Apoyo al Programa de Ahorro de Energia del Sector Electrico (FIDE), conducted innovative energy efficiency demonstration projects that brought a 5% decline in projected energy use.
- Studies have concluded that in China alone, raising the efficiency of industrial furnaces—which consume about 25% of China’s energy—would reduce the energy used by furnaces by 40% and avoid the waste of about 2.7 quadrillion Btu (2.9 EJ) per year.
- Lawrence Berkeley Laboratory has worked with the U.S. Agency for International Development to support efforts to develop motor standards in the Philippines.
- Information on the European Conference on Industrial Energy Efficiency can be found at *http://www.eva.wsr.ac.at/indeff/prog-e.htm*.
- The Alliance to Save Energy provides links to more information on industrial energy efficiency at *http://www.ase.org/programs/industrial/links.htm*.
- The European Union (DG-XVII) sponsors a number of energy efficiency programs, providing background information and funding.
http://www.europa.eu.int/en/comm/dg17/programs.htm

CONTACTS

Alliance to Save Energy
Chris Russell
Washington, DC
Tel: (202) 857-0666
Fax: (202) 331-9588
crussell@ase.org
http://www.ase.org

European Commission, DG XVII
Industrial Energy Efficiency Network
Per Finden, Department Head
Brussels, Belgium
info@dg17.cec.be

Institute for Energy Technology (IFE)
Kjeller, Norway
Tel: +47 63 80 61 07
Fax: (+47) 63 81 63 56
per.finden@ife.no

Lawrence Berkeley National Laboratory
Steve Wiel
Energy Analysis Division
Berekeley, CA
Tel: (510) 486-5396
swiel@lbl.gov
http://eetd.lbl.gov/EA.html

U.S. Department of Energy
Diane Pirkey
Manager of DSM Programs
Washington, DC
Tel: (202) 586-9839
Fax: (202) 586-1640
diane.pirkey@ee.doe.gov

United Nations Environment Program
Industry and Environment
Paris, France
Tel: 33 (1) 44 37 14 50
Fax: 33 (1) 44 37 14 74
http://www.unep.org

7.4 IMPROVING BILLING & COLLECTION SYSTEMS TO REDUCE DEMAND

CHARACTERISTICS

Customers respond to tariff structures based on their expectations about the effectiveness of revenue collection. If customers expect that their electricity bills will never be collected, electricity prices will have little or no effect on their level of end-use consumption. But, where electricity tariffs are collected regularly (with penalties imposed for nonpayment), end-users will modify their electricity consumption levels accordingly.

Improved billing & collection systems to insure that electricity consumers pay their bills will generally result in lower electricity consumption. With every kWh of fossil-fuel-generated electricity avoided, production of the associated greenhouse gases and/or air pollutants will also be avoided.

In addition, improved billing & collection systems allow utilities to monitor payment and non-payment, and to identify chronic non-paying customers. Data from the system can be used to analyze and "age" accounts receivable and target non- or late-paying customers, generate late-payment notices, calculate late payment fees, issue warnings for non-payment and ultimately disconnect service for continued non-payment. Having access to customer account information improves a utility's ability to assess its own financial situation and reliability.

SIZE:	Appropriate for all electric utilities.
FEATURES:	Utilities can use direct access payment centers that increase the ease with which customers can pay their bills. Utilities can also develop management tools and internal procedures to monitor accounts received.
COST:	This action makes economic sense regardless of the GHG benefits.
CURRENT USAGE:	There is increased use of automated systems to provide information to customers and increase convenience of bill payment throughout the world.
POTENTIAL USAGE:	All utilities may benefit from improving their billing & collection systems.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Customers may be hesitant to change their manner of payment or distrust new methods.
- Where electricity is provided by public entities, improving billing & collections may not be politically possible.
- Buildings must be metered to permit recording of electricity usage, preferably by time-of-day, to apply tariffs.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Tariffs must be set so that electricity prices induce consumers to decrease their consumption, or at a minimum encourage more efficient use of electricity.
- Programs must be long-term in scope to achieve real reductions in emissions.

EMISSION ESTIMATE: Varies according to the change in electricity demanded before/after implementing billing & collections reforms.

COST-EFFECTIVENESS: Varies according to the administrative or investment costs required. Some investments are cost-effective regardless of the energy savings achieved.[19]

SECONDARY EFFECTS: Varies according to the decrease in electricity demanded. For every kWh of fossil fuel power generation avoided, the associated emissions of air pollutants are also avoided.

RESOURCES

- The World Bank Energy Sector Management Assistance Program (ESMAP) provides country-specific assistance in evaluating and improving management of the energy sector. Previous country studies and technical assistance papers are available online at *http://www.worldbank.org/html/fpd/esmap/*
- The Staff Subcommittee on Management Analysis of the National Association of Regulatory Utility Commissioners (NARUC) sponsors operations and management training for utility executives. The NARUC website *(http://www.naruc.org)* links to minutes of recent meetings and posts articles from Management Journals.
- USAID and Hagler Bailly, Inc. are working with Armenergo, the state-owned utility, to improve transmission network and distribution system metering. By upgrading metering hardware using off-the-shelf technologies, Armenergo expects to improve commercial operations and increase cash collections.

CONTACTS

Hagler Bailly, Inc.
Michael Ellis
Principal
Arlington, VA
Tel: (703) 351-0300
Fax: (703) 351-5167
mellis@haglerbailly.com

National Association of Regulatory Utility Commissioners (NARUC)
Washington, DC
Tel: (202) 898-2200
Fax: (202) 898-2213
http://www.naruc.org

[19] Russian utility Penzagaz, has introduced an improved customer information system that allows direct payment and facilitates its billing and monitoring of customer accounts. As of January 1997, Penzagaz expected to save approximately $61 million from bank transaction fees alone.

U.S. Energy Association
John Hammond
Energy Partnership Program
Washington, DC
Tel: (202) 312-1230
Fax: (202) 682-1682
Jhammond@usea.org

World Bank
Dominique Lallement
Manager
Energy Sector Management
Assistance Program
Washington, DC. 20433
Tel: (202) 458-2321
Fax: (202) 522-3018
esmap@worldbank.org
http://www.worldbank.org/html/fpd/esmap/

7.5 CHARGING ECONOMIC TARIFFS TO REDUCE DEMAND

CHARACTERISTICS

Setting energy prices below actual cost provides incorrect market signals to producers and consumers alike. Such pricing policies distort the allocation of resources, further entrenches the use of established fuels/technologies, and creates artificial market barriers for the entry of new, more efficient technologies.

One study estimates that conventional energy technologies benefit from direct subsidies of more than $300 billion per year worldwide. This subsidy absorbs a large amount of capital, reduces the possibility of financing investments in energy efficiency, RD&D in low CO_2-emitting technologies, and other economic activities. By adopting marginal cost pricing and eliminating—or at least minimizing—energy price subsidies, technologies can compete on a "level-playing field", where more efficient power generation technologies would not be disadvantaged.

Subsidies have led to poor credit ratings for utilities, often making it difficult for them to raise capital in commercial markets. Short-term subsidies can be used, however, to support the initial market entry of GHG mitigation options such as renewables or clean coal technologies. In fact, such price guarantees or technology risk compensation mechanisms applied to low-carbon technologies would help reduce barriers to adopting those technologies that are not yet determined to be "commercially viable".

Finally, where retail prices (tariffs) are competitive, users are encouraged to use electricity efficiently and to modify their consumption patterns to purchase electricity when rates are lowest, during off-peak periods. Any reduction in fossil-fuel generated electricity would result in reduced GHG emissions.

SIZE:	Applicable for retail and wholesale electricity prices.
FEATURES:	Electricity prices reflect market rates.
COST:	N/A
CURRENT USAGE:	Many countries are undergoing energy sector market reforms and are removing subsidies to electricity and fuel prices.[20]
POTENTIAL USAGE:	Currently there are no countries whose electricity prices fully reflect market prices. In some countries rate caps are in place; in other, renewable energy is subsidized, etc. Also, no country's pricing policies internalize the costs of environmental protection, or reflect distance transactions.

[20] For instance, the Armenian Energy Commission has prepared a cost-of-service study that examines classification of residential, commercial and industrial customers and customer costs including energy, demand, overhead and administrative.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- The form of tariff regulation will affect the economic incentive of a utility to undertake end-use efficiency programs. Where rate regulation is based on total sales, there is no incentive to reduce kilowatt-hour (kWh) sales, so few DSM measures besides load management are deemed cost-effective.
- The external costs of existing and new technologies are likely to vary greatly among countries and regions. Unilateral national adoption of full-cost pricing may, in the short run, adversely affect international economic competitiveness.
- Electricity tariffs may be subsidized to meet other public policy goals such as protecting various industries or localities. In such situations, tariff reform may be hampered by political resistance.
- Government price subsidies to energy-intensive industries in effect protect the pollution produced by such industries.
- Without effective metering, billing, and collection, price signals will be ineffective in encouraging efficient electricity use patterns.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Subsidies to fossil fuels in developing countries is estimated to be about 20-25% of the value of world fossil fuel consumption at world prices. Removal of such subsidies so that electricity prices reflect market levels, would reduce demand such that a reduction of 7% of global GHG emissions would occur.

EMISSION ESTIMATE: Will vary according to changes in electricity demand before/ after price reforms and changes in the capacity mix.

COST-EFFECTIVENESS: Will vary according to individual country circumstances, but will likely be moderately to highly cost-effective.

SECONDARY EFFECTS: Where use of fossil fuels is reduced, the associated emissions of air pollutants will also be reduced.

RESOURCES

- The Energy Partnership Program (EPP), an exchange program of the U.S. Agency for International Development (USAID) and the U.S. Energy Association, has hosted training seminars on tariff-setting.
- The National Association of Regulatory Utility Commissioners (NARUC) provides information on tariff-setting at *http://www.naruc.org.*
- The University of California Energy Institute posts several working papers on pricing, with studies of U.S. and international power markets at:
  http://www.ucei.berkeley.edu/UCEI/pubs-pwp.html

CONTACTS

National Association of Regulatory
Utility Commissioners (NARUC)
Washington, DC
Tel: (202) 898-2200
Fax: (202) 898-2213
http://www.naruc.org

U.S. Energy Association
Washington, DC
Tel: (202) 312-1230
Fax: (202) 682-1682

7.6 PROMOTING ENERGY-EFFICIENT ELECTROTECHNOLOGIES

CHARACTERISTICS

Many new electrotechnologies allow the substitution of an electric process and/or electrical equipment for applications using other fuels or less-efficient electric equipment. Electrotechnologies use the electromagnetic, electrochemical and/or electrothermal effects in industrial, commercial and residential processes in place of the direct use of fossil fuels. Electrotechnologies include electrical appliances for the home, electric heating and cooling systems for commercial buildings and electric control systems and motors for industrial processes.

Where the energy chain involved in electricity production, transmission, and distribution results in lower total emissions than a current alternative, electrotechnologies will provide a net benefit to the environment.

Electrotechnologies offer high efficiencies, precise energy control capabilities, high rates of production and processing, and in many applications, increased speed. In addition, electrotechnologies may offer reduced investment and operating costs, improved product quality, and improved convenience of use. Current applications of electrotechnologies are primarily in the commercial and industrial sector; however, the number of residential applications is increasing.

SIZE:	All sizes from multi-kW residential systems to multi-MW industrial systems.
FEATURES:	Offer high efficiencies and precise controls.
COST:	Costs will vary according to replaced/replacement technology. Many options that increase efficiency may be economic regardless of their ability to reduce GHG emissions.
CURRENT USAGE:	Mostly commercial and industrial applications.
POTENTIAL USAGE:	The number of residential applications is increasing.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- There is a need to demonstrate that efficiency improvements for the overall system are made. Electrotechnologies that may appear to be very efficient could result in system inefficiencies that actually increase GHG emissions.
- The cost of equipment can be high, and a substantial up-front investment to add metering and interconnection equipment is required.
- Because of limited information and experience with new technologies, the perceived risks and uncertainties regarding their performance can deter the use of electrotechnologies.

- End-users may not have the proper incentives (either because energy is a small percentage of their expenses or their energy expenses are subsidized) to use electrotechnologies or may not be aware of their benefits.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- The higher efficiencies of electrotechnologies will reduce carbon/GHG emissions by decreasing energy use when compared with fossil-fueled processes. The exact amount of emissions avoided will depend on the replaced/replacement technologies employed. For example, a battery-driven electric lawnmower uses less energy and produces fewer emissions than a conventional gasoline-powered lawn mover.
- The GHG advantages of electrotechnologies arise from the ability to use economies-of-scale of large electric power plants to produce and distribute electricity at higher efficiencies than can be achieved by small end-use devices. However, not all electrotechnologies or applications of the technologies will result in system efficiency (and GHG) advantages.

EMISSION ESTIMATE: Varies with each specific model and type of electrotechnology. For instance, an electric lawnmower can reduce CO_2 by approximately 75% compared to gas-powered lawn mower.

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Varies with each specific electrotechnology. For instance, switching from a gas-powered to an electric lawn mower can reduce NO_x by as much as 87%.

RESOURCES

- U.S. Department of Energy programs include:
  1. *National Industrial Competitiveness through Energy, Environment, Economics* ($NICE^3$) is a cost-sharing program that gives grants to state and industry partnerships for projects developing and demonstrating advances in energy efficiency and clean production technologies. After provision of the initial grant (of amounts up to $400,000), awardees are expected to commercialize the technology.
  2. *Motor Challenge* promotes the use of efficient electric motors, drives and driven equipment, and effective electric motor system integration. Participants are provided with technical publications, education and training, an information clearinghouse, and decision software.
  3. *Industries of the Future* targets seven energy-intensive industries (steel, aluminum, metal casting, chemicals, refining, forest products, glass) to improve competitiveness. Through partnerships between the industries and government, advanced technologies are developed for manufacturing and process technologies.

4. *National Clean Industry Initiative* and *Mainstreet* Program to demonstrate electrotechnologies and move them to more widespread acceptance and use.

- The U.S. electric power industry has sponsored the EnviroTech Investment Fund, a venture capital fund for electrotechnologies and renewable energy technologies. The Fund has over $52 million to invest in companies developing commercially viable electric and renewable energy technologies that are more energy-efficient than those currently in the market.
- The Electrification Council, designs products and services to help increase effectiveness of utility sales and marketing, and also sponsors partnerships for areas of lighting and process technology to discuss marketing issues of key concern and to develop products through the Electrification Council.

CONTACTS

Electrification Council
Susan Mitchell
Washington, DC
Tel: (202) 508-5901
Fax: (202) 508-5335
tec@eei.org
http://www.eei.org/CSM/tec/

EnviroTech Investment Fund, LLP
Steve Rosenstock
Edison Electric Institute
Washington, DC
Tel: (202) 508-5571
Fax: (202) 508-5335
srosenstock@eei.org

U.S. Department of Energy
Office of Industrial Technologies
Washington, DC
Tel: (202) 586-9232
Fax: (202) 586-9234
http://www.oit.doe.gov/

U.S. Department of Energy
Motor Challenge Information Clearinghouse
Olympia, WA
Tel: (360) 956-2238
Fax: (360) 586-8303
motorline@energy.wsu.edu

7.7 INSTITUTING CUSTOMER-FOCUSED EDUCATIONAL AND INFORMATIONAL PROGRAMS

CHARACTERISTICS

In many countries, economic systems have historically subsidized energy production and consumption with the result that energy intensity may be double-to-quintuple that of industrialized countries. In such systems, energy efficiency will achieve dramatic reductions in GHG emissions in addition to improving performance and minimizing system losses.

Many people and organizations do not fully understand the benefits of energy efficiency. As people/institutions become aware of its benefits, conservation of energy resources will take place, and energy-efficient technologies will be adopted. The use of more efficient technologies will, over time, increase energy intensity, avoiding the emission levels that would have been reached in a "business-as-usual" scenario.

Examples of educational and informational programs include: training courses for adult consumers and companies on technology, environmental issues, energy management, and marketing; programs with schools that create partnerships between schools, homes, and utilities; mass media promotions; and more.

SIZE:	Can be tailored to any situation or sector.
FEATURES:	Can include training courses, public information programs, creation of school, home, utility partnerships and more.
COST:	Utility costs consist of implementation of the actual measures and marketing the program; benefits lie in the avoided supply costs. For customers, energy efficiency upgrades require an initial investment; benefits exist in savings in their electric bills over the lifetime of the technology.
CURRENT USAGE:	Many education programs for energy efficiency are underway. Activities can be monitored through the World Energy Efficiency Association, a clearinghouse of information on energy efficiency efforts worldwide.
POTENTIAL USAGE:	Programs can be tailored to all sectors and for all countries.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Analysis of the effectiveness (measured in electricity consumption reduced) of an energy efficiency education program found that consumers receiving intensive education—including in-home training—reduced their electricity consumption dramatically more than consumers who simply received general information. However, all of the education programs were found to induce reduction in electrical consumption (even over a multi-year period), and to have payback periods of less than two years.

- Consumer education has proven to be effective, but such programs are dependent on funding from governments and international organizations.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Increased consumer education may not only make them more aware of the energy/environmental implications of their electricity usage, it will likely expose them to additional consumer appliances that might only displace the reduced demand achieved by the education (rebound effect).

EMISSION ESTIMATE: Will vary with the scope, breadth and duration of each program. May be difficult to quantify.

COST-EFFECTIVENESS: Will vary with the scope, breadth and duration of each program.

SECONDARY EFFECTS: Will vary with the scope, breadth and duration of each program. May be difficult to quantify.

RESOURCES

- The U.S. Department of Energy has established a series of education programs. For utilities, the DOE sponsors the *Climate Challenge Program*—a voluntary, cooperative effort to reduce, avoid or sequester GHG emissions. DOE assists participating utilities in developing a portfolio of cost-effective initiatives to reduce greenhouse gas emissions. DOE provides workbooks/documents with several possible actions, and then links the participants with technical assistance to implement the plans. Participants benefit directly through improved efficiency of operations, and indirectly because of good will earned for their demonstration of commitment to the environment and energy conservation.

CONTACTS

Alliance to Save Energy
Washington, DC
Tel: (202) 857-0666
Fax: (202) 331-9588
info@ase.org
http://www.ase.org

American Council for an
Energy-Efficient Economy
Washington, DC
Tel: (202) 429-8873
aceee@ix.netcom.com
http://solstice.crest.org/efficiency/aceee

International Institute for Energy Conservation (IIEC)
Washington, DC
Tel: (202) 842-3388
Fax: (202) 842-1565
iiec@iiec.org
http://www.iiec.org/

U.S. Department of Energy
Diane Pirkey
Manager of DSM Programs
Washington D.C. 20585
Tel: (202) 586-9839
Fax: (202) 586-1640
diane.pirkey@ee.doe.gov

U.S. Environmental Protection Agency
Atmospheric Pollution Prevention Division
Washington, DC
Tel: (202) 564-9190

8.0 RENEWABLE ENERGY ACTIONS

Renewable energy (RE) is most often defined to be energy derived from inexhaustible sources—the sun, the wind, and the Earth. In addition, renewable energy options often include the use of wastes to produce high valued and useful energy.

The use of renewable energy has the advantage of producing little or no carbon emissions. Wind power, photovoltaics, biomass derived from sources that are continuously replenished, and hydroelectricity have no net carbon emissions. Although energy derived from wastes can emit carbon, such emissions are usually no more than for natural gas-based systems. As a result, using renewable energy in lieu of fossil-based systems would significantly lower carbon (and GHG) emissions.

Approximately 30 quadrillion Btus of renewable energy are currently consumed throughout the world. This represents approximately 8% of world energy consumption. Although the large majority of renewable energy consumption is from large hydroelectric sources (and in some countries, biomass), use of biomass, wind and photovoltaics is growing rapidly. For example, it is estimated that, for each of the last few years, more than 1,200 MW of new wind generating capacity have been installed throughout the world.

Significant market opportunities for renewable energy exist. This section provides information on the factors that will influence the viability of each type of renewable enrgy. It also provides some information on sources for financing renewable energy projects.

8.1 BIOMASS

CHARACTERISTICS

Biomass energy utilizes the energy content of agricultural residue, wood waste, animal wastes, or energy crops.[21] These materials are either combusted in boilers to produce steam and/or heat, or gasified. Direct biomass combustion technology is very similar to coal combustion technologies; it is also relatively easy to "co-fire" biomass with coal in existing boilers. Biomass can also be converted into combustible gases, much as natural gas is used to generate electricity or to fuel vehicles.

When used to offset fossil fuel use, bioenergy systems can significantly reduce or eliminate GHG emissions. While some GHG emissions may be produced through combustion of biomass for electricity, total emissions/kWh are considerably less than those produced by fossil fuels. Also, if a replacement crop is planted, equivalent to the amount of biomass used for electricity generation, the new crop absorbs the CO_2 produced by the combustion process resulting in no *net* emissions.

In the world, over two billion people are without electric power, and another billion have less than five hours a day of electricity. Most of these three billion people live in the middle latitudes where biomass grows abundantly, and can potentially be a viable source of fuel. Advances in biomass combustion technology contribute to its increasing viability. Further development of biomass gasification technology is ongoing, with expectations that the next generation of technologies will reach efficiencies of 65-70%. Conversion technologies for power plants that co-fire biomass with coal or municipal waste are also being developed.

SIZE:	2-100 MW_e, average size is ~ 20 MW
FEATURES:	Peaking power and baseload applications (>6,000 hours/year) with 15-30% efficiency; cogeneration applications can reach 60% efficiency.
COST:	Costs will vary according to local conditions, but as a guideline: $530-600/kW for industrial units $300/kW where fuel sources are geographically convenient.
CURRENT USAGE:	In the U.S., installed biomass capacity for electricity generation is over 6.5 GW (over 3% of U.S. energy consumption). In Finland, Sweden and Austria, 13-18% of electricity generated is fueled by biomass.
POTENTIAL USAGE:	Resource and market assessments identify an extremely broad range of potential, with the greatest potential in developing countries. By 2050, estimates indicate that biomass could provide 17% of the world's electricity and 38% of direct fuel use.

[21] These include: wood, bark, agricultural residues, peat, and refuse-derived fuels (with 50% moisture). All of these can be used in their raw form or can be pelletized through drying and compressing biomass materials. When pelletized fuels are used, average efficiencies reach 70-80%.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- A large, steady supply of biomass is required for reliable electricity generation. Biomass supply may be climate- or season-dependent.
- Land suitable for biomass development may face competition for other uses and/or there may be opposition to harvesting existing resources such as forests.
- The cost of procuring feedstock may be prohibitive where biomass must be transported long distances to a combustion site. Since biofuels have a relatively low energy content per ton, bioenergy facilities must be sited close to their fuel source in order to minimize transportation costs. However, co-firing biomass/coal may stabilize the fuel supply for such plants.
- Typically biomass contains 1-4% non-combustible ash by weight, which may require special disposal arrangements. Such ash often contains low levels of lead, barium, selenium and arsenic, which must be carefully landfilled.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☑ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Biomass used to produce energy can avoid a net increase of CO_2 in the atmosphere if it is replaced by new growth that absorbs an equivalent amount of CO_2.
- Total emissions will vary according to the boiler/combustor system used.

EMISSION ESTIMATE: 200 MtC/MW_e/year offset

COST-EFFECTIVENESS: Estimated *net* cost of CO_2 avoided is from $25-38/ton.

SECONDARY EFFECTS: May produce some methane (CH_4). As with carbon emissions, when biomass is used to offset fossil fuel use, bioenergy systems can significantly reduce or eliminate SO_2, NO_x and particulate matter.

RESOURCES

- Rockson, J.K. October, 1992. *Biomass for Energy and Industry*, Denmark.
- Links to bioenergy resources online: *http://www.esd.ornl.gov/bfdp/inforesr.html*
- Bioenergy Discussion Group, *bioenergy-request@crest.org, http://solstice.crest.org/renewables/bioenergy-list-archive.old/info.html*
- U.S. Department of Energy BioPower Program hosts a website providing links to program and technical information. *http://www.eren.doe.gov/biopower/program.html*

CONTACTS

American Bioenergy Association
Washington, DC
Tel: (202) 639-0384
Fax: (202) 393-5510
http://www.biomass.org

Biomass Energy Research Association
Donald Klass
President
Washington, DC
Tel: (847) 381-6320
Fax: (847) 382-5595
bera@crada.com
http://www.crada.com/bera/

European Biomass Association
Jean-Marc Jossart
Secretariat
Louvain-la-Neuve, Belgium
Tel/Fax: + 32 10 47 34 55
jossart@ecop.ucl.ac.be
http://www.ecop.ucl.ac.be/aebiom/

National BioEnergy Industries Association
Washington, DC
Tel: (202) 383-2540
Fax: (202) 383-2670
71134.1162@compuserve.com
http://www.bioenergy.org

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Ray Costello
Biomass Power Team Leader
Washington, DC
Tel: (202) 586-4898
Fax: (202) 586-5127
raymond.costello@hq.doe.gov
http://www.eren.doe.gov

8.2 GEOTHERMAL

CHARACTERISTICS

Geothermal energy channels the heat and steam stored below the earth's surface to a turbine that then drives a generator to produce electricity. Underground heat sources such as hot water reservoirs can be tapped by drilling through the earth's layers. Some surface manifestations such as hot springs and geysers may also be tapped for electric generation. High-temperature steam sources are of the greatest value for generating electricity; geothermal plants operate over temperature ranges of 122-482°F (50-250°C), a relatively low heat compared to traditional fossil or nuclear plants.[22] As long as resources are sustainably managed, geothermal can serve a baseload power generating function with high availability. The rate at which the hot water or steam is replenished—either naturally or by injecting spent fluids—determines the quantity of energy that the source is capable of supplying on a continuous basis.

Geothermal energy produces minimal amounts of carbon dioxide and only traces of nitrogen oxide and sulfur dioxide emissions. Closed-loop systems, the newest generation of geothermal technologies, produce no airborne emissions. As a generator of baseload electricity, geothermal competes with fossil fuel power sources. Thus, every kW of electricity generated by a geothermal site avoids the emissions that would have otherwise been produced by combusting fossil fuels.

For power generation, geothermal is limited to site-specific availability, and locations may not be close to a transmission grid. However, there is tremendous untapped potential for developing geothermal resources in Asia, and new technologies under development will improve the economics of using smaller geothermal sites for power generation, increasing the number of sites with economic potential. Of the five forms of geothermal energy, only two—hydrothermal reservoirs and earth energy—are currently used for electric power generation. Technological advances must be made before the three other forms—geopressured brines, hot dry rock and magma—can be commercially developed.

SIZE:	1-110 MW
FEATURES:	Geothermal power plants are highly reliably and can operate 24 hours/day. Average availability is 80%, but many plants have >95% availability.
COST:	$840-2,500/kW
CURRENT USAGE:	6,300 MW installed in 21 countries worldwide. Direct use of geothermal water occurs in >40 countries.
POTENTIAL USAGE:	Additional 6,000 MW is potentially economic worldwide. Worldwide resource potential >40,000 MW.

[22] Temperatures under 90°C are used for heating buildings and for process heat.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Availability of appropriate sites is limited and distributed unevenly.
- Production must be carefully managed if the resource is to remain sustainable.
- Initial capital and development costs are high; special materials and construction techniques are required to mitigate the erosion and corrosion caused by water and steam.
- Gases such as H_2S may be emitted from geothermal wells, but developers can collect and re-inject the gases.
- Cost per kWh is competitive with coal and nuclear power, but geothermal is not yet competitive with new NGCC technologies (where natural gas is readily available).

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Geothermal power plants meet the most stringent environmental regulations and release small amounts of CO_2. With advanced, closed-loop technologies (binary geothermal technology applied to resources with a temperature below 350°F or 177°C), no emissions are produced.

EMISSION ESTIMATE: 56 MtC/GWh avoided
Newest generation of flash-steam plant emits only 1lb/CO_2/ MWh_e.

COST-EFFECTIVENESS: *Net* cost is $0-144/ton of CO_2 avoided.

SECONDARY EFFECTS: Sulfur emission rates range from zero to a small percentage of those produced by fossil fuels. Emits traces of nitrogen oxides. Produces some H_2S.

RESOURCES

- The U.S. Department of Energy is sponsoring several initiatives to develop geothermal technologies. These include:
  1. *GT 4000*, a market initiative, with a goal to have 4,000 MW of geothermal capacity on line in the U.S. by the year 2000, and 11,000 MW by 2010.
  2. *GEOHEAT 1000* has the goal of displacing 1,000 MW of generating capacity with direct applications of low-grade geothermal energy, reducing emissions of greenhouse gases.
- Palmerini, C.G. 1993. *Geothermal Energy,* in *Renewable Energy: Sources for Fuels*
- Email discussion group and Question/Answer Service for geothermal-related questions: *iga-group@geoscience.co.uk*
- This site provides links to technical and market information for geothermal sources, and a report, titled "Geothermal Energy: Clean, Renewable Energy for the Benefit of Mankind *http://solstice.crest.org/renewables/geothermal/grc/index.html*
- Links to geothermal information sources and organizations can be found at: *http://www.eren.doe.gov/geothermal/resource.html*

CONTACTS

Geothermal Education Office
Tiburon, CA
Tel: (415) 435 4574
Fax: (415) 435 7737
geo@marin.org
http://geothermal.marin.org

Geothermal Energy Association
Washington, DC
Tel: (202) 383-2676
Fax: (202) 383-2678
gea@geotherm.org
http://www.geothermal.org

Geothermal Technology Organization
David, CA
Tel: (213) 977-7496
Fax: (213) 977-6333

International Geothermal Association
c/o IGA Secretariat, Institute of
Geological and Nuclear Sciences
Wairakei Research Centre
Taupo, New Zealand.
Tel: 64-7-374-8211
Fax: 64-7-374-8199
igasec@gns.cri.nz

U.S. Department of Energy
Allan Jelacic
Director, Geothermal Division
Tel: (202) 586-6054
Fax: (202) 586-8185
http://www.doe.gov

8.3 SMALL-SCALE HYDROPOWER

CHARACTERISTICS

Small-scale hydro-electric systems (under 20 MW) capture the energy in flowing water and convert it to electricity.[23] Systems can be either "run-of-the-river" or "pumped storage"[24] and are suitable for stand-alone (isolated) or grid-connected applications.

If they are well-designed, small hydro-electric systems blend with their surroundings and have minimal negative environmental impacts. As with larger hydro-electric systems, small hydro produces no GHG emissions.

The potential for small hydro-electric systems depends on the availability of suitable water flow. Where the resource exists, the development can provide cheap, clean, reliable electricity. Locations are numerous around the world, and are often accessible to load centers and to the grid.

SIZE:	1-20 MW
FEATURES:	Operating Efficiency: 85-88%. Capacity factors vary from 20-90% depending on the variability in streamflow. To produce 200 watts, water sources must have, at a minimum, a change in elevation (or head) of 20 feet @ 100 gallons/minute (or 100 feet of head @ 20 gallons/minute). Areas with a low head will need long runs of large-diameter pipe. Also, distances of over a few hundred feet may require construction of expensive cabling
COST:	$1,000-3,000/kW. Costs vary widely based on site-specific factors such as streamflow, geological characteristics, and extent of existing civil structures at the site. Major costs are associated with site preparation and equipment purchase.
CURRENT USAGE:	As of 1993, 20% of global electricity was generated by hydro; small-scale hydro plants of 10 MW or less account for 4% of total hydro generation.
POTENTIAL USAGE:	The continents of Africa, Asia and South America have the potential for 1.4 million MW—four times as much capacity as is currently built in North America. Less than 10% of the world's

[23] Even smaller, or microhydro (2-300 watt) systems are appropriate for residential applications.

[24] *Run-of-the-river* hydroelectric plants use the power in river water as it passes through the plant without causing an appreciable change in the river flow. Normally such systems are built on small dams that impound little water, or may be built without any reservoir or dam.

Pumped storage projects provide a means of storing energy. Excess off-peak energy is used to pump water to an upper reservoir where it is stored as potential energy. The water is then released to produce peak-load power when necessary.

(total—large and small) technical usable hydropower potential is being used today.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Availability of resources is site specific and may not be located close to demand centers.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Hydropower produces no GHG emissions. Environmental impact may occur due to land-use or siting issues.

EMISSION ESTIMATE: Produces no greenhouse gas emissions.

COST-EFFECTIVENESS: $25-38/ton of *net* CO_2 avoided

SECONDARY EFFECTS: Produces no air pollutants.

RESOURCES

- This website contains general information on small hydro and micro-hydro and provides links and a database to assist in performing feasibility studies for microhydro sites. *http://www.swan.ac.uk/civeng/research/hydro/microhydro.htm*

CONTACTS

U.S. Hydropower Council for International Development
Debby Stone
Director, Trade Promotion
Washington, DC
Tel: (202) 383-2550
Fax: (202) 383-2555

National Hydropower Association
Washington, DC
Tel: (202) 682-1700
Fax: (202) 682-9478
hydroinfo@hydro.org
http://www.hydro.org

U.S. Department of Energy
John Flynn
Hydropower Programs
Washington, DC
Tel: (202) 586-8171
Fax: (202) 586-8185
john.flynn@ee.doe.gov
http://www.inel.gov/national/hydropower

8.4 MAINTAIN OR INCREASE GENERATION OF EXISTING HYDROPOWER

CHARACTERISTICS

Most countries around the world have some existing hydropower capacity, and many countries rely heavily on hydropower for baseload electricity generation. Worldwide, hydropower supplies about one-fifth of the world's electricity; in countries or regions where hydro resources are plentiful, hydro supplies as much as 70% of electricity requirements.

Many hydro sites have been in use for several years. At many of these sites, modernizing and upgrading turbines and generators will increase their efficiency and/or electrical output. Also, many have not been designed to maximize the full capacity of the site. Additional equipment and/or equipment upgrades may be able to take advantage of this potential without requiring the construction of new dam capacity.

Maximizing hydropower generation, which is baseload generation, can divert the need for capacity from other, fossil baseload electricity sources, and thereby reduce greenhouse gas emissions overall. Also, in countries where existing facilities may be facing relicensing, some capacity may be lost due to new, stricter requirements. Maximizing capacity at other sites may help to offset potential adverse environmental impacts.

SIZE:	Upgrades to date have increased efficiency from 1-20%. (20% improvement was from a 1905-vintage machine). Adding generation capacity has increased size to as much as 165% of original design capacity.
FEATURES:	Operating efficiency is typically from 85-90%. Capacity factors vary from 20-90% depending on the variability in streamflow.
COST:	N/A because is too site-specific.
CURRENT USAGE:	As of 1993, 20% of global electricity was generated by hydro; It is estimated that increasing efficiency by 1% in the U.S. alone would result in an additional 3.3 billion kWh from hydropower.
POTENTIAL USAGE:	In the U.S., there is the potential for an additional 21.3 GW through increasing efficiency or generation of existing hydropower (existing U.S. capacity, including pumped storage, is almost 92 GW).

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Availability of resources is site specific and may not be located close to demand centers.

- Small incremental gains in capacity, efficiency, and energy production through modernization and upgrading of turbines and generators may not be enough to justify the cost of facility upgrades.

- Public may have misperceptions that increasing efficiency at existing sites may adversely impact aquatic life and habitat. Also, in some areas, the public has levied pressure on dam and reservoir operators to increase non-power flows. Public education programs highlighting energy, environmental and recreational benefits and implications of new operating conditions may be necessary.
- Regulatory uncertainty as to relicensing procedures and impact on capacity and costs during the processing period creates uncertainty for economic projections, which can jeopardize financing for improvement projects.
- Equipment changes may require amendment of the original license.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Hydropower produces no GHG emissions. Environmental impact may occur due to land-use or siting issues.

EMISSION ESTIMATE: Produces no greenhouse gas emissions.
In the U.S., in 1997, hydropower generation avoided the release of 83 million metric tons of carbon equivalent.

COST-EFFECTIVENESS: $25-38/ton of *net* CO_2 avoided

SECONDARY EFFECTS: Produces no air pollutants.

RESOURCES

- A pump-turbine upgrade program undertaken at the jointly owned (Jersey Central Power & Light/Public Service Electric & Gas) Yards Creek Station consisted of replacement of the runners, wicket gates, and associated components, along with other modifications, to improve efficiency, capacity, performance, regulating capability, and longevity. Upgrade of the first unit increased its capacity by 20 MW and its cycle efficiency by 9%.
- Several U.S. utilities are increasing capacity and/or efficiency at existing sites including: Tennessee Valley Authority (Chickamauga and Nickajack reservoirs), New York Power Authority (Robert Moses Plant), American Electric Power, and others.

CONTACTS

U.S. Hydropower Council for
International Development
Debby Stone
Director, Trade Promotion
Washington, DC
Tel: (202) 383-2550
Fax: (202) 383-2555

National Hydropower Association
Washington, DC
Tel: (202) 682-1700
Fax: (202) 682-9478
hydroinfo@hydro.org
http://www.hydro.org

U.S. Department of Energy
Paul Carrier
Office of Electricity and Generating Fuels
Policy for Hydropower Policy and
Regulation
Washington, DC
Tel: (202) 586-5659
http://www.doe.gov

U.S. Department of Energy
Ron Loose
Director for Hydropower R&D
Wind, Hydro, Ocean Technology
Washington, DC
Tel: (202) 586-8086
http://www.doe.gov

8.5 PHOTOVOLTAICS (PV)

CHARACTERISTICS

Solar cells are thin wafers of silicon or other semi-conductor material that create an electric current when sunlight strikes the semiconductor material. When a number of solar cells are mounted on a surface and are wired together in series, they become a solar module, the building block of a photovoltaic (PV) system. Current commercial PV devices have a maximum conversion efficiency of about 15%. Direct sunlight as well as diffuse light scattered by clouds or humidity may still be able to generate electricity, making PV an option in warm and in cool climates. PV is by nature an intermittent resource, but where it matches daytime power peaks, it may be economic for utility applications. Also, the solar PV module's relatively high initial cost (currently ~$5/watt) is offset by a very long life (as many as 30 years) and relatively low maintenance requirements.

PVs produce no net emissions, although some toxic chemicals are used to produce PV systems. Where PVs are used for baseload or peaking power, fossil-fuel generated electricity is avoided.

PV modules can be used without moving parts; their support structures can be fixed in place, or designed to track the sun across the sky. Large-scale photovoltaic power plants, consisting of many PV arrays installed together, can prove useful to utilities for many reasons. Utilities can build PV plants much more quickly than they can build conventional power plants because the arrays themselves are easy to install and connect together. Also, because siting PV arrays is much easier than siting conventional power plants, utilities can locate PV plants where they are most needed in the grid. Finally, unlike conventional power plants, PV plants can be expanded incrementally as consumer demand increases. New developments include increasing production capacity as well as increasing efficiencies of the technologies, helping to reduce costs.

SIZE:	Modules range from a few watts to multi-MW. For power generation, modules can be combined to produce 5-10 MW_e or larger.
FEATURES:	Maximum operating efficiency 15% (sunlight-to-electricity); average efficiency 10%. Systems using trackers that follow the sun receive about 33% more sunlight than fixed arrays.
COST:	$6,000-20,000/kW for systems of which the module costs ~$5,000/kW, although expectations are that cost will decrease to $1,000/kW by 2005-2015 and as low as $700-800/kW by 2020-2030. PV is competitive as a stand-alone power source in areas remote from electric utility grids. The levelized cost for large PV systems (> 1kW) is $0.25-.50/kWh, making PV cost-effective for residential customers more than a quarter mile (0.4 km) from the grid.
CURRENT USAGE:	About 150 MW of PV is shipped every year; more than 200,000 residential and commercial buildings use PV systems. PV demand

is increasing at a rate of 15-20% each year.[25]

POTENTIAL USAGE: Solar insolation sufficient for PV exists in areas of virtually every country in the world.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Solar insolation varies geographically.
- Once PV equipment is purchased and installed, negligible additional costs are incurred. Fuel costs are zero, so PV systems may be more economical over a project lifetime. PV is becoming the power supply of choice for remote and small-power, DC applications of 100 W or less.
- Cost of photovoltaic-produced electricity varies with atmospheric conditions—photovoltaic cells may lose 0.5% of their production efficiency for each degree Celsius above their rated temperature.
- PV cannot provide continuous power without energy storage systems. Because of its variable nature (due to the variance of sunlight), utility planners must treat a PV power plant differently than they would treat a conventional plant.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- In some applications, back-up power generators (e.g., diesel) may be necessary; where back-up power is necessary, some emissions would be produced.

EMISSION ESTIMATE: No direct GHG emissions.

COST-EFFECTIVENESS: \$26-400/ton of CO_2 avoided (net), depending on alternate fuel sources.

SECONDARY EFFECTS: Produces no air pollutants although some systems involve the use of toxic materials which can pose risks in manufacture, use and disposal.

RESOURCES

- The U.S. Department of Energy is sponsoring three commercialization efforts for utility-scale operation of PV:
  1. The *Utility PhotoVoltaic Group*, a collaborative effort of U.S. utilities and the U.S. DOE is designed to accelerate the use of cost-effective small-scale and emerging large-scale applications of PV for the benefit of electric utilities and their customers.
  2. *TEAM-UP* Utility/DOE PV Commercialization Program
  3. *Photovoltaics for Utility Scale Applications* (PVUSA) is a cooperative agreement between DOE and utilities to operate three pilot test stations. This allows participating utilities to specify, purchase, test, and evaluate utility-ready

[25] If PV prices decrease to \$3,000/kW (average), PV capacity could reach 125-150 GW worldwide by 2025.

photovoltaic equipment. The agreement is helping prepare both utilities and the PV industry for quantity installations.

- The International Finance Corporation (IFC) has established the *Photovoltaic Market Transformation Initiative*, a fund of $60 million contributed by the Global Environment Facility, to invest from $1-5 million in large-scale expansion projects for PV in a select number of eligible countries.
- The GEF has established the *PV Green Carrot Program* to cover part of the risks of PV manufacturing and marketing scale-up. This program offers a cash award to manufacturers of efficient low-cost PV technologies.
- Zweibel, K. 1990. *Harnessing Solar Power: The Photovoltaics Challenge,* Plenum Publishing Corporation, New York (US)
- PV Discussion Group online, *http://aurora.crest.org/resources/emlists/pvusers/*

CONTACTS

International Finance Corporation
Dana Younger
IFC GEF Coordinator
Environment Division
Technical & Environment Department
Washington, DC
Tel: (202) 473-4779
Fax: (202) 334-9705
DYounger@WorldBank.org
http://www.ifc.org

National Renewable Energy Laboratory
Golden, CO
Tel: (303) 275-3000
http://www.nrel.gov

Solar Energy Industry Association
Scott Sklar
Executive Director
Washington, DC
Tel: (202) 383-2600
http://www.seia.org

Utility PhotoVoltaic Group
Matt Cheney, Director
Washington, DC
Tel: (202) 884-0689
Fax: (202) 223-5537
mcheney@ttcorp.com
http://www.upvg.org

World Bank
Charles Feinstein
Senior Environmental Specialist
Global Environment Division
Environment Department
Washington, DC
Tel: (202) 473-2896
Fax: (202) 522-3256
Cfeinstein@WorldBank.org
http://www.worldbank.org

8.6 SOLAR THERMAL

CHARACTERISTICS

Unlike PV systems, which use sunlight to directly produce electricity, solar thermal systems generate electricity with heat from concentrated sunlight. Solar thermal collectors use mirrors and lenses to concentrate and focus sunlight onto a receiver mounted at the system's focal point. The receiver absorbs and converts sunlight into heat. The heat is then transported to a steam generator or engine where it is converted into electricity.

There are three main types of solar thermal electric systems: parabolic troughs, parabolic dishes and central receiver systems:

(1) trough systems—or parabolic trough collectors—use mirrored troughs to focus energy on a fluid-carrying receiver tube located at the trough's focal point. There are 354 MW of trough systems installed in southern California;

(2) dish systems use parabolic mirrors to concentrate and focus incoming solar energy onto a receiver mounted above the dish at the focal point. Each dish produces 5-50 kW of electricity that can be used independently or linked together to increase generating capacity;

(3) central receivers systems—or “Power Towers”—use thousands of individual tracking mirrors (heliostats) to reflect solar energy onto a receiver located atop a tall tower. The world’s largest central receiver plant is a 10 MW power plant near Barstow, California.

Solar energy technologies offer a clean, renewable and domestic energy source. In the U.S., solar thermal power plants produce about 480 million kWh of energy each year displacing 325,000 tons of CO_2 (6.8 tons of CO_2 /kWh) annually.

Solar energy technologies have made huge technological and cost improvements, but except for certain niche markets—such as remote power applications—are still more expensive than traditional energy sources. Researchers continue to develop technologies that will make solar energy technologies—particularly power generating technologies—cost-competitive with fossil fuels. Current research efforts are focused on developing lighter, more efficient system components and energy storage technologies

SIZE:	Parabolic troughs: 30-80 MW_e units now in deployment; 160 MW_e modules proposed. Central receiver systems: 80-200 MW_e Parabolic dish-Stirling engines: 5-50 kW_e
FEATURES:	Parabolic troughs: require ~2 hectares of land per MW_e of generating capacity, based on a daily mean direct normal insulation value of 6-7 kWh/m^{2}. Central receiver systems: require 3-5 hectares land/MW_e. Parabolic dish-Stirling engines: require about 0.7 ha/MW_e.
COST:	Parabolic troughs: \$2,890/kW_e (1991) Central receiver systems: \$3,300/kW_e—100 MW_e or

$2,800/kW$_e$—200 MW$_e$ (1991)
Parabolic dish-Stirling engines: $1,700-$3,000/kW$_e$

CURRENT USAGE: Over 354 MW$_e$ parabolic troughs, primarily in California.

POTENTIAL USAGE: Developing countries, where half the population is currently without electricity and sunlight is usually abundant, represent the biggest and fastest growing market for power producing technologies. The largest potential U.S. application is for power production.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Fuel source—sunlight—fluctuates seasonally and is nonexistent at night. For dispatchability, solar thermal technologies must have storage capacity or back-up power source, which increases the overall cost of system. However, resource availability does match daytime demand peaks.
- Requires large quantities of land for base-load electricity generation or for peaking electricity generation; may have negative impact on habitats.
- There have been reliability problems with high temperature requirements and corrosive effects on solar mirrors.
- Costs per kWh produced by stand-alone solar thermal sources are currently higher than with conventional sources.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

EMISSION ESTIMATE: 6.8 tons/kWh of CO_2 avoided

COST-EFFECTIVENESS: $88-178/ton of CO_2 avoided (net)

SECONDARY EFFECTS: Produces no emissions unless a hybrid natural gas system is used (parabolic troughs only) in which case emissions remain minimal with the exception of NO_x @ 31.8 grams/MWh.

RESOURCES

- California Energy Commission. 1990. *Solar Thermal Electric - Parabolic Troughs, Energy Staff Report* (US).
- The Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) provides an on-line directory of solar-thermal technical reports and development status. *http://www.caddet-re.org/*

CONTACTS

European Solar Energy Association
Bonn, Germany
Tel: +49-228-362373 and 362375
Fax: +49-228-361279
inter_office@eurosolar.org
http://www.eurosolar.org

Solar Energy Industry Association
Scott Sklar
Executive Director
Washington, DC
Tel: (202) 383-2600
Fax: (202) 383-2670
info@seia.org
http://www.seia.org

8.7 WASTE-DERIVED FUELS

CHARACTERISTICS

A variety of waste products can be converted into liquid and gaseous fuels for use in generating electricity. These include municipal solid waste—which can also be processed into refuse-derived fuel (RDF) that yields a higher Btu, lower ash energy source—or biogas created from organic waste or biomass through fermentation. Also, methane gas can be recovered from landfills and used in place of natural gas. Methane is a flammable gas produced from landfill wastes through anaerobic digestion, gasification or natural decay.

Using these waste-derived fuels not only consumes what would otherwise be waste, it also produces fuels with lower emissions than those associated with fossil fuels. Where methane is recovered, it avoids the release of methane, a greenhouse gas.

SIZE:	1-5 MW_e (modular combustion); 30-100 MW_e (field-erected).
FEATURES:	MSW is 25% efficient when used for power generation. Biogas can be used in internal combustion engines for shaft power or electricity; it can also be used as cooking and heating fuel. Methane recovery can achieve 70-80% efficiency.
COST:	$91,000/Mt of daily capacity for MSW; $4,750/kW$_e$ for biogas. Methane recovery can be relatively inexpensive to operate, but if pipelines or other infrastructure needs to be built, the project cost increases dramatically.
CURRENT USAGE:	Many European countries currently combust their waste streams; additional efficiency may be achieved through recovering heat or electricity. Currently, more than 100 power plants in 31 of the United States burn landfill-generated methane.
POTENTIAL USAGE:	Applicable everywhere that waste is generated. Especially applicable in highly populated regions that produce significant quantities of waste.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Creates ash as a by-product that must be disposed of, requiring a landfill. These disposal costs add to O&M costs.
- Operators must have access to a significant quantity of garbage (100 TPD). Also, a storage area is required for the waste.
- For biogas, retention time is limited—for cattle manure 20-25 days; for other animal waste 12-15 days .
- Siting of facilities can be difficult because of state regulations as well as public sentiment– "not in my backyard" (NIMBY).

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

EMISSION ESTIMATE: No carbon emissions are produced

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Some NO_x, SO_x emissions are produced (depending on fuel stock), but emissions are significantly less those generated by any fossil fuel.

RESOURCES

- Bushnell, C. et al., 1992, *Municipal Solid Waste Combustion: Testing and Evaluating the Combustion Characteristics of Waste Fuels*, Northwest RBEP, Bonneville Power Administration, Portland, OR.

CONTACTS

National BioEnergy Industries Association
Washington, DC
Tel: (202) 383-2540
Fax: (202) 383-2670
http://www.bioenergy.org

National Renewable Energy Laboratory
Dave Lazarz
Golden, CO
Tel: (303) 275-3835
Fax: (303) 275-2905
http://www.nrel.gov

Renewable Fuels Association
Washington, DC
Tel: (202) 289-3835
Fax: (202) 289-7519

United BioEnergy Commercialization Association (UBECA)
Joe Badin
Director
Columbia, MD
Tel: (301) 621-8432
Fax: (301) 621-8997
http://www.ubeca.org

8.8 WIND POWER

CHARACTERISTICS

Wind turbines range in size from a meter to a hundred meters in rotor diameter and from a hundred watts to a thousand kilowatts in power output. Wind turbines suitable for residential or village scale wind power range from 500 watts to 50 kilowatts. Even though wind is an intermittent source, on a large grid it can contribute an estimated 15-20% of annual electricity production without special arrangements for storage, backup and load management.

The amount of energy in wind speed is proportional to the cube of the wind speed. While wind speed varies over time, it generally follows daily and seasonal patterns. Utility-scale wind power plants require wind speeds of at least 13 mph (6 meters per second). A 10 kW turbine located in a moderate wind regime can generate an average of 30 kWh of power each day. For large-scale projects, 12 months of consistent observation and recording is recommended for assessing wind resources.

Wind energy produces no GHG emissions. Thus, every kWh of electricity generated by wind technologies avoids the emissions associated with a similar number of fossil-fuel generated kWh.

Advances in the fields of aerodynamics and composite materials have helped reduce the costs of wind turbines, making modern electric power-generating wind turbines a reality. Utility interconnected wind turbines can generate power synchronous with the grid. These machines are economically attractive where there is a good wind resource and where the local power costs are in excess of 15 cents (or less) per kilowatt hour. State-of-the-art wind technology can operate with 98% availability, and today's turbines perform with capacity factors over 30%.

SIZE: 100-1000 kW_e (utility-scale); 1-50 kW_e (distributed power)

FEATURES: Grid-connected or stand-alone uses, but availability is dependent on the presence of wind. Well-designed and well-maintained wind turbines at windy sites can generate 1000 kWh/m^2/year.

COST: \$1,000-1,200/kW_e (utility-scale) (1992 dollars)
\$1,900-2,200/kW_e (distributed, grid-connected)
\$2,400-5,600/kW_e (distributed, battery storage)
Cost is very dependent on average annual wind speed, but under ideal conditions, electricity can be generated from wind for as little as \$0.04/kWh, making wind competitive with conventional fuels.[26]

CURRENT USAGE: Nearly 8,000 MW worldwide at end of 1997, although several

[26] Costa Rica has installed a wind power plant of 6.4 MW that will annually save some \$3.8 million in imported fuel oil costs and reduce CO_2 by 38,600 tons over 4 years.

POTENTIAL USAGE: thousand megawatts of additional projects have been proposed. Total worldwide wind potential is enormous; in China alone total wind energy potential is estimated at 250,000 MW.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- There is aesthetic opposition to wind because of noise while in operation and location of turbines. However, turbines can be located in rural areas, with surrounding land used for agriculture or other purposes.
- Birds are attracted to the whirring noises made by the turbines; in some areas bird mortality rates have increased significantly—in some instances affecting endangered species of birds.
- Resources are site-specific and may not be located close to demand centers.
- Wind is intermittent; if not grid connected, a source of back-up power is needed, increasing costs of generation.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- If wind potential reaches the projected 700-1,000 TWh worldwide by 2020, it would avoid the production of 0.1-0.2 GtC/year of fossil fuel-fired electricity.

EMISSION ESTIMATE: 1 kWh of wind avoids 0.5-1.0 kg/CO_2 (~1-2 lbs/CO_2) from conventional sources. A wind turbine with a 500-kW capacity operating at 30% availability and producing 1.3 MWh per year avoids 351 MtC/year.

COST-EFFECTIVENESS: $21.53 ton/C

SECONDARY EFFECTS: Produces no air pollutants or greenhouse gases. Wind generation avoids up to 7 grams/kWh of SO, NOx and particulates from the coal fuel cycle (including mining and transport); 0.1 g/kWh of trace metals (including mercury); and more than 200 g/kWh of solid wastes from coal tailings and ash.

RESOURCES

- EPRI/DOE Utility Wind Interest Group (UWIG) is a utility organization that helps utilities evaluate the potential for wind generation in their service territory. UWIG also publishes a series of information brochures on technologies, costs, technical and environmental issues, resources, etc.
- The National Wind Technology Center provides a virtual library of wind-related technical publications. *http://www.nrel.gov/wind/library.html*

CONTACTS

American Wind Energy Association
(AWEA)
Randall Swisher
Executive Director
Washington, DC
Tel: (202) 383-2500.
http://www.igc.apc.org/awea/

European Wind Energy Association
London, United Kingdom
Tel: +44 171 402 7122
Fax: +44 171 402 7125
ewea@ewea.org
http://www.ewea.org/

National Renewable Energy Laboratory
Robert Thresher
Director, Wind Division
Boulder, CO
Tel: (303) 231-7199
http://www.nrel.gov/wind/

National Wind Coordinating Council
(NWCC)
Janet Stone
Washington, DC
Tel: (202) 944-2300
Fax: (202) 338-1264

National Wind Technology Center
Golden, Colorado
http://www.nwtc.gov

U.S. Department of Energy
Office of Utility Technologies
Washington, DC
http://www.eren.doe.gov/wind/

8.9 FINANCING MECHANISMS FOR RENEWABLE ENERGY PROJECTS

CHARACTERISTICS

While the emissions benefits (air pollution and greenhouse gas) of renewable energy technologies are widely recognized, the cost of renewable energy (RE) technologies remains— in most applications—greater than that of "conventional" power generation equipment. To facilitate technology deployment of renewable energy technologies various innovative financial mechanisms have been developed to 1) reduce the cost differential between conventional and renewable technologies, and 2) address investor concern about high "first costs". These mechanisms include the following:

- *Microfinancing* (i.e., financial intermediation at the local level) provides small companies (or residential users) with access to capital via loans for small-scale investments under flexible and often non-traditional lending conditions. Such financing may allow borrowers to upgrade or install energy-efficient technologies, resulting in more energy services with less energy consumption.
- *Portfolio Fees:* small-scale projects can involve relatively high transaction costs. To help save on administrative fees, developers can bundle similar projects together into a "portfolio" in which one set of procedures is developed to apply to a number of projects.
- *Tax Credits:* government at any level (local, regional or national) can authorize tax deductions for the purchase or operation of renewable energy systems.
- *Buydown Cost Differential:* In many countries, governments offer subsidies to help reduce or "buy down" the cost of using renewable energy technologies.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Renewable energy projects tend to be smaller than conventional power generation technologies meaning that transaction costs are proportionately higher for RE projects, and there are fewer economies of scale.
- Renewable energy projects are capital-intensive and usually require higher up-front costs than conventional technologies. Projects that use technologies with lower life-cycle costs and emissions but that have higher capital requirements than their alternatives may not attract the necessary finance.
- Energy supply technologies compete for limited capital with other development needs.
- Investment may yield lower returns than other opportunities.
- Over the life-cycle of a technology, the benefits of using renewable energy technologies could 1) create indigenous technology production; 2) create new local infrastructure and employment; 3) could aid in meeting a country's development goals, especially in rural areas; and 4) could outweigh, or at least compete with conventional technologies.

RESOURCES

- The U.S. Export Council for Renewable Energy (US/ECRE) has played a role in several initiatives to help finance deployment of renewable energy technologies:
  1. US/ECRE and the federal interagency Committee on Renewable Energy Commerce and Trade (CORECT) have developed *Financing Renewable Technologies*, a unified application form for financing international renewable energy projects. The single form can be simultaneously submitted for funding consideration to the U.S. Agency for International Development, Export-Import Bank of the United States, Overseas Private Investment Corporation, and the U.S. Trade and Development Agency.
  2. *Source of Financing in Latin America* identifies potential sources of investment capital for renewable energy projects to be located in Latin America.
- *Financing Energy Services for Small Scale Energy* (FINESSE) was established in 1989 to mainstream renewable energy and energy efficiency projects into the lending programs of World Bank, the Inter-American Development Bank and other multilateral organizations. By bundling a number of small-scale renewable energy projects into a larger financing package, the technologies are better able to qualify for funding from international financing institutions.
- The *Environmental Enterprises Assistance Fund* is a non-profit organization that provides equity and debt financing for non-U.S. companies in environmentally beneficial business. Seeks host country co-financing of projects.
- Through the *Small and Medium Scale Enterprise Program* the International Finance Corporation/Global Environmental Facility channel funds through financial intermediaries and non-governmental organizations to small- and medium-scale enterprises for renewable energy (as well as energy efficiency and sustainable forestry projects).
- IFC and the World Bank have developed a *Renewable Energy and Energy Efficiency Investment Fund* (RE/EEF) to provide investment funds for commercially proven and innovative renewable energy and energy-efficiency technologies, including small-scale projects.
- The U.S. Department of Energy supports R&D efforts in renewable energy technologies as well as efforts to commercialize and deploy these technologies in energy markets. The government may provide matching funds, and/or may support deployment activities for grid-connected operations with one or more electric utilities. For instance, the *Commercialization Ventures Program* provides funds to RE projects to assist in market entry and penetration, based on their technical merit.
- Green Energy Finance Discussion Group, *gef-discussion-request@energyfinance.org, http://www.energyfinance.org/list-archives/info-files/gef-discussion.html*
- The European Union sponsors programs including THERMIE and ALTENER that provide financial support on a cost-shared basis for implementing innovative renewable energy technologies (other technologies may also be eligible). *http://www.europa.eu.int/en/comm/dg17/programs.htm.*

CONTACTS

Environmental Enterprises Assistance
Fund, Inc. (EEAF)
Brooks H. Brown
Arlington, VA
Tel: (703) 522-5928
Fax: (703)-522-6450
eeaf@eeaf.org
http://www.eeaf.org

Global Environment Facility
The GEF Secretariat
Washington, DC
Tel: (202) 473-0508
Fax: (202) 522-3240
http://www.gefweb.org

International Finance Corporation
Dana Younger
IFC GEF Coordinator
Environment Division
Technical & Environment Department
Washington, DC
Tel: (202) 473-4779
Fax: (202) 334-9705
DYounger@WorldBank.org
http://www.ifc.org

9.0 OFFSET AND EMISSION TRADING ACTIONS

In addition to the “best practice” activities related to energy technology and energy management discussed in the previous sections, emission offset and trading actions are also available to reduce GHG emissions. These actions employ a market mechanism to achieve the required reductions by exchanging emission credits/allowances between entities that “overcomply” with those that “undercomply” in response to either a unit level requirement or a regional emissions cap (bubble).

Such offset and emission trading actions can supplement the emissions reduced/avoided by best practices, or facilitate the flow of capital to fund such actions. While such offset and emissions trading actions might involve improvements in the efficiency of generating, transmitting, distributing, and consuming electricity, they are typically undertaken by a third-party. The third-party sells the offset/allowance to an entity that has a marginal cost of control greater than the price of purchasing the offset/allowance.

9.1 PRESERVING AND PLANTING FORESTS, AND OTHER CARBON SINKS

CHARACTERISTICS

A stock that intakes and stores carbon is called a "sink". Sinks include the ocean, soil, fossil fuel deposits, and other natural matters, although the Earth's largest sink by far is forests sequesters. Approximately two-thirds of the carbon sequestered on earth is captured by forests. Most plants and crops release much of their carbon at the end of their season, but forests store carbon for decades, or even centuries, making them an excellent means of sequestering large amounts of carbon over relatively short periods of time.

The carbon stored in these sources can be released accidentally or expressly through forest fire or through land-clearing, logging or otherwise changing the status of forest land. Actions can be taken to minimize or to prevent carbon release as a result of such actions. For instance, if a site is cleared and vegetation is burned, most of the carbon will be released into the atmosphere. However, if the site is replanted, or is the wood is used for long-life wood products, the net release of carbon will be much smaller.

Scientists estimate that forests are taking up (sequestering) a significant portion of CO_2—possibly more than 25% of fossil fuel use.

Soils that have been or are used for agricultural purposes offer great potential as a sink for atmospheric CO_2. Agricultural practices can promote carbon sequestration by changing tilling methods, altering land-use, maximizing yield/hectare cultivated and maintaining more continuous vegetation cover.

SIZE:	No limit, except the economic trade-off between land used as a carbon sink versus that for food production, grazing, etc.
FEATURES:	In addition to sequestering carbon, forests generate economic and social benefits: for wood products, wildlife habitat, erosion control, water supply, etc.
COST:	Cost estimates vary: Reforestation costs are estimated at $15-40/ton; Southern Co. estimated costs at $5.50/ton with carbon @ 67 ton/acre. The cost of ocean-enhanced sinks is unknown.
CURRENT USAGE:	Estimated that the ocean sequesters 40,000 GtC/year, by far the overwhelming majority of C sequestered. Utilities can sponsor local or smaller-scale efforts to increase tree populations in public areas.[27]

[27] The Sacramento Municipal Utility District (SMUD) sponsored a "Community Shade Trees" program that provided free deciduous shade trees to volunteer groups for planting on public lands

POTENTIAL USAGE: Potential for up to 2 GtC/year out of the atmosphere-terrestrial flux of 60 GtC.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☑ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Due to land-use changes and tropical deforestation, an estimated 2.6 gigatonnes of C per year are not sequestered.
- Uptake is affected by land-use history, length of the growing season, cloudiness and warm temperature anomalies.
- In Northern forests where soils are thawing, net uptake of CO_2 is canceled by release of gases from deep soils caused by warming.
- When wood is burned for fuel, carbon is released; this can be counteracted by insuring that forests/fuelwood sources are managed for re-growth so that no net emissions will occur.

EMISSION ESTIMATE: Measurements indicate that a North American forest of primarily oak and maple trees, about 60 years old, sequesters ~2 tons C/hectare/year.
Global potential for 24-43 billion metric tonnes of soil C sequestration over a 50-year period through adoption of improved agricultural practices, use of set-asides and conservation buffers on marginal cropland, and restoration of degraded lands.

COST-EFFECTIVENESS: Relatively low cost, although cost-effectiveness varies by location.

SECONDARY EFFECTS: Enhanced wildlife habitat and ecosystem benefits can result.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Standards for baseline determination, additionality, leakage, verification and the potential for perverse incentives to motivate forest management decisions are internationally accepted.
- Need to establish mechanisms to measure, monitor and verify sequestration.
- Sinks must remain for 50+ years for full value of offset to be achieved; potential rebound effect if crops used for fuel or as input to make paper/pulp (energy-intensive industries).
- Land-use issues—some countries are hesitant to commit to preserving timber, etc. indefinitely when land may be wanted for future development.
- There is the possibility that monoculture crops, which are known to sequester carbon rapidly, and thus offer greater short-term carbon storage gains than the previously existing ecosystem, will replace biodiverse heterogeneous forest ecosystems.
- Scientific uncertainties remain: where/how large sinks are, why and for how long

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(schools, parks, parkways, sports fields).

sequestration occurs – difficulties in isolating impact of defined geographic area.

RESOURCES

- Through the U.S. Initiative on Joint Implementation (USIJI), several utilities have participated in carbon sequestration projects. American Electric Power (AEP), a large U.S.-based utility, partnered with The Nature Conservancy on a land-use project in Bolivia. The partners have committed to protect and preserve an environmentally sensitive forested area for 30 years, and expect to sequester 14.5 mmtC over the project lifetime. Wisconsic Electric Power (WEPCO) is also working with The Nature Conservancy on a 40-year conservation and forest management project in Belize, expected to sequester 1.3 mmtC over the project lifetime. More information on these and other projects is available at *http://www.ji.org.*
- Climate Technology Initiative (CTI) under the FCCC Task Force 7—mission is to accelerate international collaboration for R&D in the field of medium- and long-term technologies relating to greenhouse gas capture and disposal.
- IEA Greenhouse Gas R&D Programme, *http://www.ieagreen.org.uk*

CONTACTS

The Nature Conservancy
Randall Curtis
Arlington, VA
Tel: (703) 841-4864
http://www.tnc.org

Oregon State University
Ted S. Vinson, Ph.D., P.E.
Corvallis, OR
Tel: (503) 737-3494

Reforest the Tropics
Herster Barres
Mystic, CT
Tel: (203) 572-8199

Trexler and Associates
Mark Trexler
President
Oak Grove, OR
Tel: (503) 786-0559
Fax: (503) 786-9859

U.S. Initiative for Joint Implementation
Secretariat
Washington, DC
Tel: (202) 586-3288
Fax: (202) 586-3485
Fax-on-Demand: (202) 260-8677
http://www.ji.org

9.2 SUPPORTING INSTITUTIONS THAT IMPROVE CARBON SINKS

CHARACTERISTICS

Deforestation and land-use changes contribute to the removal of thousands of hectares of carbon sinks each year. Promoting development or replacement of such resources will have a significant, and relatively low-cost positive impact on offsetting emissions of greenhouse gases.

Institutions that promote and support improvement of carbon sinks can serve a valuable role in increasing the viability of and benefit to parties interested in improving carbon sinks. Development of standardized accounting procedures, and monitoring and verification guidelines, and training of independent "auditors" can facilitate increased use of carbon sinks to offset increased greenhouse gas emissions. As these organizations facilitate sharing of know-how and success stories, the complexity of subsequent projects is minimized.

Institutions that currently support improving carbon sinks include the U.S. Initiative for Joint Implementation, the Global Environment Facility, and the World Bank's Carbon Investment Fund. A significant number of bilateral agreements have taken place to improve carbon sinks.

SIZE: N/A

FEATURES: Without a mandate to reduce carbon, there is negligible incentive to improve carbon sinks.

COST: N/A

CURRENT USAGE: Several NGOs as well as multilateral organizations promote and/or support improvement of carbon sinks.

POTENTIAL USAGE: Several countries have land-use policies that allow for protection/development of carbon sinks.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☑ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- For a net carbon reduction, sinks must absorb carbon. If sink is to be harvested but subsequently replanted, the carbon will be offset.

EMISSION ESTIMATE: Will vary according to the age and lifetime of the sink.

COST-EFFECTIVENESS: Relatively low cost option.

SECONDARY EFFECTS: N/A

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- To ensure that carbon sinks investments achieve the stipulated capture (and validate the carbon offset or trade) over the lifetime of the forest, reliable monitoring and verification programs are necessary.

RESOURCES

- U.S. Initiative for Joint Implementation provides informational and instructional materials for developing carbon sink projects. Documents are available at *http://www.ji.org*.

CONTACTS

Global Environment Facility
Secretariat
Washington, DC
Tel: (202) 473 0508
Fax: (202) 522 3240
http://www.gefweb.org

U.S. Initiative for Joint Implementation
Secretariat
Washington, DC
Tel: (202) 586-3288
Fax: (202) 586-3485
Fax-on-Demand: (202) 260-8677
http://www.ji.org

World Resources Institute
Washington, DC
Tel: (202) 729-7600
Fax: (202) 729-7610
http://www.wri.org

9.3 ASSISTING IN TRADES OF EMISSIONS

CHARACTERISTICS

Concern over the costs and benefits of reducing GHG emissions has been one of the most, if not the most, important factor in discussion about climate change mitigation. Many parties make the argument that, since the atmosphere does not care where reductions of greenhouse gases are made, it makes economic sense to make reductions where they are the “least cost”. In many instances, low-cost project opportunities exist in developing countries, but it is industrialized countries that have the capital needed to undertake the projects.

Emissions trading is one of the market-based mechanisms promoted in international negotiations. Facilitating emission trades assures the completion and fruition of a greater number of projects to reduce emissions. Through this action, capital and technology flow could be enhanced. However, there are several data and administrative actions required to facilitate establishment of a viable emission trade. These actions include (but are not limited to) verifiability, cost-effectiveness, maintenance, monitoring and liability.

SIZE:	Any number of trades are possible. There may be a limit on number of reductions that a country can purchase through trades instead of taking domestic action to meet its total commitment.
FEATURES:	Potential bilateral (Activities Implemented Jointly or Joint Implementation) or through multi-lateral mechanisms.
COST:	Vary depending on limitations placed on trades (e.g., cap on purchases by country), and on share of project cost that is attributable to transaction/administrative costs.
CURRENT USAGE:	Russia/Japan; Costa Rica /U.S., Canada/U.S.
POTENTIAL USAGE:	Could be used internationally, depending on final rules approved by UNFCCC, but each country may have a limit on the share of allowances that could be used for compliance.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☑ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- All reductions must be verified.

EMISSION ESTIMATE:	N/A
COST-EFFECTIVENESS:	Will vary with each project, but the premise of emissions trading is that projects will take place where it is most cost-effective.
SECONDARY EFFECTS:	Where fossil fuel use is reduced, the associated emissions of sulfur dioxide and nitrogen oxide will also be reduced.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Many issues remain unresolved; negotiations are in process to work out internationally acceptable terms.
- It is the position of the United States that no limit on trading should be imposed as that would negatively affect the flexibility of the market to function. Analysis by the Clinton Administration reveals that the U.S. expects to meet as much as 85% of the reductions committed to through trading of emissions permits on a worldwide market.
- It is the position of the European Union that a limit on the percentage of allowable trades should be set to insure that countries take domestic actions to reduce their emissions.

RESOURCES

- Resources for the Future offers several articles explaining the mechanics of emissions trading at *http://www.weathervane.rff.org*.

CONTACTS

Emissions Marketing Association
Daniel Chartier
Milwaukee, WI
Tel: (414) 276-3819
Fax: (414) 276-3349
http://www.emissions.org

Environmental Financial Products Ltd.
Michael Walsh
Senior Vice President
Chicago, IL
Tel: (312) 554-3380
Fax: (312) 554-3373

United Nations Conference on Trade and Development (UNCTAD)
Frank Joshua
Geneva, Switzerland
Tel: +41-22-917-5834
Fax: +41-22-907-0274
frankjoshua@unctad.org

World Bank Carbon Investment Fund
Eivind Tandberg
Director, Carbon Offsets Unit
Washington, DC
Tel: (202) 473-9746

10.0 DATA, RESEARCH AND MONITORING ACTIONS

To facilitate cost-effective selection of mitigation options, baseline emissions data are needed. The data will indicate the primary sources of carbon emissions at a plant. This, in turn, will enable analysis to be conducted to determine the most cost-effective options for reducing emissions.

Emissions reporting systems are used to ensure compliance with GHG emission reduction targets. It is likely that standardized reporting systems will be agreed to under international climate change protocols.

Research on carbon sources, sinks and control options is being undertaken in many countries to assist in developing cost-effective carbon control strategies and to expand the suite of technological options available to reduce carbon emissions. Many methods for dissemination of the research results are being used.

A description of actions that can be undertaken in each of these areas is discussed in this section, and the indirect GHG emissions impact that would result are estimated, where appropriate.

10.1 IMPLEMENTING EMISSIONS REPORTING PROGRAMS

CHARACTERISTICS

Inventorying, tracking and reporting GHG emissions are critical steps in developing emissions mitigation programs and obtaining credit for reduction activities under international compliance requirements being developed within the Framework Convention on Climate Change (FCCC). Emissions reporting programs address two information needs:

(1) They identify the sources and levels of historic GHG emissions so that major emitters can be identified and the most cost-effective mitigation program can be defined.

(2) They facilitate the tracking of current emission levels to ensure that a) national/international GHG reduction requirements are achieved, and b) credit for over/under compliance is documented for reconciliation of joint implementation and emission trading exchanges.

Continuous emissions monitoring (CEM) equipment can be used on point sources (e.g., utility smokestacks) to monitor, measure and report emissions on a regular basis. Since 1995, CEMs have been required on all U.S. coal-fired powerplants. These systems electronically report the level of SO_2 emissions from each plant to the U.S. Environmental Protection Agency for purposes of comparing permitted versus actual SO_2 emissions. CEM technology can be used to monitor and report all air pollutant and GHG emissions.

Creating a credible and flexible emissions reporting system for GHG emissions is not straightforward. Several options exist—however, only a few may be endorsed by the FCCC (or its designated reporting/enforcement body).

SIZE:	N/A
FEATURES:	Emissions reporting programs consist of emissions monitoring using approved measurement techniques and reporting procedures. They must provide certainty that the data represents an accurate baseline of GHG emissions and clearly defined procedures for measuring and reporting emissions reductions from the baseline.
COST:	The cost of implementing emissions reporting programs should be small in comparison to electric utility operating and compliance costs. In some instances, international financial support might be available.
CURRENT USAGE:	Several countries—primarily those designated as Annex I within the FCCC, have been experimenting with alternative emissions reporting programs.
POTENTIAL USAGE:	Eventually, all countries that are signatories to the FCCC and any subsequent protocols will be required to have

approved emissions reporting programs.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Acceptable, consistent and equitable emissions monitoring systems are still being developed.
- There will be expenses associated with monitoring and reporting of GHG emissions that some countries will not be willing to incur until they have become signatories to the FCCC and any subsequent protocol.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Environmental improvement will depend upon the accuracy of estimating baseline emissions and the actual reductions from the baseline.

EMISSION ESTIMATE: N/A
COST-EFFECTIVENESS: N/A
SECONDARY EFFECTS: N/A

RESOURCES

- *Guidelines: Programme for National Greenhouse Gas Inventories*, have been developed by the IPCC/OECD/IEA for inventorying and reporting GHG emissions. They can be found on the worldwide web at: *http://www.iea.org/ipcc.htm*.
- The United States Initiative on Joint Implementation (USIJI) developed a *Resource Document on Project & Proposal Development under the U.S. Initiative on Joint Implementation.*
- The World Bank, Switzerland, and other bilateral donors (e.g., Finland) provide co-financing to host countries to analyze inventories, offsets, and other issues in a National AIJ/JI Strategy Study.
- The United States Country Studies Program (USCSP) provides funding and technical assistance to countries to monitor emissions and prepare national action plans.
- The United Nations Environment Programme has developed a *Workbook on Reporting Instructions.*

CONTACTS

Intergovernmental Panel on
Climate Change
c/o World Meteorological Organization
Geneva, Switzerland
http://www.ipcc.ch

International Energy Agency
Paris, France
Tel: 33-1 40 57 65 54
Fax: 33-1 40 57 65 59
http://www.iea.org

United Nations Environment Program
Geneva, Switzerland
http://www.unep.ch

U.S. Country Studies Program
Christopher Bordeaux
Washington, DC
Tel: (202)-586-3288
Fax: (202)-586-3485
http://www.gcrio.org/CSP/uscsp.html

U.S. Initiative on Joint Implementation
Washington, DC
Tel: (202) 586-3070
Fax: (202) 586-3485

World Bank
National Energy Study
Washington, DC
http://www.worldbank.org/cc/nssp.html

10.2 INVENTORY/QUANTIFICATION OF GHG EMISSIONS

CHARACTERISTICS

Developing a valid GHG emission inventory is the first step in any mitigation activity. Emissions inventories are needed to document the baseline emissions from each power plant. They are used as the basis for defining GHG emissions targets, timetables for compliance and in verifying emissions reductions.

Developing baseline emissions that are consistent from plant-to-plant and are properly documented so that they adhere to international requirements can be tricky and expensive. Several international initiatives to develop guidelines, together with baseline data activities within various developing countries as part of their preparing their national communications/country studies for submission to the Framework Convention on Climate Change (FCCC), provide information on alternative methods and issues in preparing a GHG emissions inventory.

SIZE: Internationally developed guidelines have been developed to inventory emissions on a local- and national level.

FEATURES: Methods range from simple estimates using emission factors to complex models.

COST: Could be significant if original data collection is required.

CURRENT USAGE: Countries party to Annex I have established emissions inventories.

POTENTIAL USAGE: Assistance to other countries is available through programs such as the U.S. Country Studies Program.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Baseline emissions inventories can be inconsistent unless they are developed using standardized protocols.
- It can be expensive to develop complete emissions inventories.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions inventories must be standardized and complete.
- Need accurate real-time emissions monitors to measure progress in reducing emissions against the baseline.

EMISSION ESTIMATE: N/A

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: N/A

RESOURCES

- The U.S. Environmental Protection Agency issued the *States Workbook* to provide guidance on methodologies for estimating GHG emissions.
- The IEA/OECD/IPCC issued *Programmes on National GHG Inventories* that provides guidelines for national GHG inventories.
- IPCC, *Draft Guidelines for National Greenhouse Gas Inventories.*
- UNEP, *Workbook on Performing GHG Inventories*.
- World Bank, *GHG Assessment Handbook: A Practical Guidance Document for the Assessment of Project-Level GHG Emissions–Methodology for Calculating Project-Specific GHG Impacts.*

CONTACTS

International Energy Agency
Paris, France
Tel: 33-1 40 57 65 54
Fax: 33-1 40 57 65 59
http://www.iea.org

Intergovernmental Panel on
Climate Change
c/o World Meteorological Organization
Geneva, Switzerland
http://www.ipcc.ch

United Nations Environmental Program
Geneva, Switzerland
http://www.unep.org

U.S. Environmental Protection Agency
Katherine Sibold
Climate Information Outreach
Washington, DC
Tel: (202) 260-4314
Fax: (202) 260-0290
sibold.katherine@epamail.epa.gov
http://www.epa.gov

U.S. Country Studies Program
Christopher Bordeaux
Washington, DC
Tel: (202) 586-3070
Fax: (202) 586-3485
cbordeaux@igc.apc.org

The World Bank
Odil Tunali-Payton
Tel: (202) 473-6774
Washington, DC
http://www.worldbank.org

10.3 CALCULATING COSTS AND BENEFITS OF OFFSETS

CHARACTERISTICS

Cost-benefit analysis takes into account the monetized benefits and costs of alternatives, to help in the identification and selection of those alternatives which maximize net benefits. This type of analysis is often done in conjunction with a risk assessment.

Costs and benefits can be defined broadly—one definition, used in U.S. regulation, is "reasonably identifiable significant favorable (benefits) or adverse (costs) effects, quantifiable and unquantifiable, that are expected to result directly or indirectly from implementation of a rule or other agency action." This includes benefits that are the intended or direct consequence of a regulatory action as well as the indirect and unintended favorable consequences. Direct costs would include compliance costs and governmental administrative costs. Indirect costs could encompass transition costs incurred as resources shift from one sector to another in response to a regulation (e.g., regulated facilities shed workers), as well as effects on unregulated sectors of the economy that are felt throughout the marketplace, and lower growth rates of the overall economy.

Features such as choice of baseline, the alternatives that are selected for review, whether the alternatives include incentive-based approaches, the completeness of the assessment of benefits and costs, and how intangible (i.e., unquantifiable) effects are treated will affect the outcome of the analysis.

Conducting cost-benefit analyses of GHG mitigation options is useful in determining which option will obtain the best results for the least investment. By its nature, cost-benefit analysis must be site (or country) specific. If properly done, countries and project owners will save a considerable amount of money in taking GHG emissions control measures.

SIZE:	N/A
FEATURES:	Use engineering and economic models to project potential impacts of a variety of mitigation options on emissions trajectories.
COST:	Thorough cost-benefit analyses is relatively expensive.[28]
CURRENT USAGE:	In recent years, there has been more use of cost-benefit analysis. Some countries (e.g., the U.S.) now require analysis prior to passage of new regulation.
POTENTIAL USAGE:	Cost-benefit analysis may be useful to examine a variety of

[28] In the U.S., for instance, the U.S. EPA now requires regulatory impact assessments prior to implementation of new regulation. These assessments, looking at large number of factors and assessing localized impacts throughout the entire U.S., have cost from $1 to 2 million dollars each to perform.

regulations.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- The theoretical and empirical methods to conduct cost-benefit analysis are well-established, yet even so, the number of unknowns and assumptions that must be made increase the uncertainty of the exercise. Also, many factors are unquantifiable.
- May require revision of existing regulation to require or allow for consideration of economic impacts in determining standards.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- All positive and negative outcomes of an action must be identified and quantified.

EMISSION ESTIMATE: N/A

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: N/A

RESOURCES

- World Bank *National Strategy Studies Program* provided support to countries to identify and quantify the costs and benefits of mitigation options.
- EPA *Energy Star & Related Programs - 1997 Annual Report* provides information on conducting cost-benefit analyses.
- IPCC *Methods for Assessment of Mitigation Options: Appendix IV Mitigation Assessment Handbook* provides guidelines for conducting coat-benefit analyses.

CONTACTS

Intergovernmental Panel on Climate Change
c/o World Meteorological Organization
Geneva, Switzerland
http://www.ipcc.ch

U.S. Environmental Protection Agency
Washington, DC 20460
http://www.epa.gov

The World Bank
National Strategy Studies Program
Peter Kalas
Climate Change Team
Environment Department
Washington, DC
Tel: (202) 458 5647
Fax: (202) 522 3256
pkalas@worldbank.org
http://www-esd.worldbank.org/cc/

10.4 TRANSFERRING GCC MITIGATION RESEARCH FINDINGS

CHARACTERISTICS

Many institutions/firms throughout the world are conducting research on GHG emissions sources and methods for controlling GHG emissions. Research, demonstration and initial commercial deployment of the full range of technologies and mitigation actions that can reduce, offset or avoid GHG emissions are underway in most Annex I and many non-Annex I countries. Likewise, many institutions/firms throughout the world are conducting research on the sources, sinks and effects of GHG emissions.

The results of this research are critical to utilities in defining and implementing cost-effective emissions reduction strategies. Information on the options available to reduce or avoid emissions, their applicability to siting conditions unique to each power plant, and the costs of installing and operating control equipment will enable electric utilities to choose the options that best suit their requirements.

Oftentimes, information needed by utilities must be obtained from multiple sources and may not be consistently reported. In addition, very little information is available on the capital and operating costs of many of the new technologies for site and operating conditions unique to each utility and, in many cases, individual plants. Also, some information that is important to utility decision-makers may be proprietary.

One mechanism to facilitate GCC technology transfer is the Climate Technology Initiative (CTI). The CTI was conceived in 1995 by the 23 IEA/OECD member countries to help implement and support the objectives of the Framework Convention on Climate Change (FCCC). In particular, the CTI responds to the requirement in Article 4.1 for Parties to the FCCC to

> *Promote and cooperate in the development, application, and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases.…*

It also addresses the requirements in Article 4.5 that

> *… developed country Parties and other developed Parties included in Annex II shall take all practical steps to promote, facilitate and finance as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention.*

The CTI is designed to promote national and international policies that can improve the framework for science and technology delivery systems. Membership in the CTI is open to any country that wishes to participate. The CTI is linked to practical national and international measures which aim to:

- promote awareness of technology-related activities already underway to assist with responses to climate change concerns;
- identify and share expertise and experiences between countries already working on particular topics, as well as with countries having limited expertise in particular areas;
- identify gaps in national and multilateral technology programs which could be addressed in order to strengthen climate response strategies;
- strengthen and undertake practical collaboration activities between countries to make technology responses to climate change concerns more effective.

The Climate Technology Initiative (CTI) includes activities directed at the achievement of seven broad objectives:

1. facilitate cooperative and voluntary actions among governments, quasi-government and private entities to help cost-effective technology diffusion and reduce the barriers to an enhanced use of climate-friendly technologies;
2. promote the development of technology aspects of national plans and programs prepared under the United Nations Framework Convention on Climate Change;
3. establish and strengthen the networks among renewable and energy efficiency centers in different regions
4. improve access to and enhance markets for emerging technologies;
5. provide appropriate recognition of climate-friendly technologies through the creation of international technology awards;
6. strengthen international collaboration on short, medium and long-term research, development and demonstration, and systematic evaluation of technology options;
7. assess the feasibility of developing longer-term technologies to capture, remove or dispose of greenhouse gases, and produce hydrogen from fossil fuels, and strengthen relevant basic and applied research.

To facilitate achievement of the objectives the CTI has established three working groups with individual objectives, as summarized below:

(1) *Working Group on Capacity Building*:
- Promoting the training and exchange of technical experts;
- Exploring the role of technology framework and related typed of agreements;
- Assisting with national climate action plans and national communications;
- Developing networks for information sharing; and
- Promoting and coordinating climate-friendly technology policy and practices, including assisting the Secretariat of the Framework Convention in the coordination of technology related activities.

(2) *Working Group on Technology Assessment, Analysis, and Strategy*:
- Identifying and developing case studies and indicators of performance with respect to

barriers to the diffusion of technologies;
- Conducting technology assessments with special emphasis on the role of governments to advance technology diffusion;
- Developing long-term technology strategies and scenarios; and
- Coordinating technology issues with the Secretariat of the Framework Convention.

(3) *Working Group on Research and Development*:
- Developing selection and evaluation criteria for candidate R&D projects to determine their relative merit;
- Establishing a CTI research network for collaborative R&D into medium- and long-term technology options; and
- Increasing the awareness of R&D efforts.

SIZE: N/A
FEATURES: N/A
COST: N/A
CURRENT USAGE: CTI was formed by the 23 IEA/OECD member countries.
POTENTIAL USAGE: CTI is open to any country that wishes to participate.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Published information on the technologies that can reduce or avoid GHG emissions is often reported inconsistently. In some cases, this limits a utility's ability to determine the best option. Putting all of the options on a common basis would be very expensive.
- There is no one source from which to obtain all of the information on the expected performance and costs for the full range of options.
- The Climate Technology Initiative (CTI) is a voluntary action, and its success depends on sharing information, experiences, and resources to enhance the availability and use of technologies to deal with climate change concerns.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐
CONDITIONS FOR EMISSIONS MITIGATION:
- To properly assess options for reducing or avoiding GHG emissions, a considerable amount of information in a consistent form is required for each option.

EMISSION ESTIMATE: N/A
COST-EFFECTIVENESS: N/A
SECONDARY EFFECTS: N/A

RESOURCES

- Many organizations have considerable databases on the technological options. The International Energy Agency has issued reports on a wide range of power generation options. In addition, the International Energy Agency Coal Research Service conducts analyses of most of the coal-based options.
- The Electric Power Research Institute has reports providing detailed engineering information on most conventional and some advanced power generating technologies. More detailed information is available through EPRI publications at *http://www.epri.com*.
- The U.S. Department of Energy (and some other countries) has conducted research, development, demonstration and commercial deployment on a wide range of advanced power generation systems and energy efficiency measures. DOE also publishes the *Climate Challenge Options Workbook* that provides information on many GHG mitigation options available to electric utilities.
  http://www.eren.doe.gov/climatechallenge/orig/cc_options5.htm
- Many bi-and multi-lateral energy technology research agreements exist between developed and developing countries through which information sharing is common.
- Many conferences, workshops and symposia take place throughout the world at which advanced power generation technologies are discussed.
- The UNFCCC maintains the *Climate Convention Information Exchange Programme* that provides country-specific information on GHG projects and programs.
- IEA and OECD, 1996, *Climate Technology Initiative: Inventory of Activities.*
- Eppel, S., 1998, *Enhancing Markets for Climate Friendly Technologies: Leadership Through Government Purchasing Strategies, Vol. 1,* sponsored by The Government of Japan through the New Energy Industrial Technology Development Organization (NEDO).
- NEDO, 1998, proceeding from *The First CTI/Industry Joint Seminar on Technology Diffusion in Asia*, Beijing, Peoples Republic of China (May 19-20).

CONTACTS

Edison Electric Institute
John Novak
Director of Environmental Activities
Washington, DC
Tel: (202) 508-5655
Fax: (202) 508-5225
http://www.eei.org

Electric Power Research Institute
Richard Richels
Palo Alto, CA
Tel: (650) 855-2602
http://www.epri.com

International Energy Agency
Michael Rucker
CTI Secretariat
Paris, France
Tel: +33 (1) 40 57 65 22
Fax: +33 (1) 40 57 67 59
http://www.iea.org/climat.htm
http://www.climatetech.net

International Energy Agency
Pierce Riemer
GHG R&D Programme
CRE Group Ltd.
Cheltenham, United Kingdom
Tel: +44 1242-680753
Fax: +44 1242-680758
http://iea.org

U.S. Department of Energy
Abe Haspel
Washington, DC 20585
Tel: (202) 586-5316
Fax: (202) 586-0861
http://www.doe.gov

U.S. Initiative on Joint Implementation
Washington, DC
Tel: (202) 586-3248
Fax: (202) 586-2062
http://www.ji.org

10.5 SUPPORTING GCC MITIGATION RESEARCH

CHARACTERISTICS

Research on the causes, effects, sources, sinks and options for controlling GHG emissions is critical to understanding the best approaches for addressing GHG mitigation. Country-specific research is necessary to ensure that factors unique to a country (e.g., climate, resources, income levels, emissions sources) are considered in the development of international requirements and policies and in control action plans.

Utilizing research conducted by other countries may, in some instances, result in information that provides wrong or inconclusive conclusions on the path a country should take to contribute to the reduction of GHG emissions. Tailored research to answer questions unique to a country or a specific power plant can result in the development of more appropriate and lower-cost compliance options than would otherwise be known.

Determining what research to undertake, especially for developing, cash-poor countries, is important, but sometimes difficult. With all of the research on climate change and mitigating measures taking place throughout the world, it may be difficult to ascertain if a specific subject is being researched.

One function of the Climate Technology Initiative (CTI) (see Section 10.4) is to "identify and undertake R&D projects with increased involvement by developing and transition countries". Through collaboration with developed (Annex I) countries and other developing (non-Annex I) countries, progress on research pertinent to a country can be pursued.

Another recent initiative is being promoted by the International Energy Agency called Technology Cooperation Activities (TCA). This initiative is designed to assimilate the lessons learned from the experience of facilitating 25 years of collaborative RD&D. It is anticipated that TCAs would bring developing countries together in a forum with developed (Annex I) countries and the private sector to perform cooperative RD&D.

SIZE:	N/A
FEATURES:	N/A
COST:	N/A
CURRENT USAGE:	Collaborative research and related implementing agreements are currently limited to between Annex I countries, although such initiatives are expanding in developing countries
POTENTIAL USAGE:	Unlimited potential, especially under CTI and IEA/Technology Cooperation Activities (TCA).

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Research can be expensive. This is especially true for developing countries whose limited resources must be allocated to high priority and large payoff issues.
- With the many billions of dollars being spent on research applicable to climate change, it may be difficult to determine what important research gaps exist. The existence of international coordinating bodies like the IPCC, CTI and IEA/TCA ease this problem somewhat.
- The proper research following accepted standards must be conducted.
- The results of the research must be applicable in the commercial marketplace.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐
CONDITIONS FOR EMISSIONS MITIGATION:
EMISSION ESTIMATE: N/A
COST-EFFECTIVENESS: N/A
SECONDARY EFFECTS: N/A

RESOURCES

- The International Panel on Climate Change (IPCC) compiles climate change related research being conducted throughout the world.
- The Asian Development Bank in collaboration with several developing Asian countries developed inventories of activities being undertaken in the countries related to GHG sources, sinks, impacts, and abatement—for example the *ALGAS* (Asia Least Cost Greenhouse Assessment Study) study.
- The U.S. National Science and Technology Council issued *Our Changing Planet* that provides a summary of climate related R&D in the U.S. *http://www.usgcrp.gov*
- NEDO, 1998, proceeding from *The First CTI/Industry Joint Seminar on Technology Diffusion in Asia*, Beijing, Peoples Republic of China (May 19-20).

CONTACTS

Asian Development Bank
P. Ghosh
Manila, Philippines
Tel: (632) 632-4444
Fax: (632) 636-2444

Intergovernmental Panel on Climate Change
c/o World Meteorological Organization
Geneva, Switzerland
http://www.ipcc.ch

The White House
Office of Science and Technology Policy
Tel: (202) 456-6070
http://www.whitehouse.gov/OSTP

International Energy Agency
Hans Jorgen Koch
Director, Energy Efficiency,
Technology and R&D
Paris, France
Tel: 33-1 40 57 65 54
Fax: 33-1 40 57 65 59
http://www.iea.org

U.S. Department of Energy
Abe Haspel
Washington, DC
Tel: (202) 586-5316
Fax: (202) 586-0861
http://www.doe.gov

U.S. Global Change Research Program
Anthony Socci
Director
Washington, DC 20024
Tel: (202) 314-2235
Fax: (202) 488-8676
tsocci@usgcrp.gov
http://www.usgcrp.gov

11.0 ENERGY SECTOR INSTITUTIONAL REFORM AND RESTRUCTURING ACTIONS

A country's institutional framework can greatly influence technology and fuel choice, project economics and other factors that can ultimately effect the cost-effectiveness of carbon control actions. For example, elimination of electric power monopolies increases competition thereby introducing new approaches, techniques and technologies to reduce generation, transmission and distribution costs and to address environmental problems.

A variety of techniques are being used to create the institutional environment conducive to electric power competition, lower prices, and improved technologies and technological choices. Unbundling generation, transmission and distribution is one means. Eliminating monopolies by privatizing state owned assets and selling assets to independent (non-regulated) power producers also result in increasing competition, and infusing new ideas and approaches that could result in more cost-effective means of controlling carbon emissions. In addition, restructuring utilities and utilizing modern management tools and techniques result in innovations with similar results.

This section provides information on several of the most important methods being used to reform and restructure the electric power industry. Most of them are being used today for commercial reasons—i.e., to increase competitiveness and to respond to constantly changing market conditions and needs.[29]

[29] A useful resource is the series of working papers prepared by the OECD/IEA Annex I Expert Group on the UN FCCC, especially, *Policies and Measures for Common Action*, Working Paper 18, Electricity Sector: Market Reform. These papers were prepared in support of a project, "Policies and Measures for Possible Common Actions" to provide a broad assessment of the relative potential of a range of cost-effective policies and measures for common action by countries and Parties listed in Annex I to the FCCC.

11.1 UNBUNDLING GENERATION, TRANSMISSION, AND DISTRIBUTION

CHARACTERISTICS

"Unbundling" is the separation of four utility functions—generation, transmission, distribution and retail customer services—into different units that may be in the same corporation, but separated such that no functional units of the same corporation have any competitive advantage over the corresponding functional units of other corporations or utilities. While the framework may vary from country-to-country, unbundling promotes greater economic efficiency across all sectors by making each individual entity its own profit center.

With the new market structure, the value of the services provided by each sector is represented in the end-use electricity price. Customers who wish, for example, to reduce electricity costs by avoiding the costs of transmission and distribution may turn to autogeneration (self-generation) or off-grid renewables—otherwise called distributed resources (generation). Also, where upstream costs are accurately reflected in the tariff structure, customers will have a stronger incentive to invest in energy efficiency. On the supply-side, electricity providers facing competition will streamline their operations to improve efficiency in order to provide least-cost services.

In many countries, unbundling takes place in conjunction with privatization. Where this occurs, the restructured market allows for the entry of energy services companies (ESCOs) that provide packaged energy delivery along with energy efficiency and facility maintenance. With unbundling, companies may begin to offer products such as "green power", or ancillary services such as power quality to maximize potential from existing resources.

SIZE: One or more of the electricity sectors may be unbundled.

FEATURES: Introduction of energy services, green pricing and other electricity products.

COST: Varies. Where unbundling results in increased competition, energy costs could decline.

CURRENT USAGE: The United Kingdom and Chile pioneered unbundling in the 1980s; since then, countries in Asia, South and Central America and Eastern Europe have separated their generation, transmission and distribution assets.[30] The United States is now beginning to unbundle as well.

POTENTIAL USAGE: Most countries—both OECD and non-OECD—retain a vertically-integrated electricity sector structure. For the

[30] These countries include: Argentina, Bolivia, Nicaragua, Pakistan, the Philippines, El Salvador, as well as the Indian state of Orissa. Several Eastern European countries have also begun to unbundle their power sectors.

majority of the world, unbundling is a potential source of improved efficiency with the subsequent reductions in greenhouse gas emissions.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Depending on the rate-making treatment of functional unbundling, or spin-off of generating assets, deregulation of power supply functions could actually increase retail rates for companies with power costs that are below market prices.
- The more accurately all upstream costs are reflected in the tariff structure, the stronger rural customers' incentive will be to invest in off-grid distributed power technology (e.g. renewables) and energy efficiency.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Where competition enters the marketplace with unbundling, electricity companies will be forced to improve their energy and economic efficiency in response to customers in search of the lowest-cost electricity.

EMISSION ESTIMATE: Where unbundling increases energy efficiency, C emissions/kWh will decrease.

COST-EFFECTIVENESS: Insufficient data or methods currently exist to quantitatively define the cost-effectiveness of unbundling.

SECONDARY EFFECTS: Where unbundling increases energy efficiency and decreases energy intensity so that emissions/kWh decreases, the associated emissions of other greenhouse gases and air pollutants will also decrease.

RESOURCES

- The International Energy Agency is tracking the status of unbundling (and electric power sector restructuring) on a country by country basis. This information can be found on the worldwide web at *http://dsm.iea.org/* , and in the IEA report, *Review of Existing Mechanisms for Promoting DSM and Energy Efficiency in New Electricity Business Environments-Appendix A.*
- NARUC, 1995, *Promoting Environmental Quality in a Restructured Electric Industry*, (December). This report offers an overview of environmental policy options that could be considered in many different contexts as the electric utility market moves toward competition. It also identifies and discusses a number of possible policies to integrate environmental protection goals into a competitive electricity market.

CONTACTS

International Energy Agency
Doris Justus
Paris, France
Tel: (33) 1 4057 6742

U.S. Energy Association
Ruth Cherenson
Washington, DC
Tel: (202) 312-1230
Fax: (202) 682-1682

11.2 INCREASING SENIOR AND MID-LEVEL MANAGEMENT PERFORMANCE AND EFFICIENCY

CHARACTERISTICS

Power plant equipment alone will not determine the potential efficiency and cost-effectiveness of a power plant; the performance of power plant decision-makers is as, if not more, important. Understanding when equipment should be replaced, when units should be dispatched and the quality of the fuels to be used are a few of the factors that will greatly influence the availability, reliability and performance of power plants. Experience has shown that power plant decision-makers who possess the tools *and* the capabilities to use these tools operate better-performing power plants. Techniques like benchmarking, plant audits, performance trending, fuel quality evaluation, asset management, and optimum economic performance are among the many tools available to power plant managers to help define performance targets and to prioritize equipment purchases.

These managerial and operational improvements will carry over to improvements in the ability to comply with environmental regulations. With improved management, environmental benefits will be realized by minimizing system losses and waste.

The availability of these tools, coupled with employee motivation and formal training programs, tying salaries and bonuses to plant performance, and team development, will contribute to improving human and power plant performance. Virtually every power plant in the world could benefit from such programs; some more than others.

SIZE:	Applicable to all power plants, regardless of size or type.
FEATURES:	Requires both the tools (software and equipment) and the training to use the tools effectively.
COST:	Most often a negative cost. Relatively small capital expenditures are required to obtain the tools and training; large expenditures are required for equipment replacement. However, over time, these costs are more than offset by improved plant performance.
CURRENT USAGE:	Companies around the world are in various stages of implementation of performance and efficiency improvement programs.
POTENTIAL USAGE:	Virtually every power plant can benefit from improved performance and efficiency.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Companies may meet with resistance and preferences for status quo from managers.
- It takes time to train and become proficient in the use of the tools and to develop and implement new procedures.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Will vary from plant to plant. However, a U.S. utility with a capacity of 25,000 MW reduced its CO_2 emissions by 5 million tons per year and saved $750 million per year as a result of such a program.

EMISSION ESTIMATE: May be difficult to quantify.
COST-EFFECTIVENESS: May be difficult to quantify.
SECONDARY EFFECTS: May be difficult to quantify.

RESOURCES

- The World Energy Council sponsors a committee on power plant performance.
- The National Association of Regulatory Utility Commissioners is composed of several sub-committees addressing various technical and managerial aspects of utility operations. More information is available at their website at *http://www.naruc.org*.
- The Joint UNDP/World Bank Energy Sector Management Programme (ESMAP) is a special global technical assistance program run by the World Bank's Industry and Energy Department. ESMAP provides advice to governments on sustainable energy development. Established with the support of UNDP and 15 bilateral official donors in 1983, it focuses on policy and institutional reforms designed to promote increased private investment in energy and supply and end-use energy efficiency; natural gas development; and renewable, rural, and household energy. Completed reports, country studies and other publications are available online at: *http://www.worldbank.org/html/fpd/esmap/esmap.html/*.
- A U.S.-Central and East European (CEE) Electricity Management Development Institute has been created. The Institute offers up to 16 courses annually, provided by U.S. companies and hosted by organizations in the CEE region. Course offerings address topics including: power market operation, finance and investment, and energy efficiency and environment.

CONTACTS

U.S. Energy Association
Ruth Cherenson
Washington, DC
Tel: (202) 312-1230
Fax: (202) 682-1682

World Bank Group
Energy Sector Management
Assistance Program
Tel: (202) 473-3672
Fax: (202) 522-0395
IFILES3@worldbank.org

11.3 INCREASING THE ROLE OF INDEPENDENT POWER PRODUCERS IN THE GENERATION SECTOR

CHARACTERISTICS

The realization that electricity generation is not a natural monopoly has led to the breaking up of producer monopolies, transmission and distribution networks in many countries. This has been accompanied by the entry of small and independent power producers (IPPs) into the market, allowed access to the grid for the first time. The presence of third parties introduces competition, incentivizing cost reductions and performance improvements to gain a better market position. Because of the highly competitive nature of independent power production, each company has an incentive to employ the most efficient systems and to operate and maintain them as effectively as possible.

In many countries, the introduction of independent power producers and competition in the generation sector, coupled with deregulation of energy markets resulted in significant technological advancement. This, in turn, reduced costs, improved performance and reduced emissions. Also, IPPs, that often build new or repower existing generation stations, are usually subject to new, more stringent environmental regulations than are older units. New capacity built will likely be more efficient than existing capacity.

Many OECD countries now allow independent power production. Also, other non-OECD countries that are privatizing—or have recently privatized—their generation sectors have increased the role of independent power producers in conjunction with privatization.

SIZE: Independent power producers can supply any percentage of electricity demand to the grid. For example, in the United States in 1997, independent power producers generated about 12% of U.S. electricity.

FEATURES: Independent power producers can use any fossil fuel or renewable energy source. Independent power production implies a generator that provides electricity on a merchant basis, based on the market clearing price, not the cost-of-service.

COST: Can result in net savings if independent power production drives generation prices down.

CURRENT USAGE: Countries in every region of the world have begun to allow independent power production.

POTENTIAL USAGE: Every country can benefit from increasing the role of independent power producers in the generation sector. Where independent power production has been introduced, estimates vary as to the percentage of power that IPPs will provide—e.g., as much as 20% of new capacity in Taiwan.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- In some countries more stringent environmental regulations imposed on new IPPs sometimes compel utilities to retrofit or refurbish older plants; in other countries, emission standards are kept low to reduce the cost of purchased power from the IPPs.
- IPP developers usually face a higher cost of capital and a shorter repayment period than public companies that may have access to sovereign guarantees and/or subsidies. As a result, private developers prefer technologies with low capital costs (per kW) that are highly efficient, and have short construction and payback times.
- Investors require assurance of loan repayment; not all projects will be able to guarantee the returns necessary to obtain access to capital.
- Real-time pricing, interruptible rates, and other peak-shaving options that may be introduced with the reforms that allow the introduction of independent power production, incentivize more efficient use of existing capacity.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Typically, independent power producers build new capacity, which increases the overall generation base. As demand grows, total electricity generation (kWh generated) will increase as well. Independent power production benefits GHG emissions in that it avoids the higher emissions rates of older units that would have been employed without the new capacity. Only (new) sources that produce no emissions, or produce emissions at a rate less than existing capacity can be considered to mitigate GHG emissions.

EMISSION ESTIMATE: Varies according to the change in generation mix prior to and following addition of independent power production.

COST-EFFECTIVENESS: Independent power producers are profit-driven and must make business decisions that make economic sense. Where environmental regulations are strict and enforced, it makes more economic sense to use the lowest- or no-emission electricity technologies.

SECONDARY EFFECTS: Varies according to the decrease in electricity demanded. For every kWh of fossil fuel power generation avoided, the associated emissions of air pollutants are also avoided.

RESOURCES

- IEA, 1997, *Asia Electricity Study* (Paris). This report examines the impact and mechanisms for the introduction of independent power production in Indonesia, the Philippines, and Thailand.
- The IEA Solar PACES website hosts a page of links to more information on independent power production including background information, case studies, and links to organizations offering IPP services. *http://www.SolarPACES.org/resources/utility.html*
- The U.S.-based Electric Power Supply Association (EPSA), a trade association for independent power producers, provides background information on competitive power and restructuring, as well as links to more information on independent power producers and regulators. *http://www.epsa.org/private/electricity_industry.cfm.*

CONTACTS

Electric Power Supply Association
Tiffany Elliott
Manager of Policy
Washington, DC
Tel: (202) 789-7200 ext. 105
Fax: (202) 789-7201
telliot@epsa.org

U.S. Energy Association
Ruth Cherenson
Washington, DC
Tel: (202) 312-1230
Fax: (202) 682-1682

U.S. Department of Energy
Howard Gruenspecht
Washington, DC
Tel: (202) 586-5337
Fax: (202) 586-2062
howard.gruenspecht@hq.doe.gov
http://www.doe.gov

11.4 PRIVATIZING UTILITY ASSETS

CHARACTERISTICS

Privatizing utility assets involves the transfer of at least some power sector assets to private ownership. Full privatization involves a sequence of steps; the entire process can take years to accomplish. Statutory changes must be made to allow for private participation in the power sector, and utilities often go through corporatization—changing the legal status of publicly created companies to make them subject to private-sector laws; and commercialization—introducing commercial objectives into the management and operation of a state-owned enterprise. Following these two stages, assets can be liquidated into smaller units, and finally the units are sold to investors. An independent regulatory agency is usually established at this time. The range of ownership reforms can consist of full private responsibility for the operation of existing assets and new investment, either through long-term concession or change in ownership, or the public owner may elect to maintain ownership of "strategic assets".

The newly privatized enterprise's environmental record will depend on its host country's environmental policies, and how well they are enforced.

When power markets are decentralized, their efficiency increases. Following privatization, profit-motivated companies support more rational energy pricing and improved tariff collection, which then provides incentives for energy efficiency investments. Competition also fosters fuel-switching to low-cost, most efficient fuel sources, and the separation of roles of government and the private sector allow for independent scrutiny of environmental performance.

For each of these benefits, however, there may also be negative environmental effects. As utilities streamline their operations to improve performance while cutting costs, they may elect to operate existing power plants for longer lifetimes and/or at higher capacity rates. If these power plants are old, inefficient coal-fired power plants that are low-cost because they run on inexpensive fuel but are exempt from new environmental regulations, this may dramatically increase the emissions of greenhouse gases. Also, to cut costs as much as possible, utilities may elect to stop funding programs such as demand-side management and/or renewables that reduce or avoid emissions. The influx of capital upgrades generation, transmission, and distribution assets, but new privately-developed generating capacity adds to overall capacity, increasing the number of large potential sources of greenhouse gas emissions.

SIZE: May apply to one or all power generation sectors: generation, transmission and distribution.

FEATURES: Competition induces generation choices that minimize short-term costs, so retail suppliers might seek a competitive advantage based on the environmental attributes of the generation mix.

COST: Profit motives increase utility interest in supply-side efficiency improvements and price signals raise customers' incentives to use energy efficiently.

CURRENT USAGE: Major sales of power sector asserts have occurred in most OECD countries as well as Latin America, with partial sales in Indonesia, the Philippines, and India.

POTENTIAL USAGE: Many countries retain public ownership of their energy industries; any of these could benefit from privatization.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Some methods of transferring assets to private ownership—such as sales to strategic investors and joint ventures—are more likely than others to produce environmental benefits by stimulating capital investment to replace or upgrade poorly operating equipment and bring in managerial expertise to improve operations.
- In the sale of assets, neither government officials nor private investors have strong incentives to examine environmental factors.
- Available information on a utility's environmental characteristics may be limited; in privatization sales made to date, share prices have not reflected the environmental condition of assets.
- Upon privatization, a utility's commitment to achieving a country's social objectives—which could include environmental protection and public health—may diminish.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Environmental improvement will depend on the enforcement and status of environmental policy and the political landscape following privatization.
- Privatization brings an influx of capital to increase generating capacity and may lead to increased electricity consumption in countries that would have otherwise had continued power shortages. The net environmental effect will depend on the emissions produced by the new capacity; and how its introduction affects the rest of the power system.

EMISSION ESTIMATE: Varies according to the fuel mix and change in electricity demanded prior to and following privatization.

COST-EFFECTIVENESS: Generally, privatization is a cost-effective business decision regardless of its potential benefit for GHG emissions.

SECONDARY EFFECTS: Varies according to the decrease in electricity demanded. For every kWh of fossil fuel power generation avoided, the associated emissions of air pollutants are also avoided.

RESOURCES

- USAID is providing assistance to several countries to promote energy sector privatization through its Environmental Action Programme Support (EAPS) to provide technical assistance and/or help in financing emissions reduction projects. *http://www.eni-environment.net/projects/eaps.htm.*
- Coopers & Lybrand created the privatization model for the Brazilian electricity sector. Information on this process is available from Eletrobras online at *http://www.eletrobras.com.*
- The U.S. DOE has published a number of publications analyzing electric power privatization. A list of studies and links to regular updates on status of privatization can be found at *http://www.eia.doe.gov/cneaf/electricity/page/restructure.html.*

CONTACTS

U.S. Agency for International Development
Gordon Weynand
Washington, DC
Tel: (202) 712-4810
Fax: (202) 216-3524
http://www.info.usaid.gov

U.S. Department of Energy
Howard Gruenspecht
Washington, DC
Tel: (202) 586-5337
Fax: (202) 586-2062
howard.gruenspecht@hq.doe.gov
http://www.doe/gov

11.5 CORPORATE RE-ENGINEERING TO EMPLOY MORE MARKET-ORIENTED APPROACHES

CHARACTERISTICS

In a competitive marketplace, utilities must compete to obtain and retain customers. Companies newly facing competition must employ market-oriented approaches and may require organizational restructuring and employment of new, customer-oriented services. Corporate reengineering, the redesign of workflows, systems, and procedures, can bring about significant improvements in performance.

Streamlining the organization will ultimately improve its efficiency by minimizing waste of resources and improving environmental performance overall.

Re-engineering generally involves adoption of a customer-oriented approach and incorporates structural changes that make the organization more flexible and responsive to market pressures. For utilities, this may include creation of a customer service department, rethinking and minimizing administrative procedures, developing more flexible work schedules, and creating channels for customer and employee feedback on performance and operating procedures.[31]

SIZE: Appropriate for large corporations as well as small- and medium-sized enterprises. Will usually be performed for the entire company, versus individual departments.

FEATURES: Varies depending on the needs of the organization. Performance can be measured by comparing "before" and "after" speed,

[31]Steps utilities can take include:

To improve *internal management and responsiveness*: create a database of customer information including payment history, system information (such as which transformer supplies which customers), decrease the length of processing time before customers can have their service connected; When customers contact the utility with account questions or in case of power outages or malfunctions, the utility is more easily able to identify problems and restore service.

To improve *internal accountability systems*: implement modern financial accounting methods that base investment decisions on international rate of return and net present value; automate billing and payments systems to speed up flow of revenue; employ financial instruments to reduce risk such as hedging, options, cash management; and use cost analysis to define goals and targets.

To improve *employee performance*: reorganize work schedules; employ teamwork; streamline organizational structure and design, review and minimize reporting procedures (i.e., issue annual (vs. quarterly) budgets); assess worthiness of capital investments, reevaluate power purchase agreements.

Other steps that could be taken include: public education programs that teach customers to take advantage of automated response processes (e.g., phoning in a complaint instead of making a personal visit to a company offices); implement methods for feedback from customers on company performance and services; extend hours of operation of customer service centers.

costs, number of customer complaints, etc.

COST: Varies. Costs will be minimal for structural changes, but may require capital investment to purchase new software and/or services of outside expertise.

CURRENT USAGE: Several companies are undergoing corporate re-engineering for reasons of pending or recent privatization, a merger or acquisition, or to improve market position. This is true in established and developing power markets.

POTENTIAL USAGE: Most utilities around the world could benefit from corporate re-engineering.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- The organization will defend the status quo to protect jobs and job security of current employees.
- Reengineering requires employees to shift perspective from existing, vertically-aligned relationships to horizontal information flows among functions.
- Corporate structure cannot be blamed for all internal problems. Reorganization can streamline an organization, but ineffective re-engineering can increase communication problems and create operational barriers.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Where corporate re-engineering results in a more efficient organization, waste of resources will be reduced and overall environmental performance will be improved.

EMISSION ESTIMATE: Varies.

COST-EFFECTIVENESS: N/A

SECONDARY EFFECTS: Varies.

RESOURCES

- Hammer, M. and S. Stanton, 1995, *The Reengineering Revolution.* New York: Harper Collins.
- Cross, K.F., and R.L. Lynch, 1994, *Corporate Renaissance; The Art of Reengineering*, Blackwell Publishers.
- The following website hosts an online library of corporate re-engineering resources including links to articles, books and other online resources. *http://www.prosci.com/point1.htm*
- The U.S. Energy Association Utility and Energy Partnership Programs provide information on successful re-engineering initiatives to participants.

CONTACTS

U.S. Energy Association
Ruth Cherenson
Washington, DC
Tel: (202) 312-1230
Fax: (202) 682-1682

12.0 REGULATORY REFORM ACTIONS

Regulation sends important signals to electricity generators and end-users—they affect a utility's costs, profit and choice of equipment, all of which factor in the price of services (cost of electricity). In theory, regulations "incentivize" utilities to operate at optimal efficiency in order to provide electricity at the lowest cost. In practice, however, this may not be the case.

Regulations can either *"push"* the market through setting more stringent standards—requiring companies to meet levels of emissions reductions or performance above their current compliance by a future date and penalize those that do not meet the requirements—or *"pull"* the market by providing rewards or incentives to those companies that meet or exceed (through early compliance, voluntary opt-in, etc.) regulated standards.

"Push" regulations tend to be rigid and are not easily adjustable to changing circumstances; they also require an aggressive effort on the part of the regulatory body to enforce. Examples of "push" regulations can include banning high-emitting technologies; capping the level of allowable emissions from a plant; controlling inputs, consumption or prices; and regulating rate-of-return for energy supply companies.

"Pull" regulations i.e., incentives, or fiscal measures (e.g., taxes or subsidies) are more flexible than "push" regulations, but it is difficult to determine the level of assistance that will produce the desired alterations. Fiscal incentives include emission fees or allowing trading of emissions; levying taxes on GHG sources; giving subsidies or rebates to low GHG-emitting sources; direct government expenditures for R&D or mass purchases, and others.

However, the supply and corresponding emissions response is not always straightforward. Reduced electricity demand could cause a price adjustment and a "rebound effect"—where the reduced demand is offset by increased demand elsewhere on the system so there is no net change in generation or emissions, or there is a realignment in the sources of generation, so that even with reduced electricity demand lower carbon emissions may not be realized. Quantifying the environmental impacts of regulatory actions should involve a detailed, system-specific analysis that recognizes the magnitude as well as the timing of the actions on the resultant electricity savings and generation capacity of the utility. Since these actions are dependent on the mix of fuels/technologies used to generate the electricity being displaced, a more precise estimate of carbon emissions reduced/avoided requires site-specific details.

In addition to reducing greenhouse gases, many regulatory actions and incentives offer other potential benefits. For example, improving energy efficiency also improves the competitive ability of industry in world markets; using low-or no-carbon fuels has positive benefits on local air quality and public health.

This section does not provide a complete list of measures that can be taken, nor does it prescribe the single best regulatory method to use in a given situation. Rather, it discusses types of actions possible and discusses possible effects. Usually, a combination of policies will be best suited to achieving the desired results in reducing greenhouse gases as well as other economic and/or societal goals.

12.1 DEMAND-SIDE MANAGEMENT (DSM) REGULATIONS AND INCENTIVES

CHARACTERISTICS

Demand-side management projects are designed to reduce energy consumption at the consumer-level while maintaining the same level of energy services as prior to project implementation. DSM programs consist of *energy conservation* programs including: (1) peak reduction—reducing customer use during times of system peaks; (2) load shifting—shifting usage from on-peak periods to off-peak periods; and (3) load building—increasing electricity use during off-peak periods. DSM programs can also consist of *energy (end-use) efficiency* programs—increasing the technical efficiency of end-uses. End-use efficiency programs can achieve the largest reductions in GHG emissions.

DSM programs are generally designed for one or more of the residential, commercial and industrial sectors because of similarities in the energy use patterns of end-users within each of these groups. Many DSM projects involve a combination of energy efficiency and conservation measures that result in low- and no-cost climate change mitigation options. Demand reduction can also grant flexibility to switch generating fuel mix away from less-efficient, more-polluting units to more-efficient, less-polluting ones.

DSM programs can consist of information dissemination, on-site energy audits and technical assistance, financial incentives (e.g., rebates, low-interest loans to purchase energy-efficient technologies), direct installation of energy-efficient technologies, and cooperation with trade allies (manufacturers, builders, engineers) to develop and use energy-efficient buildings and technologies.

The level (and cost) of reduction is dependent on the source of electricity. If in a "business-as-usual" case, electricity is generated by a fossil fuel (e.g., coal, oil, natural gas), then the demand reduced by DSM would translate into less generation and reduced carbon emissions. However, the supply and corresponding emissions response is not always straightforward. Reduced electricity demand could cause a price adjustment and a "rebound effect"—where the reduced demand is offset by increased demand elsewhere on the system so there is no net change in generation or emissions, or there is a realignment in the sources of generation, so that even with reduced electricity demand lower carbon emissions may not be realized.

Quantifying the environmental impacts of DSM actions should involve a detailed, system-specific analysis that recognizes the magnitude as well as the timing of the actions on the resultant electricity savings and generation capacity of the utility. Every kWh reduction in electricity use contributes to overall reduction in utility emissions of CO_2.

DSM Regulations and incentives must focus on ways of encouraging shifts in energy consumption or increasing usage of energy-efficient technologies.
Where retail prices (tariffs) are competitive, users are encouraged to use electricity efficiently and to modify their consumption patterns to purchase electricity when rates are lowest, during off-peak periods.

Examples of regulations include:
- When holding auctions for new resources, require regional and local authorities to include demand-side as well as supply-side resources in the auctions (a ban on bidding without DSM resources).
- Require utilities to expand conservation programs; fix distributor rates based on achievement of energy-efficiency goals.
- Impose tax on energy consumption to internalize environmental costs.[32]

SIZE: Can be adapted as needed.

FEATURES: DSM programs can be developed and implemented within a relatively short time period—a few years, at most. In the short-term, DSM is the only policy that can have a significant impact on reducing electricity consumption. DSM benefits end-users through cost savings as well as through improved environmental quality, economic competitiveness and energy security. May avoid or delay the need to construct additional capacity.

COST: These actions are dependent on the mix of fuels/technologies used to generate the electricity being displaced, a more precise estimate of carbon emissions reduced/avoided requires site-specific details.[33]

CURRENT USAGE: The number of utility DSM programs has increased during the past few years, leading to substantial energy savings.

POTENTIAL USAGE: Utilities in all countries can benefit from DSM programs.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- There is a lack of capital for customer purchase of new, high-efficiency equipment. Incentives from utilities, including financing, can reduce the cost of energy-efficient equipment and encourage participation in load management and

[32] One study estimated that in the U.S., a revenue-neutral tax shift lowering income taxes dollar for dollar with tax increases on fossil fuel use would lower fossil energy use by 37% (36.2 quads) in 2025 than the business-as-usual case.
[33] 90 U.S. utilities reported spending the equivalent of less than 3% of their total investment on production, transmission and distribution on DSM programs that reduced their peak demand by 21 GW. The estimated cost of this reduction was less than $36/kW.

conservation programs. Where customers lack sufficient motivation and/or resources, utilities can increase the direct installation of cost-effective conservation measures through target applications.
- Existing capital has a long life; upgrades may not be needed for a number of years.
- The form of tariff regulation will affect the economic incentive of a utility to undertake end-use efficiency programs. Where rate regulation is based on total sales, there is no incentive to reduce kilowatt-hour sales, so few DSM measures besides load management are deemed cost-effective.
- Without effective metering and collection, price signals will be ineffective in causing efficient electricity use patterns.
- End-users may not have the proper incentives (either because energy is a small percentage of their expenses or their energy expenses are subsidized) to use energy-efficient electrotechnologies or may not be aware of their benefits.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:
- Improving the energy efficiency of end-uses is the only DSM strategy likely to have a substantial effect on utility CO_2 emissions in the short-term.
- Reduced electricity demand could cause a price adjustment and a “rebound —where the reduced demand is offset by increased demand elsewhere on the system so there is no net change in generation or emissions, or there is a realignment in the sources of generation, so that even with reduced electricity demand lower carbon emissions may not be realized.

EMISSION ESTIMATE: Different DSM programs will achieve different levels of reductions.

COST-EFFECTIVENESS: Varies according to the administrative or investment costs required. Some investments are cost-effective regardless of the energy savings achieved.

SECONDARY EFFECTS: Where the use of fossil fuels is reduced, air pollutants will also be reduced.

RESOURCES

- National Association of Regulatory Utility Commissioners, 1993, *Incentives for Demand-Side Management,* (October). This is the third edition of a report profiling U.S. state regulatory commission policies and activities encouraging utility investments in demand-side management resources. The report includes a table that provides a quick summary of each commission's DSM activities, with an explanation of each type of shareholder incentive mechanism. *http://www.naruc.org*
- U.S. Department of Energy, Office of Environmental Analysis, Assistant Secretary for Environment, Safety and Health, 1989, *A Compendium of Options for Government Policy to Encourage Private Sector Response to Potential Climate Change, Volume 2,* (October).
- Synergic Resources Corporation, 1991, *Proceedings: Conference on Demand-*

Side Management and the Global Environment, (April).
- Alliance to Save Energy, 1998, *Price It Right: Energy Pricing and Fundamental Tax Reform*, (January).

CONTACTS

Alliance to Save Energy
Leslie Cordes
International Team Leader
Washington, DC
Tel: (202) 857-0666
Fax: (202) 331-9588
lcordes@ase.org
http://www.ase.org

American Council for an Energy-Efficient Economy
Washington, DC
Tel: (202) 429-8873
aceee@ix.netcom.com
http://solstice.crest.org/efficiency/aceee

International Institute for Energy Conservation (IIEC)
Washington, DC
Tel: (202) 842-3388
Fax: (202) 842-1565
iiec@iiec.org
http://www.iiec.org/

National Association of Regulatory Utility Commissioners
Washington, DC
Tel: (202) 898-2200
Fax: (202) 898-2213
http://www.naruc.org

U.S. Department of Energy
Diane Pirkey
Manager of DSM Programs
Washington, DC
Tel: (202) 586-9839

U.S. Energy Association
Ruth Cherenson
Director
Utility Partnership Program
Washington, DC
Tel: (202) 312-1230
Fax: (202) 628-1682

U.S. Environmental Protection Agency
Atmospheric Pollution Prevention Division
Washington, DC
Tel: (202) 564-9190
Fax: (202) 564-9569

12.2 ENERGY EFFICIENCY REGULATION AND INCENTIVES

CHARACTERISTICS

Energy-efficiency incentives promote the development of and increased use of technologies that maximize the energy used by different technologies. Energy-efficient regulations set standards such that the specified levels can be met only through use of energy-efficient technologies.

To promote the development of energy-efficient technologies, actions can target industrial, commercial, and residential sectors. For each of these, support can be given/required for research and development of increasingly efficient technologies. Also, regulators can require the dissemination of design and performance information on energy-efficient technologies.

Examples of regulations or incentives to promote use of energy-efficient technologies include: (1) subsidizing the cost of energy-efficient technologies—through tax rebates, a subsidized purchase price, or a mass purchase by government; (2) setting price signals—to increase cost of electricity such that energy cost savings of energy-efficient technologies is an incentive; (3) setting technology efficiency standards—to encourage manufacturers to develop increasingly efficient technologies or a "portfolio standard" requiring the use of cogeneration; and others. If regulatory bodies feel that more identification of and use of energy-efficient technologies is required, regulations to that effect can be included when implementing guidelines for wholesale power sales.

SIZE: Varies. Regulations may target use of a specific technology, or a specific industry or sector, or may apply to all end-users.

FEATURES: May offer rebates, tax credits or involve setting standards. For example, could involve setting target level for emissions or fuel consumption, and charge consumers a variable fee when actual consumption is worse than the target level, and granting consumers variable (sliding-scale) rebates for those that do better than the target.

COST: Costs may be incurred; for instance, through foregone tax revenue for rebates. Some policies may be revenue-neutral—if fees are charged for non-compliance, these funds can be directed to pay for any rebates. As manufacturers or federal policies improve efficiency levels, targets can be adjusted to maintain a revenue-neutral program. Administrative changes can also be made to make policies revenue-generating.

CURRENT USAGE: Numerous programs exist, and in many countries. For example, the Singapore Government has put in place a number of tax and financial incentives.

POTENTIAL USAGE: Energy efficiency has the potential to provide a significant amount of energy savings—in every company and in every country.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Increased energy efficiency does not guarantee that emissions reductions will occur—e.g., if demand shifts, or if generating source shifts from a low-emitting to a higher-emitting source.
- There is a lack of capital for customer purchase of new, high-efficiency equipment. Incentives from utilities, including financing, can reduce the cost of energy-efficient equipment and encourage participation in load management and conservation programs.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- The level of GHG emissions decreased or avoided will depend on the technologies used and the generation mix before and after the energy efficiency program.[34] For example, improving the efficiency of refrigerators—or other appliances that operate continuously—would result in larger energy savings than would efficiency improvements in peak technologies, such as air conditioning units. However, if baseload power is provided by a clean source (e.g., hydro) and peak power by a fossil-fuel powered source, then improving the efficiency of the peak appliance would have a greater effect on emissions.
- The greatest energy and carbon savings can be achieved in lighting, space conditioning, water heating, and miscellaneous electricity usage.

EMISSION ESTIMATE: Varies according to the change in electricity demand before/after implementation of the energy efficiency program. To quantify the level of emissions reductions, a utility can use a planning and dispatch model (or production cost model) to identify planned electricity dispatch; and an estimate of the load shape and magnitude of its DSM programs.

COST-EFFECTIVENESS: Varies according to the administrative or investment costs required. Many options are cost-effective following a very minimal cost.

[34] The Ilumex project in Mexico helped consumers purchase compact fluorescent lights using an innovative financing scheme that allowed consumers to purchase the lamps with a loan that could be repaid from electricity bill savings. More than 600,000 lamps have been sold to date at a cost of U.S.$1.64 each, resulting in estimated annual energy savings of: 160 GWh/year, 34,400 tons C, 2510 tons SO_2. The program has also allowed the Mexican utility to avoid the construction of 78 MW of new peak generating capacity.

SECONDARY EFFECTS: Varies according to the decrease in electricity demanded. For every kWh of fossil fuel power generation avoided, the associated emissions of air pollutants are also avoided.

RESOURCES

- Berman, E., M. Cooper, and H. Geller, 1987, *A Compendium of Utility-Sponsored Energy Efficiency Rebate Programs*, American Council for an Energy-Efficient Economy, (December).
- Lewis, T.R., 1992, *Designing Utility-Tailored Incentive Programs for Energy Efficiency and Conservation*, University of California Energy Institute, (September) and available online at *http://www.ucei.berkeley.edu/UCEI/pubs-pwp.html*.

- The U.S. Federal Energy Management Program, part of the Office of Energy Efficiency and Renewable Energy, provides technical assistance and other resources. More information is available at *http://www.eren.doe.gov/femp/resources.html*.

CONTACTS

Alliance to Save Energy
Leslie Cordes
International Team Leader
Washington, DC 20036
Tel: (202) 857-0666
Fax: (202) 331-9588
lcordes@ase.org
http://www.ase.org

American Council for an Energy-Efficient Economy
Washington, DC
Tel: (202) 429-8873
aceee@ix.netcom.com
http://solstice.crest.org/efficiency/aceee

U.S. Department of Energy
Greg Kats
Director of Financing
Office of Energy Efficiency and Renewable Energy
Washington, DC
Tel: (202) 586-1392
Fax: (202) 586-9260

U.S. Environmental Protection Agency
Atmospheric Pollution Prevention Division
Washington, DC
Tel: (202) 564-9190
Fax: (202) 564-9569
http://www.epa.gov/

12.3 ENERGY CONSERVATION REGULATION AND INCENTIVES

CHARACTERISTICS

Energy conservation is closely related to energy efficiency—for utilities the effects of both would be to defer the need to build additional capacity—but where energy efficiency focuses on using energy as efficiently as possible and concentrates on the technologies that use energy, energy conservation policies target the consumption of energy and seek to reduce the amount of energy used. Where energy efficiency regulations/incentives promote the use and development of technologies that maximize the energy used, energy conservation regulations and incentives focus on changing energy consumer behavior to minimize energy use.

Energy conservation can be achieved through the use of energy-efficient technologies; other options could include price signals: raising taxes on the end-use of energy, pricing energy higher during peak power periods, etc. Incentives could include promoting energy savings performance contracting, providing funding for energy audits, and more.

Taxes can take different forms: a general energy tax based on the Btu content of energy sources, or a carbon tax would be calculated based on carbon emissions.[35] A carbon tax, by taxing the highest emitters of carbon, would change the mix of energy sources in the economy, stimulating increased use of low- or no-carbon fuel sources. A carbon tax can be structured such that tax decreases as carbon content decreases. Modified forms of a carbon tax could also take methane emission into consideration, which would decrease somewhat the advantage of natural gas with respect to coal.

Tax incentives based on efficiency of technologies can drive the increased use of highly-efficient technologies. Such tools would help to reduce the overall cost of using more-efficient (the latest generation) of technologies, and reward cogeneration activities.

SIZE: Programs can be wide in focus or can target a particular end-use.

FEATURES: Can push the market (by raising energy taxes), or pull the market by permitting energy savings performance contracting.

COST: Regulatory costs are primarily administrative. Costs may be covered via a systems-benefit charge.

CURRENT USAGE: In the U.S., the 1992 Energy Policy Act (EPAct), authorized Federal agencies to contract with energy service companies (ESCOs) to acquire private-sector investment for the capital costs of installing energy and water conservation equipment and renewable energy systems. In the ESPC process, the ESCO

[35] Under a carbon tax, coal would be taxed the highest, noncarbon sources (renewable, nuclear) would not be taxed, and natural gas would be in the middle.

guarantees a fixed amount of energy cost savings throughout the life of the contract (up to 25 years) and is paid by the agency from energy cost savings after the savings start. Agencies retain the remainder of the energy cost savings for themselves. ("Energy cost savings" refers to any reduction in utilities costs at a Federal building.)

POTENTIAL USAGE: Energy conservation programs are widely applicable.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Must have effective billing and collection systems in place or price signals will be ineffective.
- Conservation programs may be most effective when undertaken in conjunction with energy efficiency programs, thereby addressing how and how much energy is used.
- There may be consumer reluctance to reduce energy consumption.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- The level of GHG emissions decreased or avoided will depend on the technologies used and the generation mix before and after any energy conservation program.

EMISSION ESTIMATE: Varies according to the change in electricity demand before/after implementation of the conservation program.

COST-EFFECTIVENESS: Varies according to the costs required (rebates, technical assistance). In most instances, direct cost savings are realized because energy expenditures decrease.

SECONDARY EFFECTS: Varies according to the decrease in electricity demanded. For every kWh of fossil fuel power generation avoided, the associated emissions of air pollutants are also avoided.

RESOURCES

- The International Energy Agency sponsors a program in support of the Implementing Agreement on Energy Conservation in Buildings and Community Systems (ECBCS). The website for this program, with publications and conference information can be found at *http://www.ecbcs.org/*.
- Several countries have passed energy conservation acts to encourage reduction in the use of energy and the design of energy-efficient structures.

CONTACTS

Alliance to Save Energy
Washington, DC
Tel: (202) 857-0666
Fax: (202) 331-9588
info@ase.org
http://www.ase.org

International Institute for Energy Conservation (IIEC)
Washington, DC
Tel: (202) 842-3388
Fax: (202) 842-1565
iiec@iiec.org
http://www.iiec.org

12.4 EMISSION CONTROL REGULATIONS AND INCENTIVES

CHARACTERISTICS

The bulk of generating capacity uses technologies that release greenhouse gases, particularly CO_2. Technologies to control SO_2 and NO_x emissions are relatively standard, but all post-combustion technologies to remove CO_2 are still expensive and need further development before they will be cost-effective.[36] For all of these emission control technologies, the cost of installing and operating can dramatically increase the cost of generating electricity from fossil fuels. Power producers will not likely install GHG controls unless they are required to do so to meet limits on emission controls.

Installing controls leads to a decline in power plant efficiencies, and an increase in initial capital investment costs as well as operating costs. In one analysis, a 90% reduction in CO_2 leads to a decline in coal-fired power plant efficiencies from 38% to 35%. Application of this technology to existing systems increases initial capital investment of 70-150%, while operating costs would increase by about 75%.

Regulations controlling emissions can include caps by *technology*—setting performance standards for amount of emissions removed or total emissions produced for individual generating plants or units, or caps by *region/sector*—limiting the amount of emissions that can be produced within a defined geographical region.

Technology caps assume the existence of technologies that can allow the equipment to meet these standards. Such caps encourage utilities to improve operating conditions (O&M, repowering, improving heat rates) to increase overall efficiency and minimize emissions. Technology caps can also consist of design standards for new generating capacity requiring use of the best available or best practical technology for efficient use of fuel. Highly-efficient technologies are still under development, making reaching this option difficult at present.

With regional caps, utilities have greater flexibility for meeting the emissions limits. Because each unit is not required individually to meet an emissions target, utilities can assess their generation fleet within the specified area and determine how best to meet the target. Regional caps allow for the use of emissions trading; such systems have so far been implemented for CFCs, SO_2 and NO_x, but are theoretically possible for controlling carbon, methane and other greenhouse gases. The government issues a limited number of permits to energy users, allowing a certain level of carbon emissions. (More permits would be needed to burn coal than to burn natural gas to produce the same amount of energy) Permits can be

[36] In April 1999, the U.S. Department of Energy released a working draft report, *Carbon Sequestration: State of the Science*, detailing the emerging science and technology of carbon sequestration. This document is intended to serve as a starting point for government, industry and academia discussion for on setting research priorities and directions for the next 25 years.

bought and sold on an open market. This system gives generators the flexibility to evaluate their compliance options: either lower emissions and sell the permits for their excess, or purchase emission permits on an emissions market.

A carbon tax achieves similar results, but the exact level of emissions is difficult to predict. A carbon tax allows more control over price; a permitting system (cap-and-trade) allows more control over emissions.

Regulation design also reflects whether the goal is to slow the rate of growth of highly-polluting capacity or to impose a moratorium on the installation of new plants.

SIZE:	N/A
FEATURES:	Consists of either technology caps or regional/sectoral caps.
COST:	Requiring installation of pollution-control technologies is quite costly for generators. Experience to date has shown that emissions trading programs have lower net costs than technology caps.
CURRENT USAGE:	World Bank member countries in general have legislation setting emission control standards equivalent to or stricter than World Bank-specified guidelines. However, these laws are not enforced in every country.
POTENTIAL USAGE:	Emissions trading systems are being considered by several countries.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- Technology cap mechanisms work best when there is a strong consensus that a specific technology exists to accomplish the stated objective. Without the existence of a clearly superior technology, it is difficult to administer the standards clearly and effectively.
- Incentives for R&D of CO_2 emission control technology will likely have benefits in the long-term; but whether this will be cost-effective is not now known. This is an expensive option and would probably require joint industry/government efforts. However, use of this policy signals governmental commitment to greenhouse issue.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☐ OFFSET ☐ REDUCED ☑

CONDITIONS FOR EMISSIONS MITIGATION:

- Emissions must be monitored and environmental regulations enforced if emissions are to be achieved.

EMISSION ESTIMATE:	Determined by the control levels specified.
COST-EFFECTIVENESS:	Varies according to the instrument used.
SECONDARY EFFECTS:	Determined by the control levels specified.

RESOURCES

- The World Bank sponsors an ongoing dialogue and research effort—New Ideas in Pollution Regulation—to increase understanding and facilitate dialogue on environmental pollution control strategies. *http://www.worldbank.org/NIPR/*
- U.S. Department of Energy, Office of Environmental Analysis, Assistant Secretary for Environment, Safety and Health, 1989, *A Compendium of Options for Government Policy to Encourage Private Sector Response to Potential Climate Change, Volume 2*, (October).
- U.S. Department of Energy, 1999, *Carbon Sequestration: State of the Science*, (April). *http://www.fe.doe.gov/techline/tl_seqrpt.html*

CONTACTS

Electric Power Research Institute
Richard Richels
Palo Alto, CA
Tel: (650) 855-2602
rrichels@epri.com
http://www.epri.com

International Energy Agency
Richard Baron
Paris, France
Fax: 33 1 40 57 67 39
richard.baron@iea.org
http://www.iea.org

United Nations Conference on Trade and Development (UNCTAD)
Frank Joshua
Geneva, Switzerland
Tel: +41-22-917-5834
Fax: +41-22-907-0274
frankjoshua@unctad.org
http://www.unctad.org

U.S. Department of Energy
Richard Bradley
Senior Advisor for Global Change
Office of Policy and International Affairs
Washington, DC
Tel: (202) 586-0154
Fax: (202) 586-0861
http://www.doe.gov

U.S. Department of Energy
Howard Gruenspecht
Washington, DC
Tel: (202) 586-4767
http://www.doe.gov

U.S. Environmental Protection Agency
Albert McGartland
Director of Economy and Environment
Washington, DC
Tel: (202) 260-3354
Fax: (202) 401-0454
http://www.epa.gov

U.S. Environmental Protection Agency
Paul Stolpman
Washington, DC
Tel: (202) 564-9140
Fax: (202) 565-2149
http://www.epa.gov

World Bank
Economics of Industrial Pollution Control Research Project
Washington, DC
http://www.worldbank.org/NIPR

12.5 OTHER REGULATIONS AND INCENTIVES THAT CONTRIBUTE TO CLIMATE CHANGE MITIGATION

CHARACTERISTICS

In addition to actions that encourage changes in energy consumption and limiting emissions, other regulatory options and incentive mechanisms exist. Examples of these include:

Promote least-cost utility planning (integrated resource planning): Before utilities decide to construct new capacity, they should consider all options as to how best meet anticipated electricity demand. These include: demand-side management options to reduce load growth, purchase of power from other utilities or independent power producers. For new capacity decisions, evaluate size, fuel type, capital costs, requirements for regulatory approval.

Increase capital turnover rate in generating capacity to develop a market for new technologies in the short and medium term: Where electricity prices are regulated, regulatory bodies can set prices such that capacity remains in service for its full operating lifetime which can be 40 years or more and beyond its financial lifetime, typically 30 years. Changes in pricing can encourage faster turnover in capacity, creating a market in the short- to medium-term for advanced, more efficient technologies. Benefits can be two-fold: advances the development of low-cost, efficient technologies and decreases the emissions produced by generating technologies.

Promote use and research & development of renewable energy technologies: By limiting emissions, setting portfolio standards requiring a percentage of generation to be provided by renewable energy sources, offer subsidies to buy-down costs of renewable energy, etc. Investing in R&D will advance the market-ready date of energy technologies now in testing phases. Government assistance can help decrease the risk associated with new technologies. Government-backed loans can also support demonstration of renewable energy technologies. Regulatory incentives can also be used to encourage further assessment of renewable energy resources – as well as for natural gas.

Promote the use of carbon sequestration: A portion of fossil fuel is lost during extraction and transport. Of special concern is the methane from natural gas that is released—intentionally or unintentionally—because of methane's contribution to the greenhouse effect. Limits on allowable methane release can be regulated, to encourage better protection/safeguards against flaring/accidental release, or can encourage the reinjection of gas into oil wells, for instance. Carbon can be sequestered in underground caverns or channeled into the ocean. Both financial and regulatory incentives can be used to promote all of these, as well as coal-bed methane.

Promote the use of biological offsets such as afforestation or management of non-utility land to offset power plant emissions.

SIZE: Varies according to the policy chosen. May target or impact one or several sectors.

FEATURES: Varies.

COST: Varies according to the option chosen, but costs for least-cost planning and sequestration, e.g., may be minimal.

CURRENT USAGE: Use of such options is widespread and increasing at local, regional and national levels.

POTENTIAL USAGE: Implementation of similar policies has widespread applicability. The potential impact on climate change may also be large—developing sinks can offset as much as 2 GtC/year.

ISSUES ASSOCIATED WITH IMPLEMENTING ACTION

- There is a lack of awareness as to the benefit of such options. Providing public seminars/training programs may increase understanding and success.
- There is a lack of available energy-efficient equipment in the marketplace, and what *is* available usually has a higher initial cost relative to conventional technologies. Technical potential for improved electric products exists, but will not be produced until manufacturers are assured of sufficient demand.

CLIMATE CHANGE IMPACT

EMISSION EFFECT: AVOIDED ☑ OFFSET ☐ REDUCED ☐

CONDITIONS FOR EMISSIONS MITIGATION:

- Policies will avoid emission of greenhouse gases *indirectly* by e.g., increasing efficiency, delaying capacity additions or other methods.

EMISSION ESTIMATE: Varies according to the fuel mix used for generation.

COST-EFFECTIVENESS: For some options, costs incurred may be offset by value added. For instance, forests, while sequestering carbon, also generate economic and social values (wood products, wildlife habitat, erosion control, water supply); also, the cost of renewable energy R&D may be offset by cost savings in the long-term.

SECONDARY EFFECTS: Varies. Where fossil fuel use is reduced, the associated emissions of air pollutants will also be avoided.

RESOURCES

- Ban, S. D., 1990, *Least Cost Planning: An Old Concept With New Relevance.*, Gas Research Institute.
- Swoboda, P., 1996, *Least-Cost Planning in Austria*, (Least-Cost Planning in Österreich), (October). *http://www.eva.wsr.ac.at/projekte/lcp.htm.*

- CADDET provides information on the status of renewable energy technologies. *http://www.caddet-re.org*
- The Australian government Greenhouse Challenge Office offers a workbook to assist Australian companies in quantifying results achieved by investing in forestry plantations to offset CO2 emissions.

CONTACTS

Executive Office of the President
Environment Division, Office of Science and Technology Policy
Washington, DC
Tel: (202) 456-6202
Fax: (202) 456-6025
http://www.whitehouse.gov

Oak Ridge National Laboratory (ORNL)
Eric Hirst
Oak Ridge, TN
Tel: (423) 574-6304
Fax: (423) 576-8745
http://www.ornl.gov

U.S. Department of Energy
L. Douglas Carter
Office of Fossil Energy
Washington, DC
Tel: (202) 586-9684
Fax: (202) 586-1188
http://www.fe.doe.gov

U.S. Department of Energy
Eric Petersen
Office of Energy Efficiency and Renewable Energy
Washington, DC
Tel: (202) 586-5389
Fax: (202) 586-2176
http://www.eren.doe.gov

U.S. Department of Energy
Charles Schmidt
Federal Energy Technology Center
Pittsburgh, PA
Tel: (412) 892-6290
schmidt@fetc.doe.gov
http://www.fetc.doe.gov

13.0 SOURCES OF SUPPORT FOR CLIMATE CHANGE MITIGATION ACTIONS

There are many sources of support for climate change mitigation actions. These sources provide data, funding, advice and other useful information. Organizations like the Intergovernmental Panel on Climate Change (IPCC), the U.S. Initiative for Joint Implementation, the U.S. Country Studies Program and other organizations provide a wealth of information on GHG sources, trends, technological options, and in some cases, financial support.

This section of the Handbook provides summary information on several programs that provide financial support to greenhouse gas or related projects. The programs summarized in this section do not include all of the programs that provide financial support but highlight a few of the major programs.

13.1 Climate Change Mitigation Project Support Fund With EEI Affiliate

The International Utility Efficiency Partnerships (IUEP) is a separately funded activity within the Edison Electric Institute (EEI) formed in early 1995 to identify international energy project development opportunities, to sponsor workshops with host country government personnel in facilitating project investment and development, and to demonstrate U.S. utility commitment to voluntary approaches to global climate issues. Participation is open to EEI investor-owned electric companies, EEI International Affiliates, EEI Associates, and energy product manufacturers and service providers. As the association of investor-owned electric utilities, EEI is uniquely qualified to coordinate industry involvement in public-private partnership programs like the IUEP.

The International Utility Efficiency Partnerships (IUEP) program is an initiative of the Climate Challenge, a joint program between the Department of Energy (DOE) and the U.S. electric utility industry. The Climate Challenge is part of the President's Climate Change Action Plan to reduce greenhouse gas emissions.

The goal of the IUEP is to identify and support international activities, sponsored by the U.S. utilities, which reduce, limit or avoid emissions of greenhouse gases. In addition, the program will provide a window on developments in the world's fastest growing emerging markets and access to new business opportunities.

The International Utility Efficiency Partnerships are between the electric utility industry, government, and international organizations. These relationships promote energy efficiency in international power projects. The United States has some of the most energy-efficient and environmentally friendly power plants in the world. The people who build and operate these plants have a great deal of expertise to offer foreign governments and project developers. IUEP will organize the necessary technical and financial support from U.S. utilities and institutions to assist foreign project sponsors and governments in improving the efficiency of their power systems.

Electric utilities will provide technical and management skills to organizations in implementing projects that improve the operation and efficiency of electric power and thermal energy systems. Utilities have extensive experience using technologies that reduce greenhouse gases, promote the use of electric technologies, and establish energy efficiency and Demand Side Management programs.

The IUEP will identify and review energy efficiency, fuel switching, renewable energy and other greenhouse gas reducing projects in the developing world. U.S. electric utilities will evaluate proposed IUEP projects and offer financial and technical assistance to those that they elect to join.

IUEP operations are supported directly by member utilities and their subsidiaries. In addition, the IUEP will engage in partnerships with the U.S. Department of Energy and other agencies to support the development of JI projects through feasibility work, project review, USIJI program development and related activities.

IUEP will work closely with officials from the United States Initiative on Joint Implementation (USIJI) to gain official recognition for selected IUEP projects as Joint Implementation (JI). Many IUEP activities qualify for recognition under the JI international pilot phase sanctioned by the international community at the First Conference of Parties to the Framework Convention on Climate Change in Berlin, Germany in April 1995.

On December 19, 1995, the Bio-Gen Biomass Power Project in Honduras was recognized by the USIJI as a certified JI pilot phase project. Bio-Gen, sponsored by lead developer Tucson Electric/Nations Energy and the IUEP, will use waste material from the local forest products industry as fuel. The plant will generate clean and environmentally sustainable energy for the local power grid, with fuel that was previously disposed of as waste in an intensively greenhouse gas emitting manner. When the project is eventually expanded to 45 MW, it will cover up to 15% of Honduran electricity demand and liberate the country from expensive reliance on imported fossil fuels. Bio-Gen will be the model for an expanded effort to involve the investor-owned utility industry in more JI projects in 1996 and beyond.

The IUEP issued a Request for Proposals (RFP) that closed on September 1, 1995 calling for projects that supported the IUEP effort to develop cost-effective greenhouse gas mitigation options. In all, 44 projects from 18 countries were submitted. These projects covered a variety of generation technologies, energy efficiency and demand-side management procedures. The proposals were dispersed over a wide geographical area in strategic international markets of interest both to U.S. utility business developers, and to government officials interested in globalizing the JI pilot program. Currently, the IUEP is considering these proposals and will select a group of projects for feasibility and project development support.

The IUEP intends to coordinate the diverse technical and managerial skills of its membership in management training programs held in the developing world. Many developing countries have the potential to receive significant investment in efficiency projects, but lack basic project facilitation and organizational capability. The management training partnership will have immediate benefits for both U.S. and host country participants. Host country personnel will learn how to structure projects to satisfy the financial, technical, and managerial

requirements for financing from U.S. electric utilities.
Their U.S. counterparts will make valuable personal contacts and increase their understanding of emerging markets.

The IUEP hosts a website, *http://www.ji.org*, on the World Wide Web to enhance communications between JI project developers worldwide.

13.2 World Bank Global Environmental Facility

The Global Environmental Facility (GEF) is a mechanism for international cooperation to provide new, and additional, grant and concessional funding (up to $10 million per project) to meet incremental costs for projects that generate global environmental benefits in four areas, including greenhouse gas emissions. The GEF is managed by three implementing agencies: the World Bank, the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP).

The GEF is striving for universal participation and currently 156 countries are participants. Countries may be eligible for GEF funds in one of two ways: (1) if they are eligible for financial assistance through the financial mechanism of either the Climate Change Convention or the Convention on Biological Diversity; or (2) if they are eligible to borrow from the World Bank (IBRD and/or IDA) or receive technical assistance grants from UNDP through a Country Programme. A country must be a party to the Climate Change Convention or the Convention of Biological Diversity to receive funds from the GEF in the relevant focal area.

Through parallel and co-financing arrangements and contributions to the GEF core fund, industrialized and developing countries have pledged no less than U.S. $2 billion to support the program. The program has completed its pilot phase and is now established as a permanent mechanism.

The GEF has a diverse portfolio that includes:

- a range of approaches that address the need for ongoing innovation, experimentation, demonstration and replicability.
- finance programs and projects that address the underlying causes of global environmental deterioration.
- finance actions that have long-term sustainable global benefits, such as reduction in costs of technologies or demonstration of alternative, environmentally sound, and viable approaches.
- finance actions that are cost-effective and catalyze complementary actions or have a multiplier effect.

- finance actions that involve a range of project executors from the public, non-government, and private sectors.
- finance programs that advance the scientific and technical capacities in recipient countries to reduce global environmental threats.

In implementing its program, the GEF will provide assistance for:

- Enabling activities, including inventories, compilation and analysis of information; policy analysis and action plans.
- Capacity building for enabling activities, institutional strengthening, and targeted research.
- Information dissemination and networking with other countries.
- Building public awareness of relevant programs and public policy issues related to its charter.

The GEF provides new and additional grant and concessional funding to meet the incremental costs of measures to achieve agreed global environmental benefits. Its financing is only used for incremental costs beyond those of achieving national developmental goals. GEF has developed procedures for estimating incremental costs.

The GEF's projects will be in three general areas: (1) operational programs, (2) enabling activities, and (3) short-term response measures. For climate change, three operational programs will initially be the areas funded by the GEF. These include: (1) removal of barriers to energy conservation and energy efficiency, (2) promotion of the adoption of renewable energy by removing barriers and reducing implementation costs, and (3) reduction of the long-term costs of low greenhouse gas-emitting energy technologies.

Enabling activities provide the foundations to address climate change through country-driven projects. They include capacity building, institutional strengthening, training, research and education that will facilitate response measures called for in international greenhouse gas conventions.

Short-term projects can be funded if they are country priorities, cost-effective in the short-term, and likely to succeed. Short-term projects may include mitigation measures in areas where operational programs have not yet been developed such as transport, carbon sequestration, and agricultural waste.

GEF projects must be country-driven, incorporate consultation with local communities and, where appropriate, involve non-governmental organizations in project implementation. Proposals for GEF funding can be generated in several different ways. Governments, the World Bank, UNDP, and UNEP, as well as non-governmental organizations (NGOs) and the private sector, can put forward projects. All projects must be endorsed by the government of the country in which the project is situated. Governments may apply for GEF funds direct to the UNDP or the World Bank; NGOs can do the same once the host government has accepted the project in principle. Private firms can apply to the International Finance Corporation for eligible investment projects. A $5 million small grants fund supports community-based activities by grassroots organizations and NGOs in developing countries. Projects submitted under this program do not require host government approval.

All proposals submitted for GEF support undergo a technical review. Projects cleared by the technical panel are submitted to the Implementation Committee who choose a group of projects that represents a balance among the regions and the four thematic areas covered by the GEF. The projects selected by the committee are forwarded to the participating governments for review. Approved projects return to their sponsoring agency for further preparation, appraisal, and final approval.

More information on the GEF can be obtained by going to its web site, located at http://www.gefweb.com/.

13.3 U.S. Trade and Development Agency Feasibility Studies

The U.S. Trade and Development Agency (TDA) provides funding of feasibility studies, orientation visits, specialized training grants, business workshops, and various forms of technical assistance. TDA's funding may be used only for services based in the United States. However, up to 20% of the TDA funding may be subcontracted to host country organizations. If the project is implemented, TDA may require the repayment of most or all of its investment.

Projects that TDA provides funding for can be public sector undertakings, planned and implemented by government ministries or agencies, or private sector projects in which U.S. companies take an equity position. TDA only works on projects that have the potential to mature into significant business opportunities.

TDA funds can support several activities including:

- feasibility studies to evaluate the technical, legal, economic, and financial aspects of a development project in the concept stage.
- definitional missions/desk studies to gather information on projects to assist in project evaluation.
- orientation visits to bring foreign representatives to the U.S. to advance promising projects.
- training.
- technical assistance.
- financial packaging to assist in developing a financing strategy.

When a viable overseas project is identified, TDA determines the type, timing, and amount of funding that is essential to fostering the involvement of U.S. business. A grant agreement is signed directly with the foreign government or foreign entity sponsoring the project contingent upon contracting with a U.S. firm to do the work. The foreign sponsor selects the U.S. firm that will do the work.

More information on TDA and its programs can be obtained from its website at *http://www.tda.gov/*.

13.4 The Global Carbon Initiative of the World Bank

The World Bank Global Carbon Initiative (GCI) aims to promote a global market in greenhouse gas emissions reductions that serve its client countries' development needs. The program, which is still in its formative stages, has the following objectives:

1. to explore market based instruments for GHG emission reductions;
2. to create awareness and provide input into the international decision-making process in order to facilitate the creation of efficient global GHG emission reduction markets; and
3. subject to international agreement on market based instruments and mechanisms, establish effective market based instruments that:

    a) create a level playing field for buyers and sellers of GHG emissions offsets; and
    b) increase private sector transfer of technology and flows of financial resources for environmental and developmental purposes.

The GCI explores market-based instruments for greenhouse gas emission reductions. It develops four products, including Carbon Investment Funds, Carbon Neutral Products, Specific Purpose Funds and Specific Services.

The development of a series of carbon investment funds (CIFs) is the primary product of the GCI. These funds will be increasingly tailored to the needs of investors and client countries, for example, via a geographical, sectoral or technical focus.

Carbon-neutral products involve the development of funds designed to tap green consumer's willingness to pay for neutralizing the climate change impacts of their consumption. Potential examples include marketing carbon-neutral gasoline.

Specific purpose funds will explore the potential establishment of funds for specific purposes. The establishment of a specific-purpose fund will have to be justified by the size and specific nature of the project that prevents it from being directly linked to a general CIF. Examples include those where a single, or group, of investors are interested in a specified investment strategy, such as investments in a particular sector and/or in a particular region.

Specific services include experiences gained in the development and implementation of the products can be shared with others. Areas of expertise may include baseline assessment, legal advice, project identification and implementation, etc.

Information on the CIF can be obtained from the World Bank Group, Carbon Offset Unit at (202) 522-3256.

13.5 U.S. Agency for International Development (USAID) Credit Authority

Development Credit Authority (DCA) is a general authority that permits USAID to offer credit assistance (direct loans or loan guarantees) for any development purpose of the Foreign Assistance Act. As a financial tool, DCA will help USAID achieve the development goals that can be achieved more effectively by using loans and loan guarantees rather than the more costly grants. DCA will be used, for the most part, for credit enhancement purposes, i.e., loan guaranties shall be given preference over direct loans.

<u>DCA Loan Guaranties</u> of dollar or local currency loans will be used where participating private institutions (banks or businesses) engage in true risk sharing with USAID. Generally,

USAID guaranties will cover not more than 50% of a participating private institution's risk of loss. USAID will conduct detailed financial feasibility analysis of the project as a prerequisite to financing, and only provide assistance for activities that promise verifiable cash flows and positive rates of return.

DCA Direct Loans will be denominated in dollars. The interest rate on the loans will be at or above the U.S. Treasury cost of borrowing for similar maturities. USAID will not finance more that 50% of the total cost of any project. As with the loan guaranties, USAID will conduct detailed financial feasibility analysis of projects as a prerequisite to financing, and credit assistance will only be provided for activities that promise verifiable cash flows and positive rates of return. Loan terms shall be related to the needs of each project but shall not exceed 20 years. The loan amounts, for direct loans, are expected to be in the range of $2-20 million, depending on the needs of the projects. A maximum loan amount of $100 million is prescribed by statute.

USAID will charge a risk-based DCA credit assistance fee to its partners. Depending on the transaction, a one-time loan origination or commitment fee will be charged on direct loans and loan guaranties. In addition, for loan guaranties, an annual fee will be charged on the outstanding principal.

Credit assistance under DCA furthers the Agency's development agenda in countries where USAID has an on-the-ground presence and where the commercial institutions are sufficiently advanced to permit the use of credit as a tool for encouraging those countries to increasingly assume the cost of financing development themselves. DCA assistance is offered at or near commercially-determined rates and requires others to assume the majority of project financial risk. It has the immediate benefit of directly engaging the private sector in furthering development and subjecting the attainment of development objectives to the discipline of local private sector credit markets and the Federal Credit Reform Act of 1990. Thus, DCA is a tool that permits USAID to logically evolve or transition its programs from being totally grant funded to being a mixture of grants and credit in those settings where USAID is seeking to (i) change its relationship with the recipient country , and (ii) phase out the presence of USAID staff.

In addition, DCA can be used to further the Agency's development agenda that addresses specific global objectives. All the preconditions for using DCA, such as the sharing of risk must still be satisfied.

In contrast to the use of Export-Import Bank and Overseas Private Investment Corporation credits, the use of DCA is driven by local demand, and crafted in the recipient country by on-the-ground USAID operating units and their partners in order to adapt to local conditions and be responsive to local development needs.

More information on the Direct Credit Authority program or other programs sponsored by the U.S. Agency for International Development can be obtained through its web site at: *http://www.info.usaid.gov/.*

13.6 Export-Import Bank Environmental Exports Program

The Export-Import Bank of the United States has established an "Environmental Exports Program" which increases the level of support it provides to exporters of environmentally beneficial goods and services, as well as to exporters participating in foreign environmentally beneficial projects. This program affords exporters a special level of support in conjunction with either the Bank's Insurance Program or with its loan and guarantee programs.

The Environmental Exports Program will provide enhanced levels of support for a broad range of environmental exports. The major features of the program are:

- A short-term Environmental Export Insurance Policy will provide enhanced short term, multi-buyer and single buyer insurance coverage for small business environmental exporters. Features of the program include policies that deliver 95% commercial coverage and 100% political coverage with no deductible.

- Enhanced medium and long-term support for environmental projects, products and services. These enhancements, which are reflected in Ex-Im Bank loan and guarantee programs, include:

    1. Local cost coverage equal to 15% of the U.S. contract price.
    2. Capitalization of interest during construction.
    3. Maximum allowable repayment terms permissible under OECD guidelines.

These features are intended to substantially improve the competitive position of U.S. environmental exporters. In addition, the Bank will aggressively use its tied aid resources to offset foreign concessionary financing offers for environmental projects.

Exports of products and services specifically used to aid in the abatement, control or prevention of air, water and ground contamination or pollution, or which provide protection in the handling of toxic substances will be considered eligible for support, subject to a final determination by the Bank.

The following are examples of the types of exports generally considered eligible:

- Instruments to measure or monitor air or water quality
- Emission control devices
- Effluent pollution control devices
- Equipment for systems for waste disposal, refuse collection and waste water treatment
- Services to upgrade environmental regulations: environmental assessments, design and training
- Ecological studies; ecological monitoring equipment
- Toxic material handling devices
- Certain renewable and alternative energy equipment
- Exports of products and services for foreign environmental projects entirely dedicated to the prevention, control or cleanup of air, water or ground pollution, including facilities to provide for control or cleanup, and the retrofitting of facility equipment

for the sole purpose of mitigating, controlling or preventing adverse environmental effects will be considered eligible, subject to final determination by the Bank.

Although there are no specific programs at the Bank for the control of greenhouse gas emissions, many technologies that are eligible for the program can reduce greenhouse gases. Exports for the following types of projects are generally considered eligible:

- Air or water (river) pollution cleanup
- Ecology or forestry management
- Certain renewable or alternative energy projects (photovoltaic, wind, hybrid, biomass)
- Water treatment or waste treatment projects
- Toxic waste or substance cleanup projects

More information on the Environmental Exports Program and on the Bank can be found through the Internet at *http://www.exim.gov/*.

13.7 Overseas Private Investment Corporation (OPIC) Services

The Overseas Private Investment Corporation is an independent U.S. Government agency that sells investment services to assist U.S. companies investing in emerging economies around the world. OPIC accomplishes this through provision of four services:

- Insurance of overseas investments against a range of political risks (currency inconvertibility, expropriation, political violence);
- Finance of overseas business transactions through loans and loan guaranties (corporate finance and project finance direct loans);
- Finance of private investment funds that provide equity to businesses overseas; and
- Advocacy of American business interests overseas.

OPIC is also cooperating with the United States-Asia Environmental Partnership, a program led by the U.S. Agency for International Development, to provide funding to U.S.-based non-governmental organizations for innovative environmental management and/or technology projects in Asia. One million dollars in financing is available for pilot phase to support environmentally sustainable development. Although a portion of the financing will be in the form of a grant, OPIC's policy and credit underwriting criteria will apply for all funds disbursed, and repayment of the loan portion of the facility will be required.

Examples of eligible projects include:

- Community-based environmental services projects, including urban and rural water supply, distribution, and sanitation.
- Environmentally sustainable projects or agro-industry pollution reduction activities.
- Projects that reduce greenhouse gases through enhanced supply, from renewable sources, or demand-side management

More information, including applications forms and eligibility guidelines, is available at *http://www.opic.gov* or by telephone at (202) 336-8400.

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United States Energy Association

United States Energy Association
1300 Pennsylvania Avenue, NW
Suite 550, Mailbox 142
Washington, DC 20004-3022
Telephone: 202-312-1230
Facsimile: 202-682-16